Produced Water Impacts on Louisiana Wetlands

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Please note the following corrections:

Page ii:
- on sixth line from top of page, "terstitial" should be "terrestrial"
- on second line from bottom of page, "10^{-9} curies" should be "10^{-12} curies"

Page vii:
- in table at top of page, the units "ug/g" should be "mg/l" and "34" in the last column should be "31"

Page 114:
- on seventh line from top of page, "THP" should be "TPH"

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Health and Environmental Sciences Department

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API Staff: Dr. Frank Prince

We also thank the operators of the various facilities sampled, listed in Table 2 of the report, for their permission and assistance in the project.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF FIGURES (Cont.)

LIST OF FIGURES (Cont.)

ABBREVIATIONS AND DEFINITIONS

Brackish Marshes - those areas inundated or saturated by surface water or groundwater of moderate salinity at a frequency and duration sufficient to support, and that under normal circumstances do support, emergent vegetation characterized by a prevalence of species typically adapted for life in such soil and contiguous surface water conditions. Typical vegetation would include wiregrass (*Spartina patens*), three-cornered grass (*Scirpus olneyi*), coco (*Scirpus robustus*), and widgeon-grass (*Ruppia maritima*). Brackish marshes are also characterized by interstitial water salinity that normally ranges between 7 and 15 parts per thousand.

Freshwater Marshes - those areas inundated or saturated by surface water or groundwater of negligible to very low salinity at a frequency and duration sufficient to support, and that under normal circumstances do support, emergent vegetation characterized by a prevalence of species typically adapted for life in such soil and contiguous surface water conditions. Typical freshwater marsh vegetation would include bulltongue (*Sagittaria* spp.), maiden cane (*Panicum hemitomon*), water hyacinth (*Eichornia crassipes*), pickerelweed (*Pontederia cordata*), alligatorweed (*Alternanthera philoxeroides*), and *Hydrocotyl* spp. Freshwater marshes are also characterized by interstitial water salinity that is normally less than 2 parts per thousand.

Intermediate Marshes - those areas inundated or saturated by surface water or groundwater of low salinity at a frequency and duration sufficient to support, and that under normal circumstances do support, emergent vegetation characterized by a prevalence of species typically adapted for life in these soil and contiguous surface water conditions. Typical vegetation includes wiregrass (*Spartina patens*), bulltongue (*Sagittaria* spp.), wild millet (*Echinochloa walteri*), bull-whip (*Scirpus californicus*), and sawgrass (*Cladium jamaicense*). Intermediate marshes are also characterized by interstitial water salinity that normally ranges between 3 and 6 parts per thousand.

Saline Marshes - those areas that are inundated or saturated by surface or groundwater of salinity characteristic of nearshore Gulf of Mexico ambient water at a frequency and duration sufficient to support, and that under normal circumstances do support, emergent vegetation characterized by a prevalence of species typically adapted for life in such soil and contiguous surface water conditions. Typical vegetation includes oystergrass (Spartina alterniflora), glasswort (Salicornia spp.), black rush (Juncus romerianus), saltwort (Batis maritima), black mangrove (Avicinnia germinans), and salt grass (Distichlis spicata). Saline marshes are also characterized by terstitial water that normally exceeds 16 parts per thousand.

Salinity Stratification - defined for the purposes of this study as a greater than 1 part per thousand difference between surface and bottom salinities.

^{226}Radium - an intermediate member of the ^{238}Uranium (^{238}U) decay series and immediate daughter of ^{230}Thorium (^{230}Th). ^{226}Radium (^{226}Ra) has a mean life of 2308 years, a half-life of 1600 years, and decays by emission of an alpha particle to ^{222}Radon (^{222}Rn).

^{228}Radium - produced directly by the alpha decay of ^{232}Th. ^{228}Radium (^{228}Ra) has a mean life of 8.3 years, a half-life of 5.75 years, and decays to ^{228}Actinium by the emission of a beta particle.

bbl/day - barrels per day (1 barrel is 42 gallons of oil)

cm/sec - centimeters per second

curie - a unit of radioactivity defined as that quantity of any radioactive nuclide undergoing 3.7×10^{10} disintegrations per second.

ft/sec - feet per second

GC/MS - Gas Chromatography/ Mass Spectroscopy

IR - Infrared Spectroscopy

LLD - Lower Limit of Detection

LOI - Loss on Ignition

mg/l - milligrams per liter

OCS - Outer Continental Shelf

pCi - picocurie - 10^{-9}curies

pCi/gm - picocuries/gram

pCi/l - picocuries/liter

ppt - parts per thousand

PW - Produced Water

QA/QC - Quality Assurance/Quality Control

S.D. - Standard Deviation

TPH - Total Petroleum Hydrocarbons

ug/g - micrograms/gram (parts per million)

EXECUTIVE SUMMARY

Produced water discharges from shallow water production facilities in coastal wetlands of the U.S. Gulf of Mexico have recently become an issue of significant regulatory concern. This study, commissioned by the American Petroleum Institute, was designed to:

1) determine the extent of produced-water-related salinity stratification,

2) collect a large hydrologic data set near the discharges for future plume dynamics modeling, and

3) collect limited sediment hydrocarbon and water and sediment radionuclide data to determine if these parameters are concentrating near the discharges.

The site selection procedure resulted in 36 produced water discharges selected for sampling, which were in a variety of habitats and physical settings including fresh/intermediate marshes, brackish marshes, saline marshes, dead-end canals, two-way canals and open water sites along the Louisiana coast. The sites were chosen from the API-LAMOGA produced water database.

SAMPLING AND ANALYSES

At each discharge, one grab sample of the produced water was collected for total petroleum hydrocarbons (TPH) and chloride analyses. Water column salinity and current profiling stations were on a transect 15, 90 and 300m (50, 300 and 1000ft) from the discharge. At sites where salinity stratification was present, additional profiling stations were located on the transect at 45 and 150m (150 and 500ft) from the discharge. For the purposes of this study, salinity stratification is defined as a greater than 1.0 part per thousand (ppt) difference between the surface and bottom salinities.

Water column TPH samples were collected 15, 90 and 300m from the discharge both at the surface and below any salinity stratification layer, if present. At six of the discharge locations, bottom sediment samples were also collected. Duplicate bottom sediment samples for TPH analysis were collected at the discharge 15, 45, 90, 150 and 300m upstream and downstream of the discharge where structures, shallow water or land did not interfere.

Surface and bottom water column and bottom sediment samples were collected at six stations for radionuclide analysis. These samples were collected at the 15m (50ft) up and down current locations.

Fathometer data and sampling observation showed that most discharges were into shallow 3-10ft (1-3m) waters. Only 6 of 36 discharges were into 4-5m (13-16.5ft) depths.

RESULTS AND DISCUSSION

(1) Discharged Hydrocarbons

The TPH concentrations of the produced water discharges ranged from 1.7 to 119 mg/l. Discharge salinities ranged from 10 to 227 ppt. Both these ranges are similar to those reported in other studies of produced water discharges by Jackson et al. (1981), Lysyz (1982), Kraemer and Reid (1984), Neff et al. (1989) and Boesch and Rabelais (1989b).

No surface water samples contained detectable (0.5 mg/l) concentrations of TPH. Dispersion of discharged TPH to below detectable levels occurred within 300m (1000ft) of the discharge in the bottom water samples. Less than half of the bottom water samples had detectable TPH concentrations. A summary of TPH concentrations in water is as follows:

Distance from Discharge feet (meters)	Surface TPH All Stations (Avg. ug/g)	Maximum Bottom TPH All Stations (Avg. ug/g)
0	<0.5	-
50 (15)	<0.5	34
150 (45)	<0.5	-
300 (90)	<0.5	8
1000 (300)	<0.5	-

(2) Salinity

Salinity stratification was found at 20 of 36 produced water discharge stations sampled. Three of the twenty stations exhibited area-wide stratification not related to the discharges. Two additional stations showed salinity stratification at 300m (1000ft) from the discharge but not at closer sample locations. Stratification at these two stations did not appear to be related to the produced water discharges but instead appeared to be related to bottom topography. Bottom water salinity stratification associated with produced water discharges appeared to be localized within 300m (1000ft) of the production facility.

3) Sediment

The limited sediment data collected in this study (six discharge stations) showed high levels of petroleum hydrocarbon contamination in sediment at 300m (1000ft) from the discharge. Of the 17 samples taken at this distance from the six stations, 8 samples had concentrations higher than 500 ug/g, 6 samples had concentrations between 100 and 500 ug/g, and 3 samples had concentrations below the detection limits.

Where sediment TPH approached background concentrations of 10-50 ug/g, as defined by Boehm and Requejo (1986) for the coastal Gulf of Mexico, unique circumstances existed. Sampling locations with low TPH concentrations were located in waterways adjacent to the one in which the discharge was located. These waterways were deeper with stronger current than the canal receiving the discharge.

The pattern of generally decreasing sediment hydrocarbon concentrations away from the discharge does indicate that produced water is the primary source of the hydrocarbons.

4) Radioactivity

Water column radionuclide activities that ranged from 0.0 to 3.5 pCi/l $^{226+228}$Radium were elevated above the single background sample value reported by Hanan (1981) at a distance of 15m (50ft) from the discharge at some stations. None of the samples exceeded the primary drinking water standards of 5.0 pCi/l $^{226+228}$Radium activities.

Two of ten sediment samples contained ^{226}Radium activities of 1.7 and 6.3 pCi/gm, both above the control values (1.05 $\pm$ 0.04 to 1.46 $\pm$ 0.07 pCi/gm) reported by Hanan (1981). Limited data are available for comparison from Hanan (1981) who sampled a single discharge station and a single control station. Sediment radionuclide levels in this study are generally low and do not appear to be accumulating to high levels near the discharges.

A. INTRODUCTION

The fate and possible effects of discharged saline formation waters from oil and gas operations on shallow water coastal wetlands have recently become an issue of significant environmental concern. Although some of these discharges have been ongoing for 20 to 40 years or more, until recently relatively little scientific attention has been paid to the effects, composition, volume, number and distribution of PW discharges, both onshore and offshore.

Proposed U.S. Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES) permit regulations would prohibit the discharge of produced water from production facilities into shallow coastal waters of the Gulf of Mexico. These proposed regulations are a response to growing concern about the possible impacts of produced waters on productive fresh-intermediate, brackish and saline marsh habitats and the biota they support. A relatively small number of production facilities in these habitats have been studied to examine the interactions among discharged produced waters, the receiving water column and sediments surrounding the production facilities.

As part of an ongoing data collection program, the American Petroleum Institute (API) and the Louisiana Division of the Mid-Continent Oil & Gas Association (LAMOGA) commissioned Steimle and Associates, Inc. to collect physical and chemical data near a large number of produced water discharges in Louisiana coastal fresh, brackish and saline wetlands to determine the potential area of impact near the discharges.

The study goals were as follows:

- Determine if and to what extent salinity or hydrocarbon stratification occurs near a large number of PW discharges in a variety of habitats in coastal Louisiana.

- Collect a large body of bottom contour, salinity, temperature, current velocity and direction data near production facilities for future modeling of discharge plume dynamics.

- Collect bottom sediment samples to determine sediment hydrocarbon concentrations within 300m (1000ft) of a limited number of discharges.

- Determine if and to what extent naturally occurring radionuclides are accumulating in close (15m or 50ft) proximity to a limited number of discharges.

The study was designed to collect hydrologic data, water column salinity, and TPH data in the close vicinity of 38 coastal produced water discharges. Additionally, bottom sediment samples were collected at six of the discharge locations to determine to what extent the sediments have accumulated these hydrocarbons. At these same six locations, water and sediment total ^{226}Radium and ^{228}Radium samples were collected at the sample locations closest to the discharge.

Salinity, conductivity, temperature, current velocity and direction data as well as surface and bottom water TPH concentration data are part of a separate Appendix. Due to the volume of data, these results are incorporated by reference only.

B. LITERATURE REVIEW

Previous studies of PW discharges to the environment have concentrated on biological and chemical impacts at a small number of sites. Sites located in offshore areas with deep water columns, high current velocities, high salinities and the associated biotic communities were studied. These were different from the fresh-intermediate, brackish and saline marsh zones of coastal Louisiana, which comprise this study.

Several authors have reviewed the literature on the fate and effects of PW discharges to coastal and offshore habitats. Middleditch (1984) used two approaches to determine the ecological effects of these discharges. The predictive approach was based on determining the components of the discharge and the toxicities of the individual components. He reviewed effluent toxicity data for the individual contaminants, where available, and field data showing the real effect of the contaminants on the environment. Using these data, an attempt was made to predict the impact of PW discharges on a given site. Only limited success was obtained using this approach due to data gaps in the dispersion, degradation and toxicity of the components of PW.

A second approach, an observational method, based on the assessment of impacts was on a "real world" measurement of ecological impacts. While this provides a high level of impact assessment reliability, the conclusions reached are generally site specific and cannot easily be applied to other habitats. An additional disadvantage of this approach is that the impacts of the PW discharge are difficult to separate out from anthropogenic disturbances and natural ecosystem perturbations.

Middletich (1984) concluded that discharged hydrocarbons and other individual components were unlikely to cause toxic or sublethal effects in the water column beyond the immediate vicinity of the mixing zone. This study also concluded that dispersion and dilution of the discharge is generally rapid offshore but might be a more significant problem under shallow, quiescent conditions nearshore. Benthic communities may be suppressed in the immediate vicinity of produced water discharges in shallow coastal waters but not in deeper waters.

Neff (1987) concluded that little laboratory data was available on the sublethal or chronic effects of produced water on marine organisms. Like Middleditch (op cit.), he concluded that hydrocarbons from PW accumulated in bottom sediments and benthic diversity and numbers of individuals were severely depressed within approximately 150-200m (492-656ft) of the outfall in shallow waters. However, few impacts have been documented for PW discharges in deep water. Neff (1988) reviewed the bioaccumulation and biomagnification of PWs and found that there was generally low toxicity to marine organisms.

Other findings were that PW hydrocarbons were bioavailable and rapidly bioaccumulated. However they were not persistent in animal tissues and did not biomagnify in marine food webs. Because of the relatively rapid release of hydrocarbons and the lack of biomagnification, PW hydrocarbons were considered unlikely to pose a health hazard to consumers of seafood.

Over the last 40-50 years of oil production in the northern Gulf of Mexico estuaries, PW effects have been studied by different methods. Mackin and Hopkins (1962), studied the impact of PW on the American oyster Crassostrea virginica. Their studies showed high sediment and water levels of "unsaponifiable hydrocarbons" in close proximity to PW outfalls which decreased rapidly with distance away from the source. PW caused increased oyster mortalities within 15-23m (50-75ft) of the discharge. Decreased shell growth and glycogen storage in oysters were reported at 46m (150ft) and no measurable effects were found in oysters more than 46m from the PW outfall. Laboratory studies showed that high concentrations of PW could slow pumping and filtering rates in oysters, but the effects were temporary and reversible. They concluded that a microorganism Dermocystidium marinum (now Perkinsus marinus) not oil field operations was responsible for the observed widespread oyster mortalities in the summer months across Louisiana.

First Mackin (1971) and later Armstrong et al. (1979) investigated the impacts of PW discharges on estuarine organisms in Texas bays. Mackin found results ranging from no impacts around outfalls in LaVaca and Matagorda Bays to deeply depressed numbers of benthic organisms in zones extending up to 106m (350ft) from discharges in Trinity Bay. He also found what appeared to be a zone of benthic stimulation beginning at 150m (500ft) from the Trinity Bay discharges and extending several hundred meters. The study by Armstrong et al. (1979) re-examined one of Mackin's Trinity Bay sites. They attributed the low numbers of benthic organisms near the discharge to high naphthalene levels in the sediment. In their study the area of depressed benthic abundances extended out as far as 455m (1,500ft) and although numbers of benthic organisms were generally higher in the zone of enrichment found by Mackin (1971), they were not significantly higher when tested statistically. Armstrong et al. (1979) concluded that high sediment naphthalene levels resulted from a discharge only 1m (3ft) from the bottom in a bay 2.5m (7.5ft) deep. High turbidity of clay-sized particles absorbed most of the hydrocarbons from the water column and deposited them at the bottom during settling.

Neff et al. (1989) compared the distribution and biological effects of PW and drilling fluid components in sediments around separator platforms in both shallow (2-5m or 7-16ft), semi-enclosed waters and deeper (5-15m or 16-50ft) offshore coastal waters of Louisiana. Their study found low to moderately elevated sediment TPH levels less than 300m (1,000ft) from the Lake Pelto site located in 2m (7ft) of water (1,700-3,000 bbl/day). At the deeper water site (8.5m or 72ft) in Eugene Island Block 105, low level TPH contamination extended less than 100m (330ft) from the (264-3500 bbl/day) discharge. Benthic communities within 20m

(66ft) of both discharges were influenced by sediment contamination. Beyond 20m, sediment grain size characteristics appeared to control benthic community gradients. The benthic data analysis was complicated by periodic bottom water hypoxia and high sediment inputs from the Mississippi River.

In an attempt to quantify the locations and characteristics of outer continental shelf (OCS) produced water discharged in central coastal Gulf of Mexico habitats, Boesch and Rabalais (1989a) edited an inventory of the discharge records of regulatory agencies in Texas and Louisiana. The total reported volume of PW discharged in Louisiana coastal waters during 1986 was just under 2 million bbl/day, including 192,386 bbl/day discharged into the 3-mile state territorial sea. Field assessments of the chemical and biological impacts of OCS generated PW discharged into coastal Louisiana waters were made. Their study of three sites found "moderate" levels of TPH contamination, low benthic faunal densities and few species at distances of 600-800m (1,970-2,620ft) from the discharges. Background levels of bottom sediment hydrocarbons were found within 800-2,800m (2,620-9,200ft) depending on the site. These distances of moderate hydrocarbon contamination and benthic impact are substantially higher than those found in other studies (Neff et al., 1989; Middleditch, 1981; Armstrong et al., 1979). This is probably due, in part, to the orders of magnitude greater discharge rates at the OCS sites sampled. At the Bayou Rigaud site, the discharge rate was 105,000 bbl/day. The other two sites, Port Fourchon and East Timbalier Island, respectively, had discharge rates of 45,000 and 20,000 bbl/day.

A second study by Boesch and Rabalais (1989b) examined the potential for PW discharge impacts on coastal zone salinity regimes, wetland vegetation and biota using hydrological, chemical and biological field surveys. The three stations examined were part of three fields evaluated in the API study. Discharge rates at these stations (Bayou Sale = 2,500 bbl/day; Lafitte = 3,676 bbl/day; Golden Meadow = 2,845 bbl/day were similar to those in our survey. No significant increase in mean salinity related to PW discharge and no salinity related impacts on marsh vegetation loss rates were reported. The field surveys showed increased bottom salinities near the discharges, rapid dilution and bottom salinities returning to background levels within a maximum of 1000m (3,280ft) from the discharge point. Moderately elevated bottom sediment hydrocarbon levels were found a maximum of 100, 500 and 500m (330, 1,640 and 1,640ft), respectively, from the three discharges. The differences in the distances were attributed to current velocities and bottom sediment types. Background hydrocarbon levels were found within 750-1000m (2460-3280ft) of the discharge point. The maximum distance observed for a benthos impact was 250-300m (820-980ft) from the platform.

The significance of naturally occurring radionuclide concentrations in PW discharged to shallow coastal habitats is largely unknown and unstudied. Kraemer and Reid (1984) studied the geochemistry of Radium (Ra) in formation waters from the U.S. Gulf Coast region. Their findings show a direct relationship between the salinity of the produced water and radium content. They also provide a detailed discussion of the radiochemistry of naturally occurring isotopes found in produced water from hydrocarbon, geothermal and geopressure wells.

Hanan (1981) documented an average doubling of the ^{226}Ra concentration in bottom sediments near a 22,000-bbl/day PW discharge when compared to a nearby control site in a fresh marsh habitat off the mouth of the Mississippi River. He found that the uptake of this radionuclide by sediments was correlated with the cation exchange capacity of the sediment. High salinity brines accumulating on the bottom tended to inhibit the absorption of ^{226}Ra onto sediment particles. Clay-sized particles were found to provide the highest number of sorption surfaces for ^{226}Ra.

In conjunction with Hanan's work, Landa and Reid (1982) investigated the factors influencing the sorption and retention of

^{226}Ra in sediments from the same study site. Their laboratory data show that naturally occurring and PW-adsorbed ^{226}Ra in sediments are tied almost exclusively to the mineral fraction and only a small percentage was lost when the organic fraction was removed. This demonstrated that sediment organic matter doesn't readily absorb Ra and is unlikely to provide a pathway into the food chain for this radionuclide. Additionally, their results show that the mobility of dissolved Ra was enhanced in produced brines discharged to low to moderate salinity waters, leading to a wider area of sorption and deposition. This would reduce the probability of Ra concentrating to unacceptable levels in the near vicinity of the discharge. The authors concluded that other coastal processes such as daily and seasonal differences in salinity, rainfall/runoff, tides and surface sediment dispersal would diminish the likelihood of an environmental radiation hazard due to long-term Ra deposition from PW.

C. SITE SELECTION

The individual PW discharges selected for sampling were in a variety of habitats and physical settings including fresh/intermediate marshes, brackish marshes, saline marshes, dead-end canals, two-way canals and open water sites. The sites were chosen from the API-LAMOGA PW database provided on diskette by API.

Sites with 0.0 bbl/day discharge rates and sites with obviously faulty location data were not considered possible sampling sites. Site selection criteria were based on fresh/intermediate, brackish and saline marsh habitat types from Chabreck and Linscombe (1978), three categories of discharge flow: Low (1) = 200-600 bbl/day, Moderate (2) = 1,000-3,000 bbl/day, and High (3) = 3,000-6,000 bbl/day; and three categories of Ra activity: Low (1) $^{226+228}Ra$ = <200 pCi/l, Moderate (2) $^{226+228}Ra$ = 200-600 pCi/l, and High (3) $^{226+228}Ra$ = >600 pCi/l. The cut-off of the discharge flow criteria at 6,000 bbl/day was based on Boesch and Rabalais (1989a), who found that only 10% of the reported PW discharges in Louisiana waters exceed 5,000 bbl/day.

Additional site criteria included the placement of the fresh/intermediate marsh sites in the areas influenced by the Mississippi and Atchafalaya Rivers, the placement of some sites in known oyster growing areas, the exclusion of previously studied sites and a broad coverage of the portion of coastal Louisiana where most of the discharges are located. The greatest portion of the sampling effort was divided between the brackish and saline marsh zones, with only seven sites chosen in the fresh/intermediate zone.

Two additional selection criteria were considered but rejected. The history of the individual discharges was considered as a possible selection criteria. Unfortunately these data were not readily available for all of the possible sites. In general, the sites chosen were in long established fields with long (10-40 years) discharge histories. The other rejected criterion was the physical configuration of the discharge. Some of the discharge configurations include (1) above the water surface, below the surface or immediately above the bottom, (2) vertically oriented or horizontally oriented, or (3) from ponds, skimmer piles or tanks. The number of existing discharge configurations and combinations eliminated this as an option. The general configuration of the discharge was, however, noted during sampling.

The 38 sites which were selected cover six of Louisiana's ten estuarine basins and concentrate on Barataria (14 stations) and Terrebonne-Timbalier (11 stations) Basins where most of the discharges are located. The Chandeleur Sound and Atchafalaya Bay Basins had the fewest sampling stations with two each. The Mississippi River Delta and the Vermilion Bay Basins had three and six stations, respectively. Due to a lack of discharge at one site in the Timbalier-Terrebonne Basin and inaccessibility by boat at an Atchafalaya Bay Basin site, only 36 discharges were actually sampled.

Table 1 is a list of stations showing the results of selections based on the above criteria. The sites are listed by marsh vegetation types, PW discharge rate and Ra activity criteria. The table also lists the physical configuration of the receiving water body (dead-end canal, multiple direction canal or open water). Figure 1 is a map of coastal Louisiana showing the approximate locations of the discharges.

TABLE 1

SAMPLING SITES
API LOUISIANA WETLANDS STUDY

STATION NUMBER	FIELD	FACILITY NAME	MARSH HABITAT TYPE	STATION CONFIG.	SAMPLE TYPES	PROD. WATER DISCH. CRITERIA	Ra 226 +228 CRITERIA
31	GOLDEN MEADOW	TB#12	B	C2	W	2	3
32	GOLDEN MEADOW	TB#13	B	OW4	W	1	1
33	GOLDEN MEADOW	TB#5	B	C2	W	2	3
34	GOLDEN MEADOW	CF#3TB#3	B	C2	W	2	3
35	GOLDEN MEADOW	CF#6TB#6	B	OW4	W	2	1
36	GOLDEN MEADOW	TB#10	B	C2	W	2	2
53	DOG LAKE	TB#7CF#6	S	C3	W	1	2
57	BAY DE CHENE	CF#2TB#5	S	OW4	W,S,R	3	2
58	QUEEN BESS	CF#4TB#3	S	OW4	W	1	1
59	BAY DE CHENE	CF#1TB#6	S	OW4	W	3	1
62	BAY DE CHENE	CF#4TB#4	S	OW4	W	2	2
65	LAKE WASHINGTON	S/L 212A CF#1	S	OW4	W	2	2
66	QUEEN BESS	CF#3TB#4	S	OW4	W	1	3
67	BAY DE CHENE	CF#5TB#7	S	OW4	W	3	2
69	LAFITTE	CF#10TB#8	B	C2	W	2	2
72	LAFITTE	CF#4TB#3	B	C2	W	2	2
82	DELTA DUCK CLUB	CF#4	F-I	C2	W	1	1
88	DELACROIX ISLAND	TB#1	B	C1-OW3	W,S,R	2	3
97	DELACROIX ISLAND	TB#2	B	C2	W	2	2
157	WEST BAY	FAC. #12	F-I	C2	W,S,R	3	3
165	W/D117-41&S.E.B.B.	DEL.GTR.STA.	F-I	C2	W,S,R	3	2
170	FOUR ISLE DOME	LL&E 12-14	S	C2	W	1	3
177	FOUR ISLE DOME	TANK BATTERY	S	C2	W	3	2
179	FOUR ISLE DOME	LL&E 22-7	S	*	*	2	2
181	FOUR ISLE DOME	LL&E 22-2D	S	C1	W,S,R	2	3
185	WEEKS ISLAND	CTB#1	F-I	C2	W	2	1

F-I=	FRESH-INTERMEDIATE MARSH
B=	BRACKISH MARSH
S=	SALINE MARSH
C#=	CANAL CONFIGURATION& NUMBER OF TRANSECTS
OW#=	OPEN WATER CONFIGURATION & NUMBER OF TRANSECTS
*	LOCATIONS SELECTED BUT NOT SAMPLED
SAMPLE TYPES:	W=WATER S=SEDIMENT R=RADIONUCLIDE
DISCH. CRITERIA:	1=200-600 BPD 2=1000-3000 BPD 3=3001-6000 BPD
Ra 226+228 CRITERIA:	1=<200 PlC/L 2=200-600 PlC/L 3=>600 PlC/L
NOTE:	MARSH TYPES BASED ON CHABRECK AND LINSCOMBE (1978)

TABLE 1 (cont.)

SAMPLING SITES
API LOUISIANA WETLANDS STUDY

STATION NUMBER	FIELD	FACILITY NAME	MARSH HABITAT TYPE	STATION CONFIG.	SAMPLE TYPES	PROD. WATER DISCH. CRITERIA	Ra 226 +228 CRITERIA
186	WEEKS ISLAND	R.H.GOODRICH	F-I	C2	W	3	2
190	BAYOU SALE	SWD#1	F-I	*	*	1	1
211	LAKE WASHINGTON	CENTRAL TB	S	OW3	W	1	3
214	LAKE WASHINGTON	HOMEPLACE TB	S	C1	W,S,R	1	1
217	LAKE WASHINGTON	COCKRELL 2 TB	S	OW3	W	2	3
219	WEST POTASH	CTB#4	S	OW2	W	2	2
224	LAKE WASHNGTON	CM-3	S	OW4	W	2	1
235	VERMILLION BAY	TB#1	B	OW4	W	2	2
242	BAYOU SALE	CF#2TB#2	F-I	C2	W	1	1
243	BELLE ISLE	TB "A"	F-I	C3	W	1	2
244	RABBIT ISLAND	TB "A"	B	OW4	W	2	3
275	REDFISH POINT	S/L 3306	B	OW4	W	1	2

F-I=	FRESH-INTERMEDIATE MARSH
B=	BRACKISH MARSH
S=	SALINE MARSH
C#=	CANAL CONFIGURATION& NUMBER OF TRANSECTS
OW#=	OPEN WATER CONFIGURATION & NUMBER OF TRANSECTS
*	LOCATIONS SELECTED BUT NOT SAMPLED
SAMPLE TYPES:	W=WATER S=SEDIMENT R=RADIONUCLIDE
DISCH. CRITERIA:	1=200-600 BPD 2=1000-3000 BPD 3=3001-6000 BPD
Ra 226+228 CRITERIA:	1=<200 PIC/L 2=200-600 PIC/L 3=>600 PIC/L
NOTE:	MARSH TYPES BASED ON CHABRECK AND LINSCOMBE (1978)

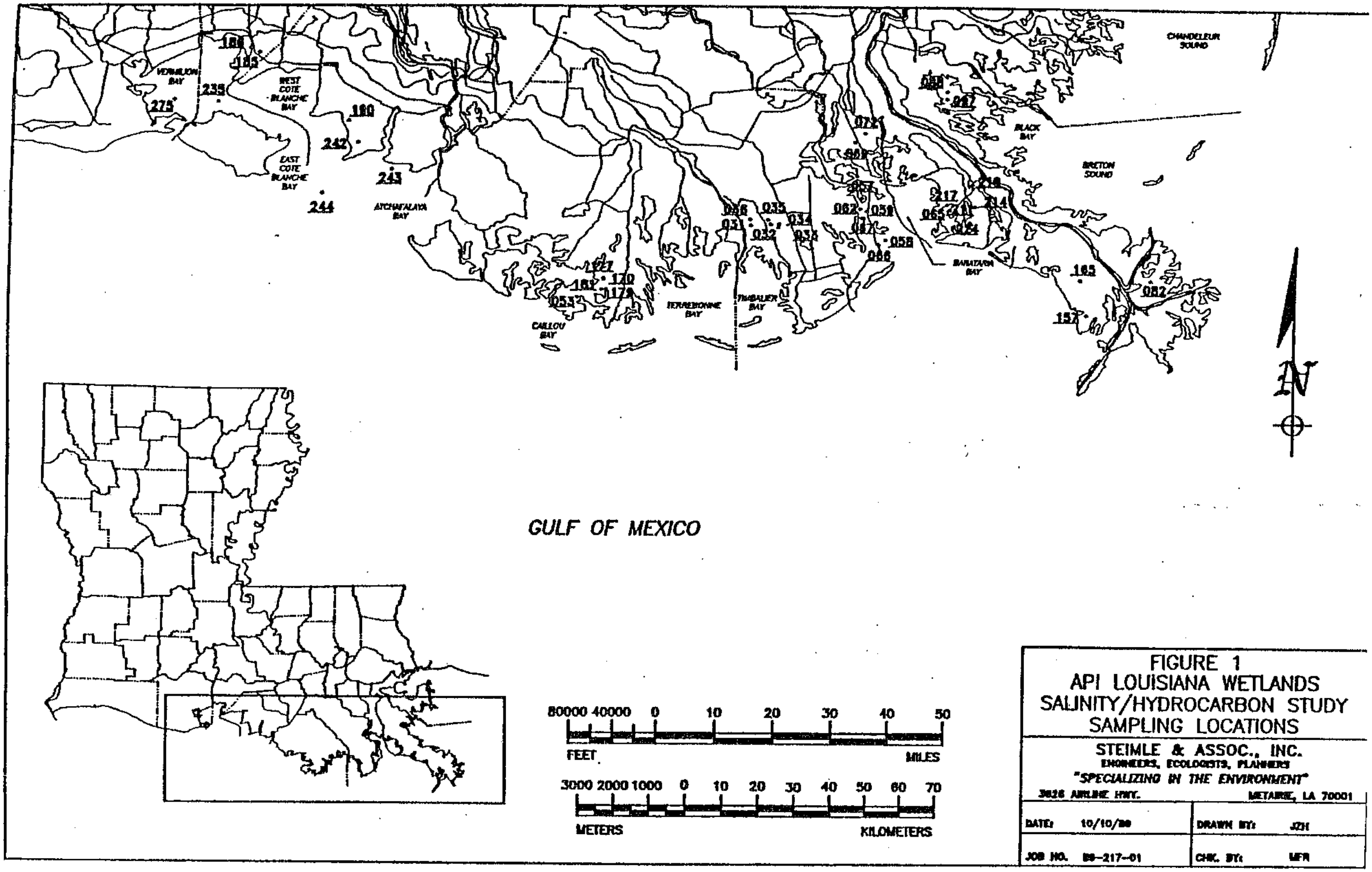


FIGURE 1
API LOUISIANA WETLANDS
SALINITY/HYDROCARBON STUDY
SAMPLING LOCATIONS

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3828 AIRLINE HWY. METAIRIE, LA 70001

DATE:	10/10/89	DRAWN BY:	JZH
JOB NO.	89-217-01	CHK. BY:	MFR

D. SITE DESCRIPTIONS

A list of the stations, field names, operators and estuarine basins is given in Table 2. Figures 2-39 are vicinity maps of the discharge stations and the sampling locations around them. Figure 40 is an idealized drawing of a typical inshore coastal production facility showing the major features of the PW treatment and discharge elements. Unlike Figure 40, many of the facilities sampled during this study had multiple treatment and/or separator trains present on the production platforms.

In the canal configuration, the typical facility was located adjacent to one bank, with the discharge located either at one end of the platform or coming from a treatment pond located some distance from the facility. At open water facilities, the discharges were generally located at the center or on one end of the platform.

Stations 31, 32, 33, 34, 35 and 36 were located in the Golden Meadow Field. The field is located in a brackish marsh habitat in and surrounding Catfish Lake in the Timbalier-Terrebonne Basin. Four of the stations are located in canals (31, 33, 34 & 36) and two are in the open water of Catfish Lake (32 & 35).

The other stations located in the Timbalier-Terrebonne Basin were 53 (Dog Lake Field) and 170, 177, 179 and 181 (Four Isle Dome Field). These sites are all in the saline marsh zone south and east of Bayou Grand Caillou and north of Caillou Bay. All these sites were located on canals.

Stations 69 and 72 are located in Lafitte Field, in the brackish marsh zone of the Barataria Basin. Both stations are on canals. Stations 57, 59, 62 and 67 are located in the Bay De Chene Field and Stations 58 and 68 are located in the Queen Bess Field. Both fields are in the saline marsh zone of the south central

TABLE 2

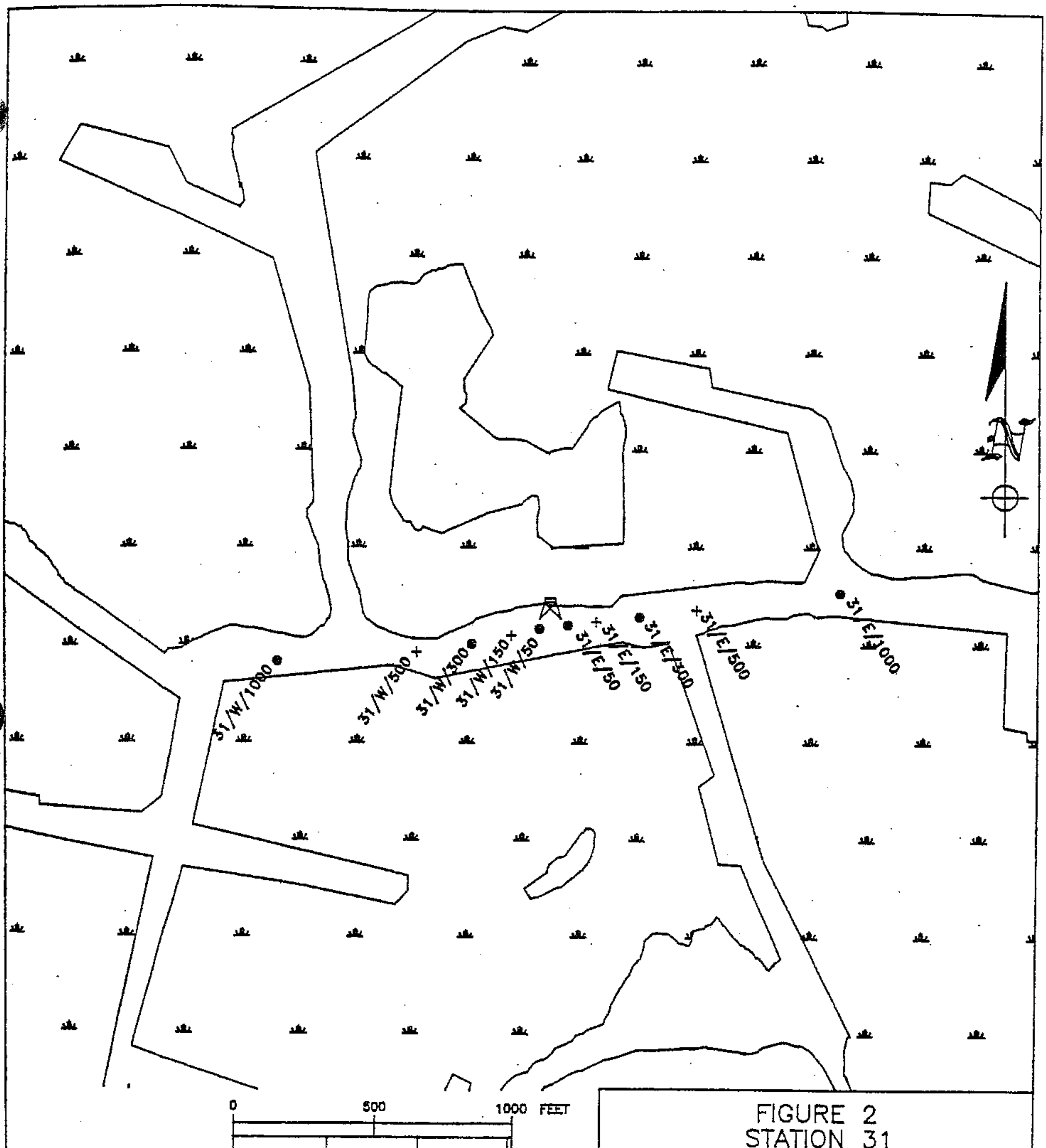
STATION DISTRIBUTION
BY ESTUARINE BASIN
API LOUISIANA WETLANDS STUDY

Station	Field/Operator	Estuarine Basin
31,32,33,34, 35,36	Golden Meadow/ Texaco	Timbalier-Terrebonne
53	Dog Lake/Texaco	Timbalier-Terrebonne
57,59,62,67	Bay De Chene/ Texaco	Barataria
58,66	Queen Bess/Texaco	Barataria
65	Lake Washington/ Texaco	Barataria
69,72	Lafitte/Texaco	Barataria
82	Delta Duck Club/ Texaco	Mississippi River Delta
88,97	Delacroix/Texaco	Chandeleur Sound
157	West Bay/Chevron	Mississippi River Delta
165	West Delta 117/41 & Southeast Black Bay/ Chevron	Mississippi River Delta
170,177,179, 181	Four Isle Dome/Mobil	Timbalier-Terrebonne
185,186	Weeks Island/Exxon	Vermilion
190	Bayou Sale/Exxon	Vermilion
211,214,217	Lake Washington/ Phillips Petroleum	Barataria
219	West Potash/Exxon	Barataria
224	Lake Washington/Exxon	Barataria

TABLE 2 (continued)

STATION DISTRIBUTION
BY ESTUARINE BASIN
API LOUISIANA WETLANDS STUDY

Station	Field/Operator	Estuarine Basin
235	Vermilion Bay/Texaco	Vermilion
242	Bayou Sale/Texaco	Vermilion
243	Belle Isle/Texaco	Atchafalaya
244	Rabbit Island/Texaco	Atchafalaya
275	Redfish Point/Amoco	Vermilion



LEGEND

- DISCHARGE POINT
- ● WATER SAMPLE LOCATION
- \+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 2
STATION 31
TANK BATTERY #12
SAMPLE LOCATIONS
GOLDEN MEADOW FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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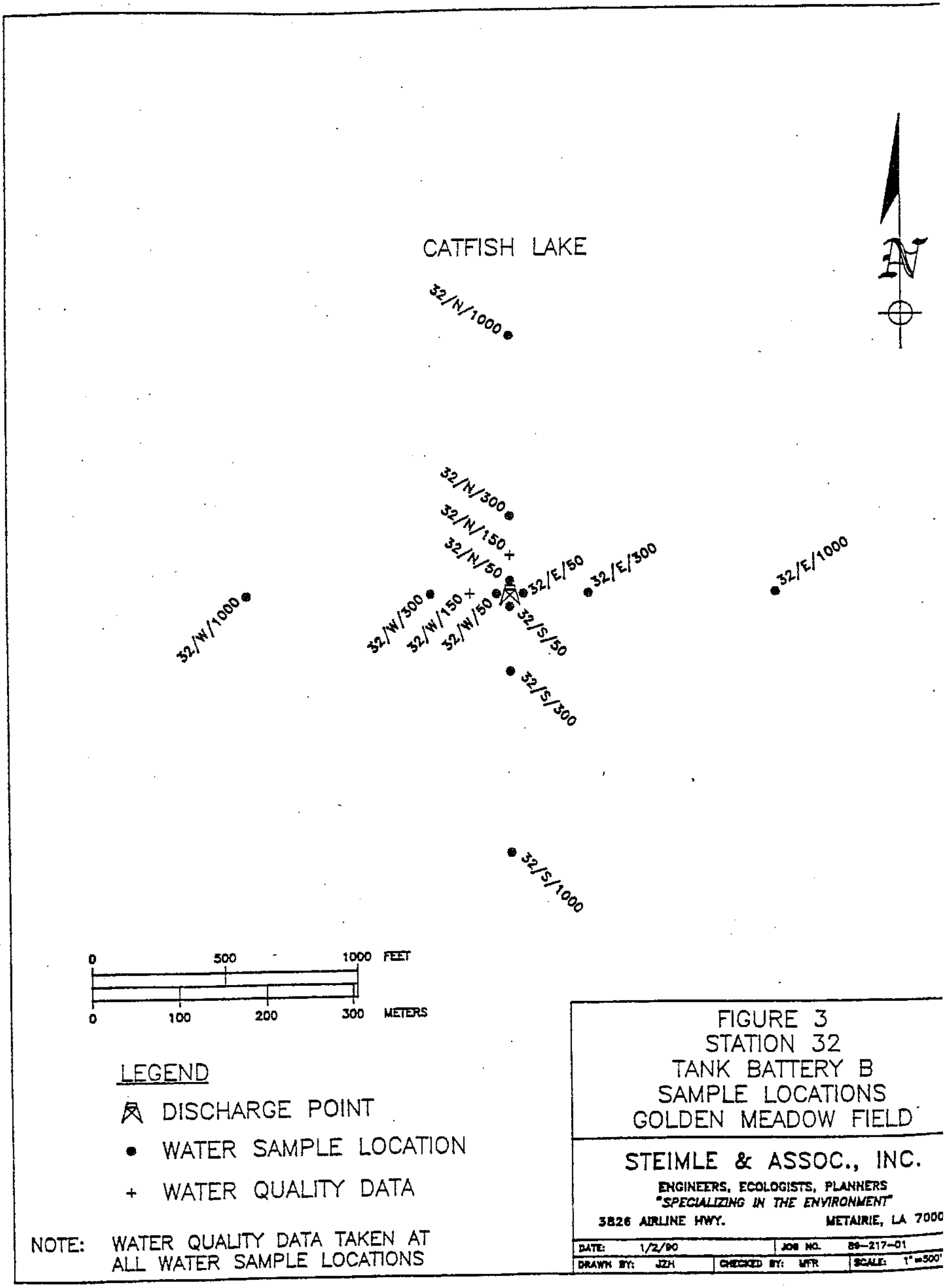

LEGEND

- DISCHARGE POINT
- ● WATER SAMPLE LOCATION
- \+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 3
STATION 32
TANK BATTERY B
SAMPLE LOCATIONS
GOLDEN MEADOW FIELD

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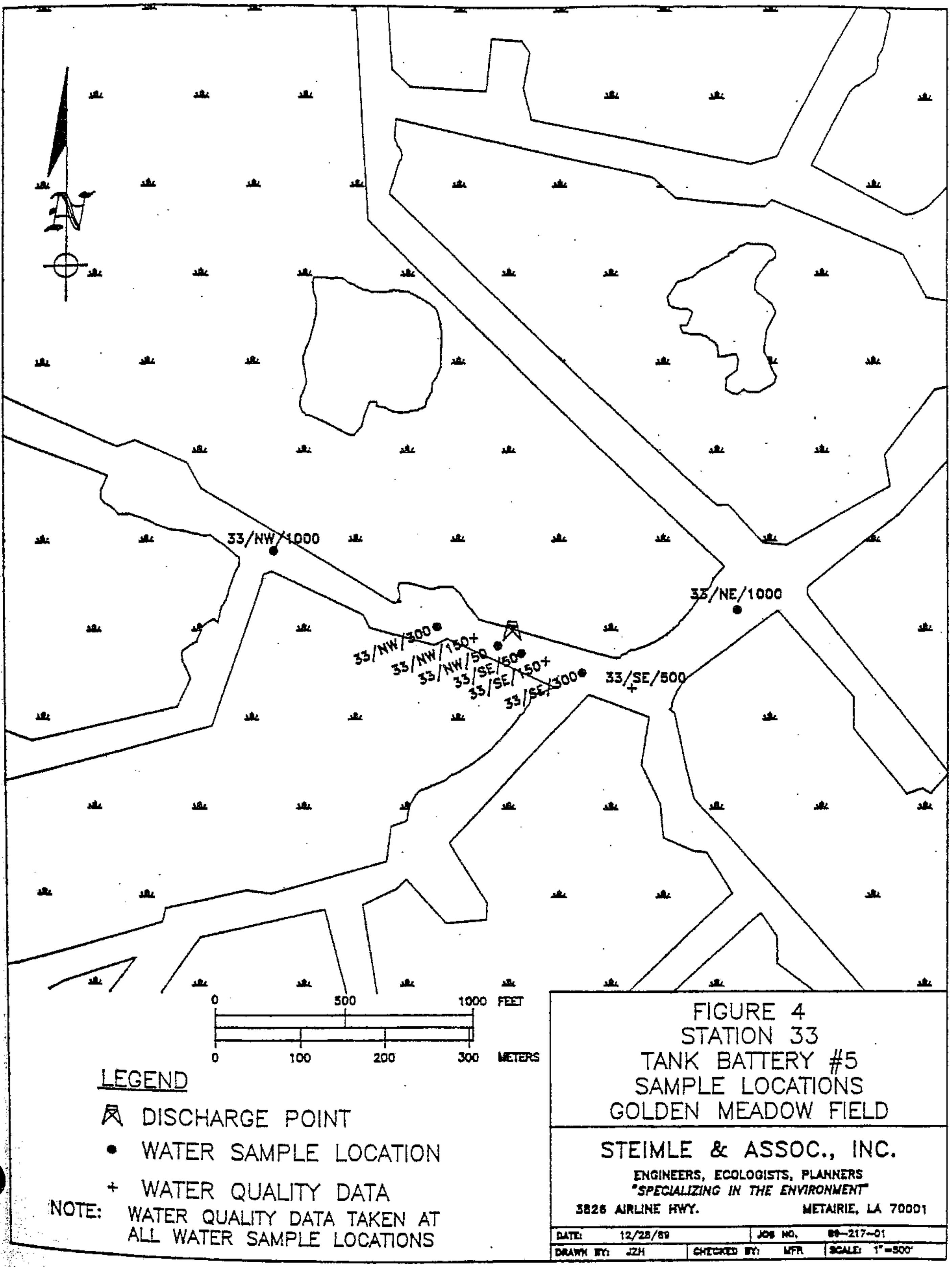

FIGURE 4
STATION 33
TANK BATTERY #5
SAMPLE LOCATIONS
GOLDEN MEADOW FIELD

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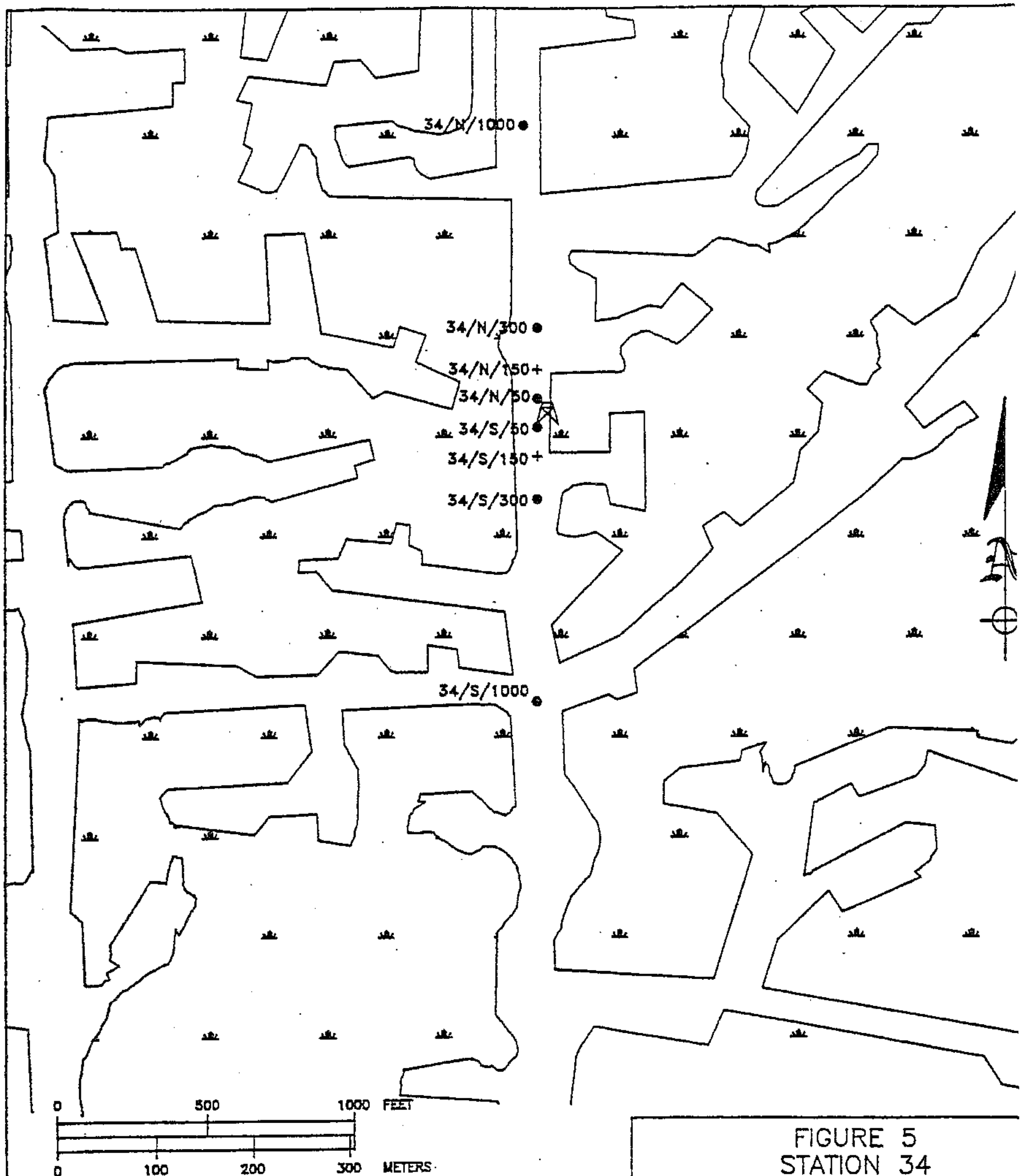
DATE: 12/28/89		JOB NO.	-217-01
DRAWN BY: JZH	CHECKED BY: MFR	SCALE: 1"=500'	



LEGEND

DISCHARGE POINT

● WATER SAMPLE LOCATION

+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 5
STATION 34
CF #3 TANK BATTERY #3
SAMPLE LOCATIONS
GOLDEN MEADOW FIELD

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"

3826 AIRLINE HWY. METAIRIE, LA 7

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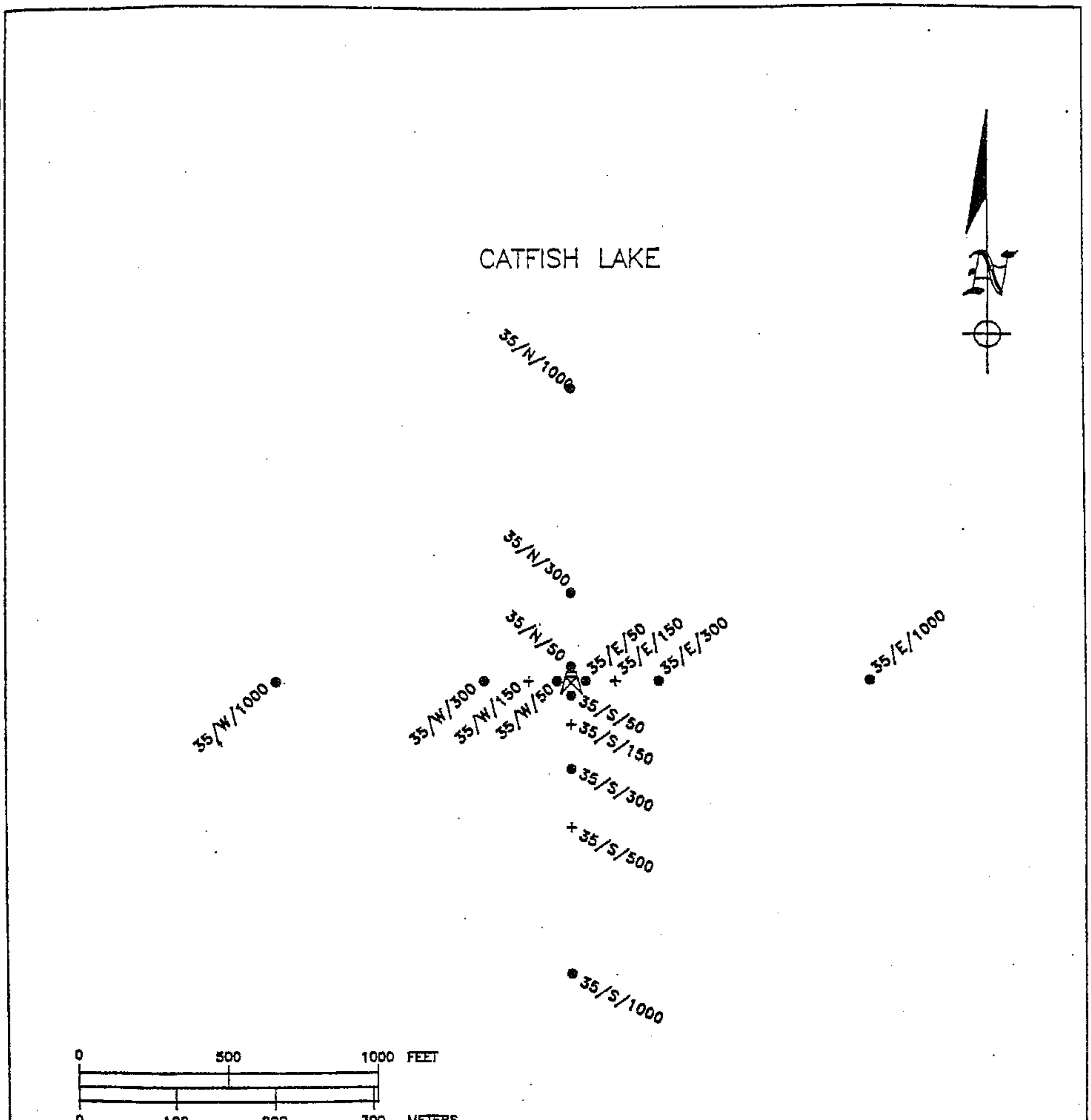

LEGEND

- DISCHARGE POINT
- • WATER SAMPLE LOCATION
- \+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 6
STATION 35
CF #6 TANK BATTERY #6
SAMPLE LOCATIONS
GOLDEN MEADOW FIELD

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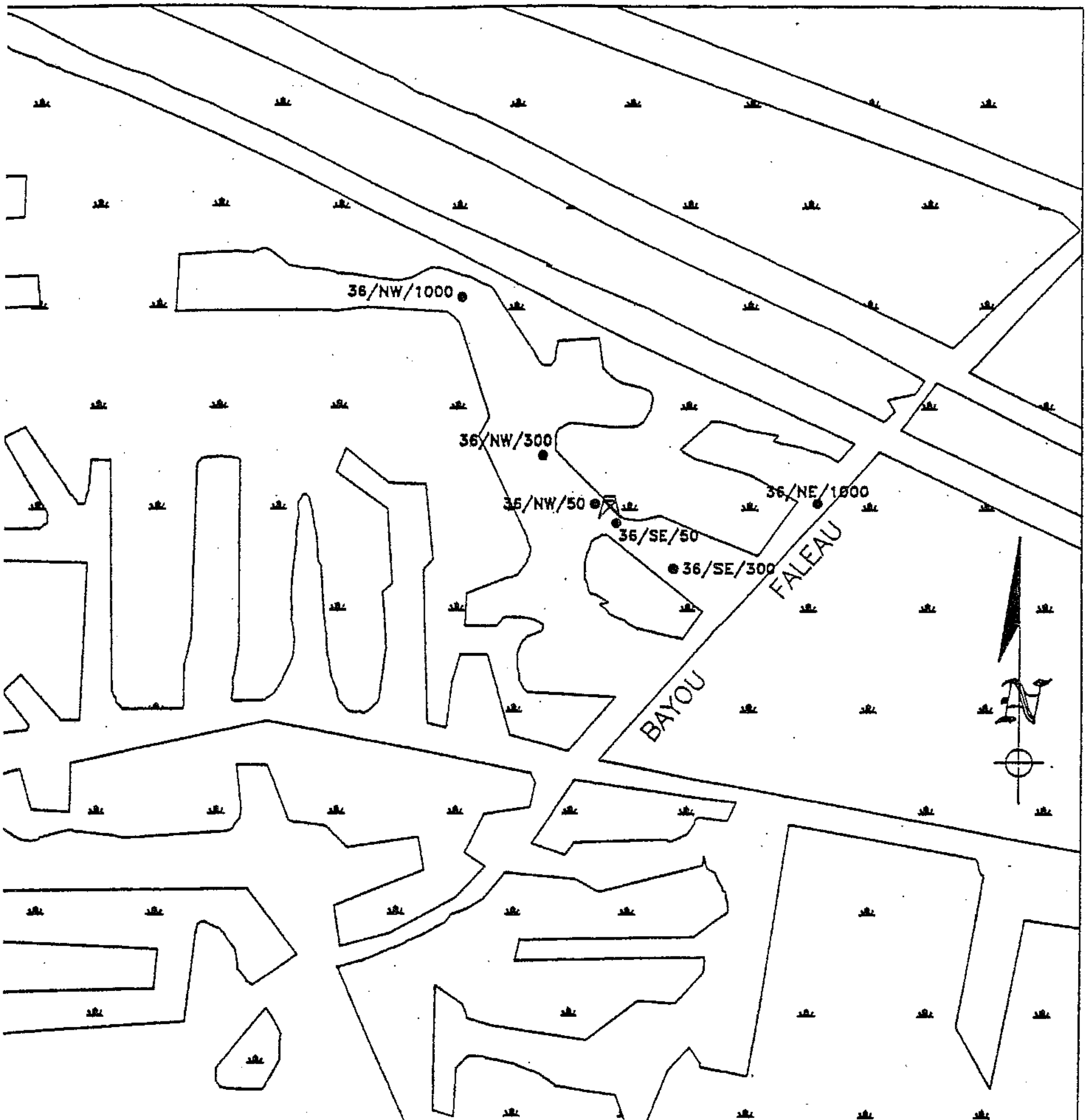

0 500 1000 FEET

0 100 200 300 METERS

LEGEND

DISCHARGE POINT

• WATER SAMPLE LOCATION

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 7
STATION 36
TANK BATTERY #10
SAMPLE LOCATIONS
GOLDEN MEADOW FIELD

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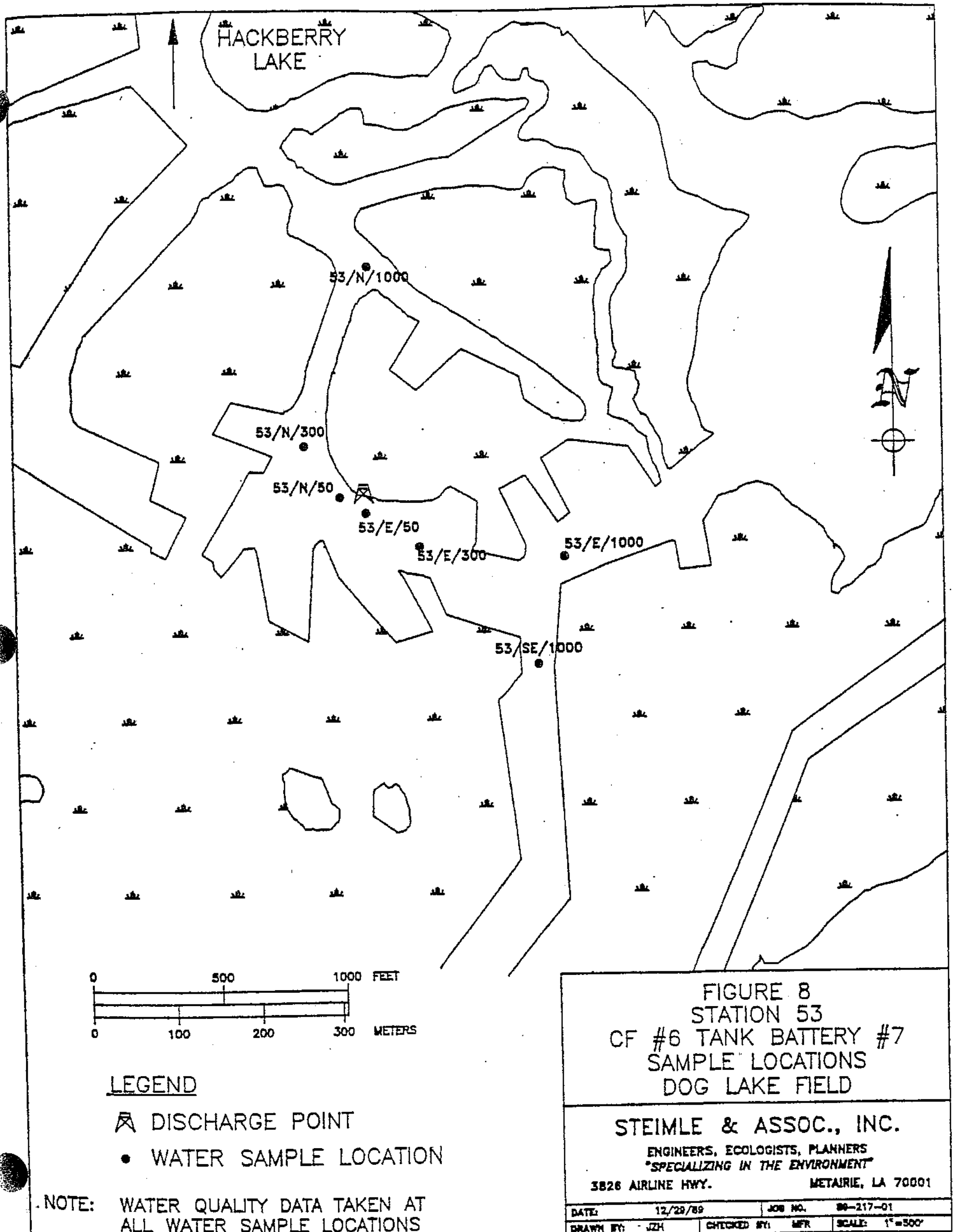
HACKBERRY LAKE
53/N/1000
53/N/300
53/N/50
53/E/50
53/E/300
53/E/1000
53/SE/1000
0 500 1000 FEET
0 100 200 300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 8
STATION 53
CF #6 TANK BATTERY #7
SAMPLE LOCATIONS
DOG LAKE FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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3826 AIRLINE HWY.
METAIRIE, LA 70001
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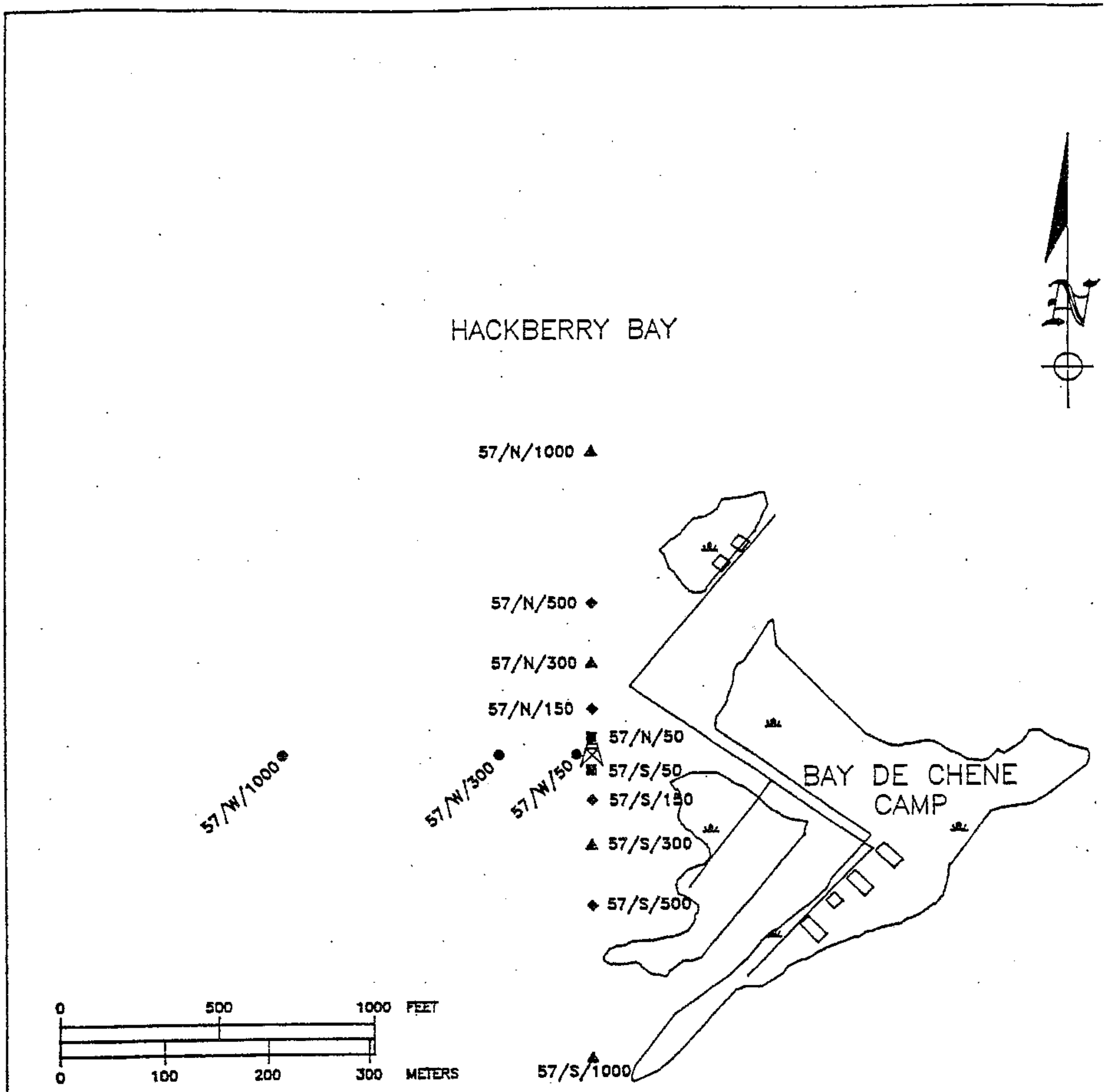
CHECKED BY: MFR
SCALE: 1"=500'



LEGEND

- DISCHARGE POINT
- WATER SAMPLE LOCATION
- SEDIMENT SAMPLE LOCATION
- WATER & SEDIMENT SAMPLE LOCATION
- WATER, SEDIMENT & RADIO-NUCLIDE SAMPLE

NOTE: SEDIMENT SAMPLE TAKEN AT DISCHARGE POINT

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER & SEDIMENT SAMPLE LOCATIONS

FIGURE 9
STATION 57
CF #2 TANK BATTERY #5
SAMPLE LOCATIONS
BAY DE CHENE FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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3826 AIRLINE HWY. METAIRIE, LA 70001

DATE:	1/3/90	JOB NO.	89-217-01
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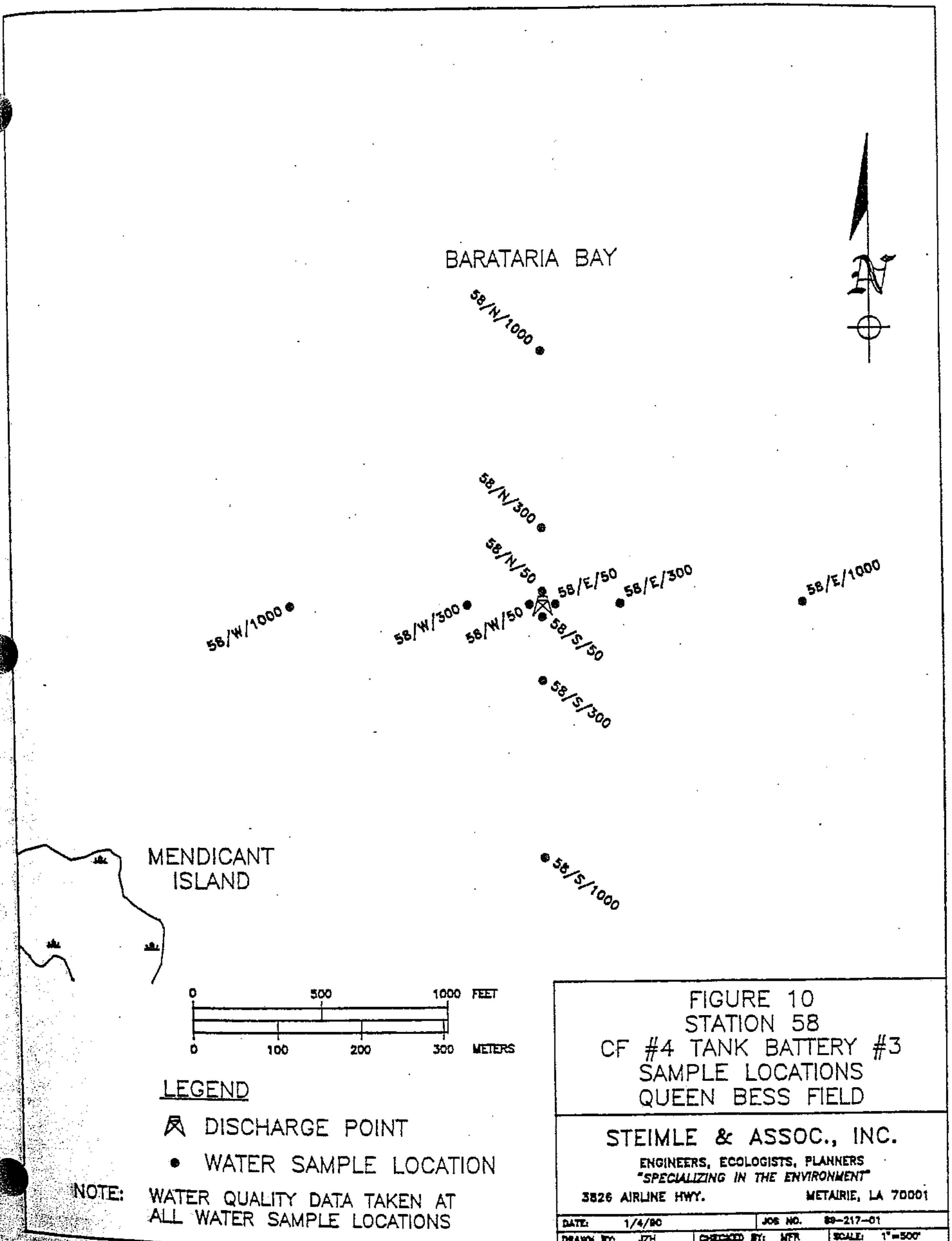
BARATARIA BAY
58/N/1000
58/N/300
58/N/50
58/E/50
58/E/300
58/E/1000
58/W/1000
58/W/300
58/W/50
58/S/50
58/S/300
58/S/1000
MENDICANT ISLAND
0 500 1000 FEET
0 100 200 300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 10
STATION 58
CF #4 TANK BATTERY #3
SAMPLE LOCATIONS
QUEEN BESS FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY.
METAIRIE, LA 70001
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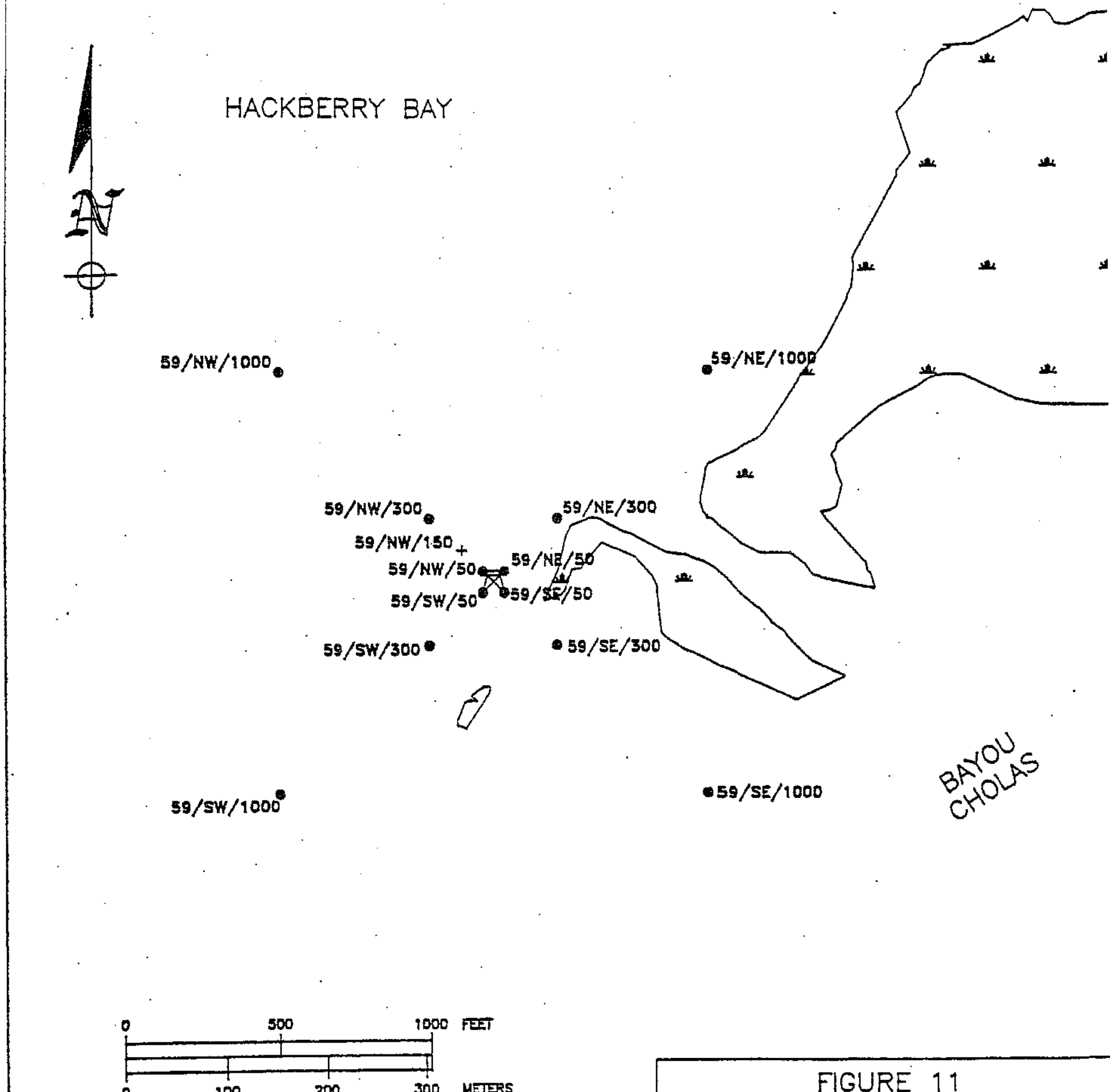
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=500'



LEGEND

DISCHARGE POINT
• WATER SAMPLE LOCATION
+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 11
STATION 59
CF #1 TANK BATTERY #6
SAMPLE LOCATIONS
BAY DE CHENE FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY. METAIRIE, LA 70001

DATE:	1/3/90			JOB NO.	89-217-01
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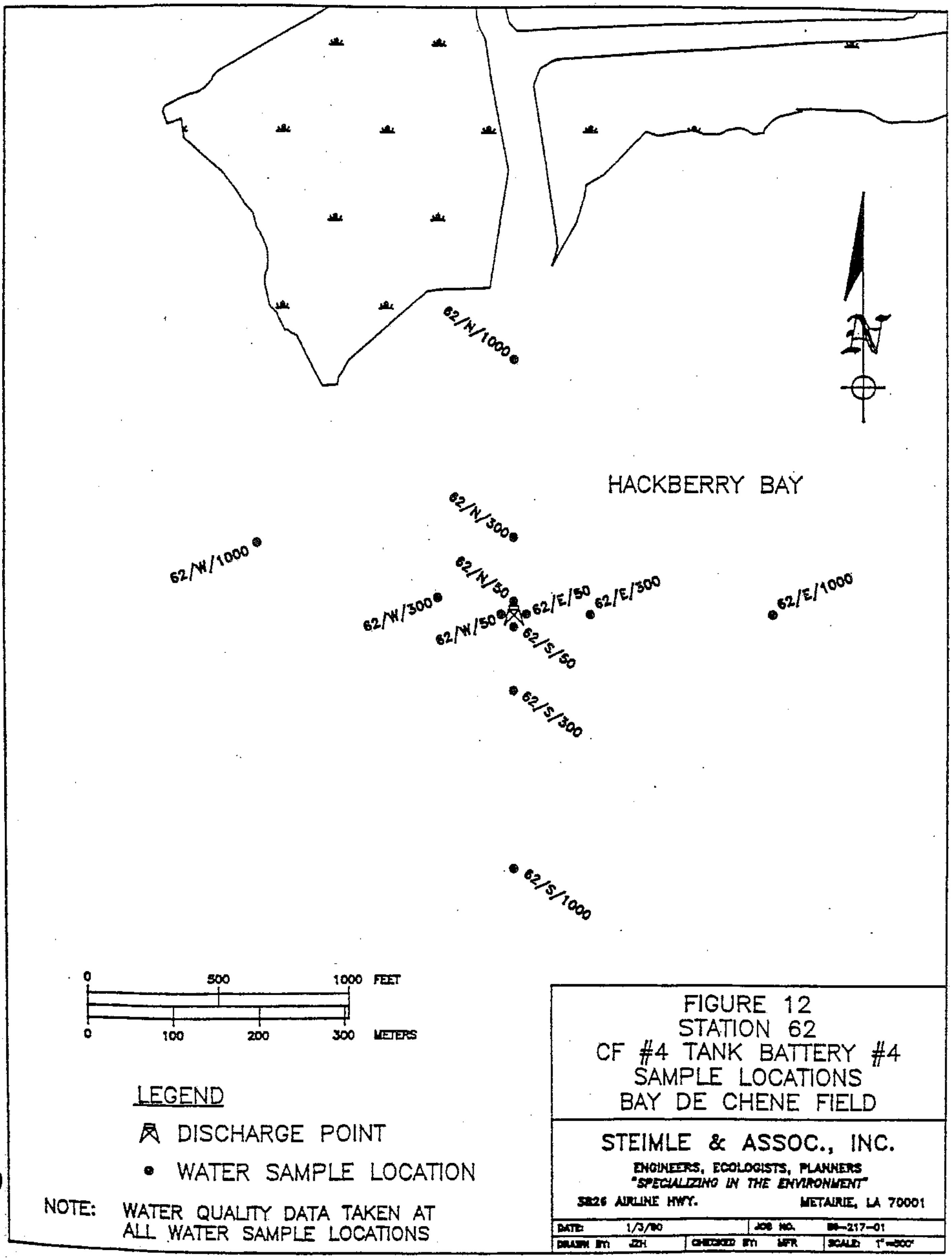

FIGURE 12
STATION 62
CF #4 TANK BATTERY #4
SAMPLE LOCATIONS
BAY DE CHENE FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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5826 AIRLINE HWY. METAIRIE, LA 70001

DATE: 1/3/90		JOB NO. [illegible]-217-01	
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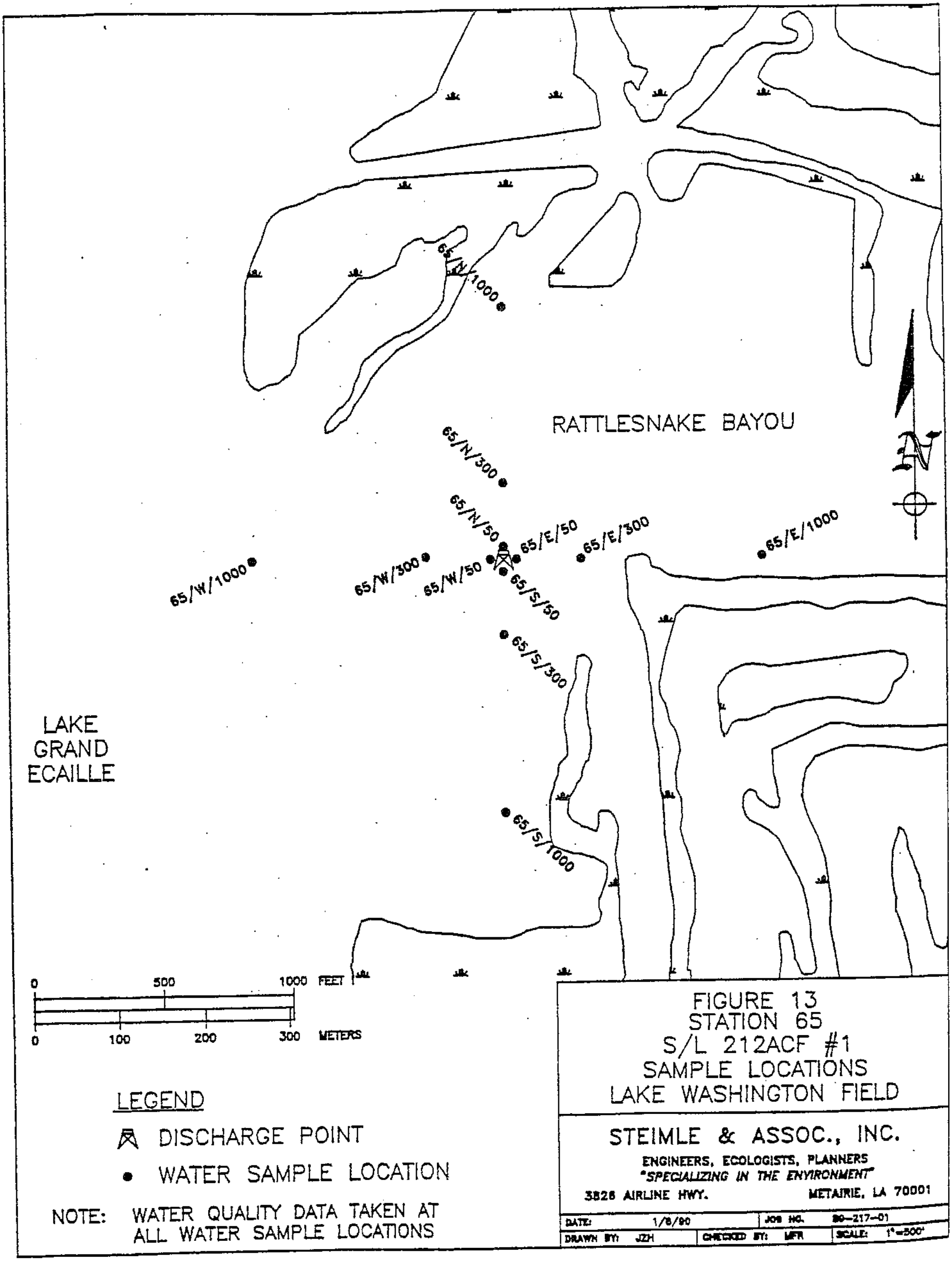
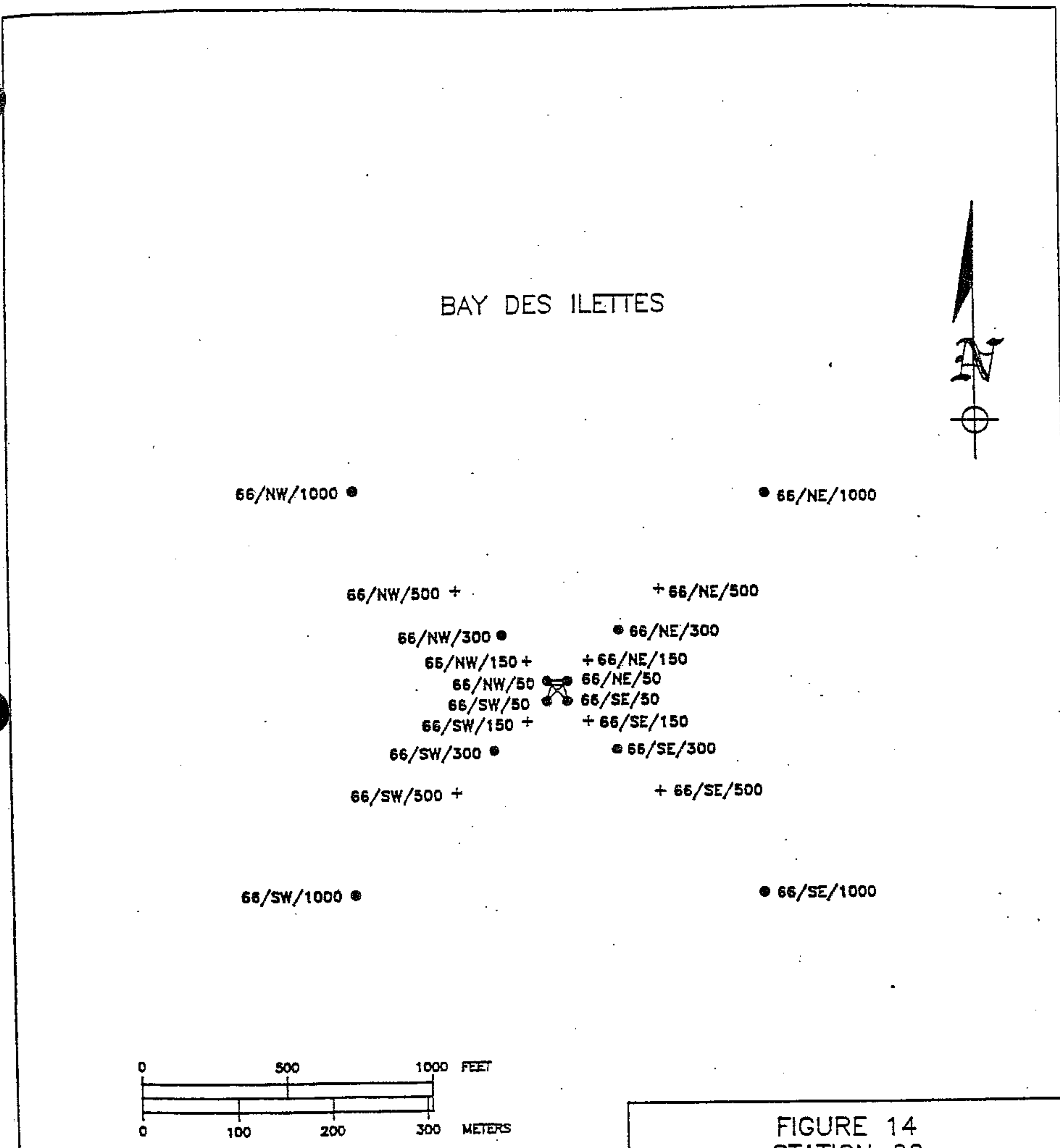

RATTLESNAKE BAYOU
LAKE GRAND ECAILLE
65/N/1000
65/N/300
65/N/50
65/E/50
65/E/300
65/E/1000
65/W/1000
65/W/300
65/W/50
65/S/50
65/S/300
65/S/1000
0 500 1000 FEET
0 100 200 300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 13
STATION 65
S/L 212ACF #1
SAMPLE LOCATIONS
LAKE WASHINGTON FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3828 AIRLINE HWY.
METAIRIE, LA 70001
DATE: 1/8/90
JOB NO. 90-217-01
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=300'



LEGEND

- DISCHARGE POINT
- ● WATER SAMPLE LOCATION
- + WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 14
STATION 66
CM#3 TANK BATTERY #4
SAMPLE LOCATIONS
QUEEN BESS FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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3826 AIRLINE HWY. METAIRIE, LA 70001

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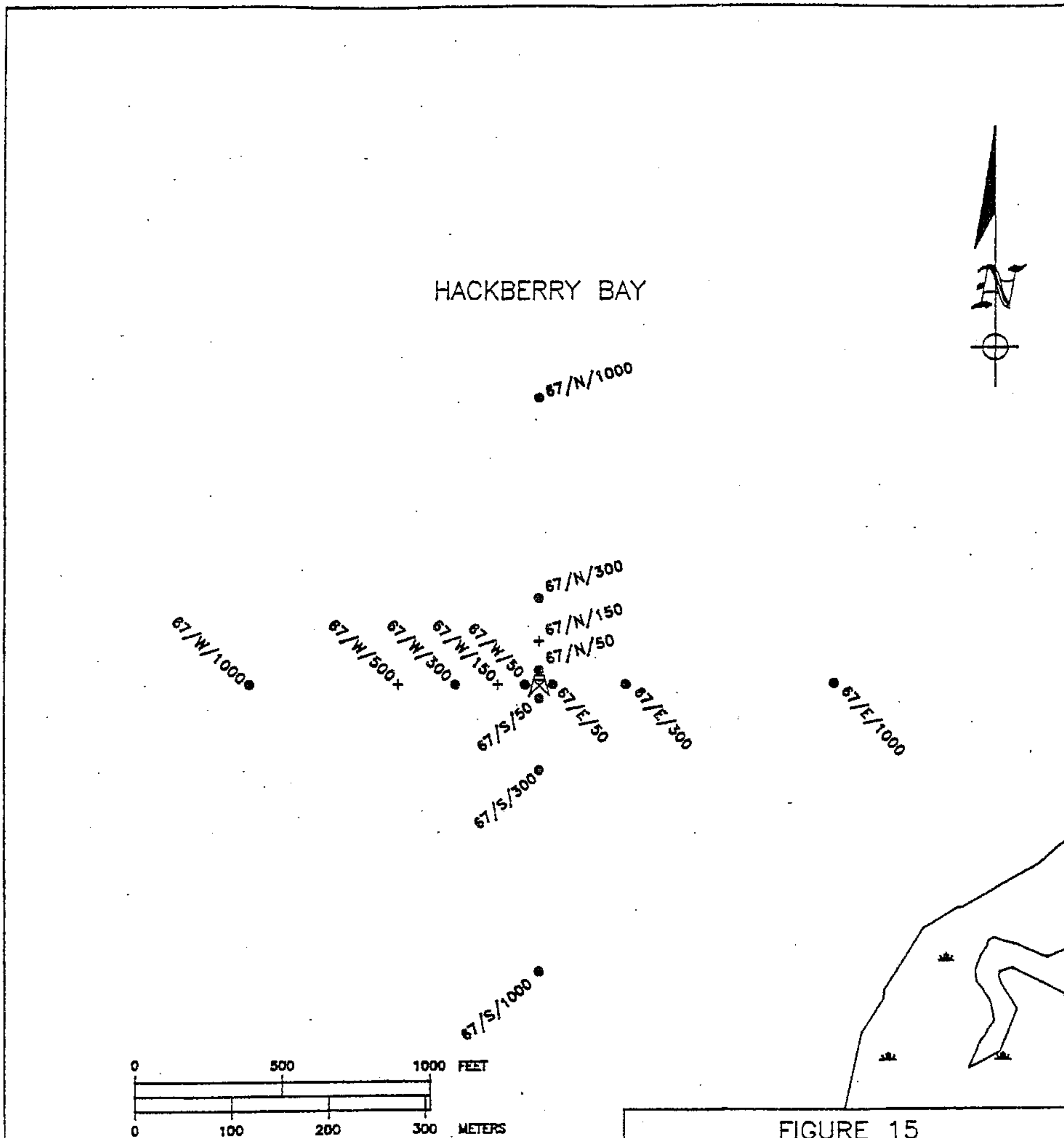

LEGEND

DISCHARGE POINT

• WATER SAMPLE LOCATION

+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 15
STATION 67
CF #5 TANK BATTERY #7
SAMPLE LOCATIONS
BAY DE CHENE FIELD

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"

3826 AIRLINE HWY. METAIRIE, LA 70001

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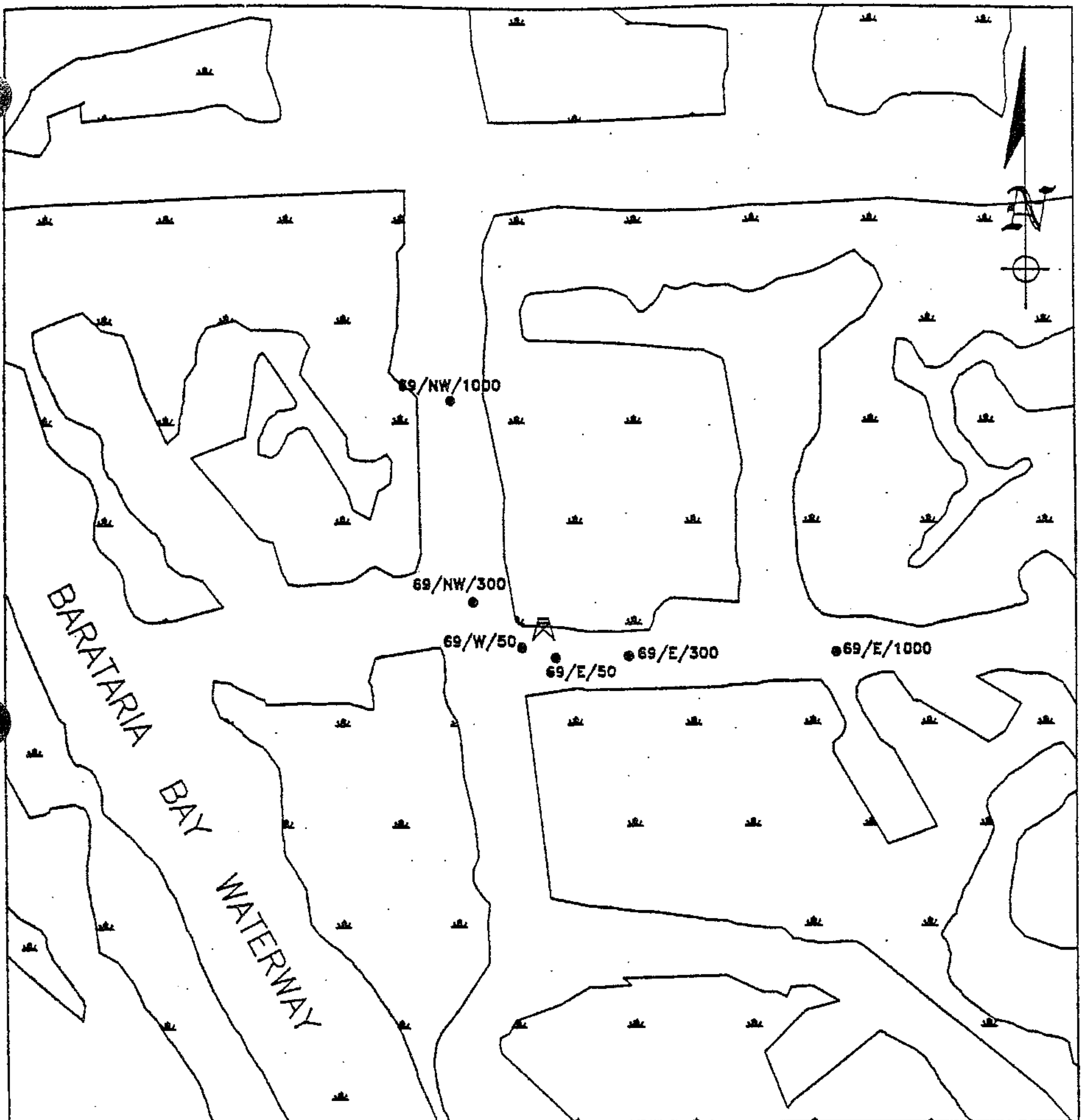

FIGURE 16
STATION 69
CF #10 TANK BATTERY #8
SAMPLE LOCATIONS
LAFITTE FIELD

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3826 AIRLINE HWY. METAIRIE, LA 70001

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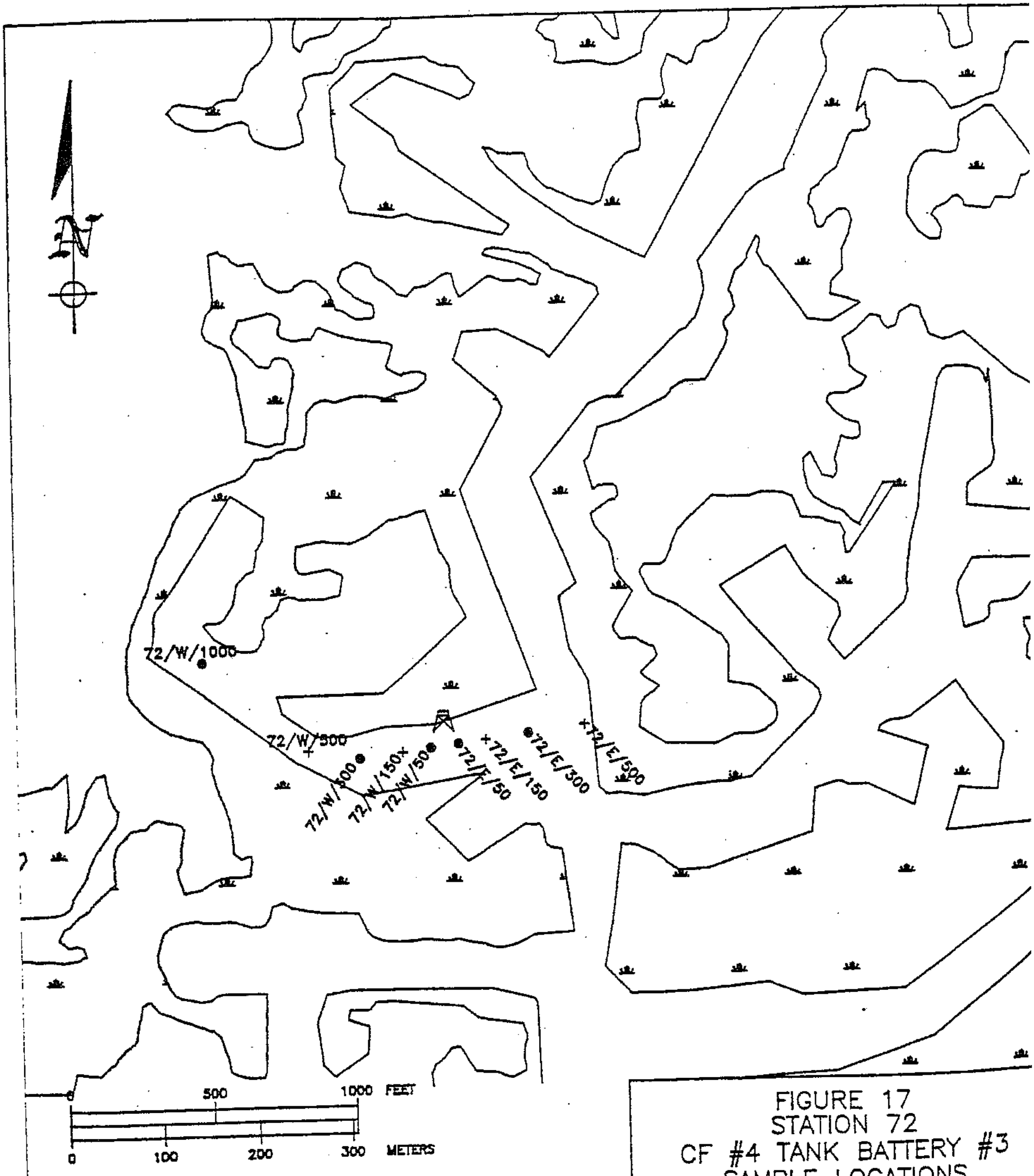
LEGEND

DISCHARGE POINT

WATER SAMPLE LOCATION

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS



LEGEND

DISCHARGE POINT

• WATER SAMPLE LOCATION

+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 17
STATION 72
CF #4 TANK BATTERY #3
SAMPLE LOCATIONS
LAFITTE FIELD

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"

3826 AIRLINE HWY. METAIRIE, LA 70001

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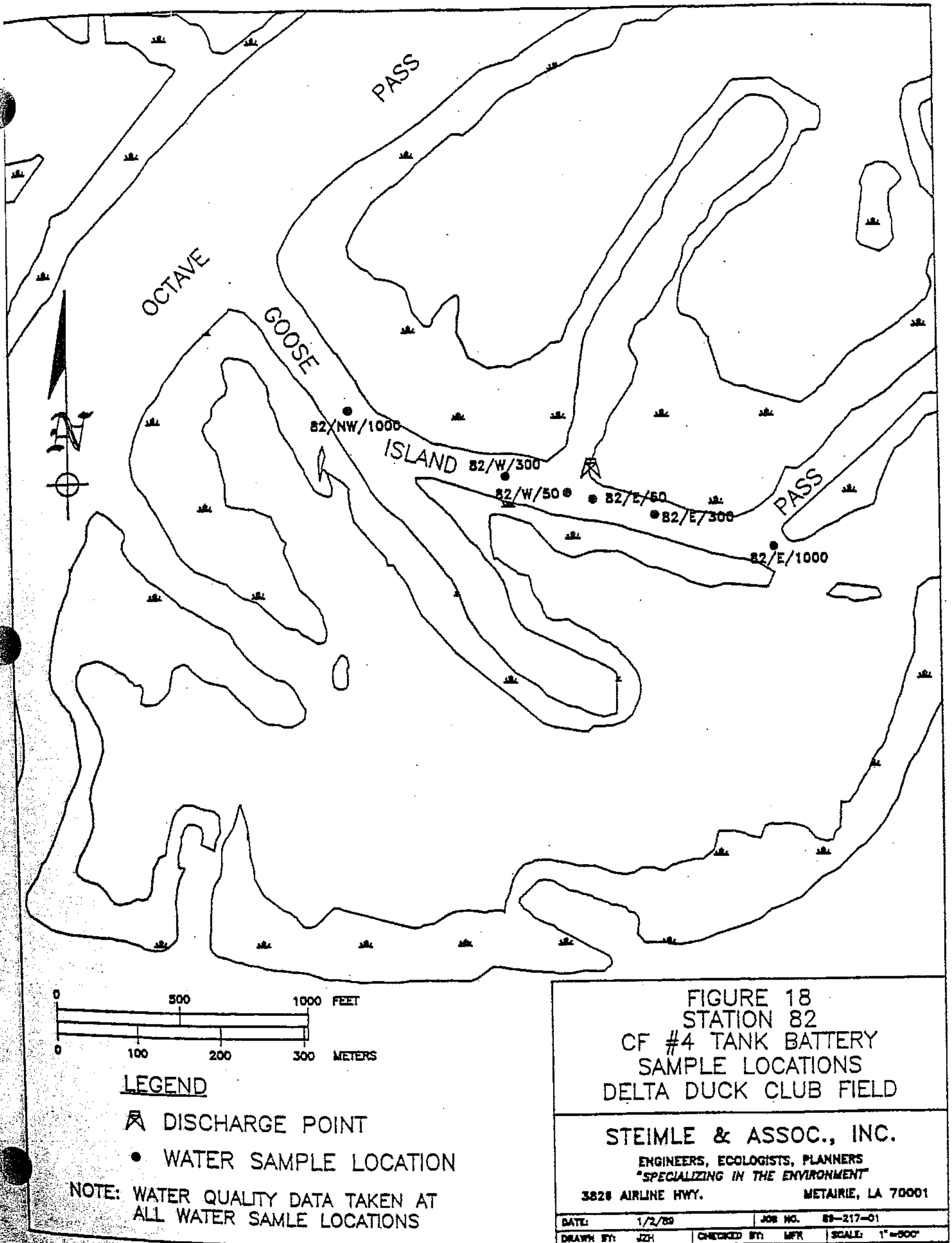
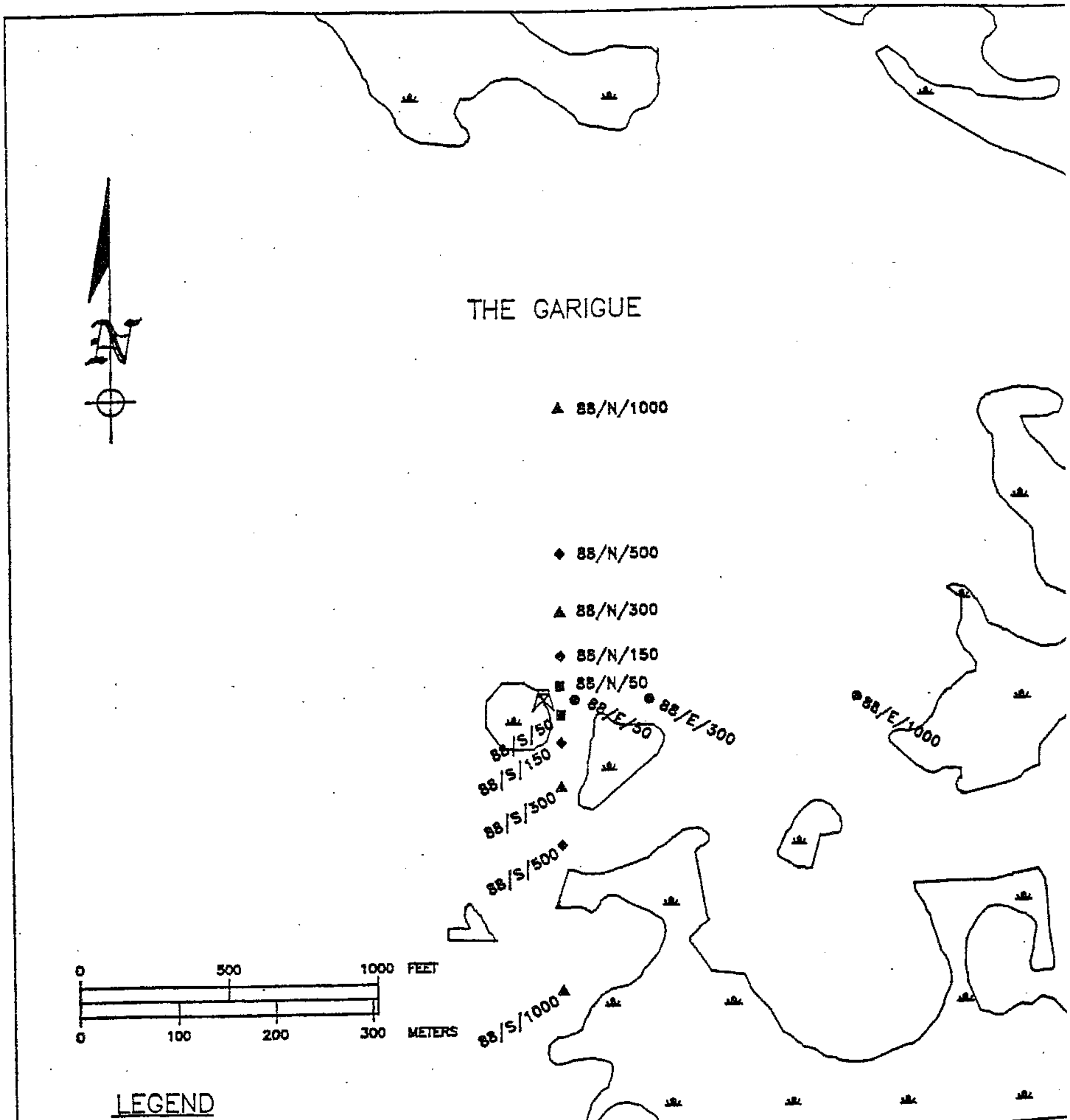


FIGURE 18
STATION 82
CF #4 TANK BATTERY
SAMPLE LOCATIONS
DELTA DUCK CLUB FIELD



LEGEND

- DISCHARGE POINT
- WATER SAMPLE LOCATION
- SEDIMENT SAMPLE LOCATION
- WATER & SEDIMENT SAMPLE LOCATION
- WATER, SEDIMENT & RADIO-NUCLIDE SAMPLE

NOTE: SEDIMENT SAMPLE TAKEN AT DISCHARGE POINT

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER & SEDIMENT SAMPLE LOCATIONS

FIGURE 19
STATION 88
TANK BATTERY #1
SAMPLE LOCATIONS
DELACROIX FIELD

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ENGINEERS, ECOLOGISTS, PLANNERS
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3826 AIRLINE HWY. METAIRIE, LA 70001

DATE:	1/8/90		JOB NO.	89-217-01
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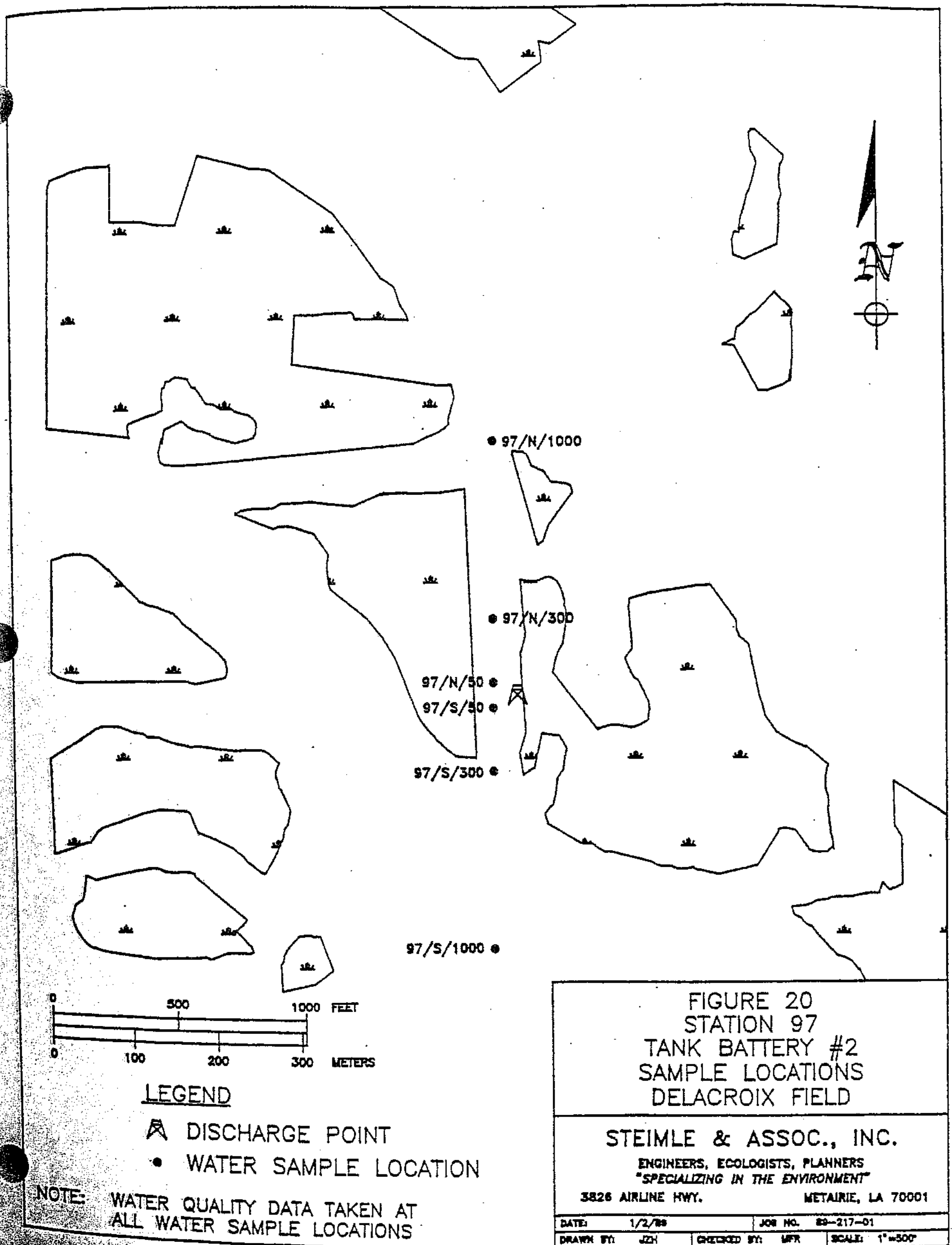
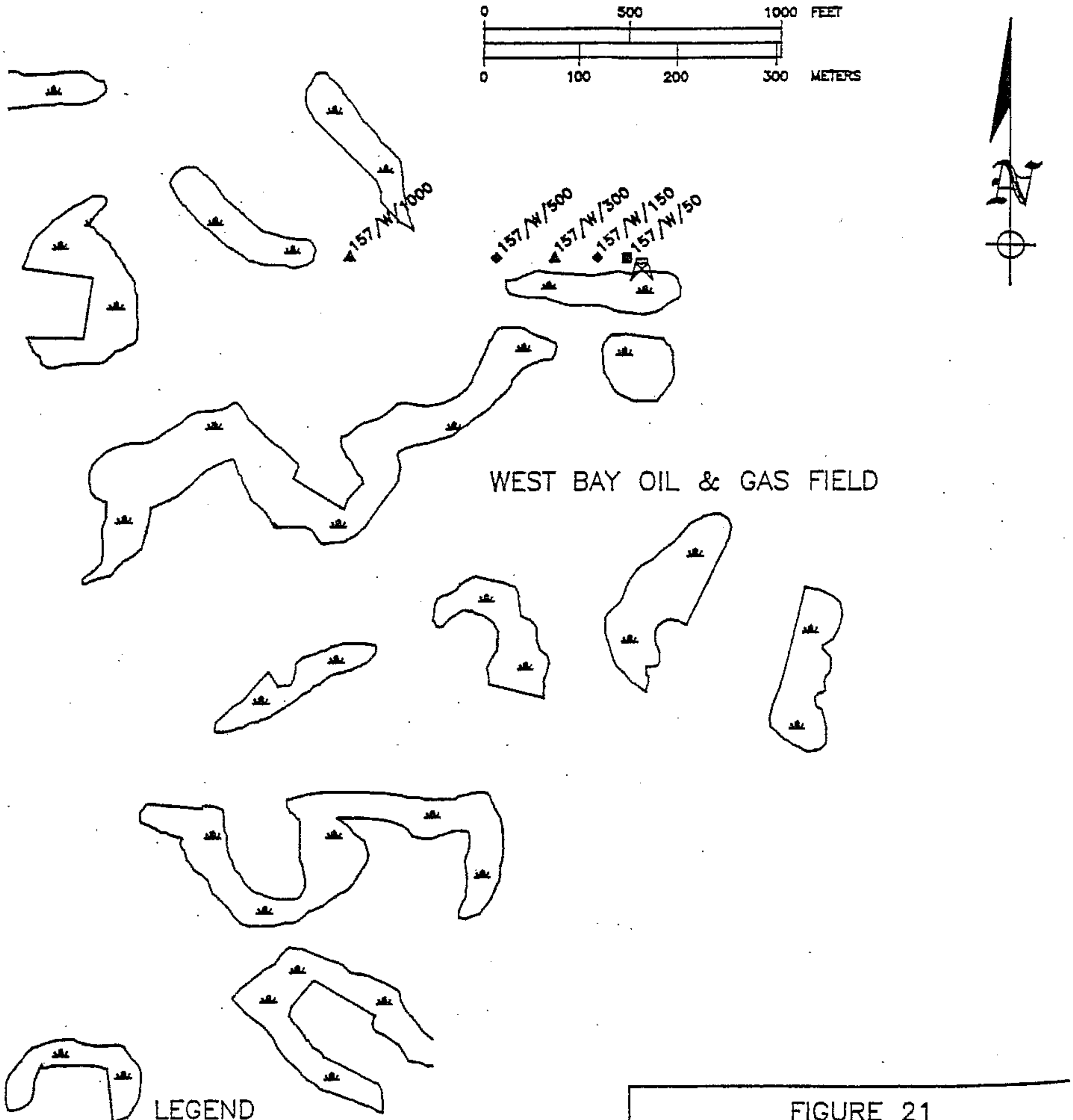


FIGURE 20
STATION 97
TANK BATTERY #2
SAMPLE LOCATIONS
DELACROIX FIELD



LEGEND

- DISCHARGE POINT
- ■ WATER, SEDIMENT & RADIONUCLIDE SAMPLE LOCATION
- ● SEDIMENT SAMPLE LOCATION
- ▲ WATER & SEDIMENT SAMPLE LOCATION

NOTE: SEDIMENT SAMPLE TAKEN AT DISCHARGE POINT

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER & SEDIMENT SAMPLE LOCATIONS

FIGURE 21
STATION 157
FACILITY #2
SAMPLE LOCATIONS
WEST BAY FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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3826 AIRLINE HWY. METAIRIE, LA 70001

DATE: 12/21/89		JOB NO. 89-217-01	
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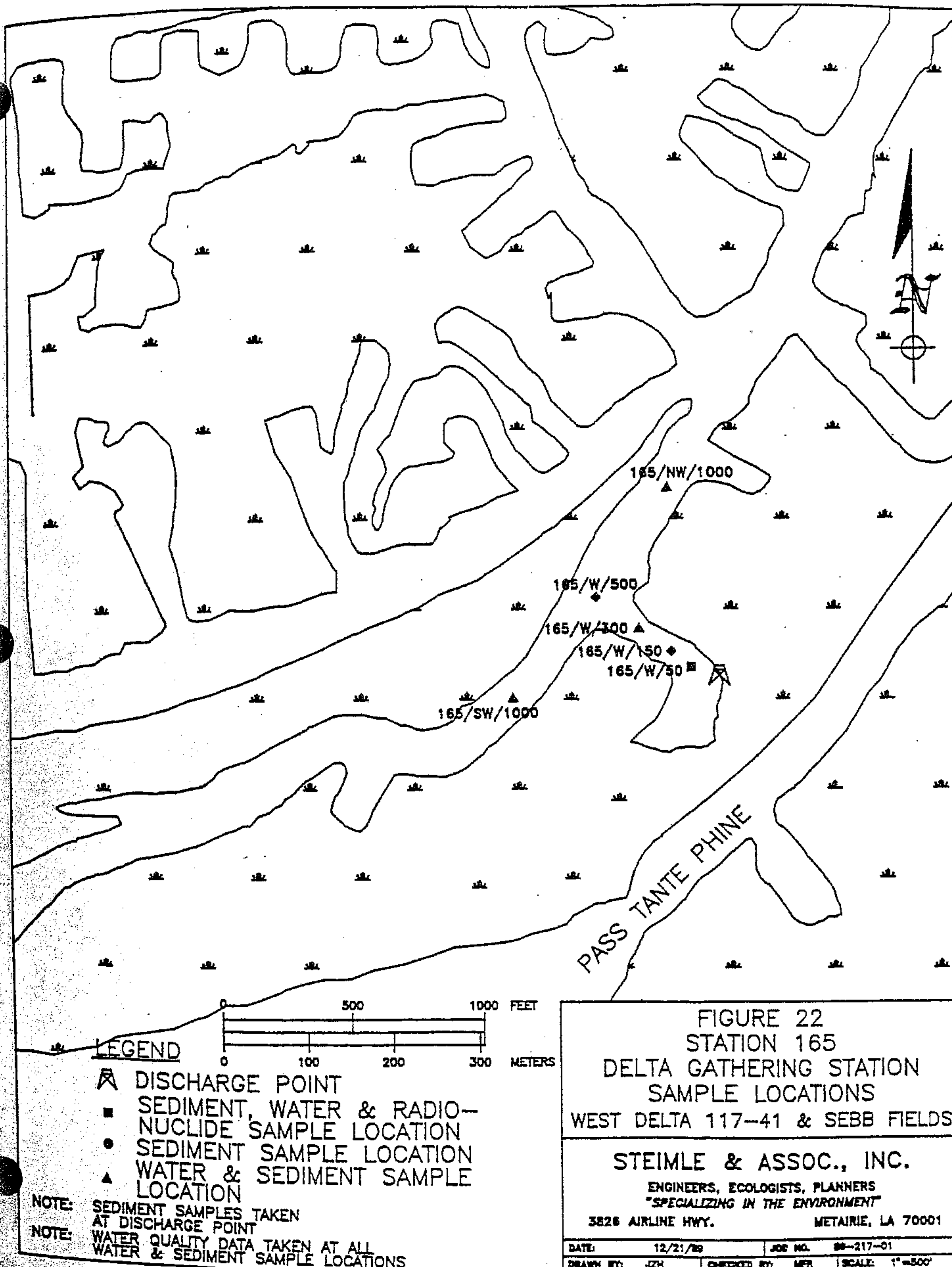
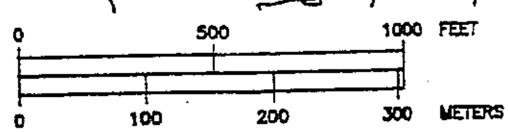


FIGURE 22
STATION 165
DELTA GATHERING STATION
SAMPLE LOCATIONS
WEST DELTA 117-41 & SEBB FIELDS

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY. METAIRIE, LA 70001

DATE: 12/21/89	JOB NO. 89-217-01	
DRAWN BY: JZH	CHECKED BY: MFR	SCALE: 1"=500'



LEGEND

- DISCHARGE POINT
- ● WATER SAMPLE LOCATION
- + WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 23
STATION 170
LL&E WELL 12-14
SAMPLE LOCATIONS
FOUR ISLE DOME FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
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3826 AIRLINE HWY. METAIRIE, LA 70001

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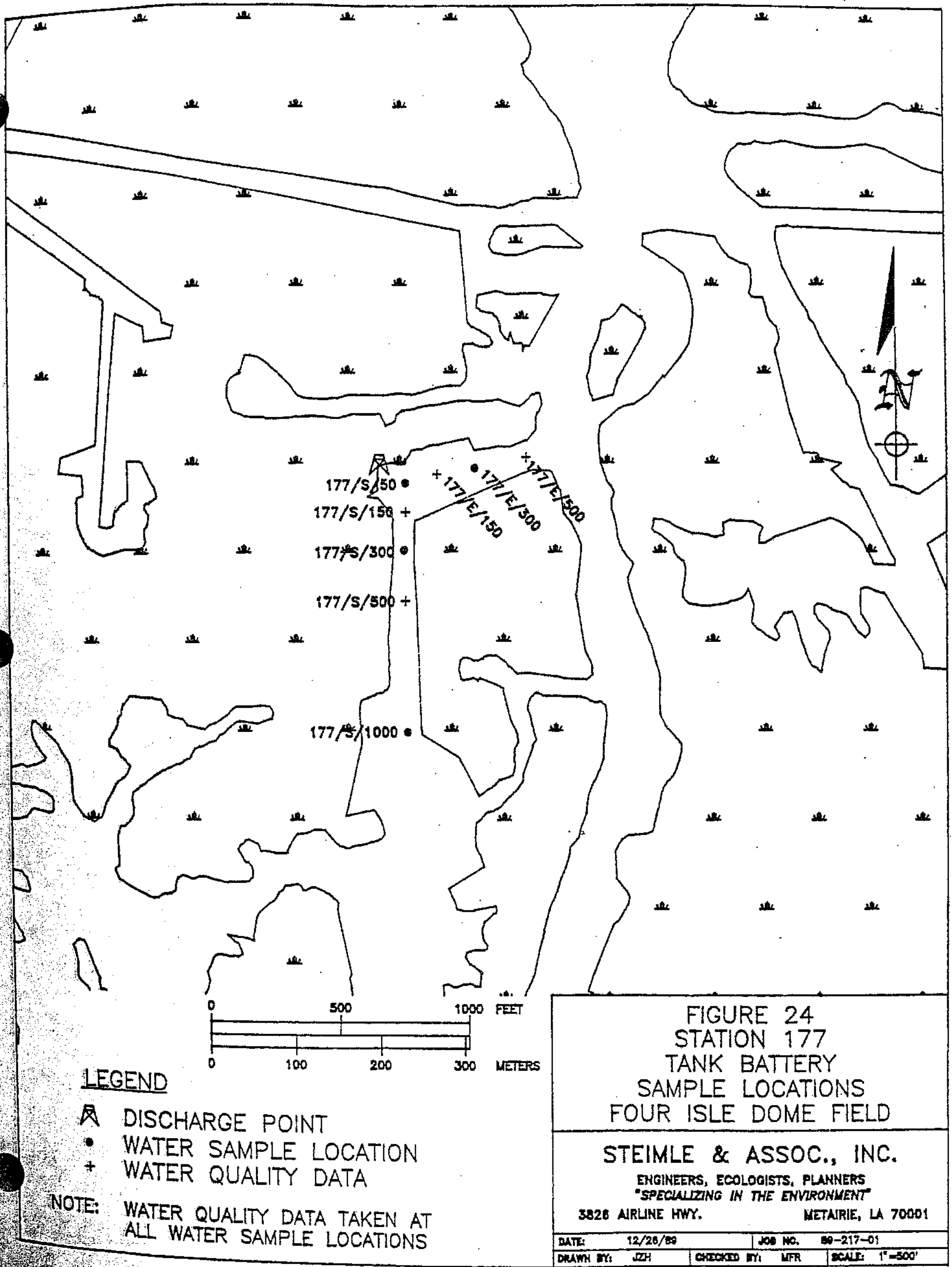

FIGURE 24
STATION 177
TANK BATTERY
SAMPLE LOCATIONS
FOUR ISLE DOME FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY. METAIRIE, LA 70001

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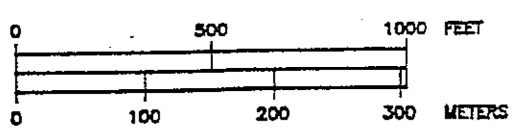


LEGEND

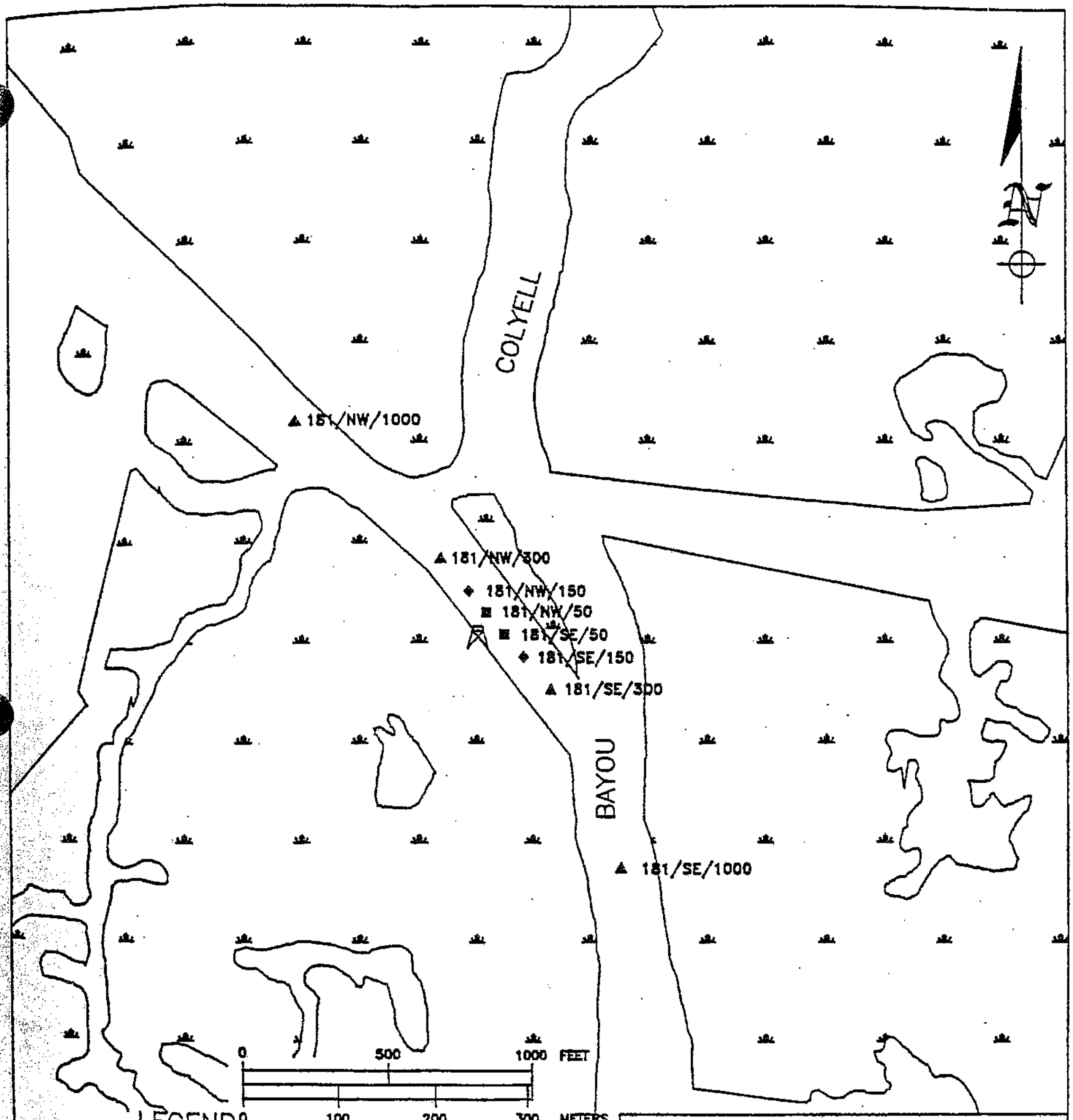
DISCHARGE POINT

NOTE: NO DISCHARGE AT THIS LOCATION AT TIME OF SAMPLING

FIGURE 25
STATION 179
LL&E WELL 22–7
LOCATION OF DISCHARGE POINT
FOUR ISLE DOME FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY. METAIRIE, LA 70001

DATE: 12/28/89		JOB NO. 89-217-01	
DRAWN BY: JZH	CHECKED BY: MFR		SCALE: 1"=500'



LEGEND

- DISCHARGE POINT
- ● SEDIMENT SAMPLE LOCATION
- ▲ WATER & SEDIMENT SAMPLE LOCATION
- ■ WATER, SEDIMENT & RADIO-NUCLIDE SAMPLE LOCATION

NOTE: SEDIMENT SAMPLE TAKEN AT DISCHARGE POINT

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER & SEDIMENT SAMPLE LOCATIONS

FIGURE 26
STATION 181
LL&E WELL 222-D
SAMPLE LOCATIONS
FOUR ISLE DOME FIELD

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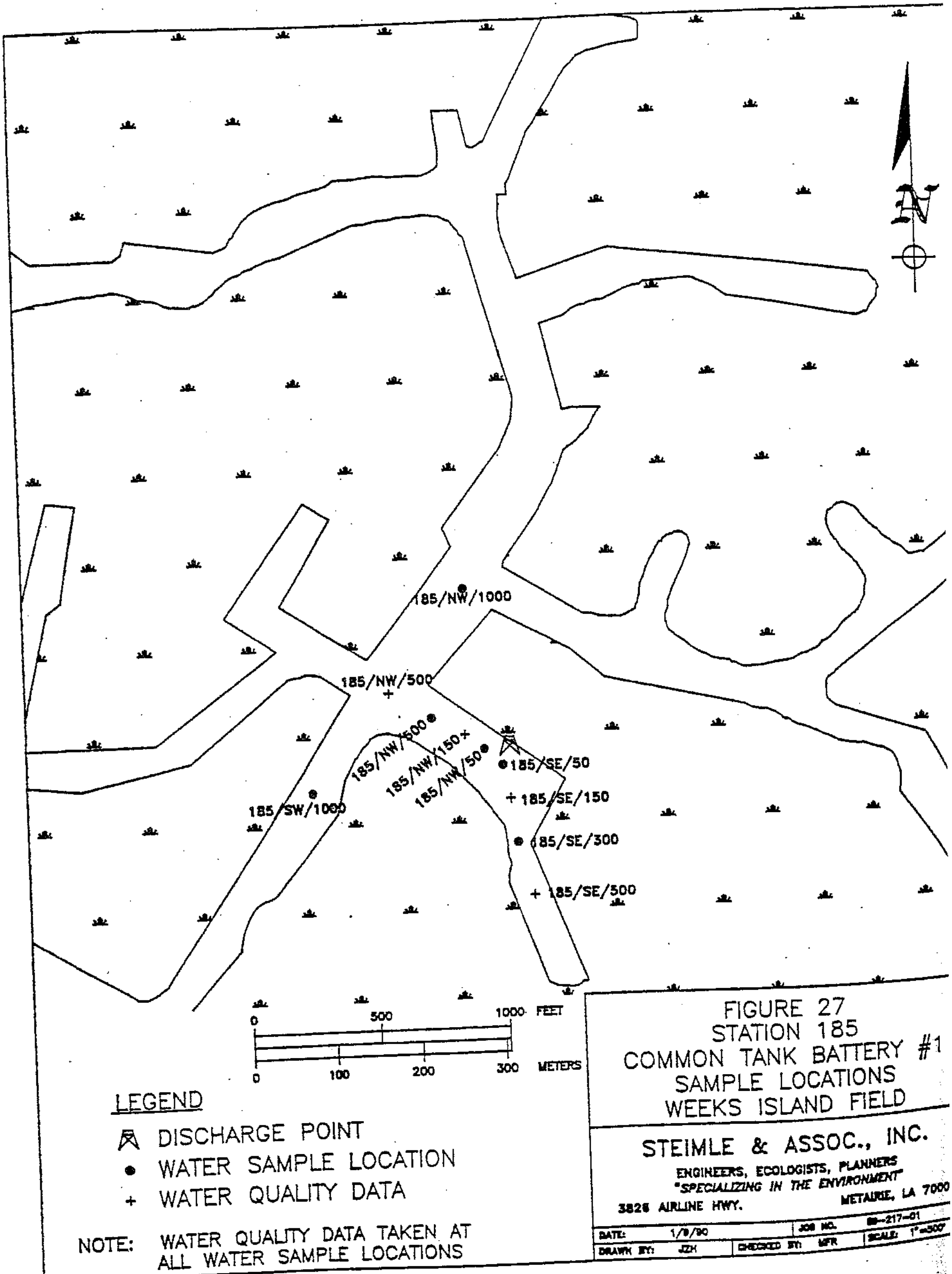
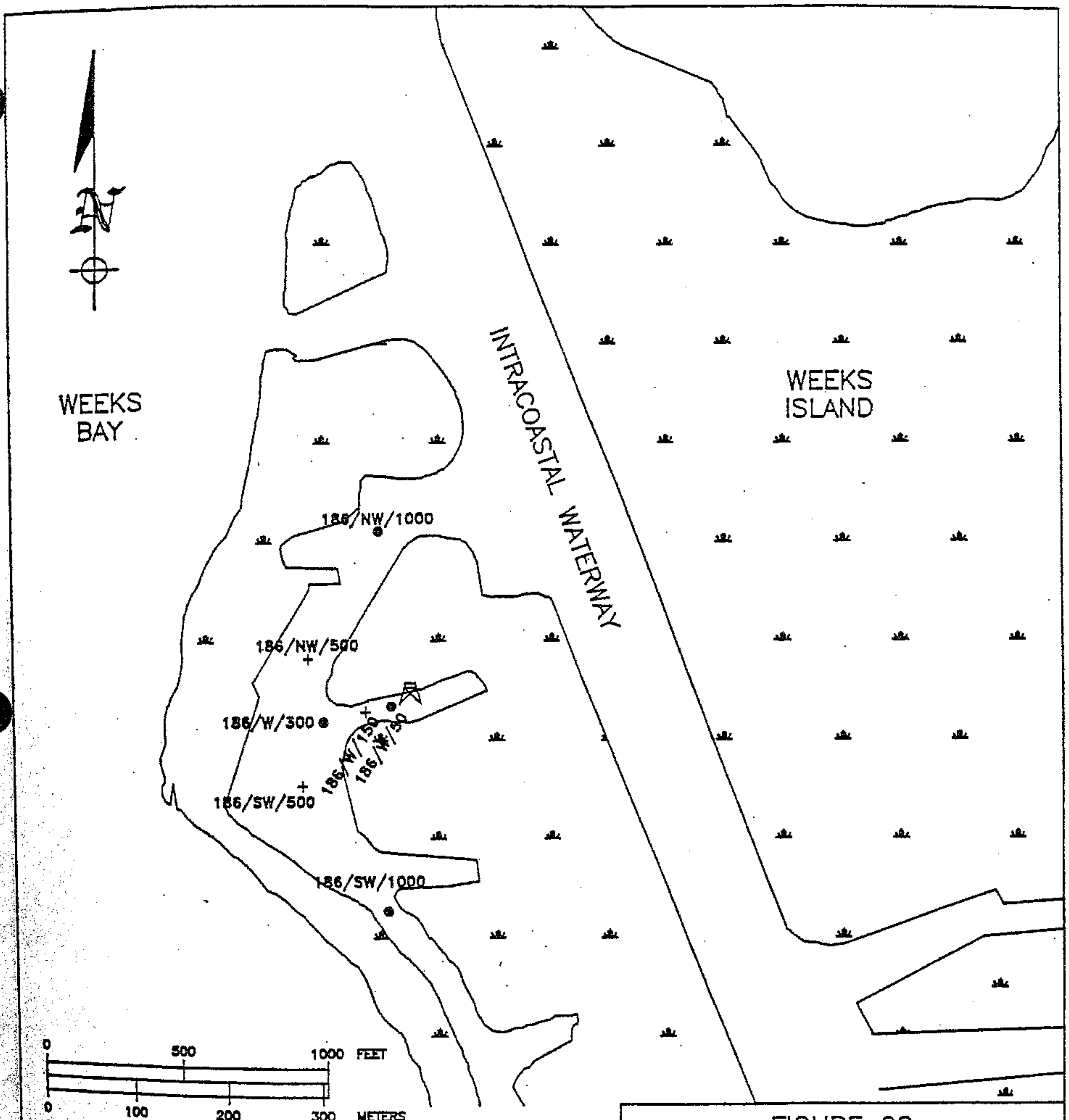
3826 AIRLINE HWY. METAIRIE, LA 70001

DATE: 12/26/89		JOB NO.	89-217-01
DRAWN BY: JZH	CHECKED BY: MFR		SCALE: 1"=500'


185/NW/1000
185/NW/500
185/NW/300
185/NW/150
185/NW/50
185/SW/1000
185/SE/50
185/SE/150
185/SE/300
185/SE/500
0 500 1000 FEET
0 100 200 300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
WATER QUALITY DATA
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 27
STATION 185
COMMON TANK BATTERY #1
SAMPLE LOCATIONS
WEEKS ISLAND FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3825 AIRLINE HWY.
METAIRIE, LA 7000
DATE: 1/9/90
JOB NO.
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=500'



LEGEND

DISCHARGE POINT

• WATER SAMPLE LOCATION

+ WATER QUALITY DATA

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS

FIGURE 28
STATION 186
R.H. GOODRICH TANK BATTERY
SAMPLE LOCATIONS
WEEKS ISLAND FIELD

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ENGINEERS, ECOLOGISTS, PLANNERS
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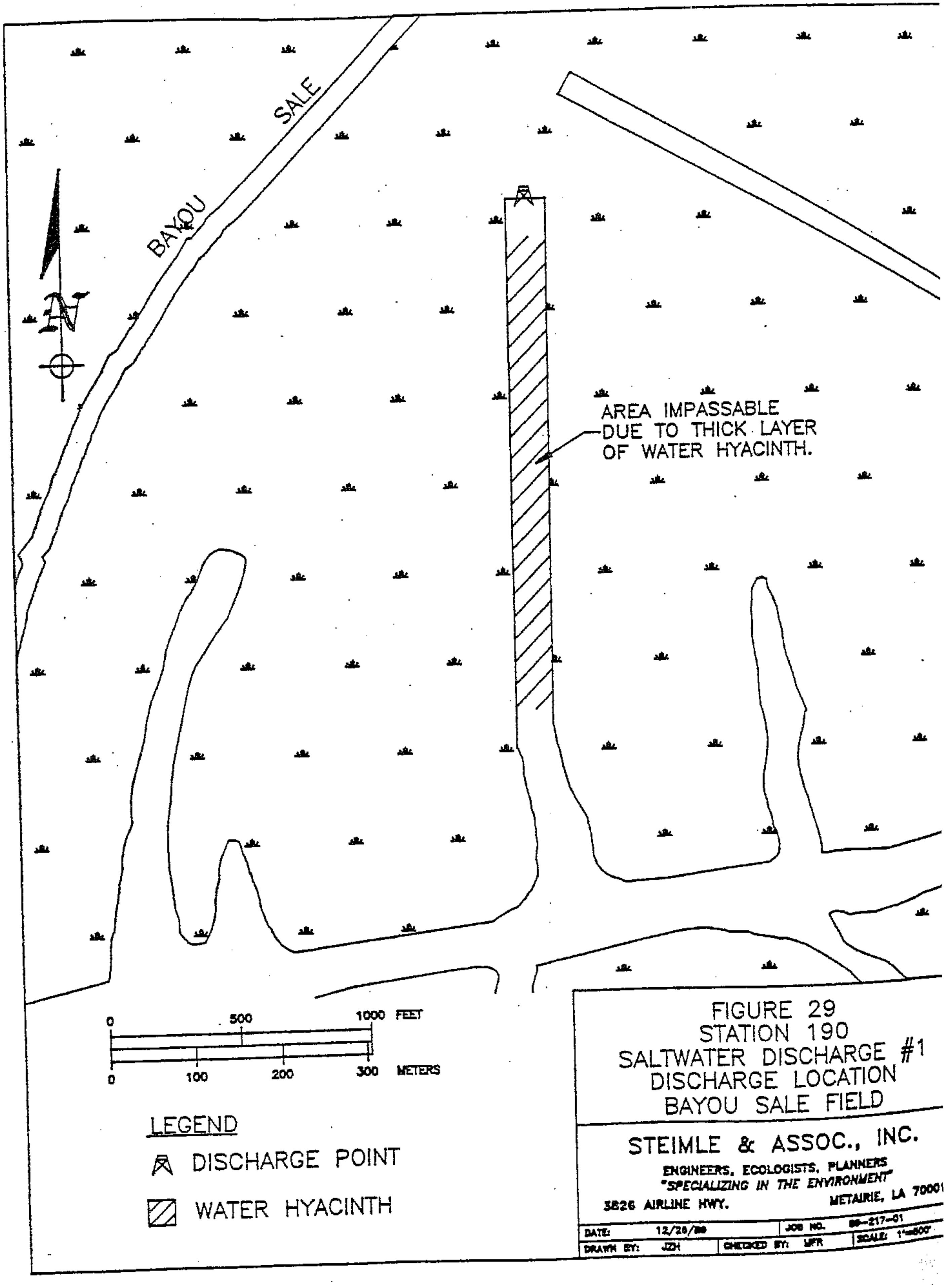
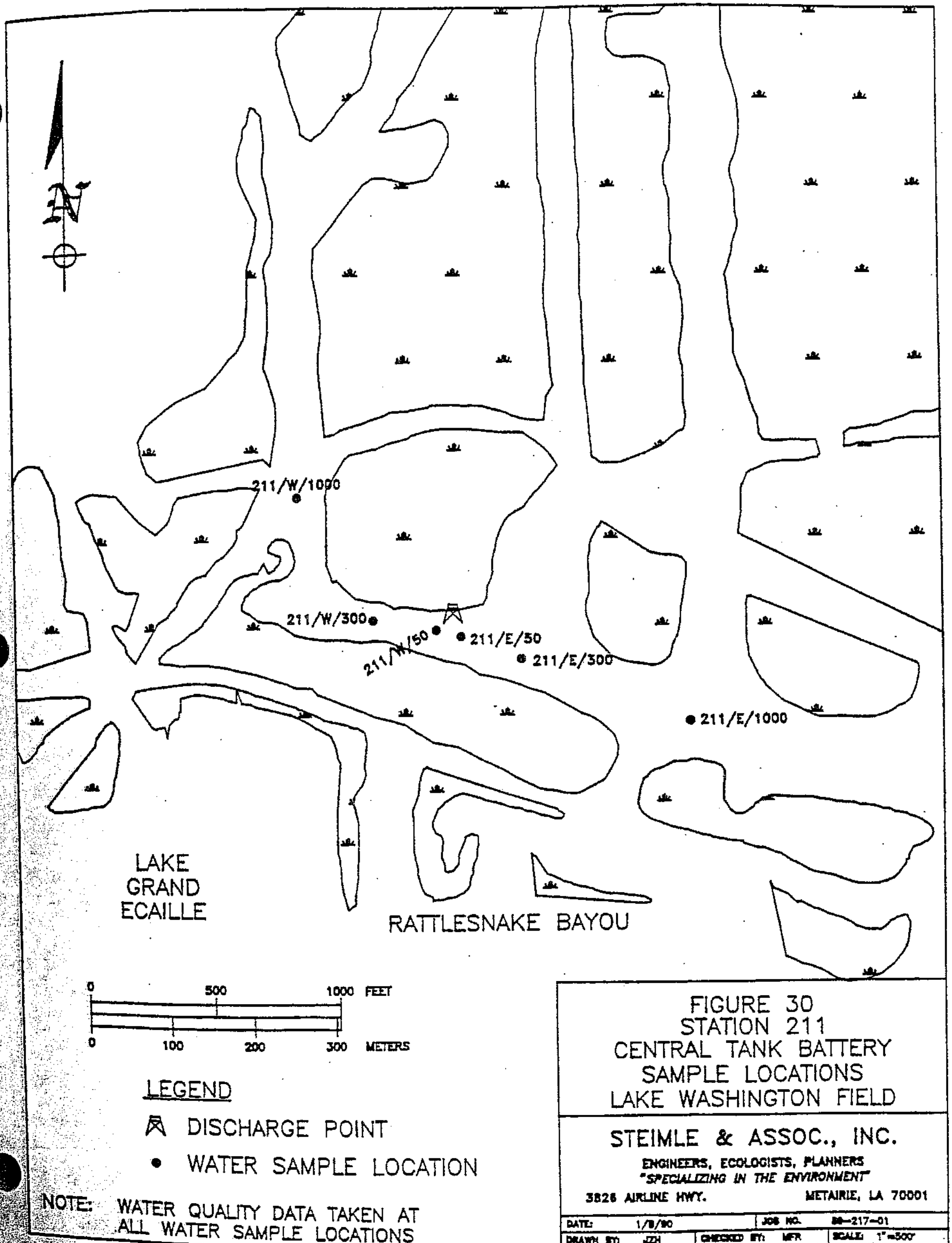
3828 AIRLINE HWY. METAIRIE, LA 70001

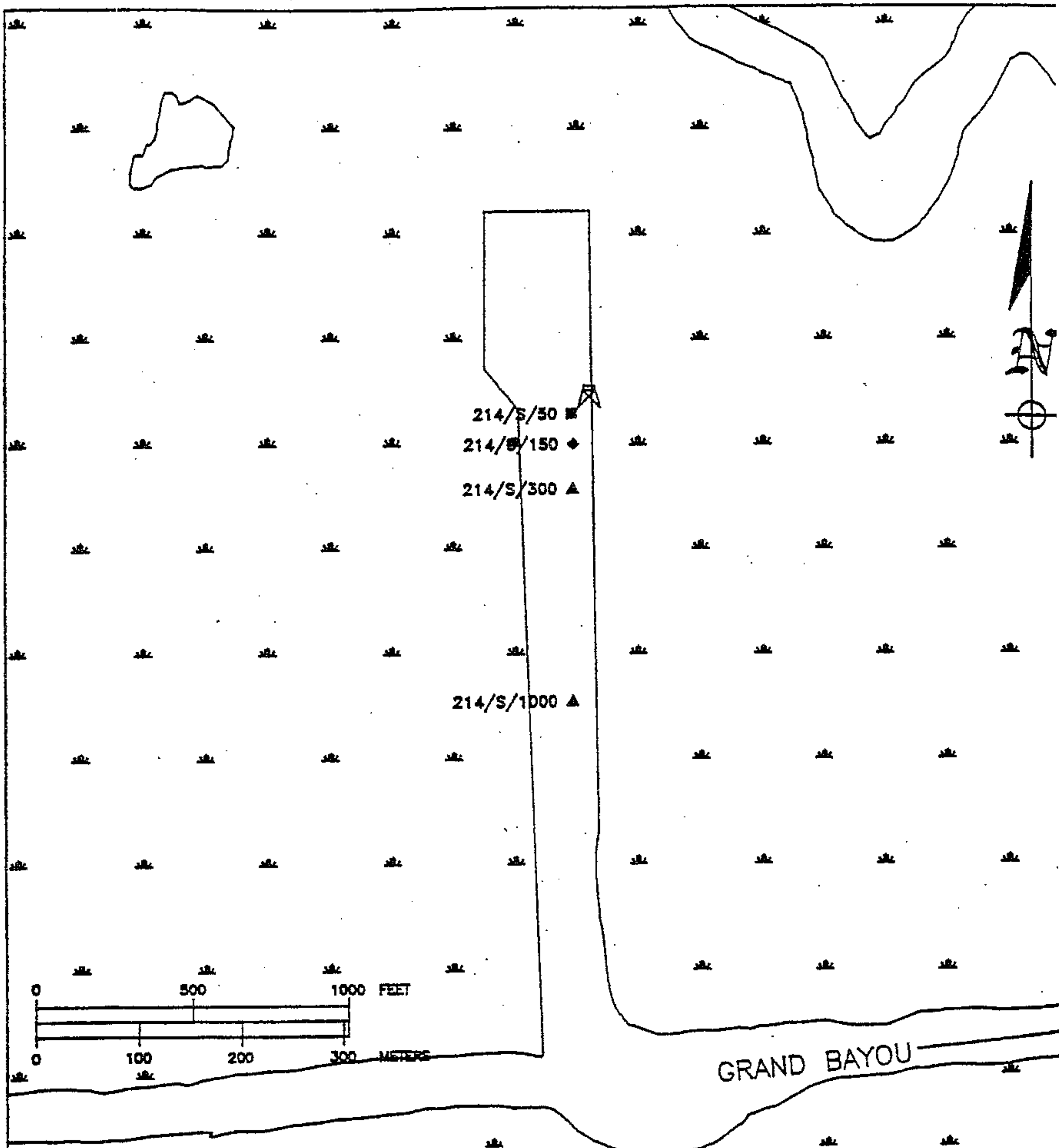
DATE: 1/9/90		JOB NO. 89-217-01	
DRAWN BY: JZH	CHECKED BY: MFR		SCALE: 1"=500'



BAYOU SALE
AREA IMPASSABLE DUE TO THICK LAYER OF WATER HYACINTH.
0
500
1000 FEET
0
100
200
300 METERS
LEGEND
DISCHARGE POINT
WATER HYACINTH
FIGURE 29
STATION 190
SALTWATER DISCHARGE #1
DISCHARGE LOCATION
BAYOU SALE FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY.
METAIRIE, LA 7000
DATE: 12/28/89
JOB NO. 89-217-01
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=500'



211/W/1000
211/W/300
211/W/50
211/E/50
211/E/300
211/E/1000
LAKE GRAND ECAILLE
RATTLESNAKE BAYOU
0
500
1000 FEET
0
100
200
300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 30
STATION 211
CENTRAL TANK BATTERY
SAMPLE LOCATIONS
LAKE WASHINGTON FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY.
METAIRIE, LA 70001
DATE:
JOB NO.
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=500'



LEGEND

- DISCHARGE POINT
- ● SEDIMENT SAMPLE LOCATION
- ▲ WATER & SEDIMENT SAMPLE LOCATION
- ■ WATER, SEDIMENT & RADIO-NUCLIDE SAMPLE

NOTE: SEDIMENT SAMPLE TAKEN AT DISCHARGE POINT

NOTE: WATER QUALITY DATA TAKEN AT ALL WATER & SEDIMENT SAMPLE LOCATIONS

FIGURE 31
STATION 214
HOMEPLACE TANK BATTE
SAMPLE LOCATIONS
LAKE WASHINGTON FIEL

STEIMLE & ASSOC., INC
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3828 AIRLINE HWY. METAIRIE, LA

DATE: 12/28/88	JOB NO. 88-217-01
DRAWN BY: JZH / CHECKED BY: MFR	SCALE: 1"

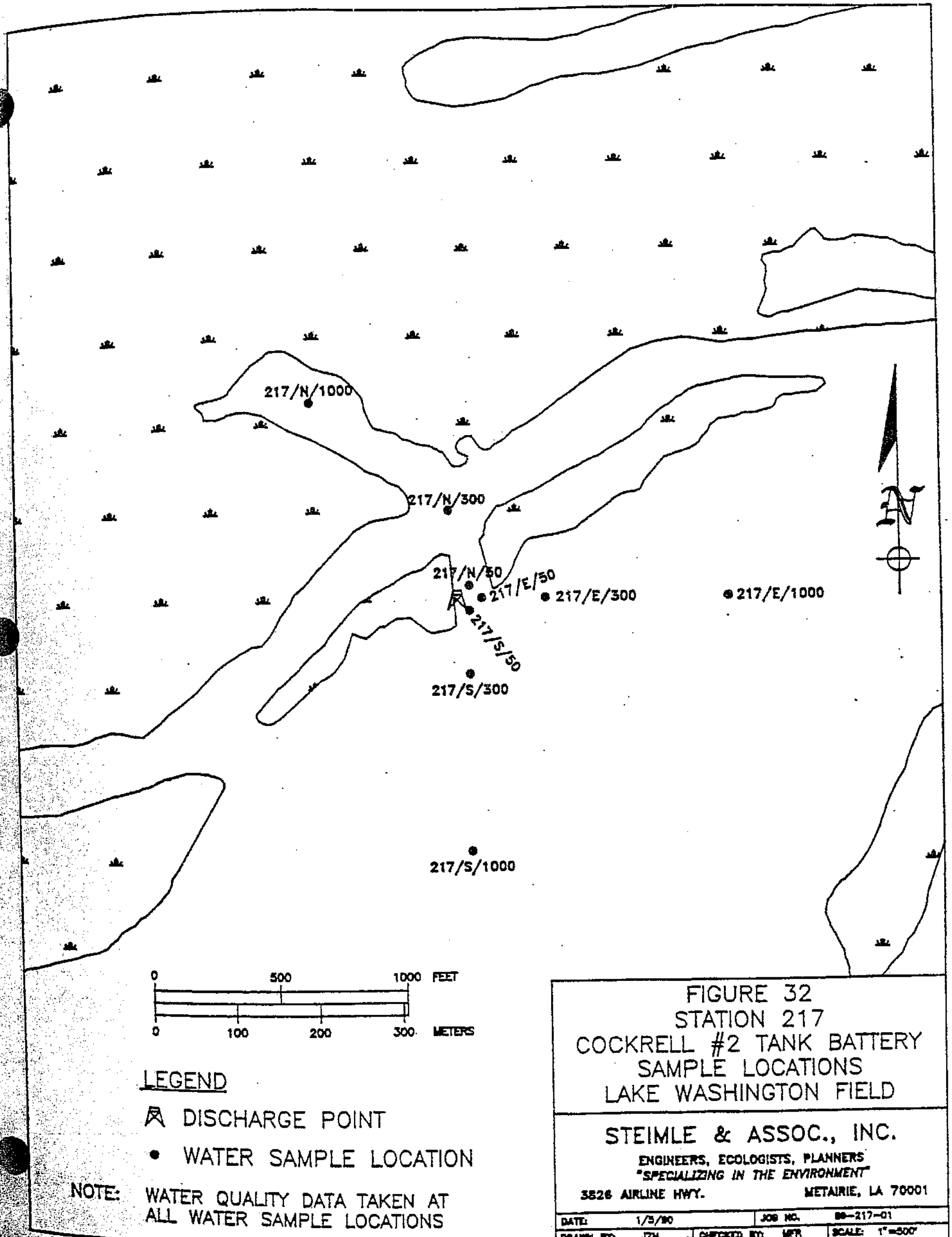
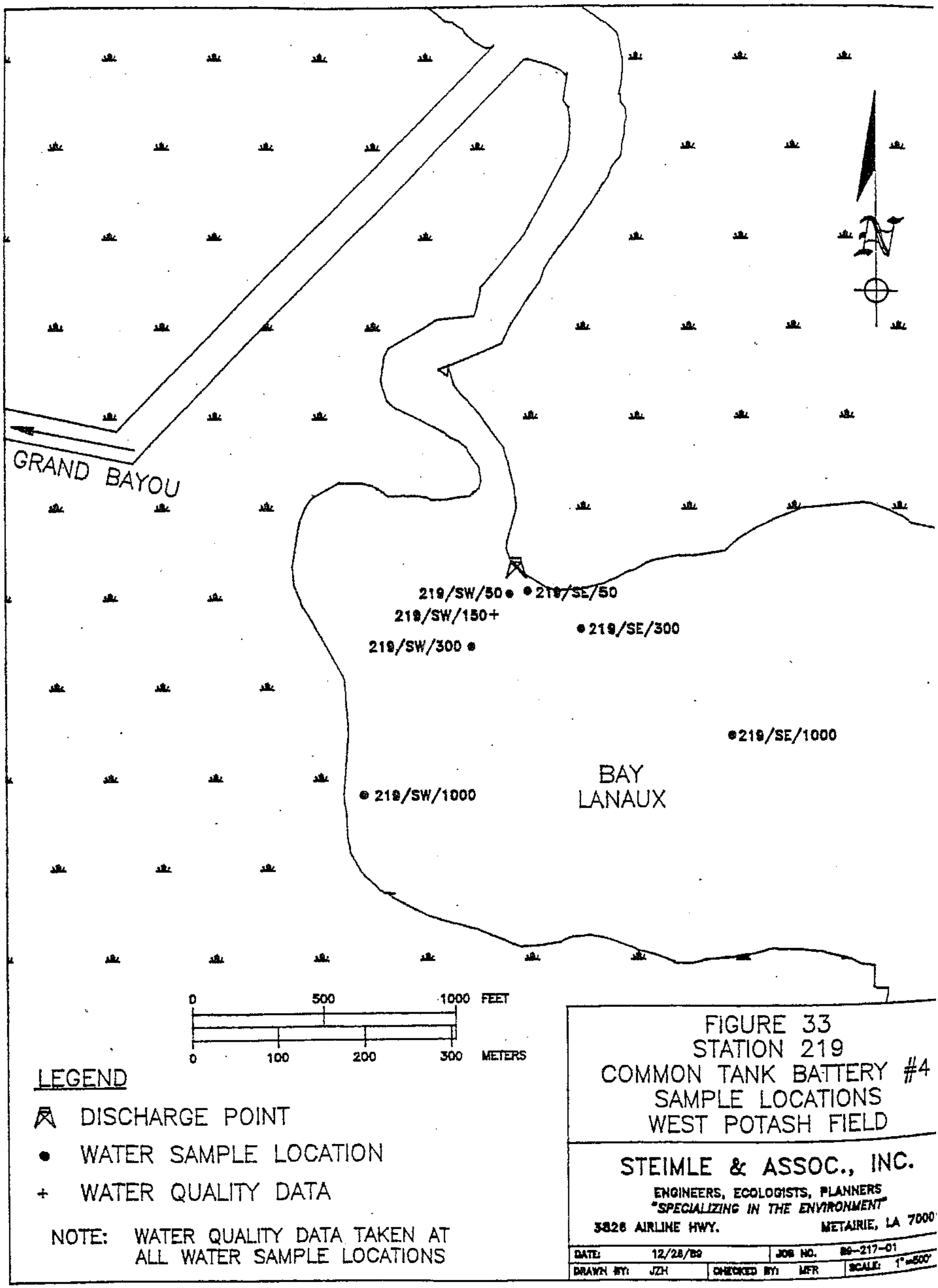


FIGURE 32
STATION 217
COCKRELL #2 TANK BATTERY
SAMPLE LOCATIONS
LAKE WASHINGTON FIELD


GRAND BAYOU
219/SW/50
219/SE/50
219/SW/150+
219/SE/300
219/SW/300
219/SE/1000
219/SW/1000
BAY
LANAUX
0
500
1000 FEET
0
100
200
300
METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
WATER QUALITY DATA
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 33
STATION 219
COMMON TANK BATTERY #4
SAMPLE LOCATIONS
WEST POTASH FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY.
METAIRIE, LA 7000
DATE: 12/28/89
JOB NO. 89-217-01
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=500'

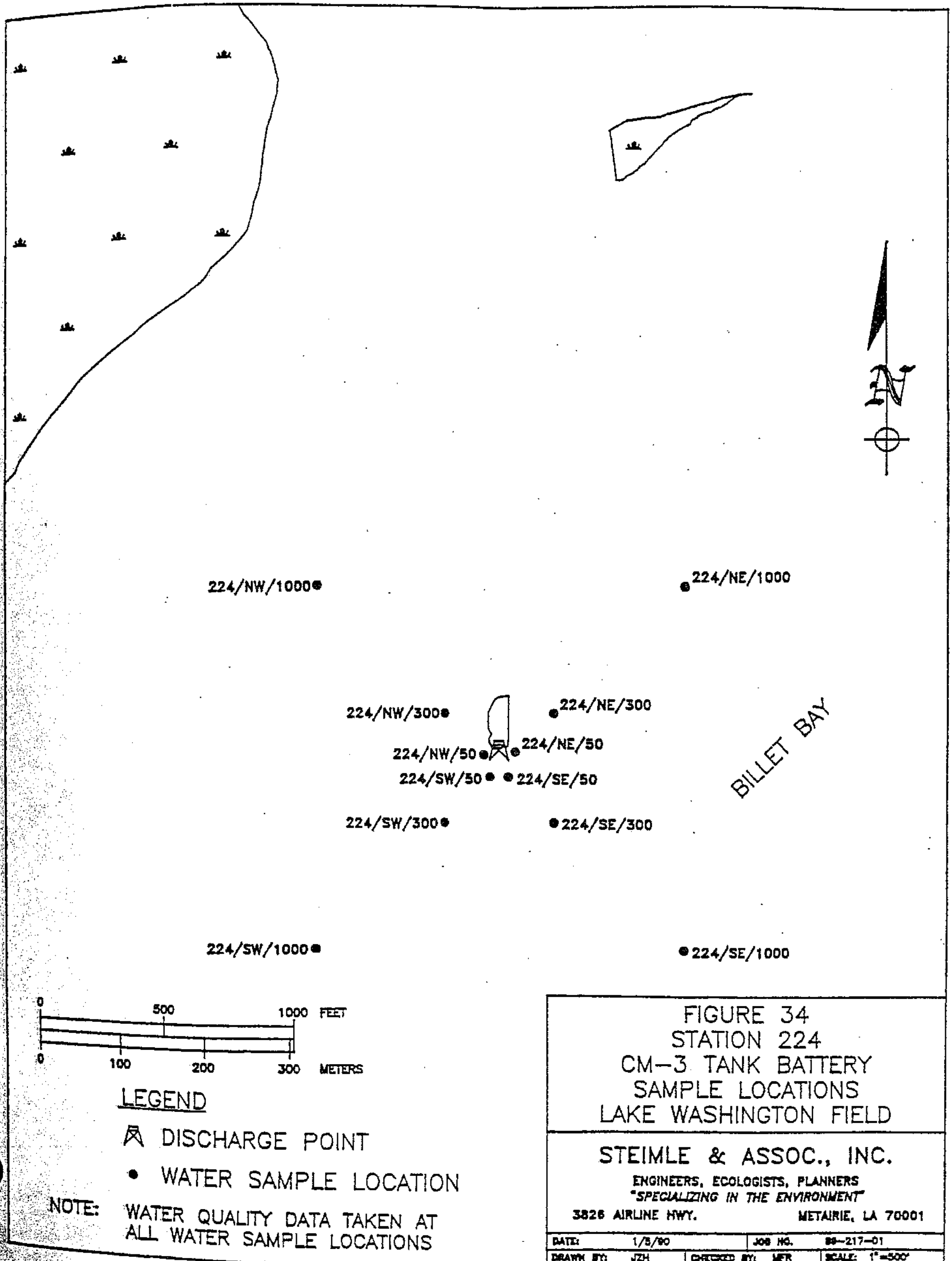


FIGURE 34
STATION 224
CM–3 TANK BATTERY
SAMPLE LOCATIONS
LAKE WASHINGTON FIELD

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY. METAIRIE, LA 70001

DATE:	1/5/90	JOB NO.	217–01
DRAWN BY: JZH	CHECKED BY: MFR	SCALE: 1"=500'	

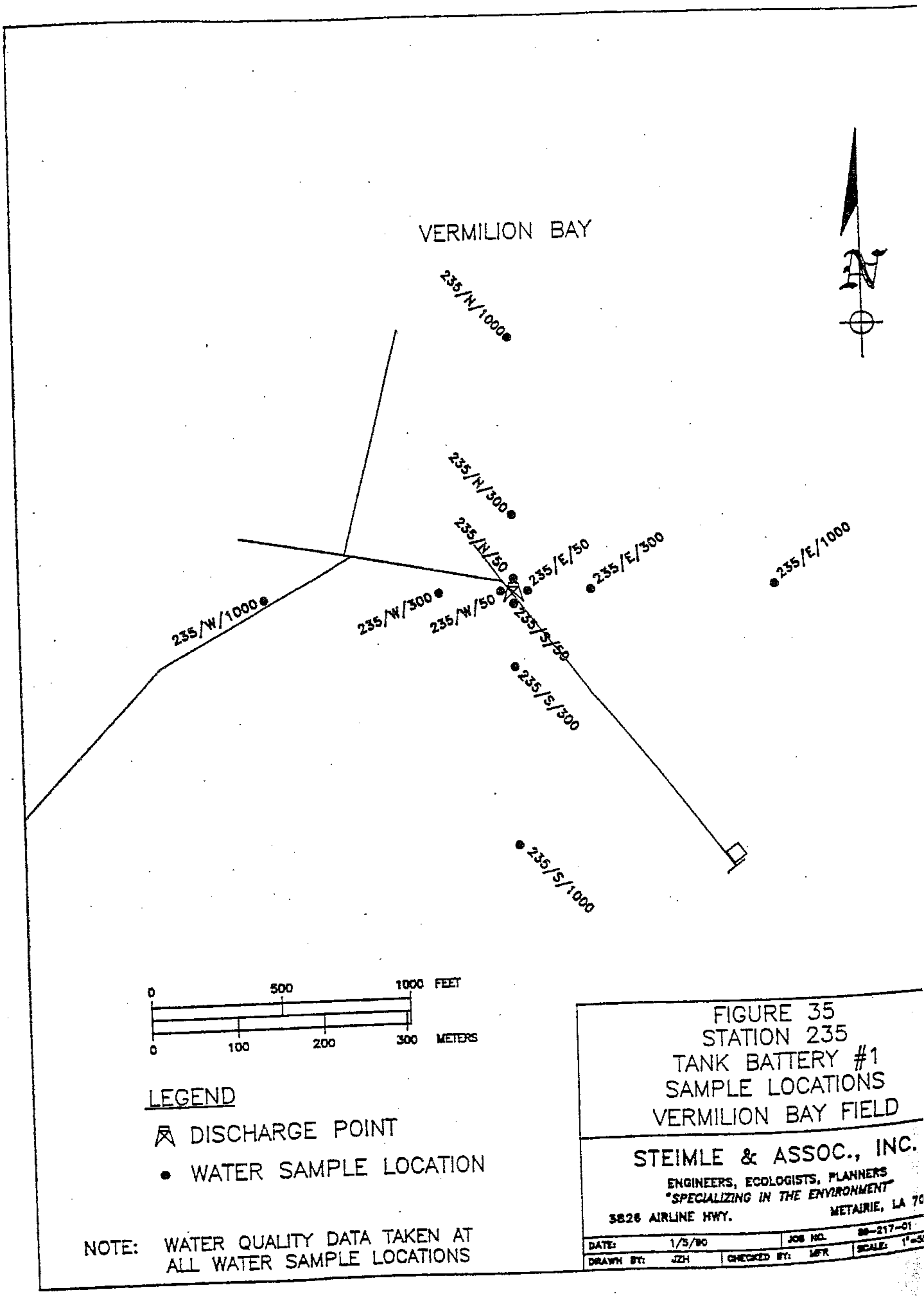


FIGURE 35
STATION 235
TANK BATTERY #1
SAMPLE LOCATIONS
VERMILION BAY FIELD

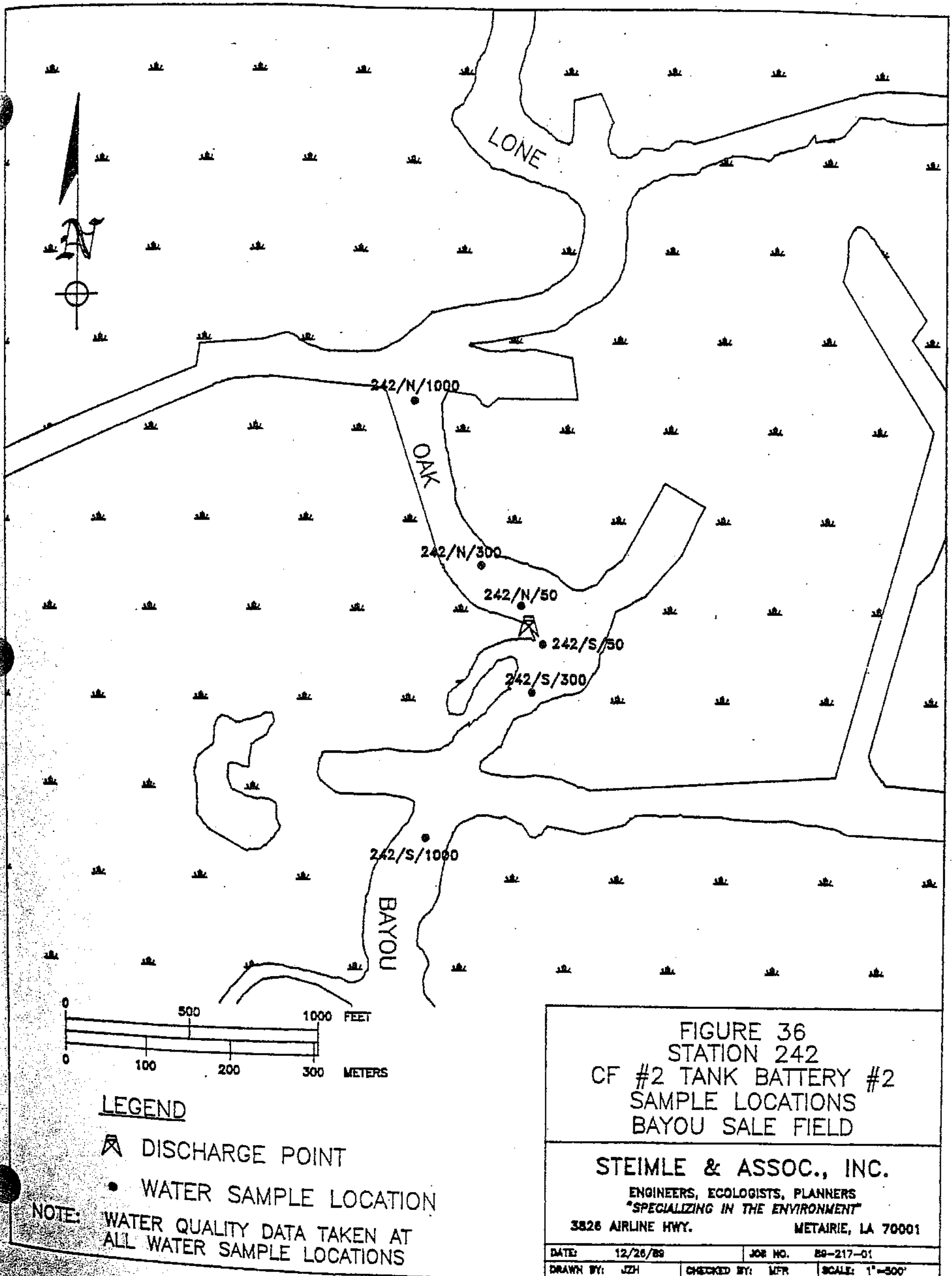


FIGURE 36
STATION 242
CF #2 TANK BATTERY #2
SAMPLE LOCATIONS
BAYOU SALE FIELD

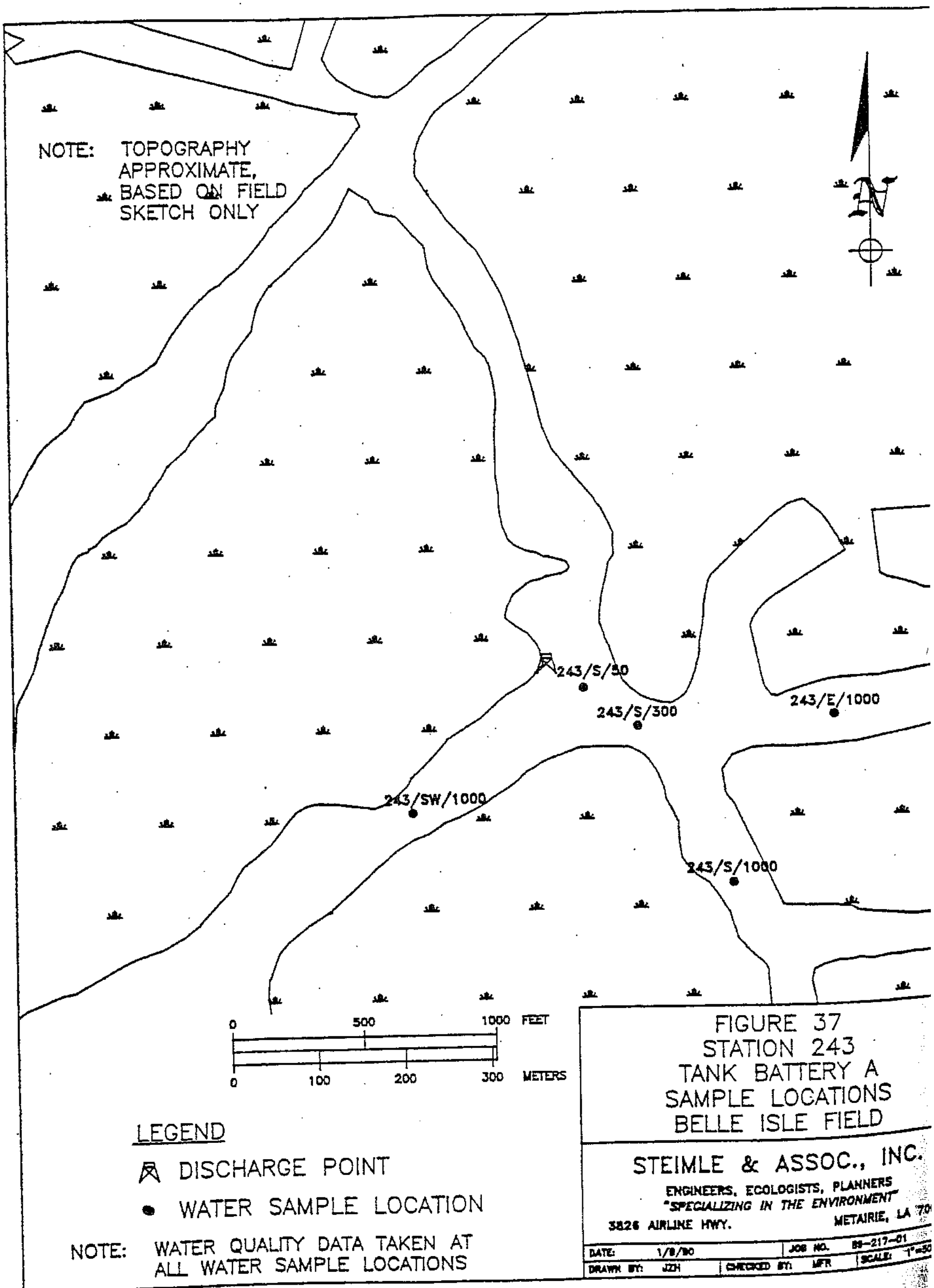
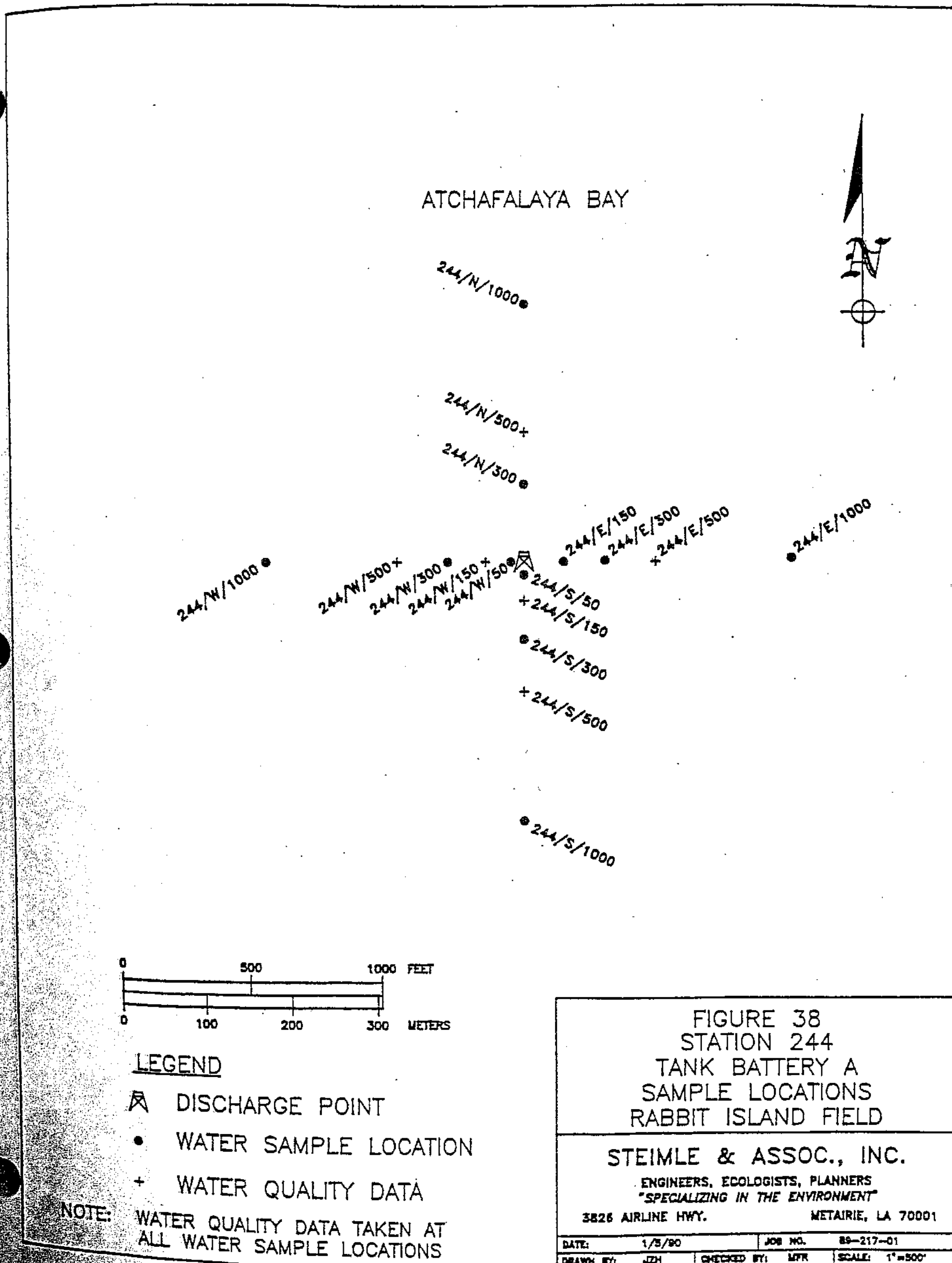
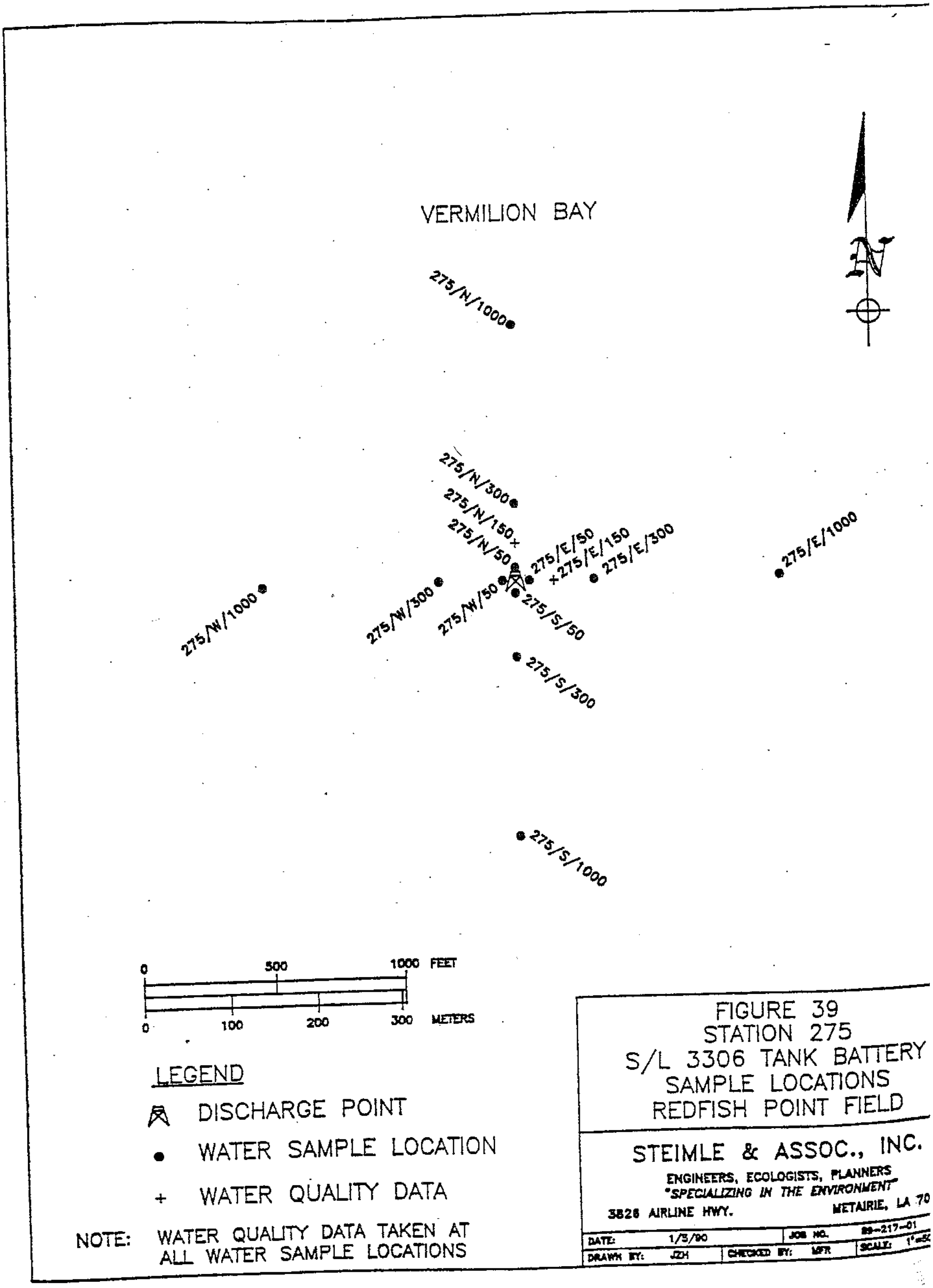
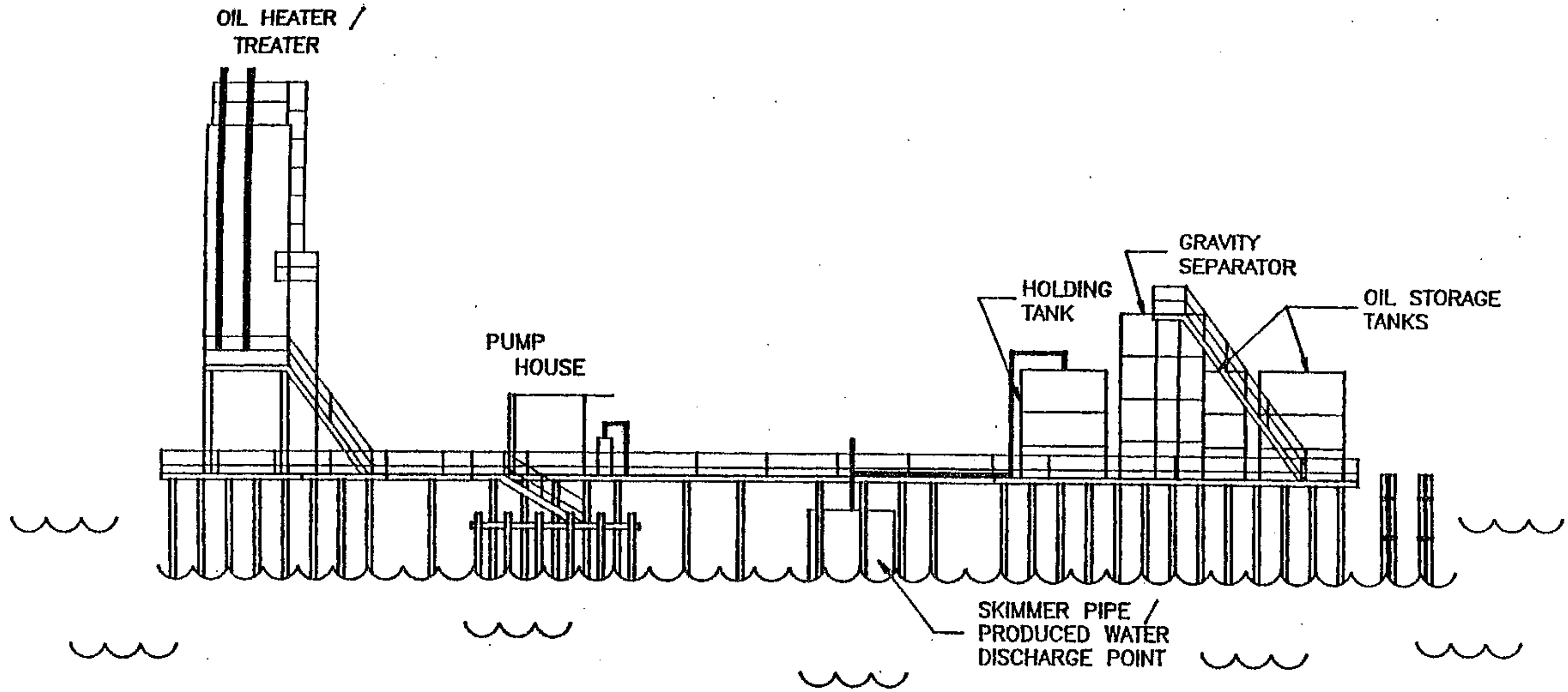


FIGURE 37
STATION 243
TANK BATTERY A
SAMPLE LOCATIONS
BELLE ISLE FIELD


ATCHAFALAYA BAY
N
244/N/1000
244/N/500
244/N/300
244/W/1000
244/W/500
244/W/300
244/W/150
244/W/50
244/E/150
244/E/300
244/E/500
244/E/1000
244/S/50
244/S/150
244/S/300
244/S/500
244/S/1000
0 500 1000 FEET
0 100 200 300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
+ WATER QUALITY DATA
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 38
STATION 244
TANK BATTERY A
SAMPLE LOCATIONS
RABBIT ISLAND FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3826 AIRLINE HWY. METAIRIE, LA 70001
DATE: 1/5/90
JOB NO. 89-217-01
DRAWN BY: JZH
CHECKED BY: MFR
SCALE: 1"=500'


VERMILION BAY
275/N/1000
275/N/300
275/N/150
275/N/50
275/E/50
275/E/150
275/E/300
275/E/1000
275/W/1000
275/W/300
275/W/50
275/S/50
275/S/300
275/S/1000
0
500
1000 FEET
0
100
200
300 METERS
LEGEND
DISCHARGE POINT
WATER SAMPLE LOCATION
+ WATER QUALITY DATA
NOTE: WATER QUALITY DATA TAKEN AT ALL WATER SAMPLE LOCATIONS
FIGURE 39
STATION 275
S/L 3306 TANK BATTERY
SAMPLE LOCATIONS
REDFISH POINT FIELD
STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3828 AIRLINE HWY.
METAIRIE, LA 70
DATE: 1/5/90
JOB NO. 89-217-01
DRAWN BY: JZH
CHECKED BY: MFR
SCALE:



NOT TO SCALE

FIGURE 40

TYPICAL PRODUCTION PLATFORM

API LOUISIANA WETLANDS STUDY

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS

"SPECIALIZING IN THE ENVIRONMENT"

3826 AIRLINE HWY. METAIRIE, LA 70001

DATE: 8/22/90		JOB NO. 89-217-01
DRAWN BY: RAP	CHECKED BY: MFR	SCALE: N.T.S.

portion of Barataria Bay. These facilities are all located in open water.

The Lake Washington (Stations 65, 211, 214, 217 & 224) and the West Potash (Station 219) Fields are located in the eastern portion of the Barataria Basin in the saline marsh zone. All but Station 214 were located in open water.

The three fresh-intermediate marsh sites sampled in the Mississippi River Delta Basin were Station 82 (Delta Duck Club Field), Station 157 (West Bay Field) and Station 165 (West Delta 117-41 & Southeast Black Bay Fields). All three sites were located on canals, although the canal banks were almost completely eroded/subsided away at Station 157.

In the brackish marsh zone of the Chandeleur Sound Basin, two locations (Stations 88 & 97) were sampled in the Delacroix Island Field. Station 88 was located at the intersection of a canal and a small bay. The other station (97) was located at the southern end of a canal.

Stations 243 (Belle Isle Field) near the mouth of the Wax Lake Outlet and 244 (Rabbit Island Field) in western Atchafalaya Bay were both located in the Atchafalaya Bay Basin. The Belle Isle Field location was originally in open water, and is shown that way on older maps. Recent delta building by the Wax Lake Outlet has produced exposed mud flats and vegetated fresh marsh areas surrounding the canal used to access the facility. The Rabbit Island facility is located near the Gulf of Mexico, with no land between it and the Gulf. With seasonally variable Mississippi River fresh water flows into Atchafalaya Bay and the proximity of the Gulf of Mexico, the salinity in the vicinity of Rabbit Island may fluctuate between fresh and saline on a time scale of days to weeks and may show salinity stratification on a regular basis. Based on the salinities at the time of sampling and the vegetation zones on the nearest land (Marsh Island), this station was considered to be in the brackish marsh zone.

The remaining six stations were located in the Vermilion Basin. Two of the stations were located in the Bayou Sale Field (Stations 190 & 242), two in the Weeks Island Field (Stations 185 & 186) and one each in the Vermilion Bay (Station 235) and Redfish Point (Station 275) Fields. The Bayou Sale Field stations are located on canals in a fresh-intermediate marsh between the northeastern shore of East Cote Blanche Bay and Wax Lake. Weeks Island Field is located adjacent to the northeast corner of Vermilion Bay. Both stations in this field were located on canals in a fresh-intermediate marsh zone near the fresh-intermediate/brackish marsh boundary. The Vermilion Bay and Redfish Point Field sites are located, respectively, in the southeastern and southwestern portions of Vermilion Bay. Both sites are in the brackish marsh zone and are open water sites.

E. MATERIALS AND METHODS

One grab sample of the undiluted PW from the discharge was collected at each discharge station for total petroleum hydrocarbon analysis. A separate grab sample was collected for chloride analysis.

The salinity and current profiling locations around the discharge were finalized in the field based on the physical configuration of each site. Typically the sampling locations were on a transect 15, 90 and 300m (50, 300 and 1000ft) from the discharge. At sites where salinity stratification was present, additional profiling locations were placed on the transect at 45 and 150m (150 and 500ft) from the discharge. For the purposes of this study, salinity stratification is defined as a greater than 1.0 part per thousand (ppt) difference between the surface and bottom salinities. In dead-end canals these locations were downstream of the discharge. In two-way canals, the sampling locations were both up and downstream of the discharge. At open water stations, the profile transects were established upstream and downstream (based on current direction at the discharge) and at 90° on either side of the upstream-downstream line.

At each profile location salinity, temperature and conductivity were measured at 0.3m (1ft) intervals from the surface down to 0.7m (2ft) from the bottom. In the lowest 0.7m (2ft) of the water column salinity, temperature and conductivity were measured at 15cm (6in) intervals. Current velocity and direction data were generally collected at the surface, mid-depth and 15cm (6in) above the bottom. At locations with highly variable current velocities, readings were taken at 0.3m (1ft) increments through the water column. Salinity, conductivity, temperature and depth data were collected using a YSI Model 33 S-C-T meter calibrated in the field according to the manufacturer's directions. Current velocity and direction data were collected using a Marsh-McBirney Model 201 flow meter calibrated according to manufacturer's directions.

Water column TPH samples were collected 15m (45ft), 90m (300ft) and 300m (1000ft) from the discharge, both at the surface and below any salinity stratification layer, if present. If salinity stratification was absent, the bottom water sample was taken from the lowest foot of the water column using a Meyer type sampler. At locations where stratification was present a modified pole mounted Meyer sampler was used to collect samples from the stratified layer. Depending on the site configuration, the water column samples would be collected downstream of the discharge (dead-end canal), both up and downstream of the discharge (two-way canals) or, in the case of open water sites, up and down current as well as 90^{o} on either side of the up current/down current line.

Produced water and water column samples were collected in washed and solvent-rinsed 1-quart borosilicate glass containers with foil-lined caps as per ASTM D 3325-85. Approximately every twentieth water sample was collected in duplicate for QA/QC sample analysis.

At six of the discharge locations, bottom sediment samples were also collected. Duplicate bottom sediment samples for TPH were collected at the discharge, 15m (45ft), 45m (150ft), 90m (300ft), 150m (500ft) and 300m (1000ft) upstream and downstream of the discharge, where structures, shallow water or land did not interfere. These samples were collected using a WILDCO liner type 5.0cm (2.0in) diameter corer with a new, washed and solvent-rinsed liner for each sample. The samples consisted of the top 10cm of each core sample. Each duplicate bottom sediment sample was removed from the liner, placed in a wide-mouth glass jar, and sealed with a foil-lined cap. Approximately every tenth sediment TPH sample was collected in duplicate for QA/QC sample analysis.

Surface and bottom water column and sediment samples were collected at six stations for radionuclide analysis. These samples were collected 15m (50ft) from the discharge pipe both upstream and downstream. The surface water samples were collected as grab samples and the bottom samples were collected using a horizontal VanDorn sampler. The sediment samples were collected using the previously described corer. Both water and sediment samples were placed in clean 0.5l plastic containers. The water samples were acidified and iced immediately after collection. The top 10cm (4in) of the sediment core samples were transferred to the plasti containers and iced upon collection.

All samples were labeled on the outside of the bottle with the date, sample site designation, sample location, collectors ar time of sampling. All nonradionuclide samples were iced immediately upon collection and delivered to the laboratory within 48-7 hours. The radionuclide samples were iced on collection and store at room temperature until they were shipped to the laboratory fo analysis.

Produced water, ambient water column and bottom sediment samples were collected and preserved in accordance with ASTM Procedure D 3326-85. Water samples were analyzed for TPH using liquid extraction and IR according to EPA Method 418.1 (EPA, 1983). Produced water samples were analyzed for chlorides to calculate equivalent salinity according to EPA Method 9252. Bottom sedimen were analyzed for TPH using a Soxhlet extraction procedure accor ing to EPA Methods 9071 and 418.1. Sediment samples were analyze for grain size content using ASTM Method D 422-63 and loss on ignition using Method 2540G (APHA,1989). Water samples for radionuclide analysis were preserved in the field with acid. The samples were analyzed for total ^{226}Ra and ^{228}Ra according to EPA Methods 903.1 and 904.0, respectively (EPA, 1980). Laboratory QA/QC procedures follow EPA Publication SW-846 (EPA, 1986).

F. RESULTS

F.1. Sampling Locations

The topography shown on the maps in Figures 2 through 39 reflects the most recent USGS quadrangles, which in many cases are ten or more years old and may not accurately reflect the current landform. Also, areas shown as water on the maps may be too shallow to access by boat.

No samples were collected at discharges 179 and 190. During our sampling of the Four Isle Dome Field, we discovered that the 179 facility was no longer discharging. After confirming this with the field personnel, no sampling was attempted at this site. Discharge 190 in the Bayou Sale Field was not sampled due to a 400m (1300ft) long, dense mat of water hyacinth blocking access to the discharge.

F.2. Fathometer Profiles

Sixty individual fathometer transects were run over at least one each of the stations located on canals. Table 3 lists the stations, transect locations, approximate transect width and maximum depth. Appendix A Figure A-1 contains copies of the individual station/location transects.

F.3. Current Velocity and Direction

Table 4 presents a summary of the current velocity data. The surface water column velocity data gives the maximum value recorded at depths between 0.3m (1.0ft) and 0.5m (1.5ft) below the surface. The bottom velocity minima and maxima were from readings taken between 0.05m (2in) and 0.15m (6in) above the bottom. The range of depths at the individual sampling locations within a station are also listed in Table 4 for comparison.

TABLE 3

FATHOMETER DATA SUMMARY
API LOUISIANA WETLAND STUDY

STATION/TRANSECT	LOCATION	APPROXIMATE WIDTH (FT)	MAXIMUM DEPTH (F
31-1	000	100	7
31-2	W/50	160	7
31-3	E/50	100	7
33-1	000	90	7
33-2	NW/50	90	7
33-3	SE/50	100	8
36-1	000	80	6
36-2	NW/50	100	6
36-3	SE/50	80	6
53-1	E/1000	200	5
53-2	SE/1000	70	7
53-3	000	100	8
53-4	N/1000	150	6
62-1	E/50	---	5
62-2	E/300	---	5
62-3	E/1000	---	6
62-4	W/50	---	9
62-5	W/300	---	8
62-6	W/1000	---	9
62-7	000	---	7
72-1	000	160	7
72-2	W/50	160	6
72-3	W/150	170	7
72-4	W/300	160	6
72-5	W/500	100	7
72-6	W/1000	180	7
72-7	E/50	170	7
72-8	E/150	180	6
72-9	E/300	220	6
72-10	E/500	220	6
72-11	ACROSS BAYOU	160	7
82-1	000	60	5
88-1	000	160	5
97-1	000	150	6
157-1	000	100	5
165-1	W/50	550	5
170-5	S/1000	250	7
170-6	000	100	6
170-7	N/1000	400	6

TABLE 3 (Cont.)

FATHOMETER DATA SUMMARY
API LOUISIANA WETLAND STUDY

STATION/TRANSECT	LOCATION	APPROXIMATE WIDTH (FT)	MAXIMUM DEPTH (FT)
177-1	000	180	6
177-2	S/150	100	6
177-3	E/150	180	5
181-1	000	150	5
181-2	SE/150	150	5
181-3	NW/50	150	5
186-1	000	60	4
186-2	W/50	50	5
186-3	W/300	110	4
211-1	E/1000	250	8
211-2	E/300	225	7
211-3	E/50	150	7
211-4	000	150	7
211-5	W/50	150	7
211-6	W/300	110	7
211-7	W/1000	180	8
214-1	S/1000	180	6
214-2	S/300	180	6
214-3	S/150	180	8
214-4	W/50	180	5
242-1	N/50	150	14
242-2	000	200	16
242-3	S/50	200	14
243-1	000	100	10
243-2	S/300	150	14
243-3	SE/1000	100	9
243-4	SW/1000	100	13

TABLE 4

CURRENT VELOCITY DATA SUMMARY
API LOUISIANA WETLANDS STUDY

STATION	MARSH HABITAT	STATION CONFIGURATION	STATION DEPTH RANGE (FT)	UPPER WATER COL. MAX. VEL. (FT./SEC)	BOTTOM WATER VELOCI MIN (FT./SEC)	(FT
31	B	C2	7.5-10.0	0.28	0.01	
32	B	OW4	6.0	0.23	0.00	
33	B	C2	6.5-8.0	0.55	0.00	
34	B	C2	8.0	0.85	0.00	
35	B	OW4	5.0-6.5	0.18	0.02	
36	B	C2	5.0-9.0	0.76	0.02	
53	S	C3	4.5-8.0	0.46	0.00	
57	S	OW4	4.0-6.0	0.30	0.00	
58	S	OW4	6.0-7.0	0.30	0.05	
59	S	OW4	4.5-6.0	0.33	0.00	
62	S	OW4	4.0-5.0	0.20	0.00	
65	S	OW4	3.5-9.5	0.50	0.06	
66	S	OW4	5.0-6.0	0.15	0.00	
67	S	OW4	5.0-6.0	0.13	0.00	
69	S	C2	5.0-7.0	0.30	0.10	
72	S	C2	3.5-7.0	0.10	0.00	
82	F-I	C1/OW3	5.0-6.5	0.26	0.00	
88	B	C2	4.0-6.5	0.50	0.00	
97	B	C2	3.5-8.5	0.90	0.00	
157	F-I	C2	6.0-7.0	0.35	0.28	
165	F-I	C2	4.0-12.0	1.20	0.00	
170	S	C2	6.5-11.0	0.28	0.00	
177	S	C2	7.0-8.0	0.32	0.00	
181	S	C1	5.0-17.0	0.64	0.00	
185	F-I	C2	2.5-5.0	0.22	0.00	
186	F-I	C2	4.0-6.0	0.52	0.00	
211	S	OW3	7.0-8.0	0.90	0.30	
214	S	C1	3.5-5.0	0.60	0.10	
217	S	OW3	2.5-6.5	0.40	0.00	
219	S	OW2	2.5-7.0	0.30	0.10	
224	S	OW4	5.5-10.0	0.40	0.00	
235	B	OW4	4.5-8.0	0.50	0.00	
242	F-I	C2	12.0-17.0	1.81	0.10	
243	F-I	C3	7.0-11.0	0.73	0.00	
244	B	OW4	7.5-9.5	1.14	0.00	
275	B	OW4	6.5-8.0	0.35	0.00	

Station upper water column current velocity maxima ranged from 3 cm/sec (0.10 ft/sec) to 55 cm/sec (1.81 ft/sec). Minimum bottom water velocities of 0 cm/sec were found at 26 stations and the minima ranged from 0-9 cm/sec (0-0.28 ft/sec). The maximum bottom velocities ranged from 2-31 cm/sec (0.06-1.02 ft/sec).

Many of the stations sampled were located in shallow water. Eighteen of thirty six stations had maximum depths of 2.0m (7ft) or less deep. Twelve of the stations had maximum depths between 2.0-3.0m (7-9.5ft). Four stations had maximum depths of 3.0-4.0m (9.5-12ft) and only two stations had maximum depths of 5.0m (17ft).

F.4. Produced Water

Data from the PW discharge samples are presented in Table 5. The mean TPH concentration was 28.2 mg/l, with the individual values ranging from 1.6 (Station 88) to 119 mg/l (Station 242). The mean TPH concentration was 28.2 mg/l, with a standard deviation (S.D.) of 23.5 mg/l. Ten of the thirty-six samples contained TPH concentrations greater than 30 mg/l.

The salinity of the PW discharges was calculated from the chloride content according to the following formula:

$$\text{Salinity (ppt)} = 0.03 + 1.805 \times \text{Chlorinity (ppt)}$$

Salinities ranged from 10 (Station 58) to 227 (Station 275) parts per thousand (ppt) and the mean of all the samples was 141 ppt (S.D.= 47).

F.5. Salinity Stratification

Table 6 is a summary of the salinity stratification and bottom water TPH data. Figure 41 is a graph showing the maximum

TABLE 5

PRODUCED WATER TOTAL PETROLEUM, HYDROCARBON
CHLORIDE AND SALINITY DATA
API LOUISIANA WETLANDS STUDY

STATION NUMBER	TPH (mg/L)	CHLORIDE (mg/L)	SALINITY (ppt)
31	27	81500	147
32	14	63500	115
33	55	71000	128
34	26	76500	138
35	13	67000	121
36	31	84000	152
53	18	84500	153
57	30	89000	161
58	16	5500	10
59	62	72250	130
62	24	76000	137
65	6.9	108500	196
66	13	98500	178
67	43	63500	115
69	29	75000	135
72	30	76250	138
82	8.2	35000	63
88	1.6	85500	154
97	24	87500	158
157	23	61750	111
165	1.7	87500	158
170	4.6	102500	185
177	14	102500	185
181	20	90000	162
185	26	95750	173
186	34	109500	198
211	8.2	111500	201
214	63	19000	34
217	40	106000	191
219	40	74500	135
224	5.3	25000	45
235	80	77000	139
242	119	43500	79
243	27	92500	167
244	28	82000	148
275	11.6	125500	227
MEAN VALUE	28.2	77958	141
S.D.	23.5	26004	47

TABLE 6

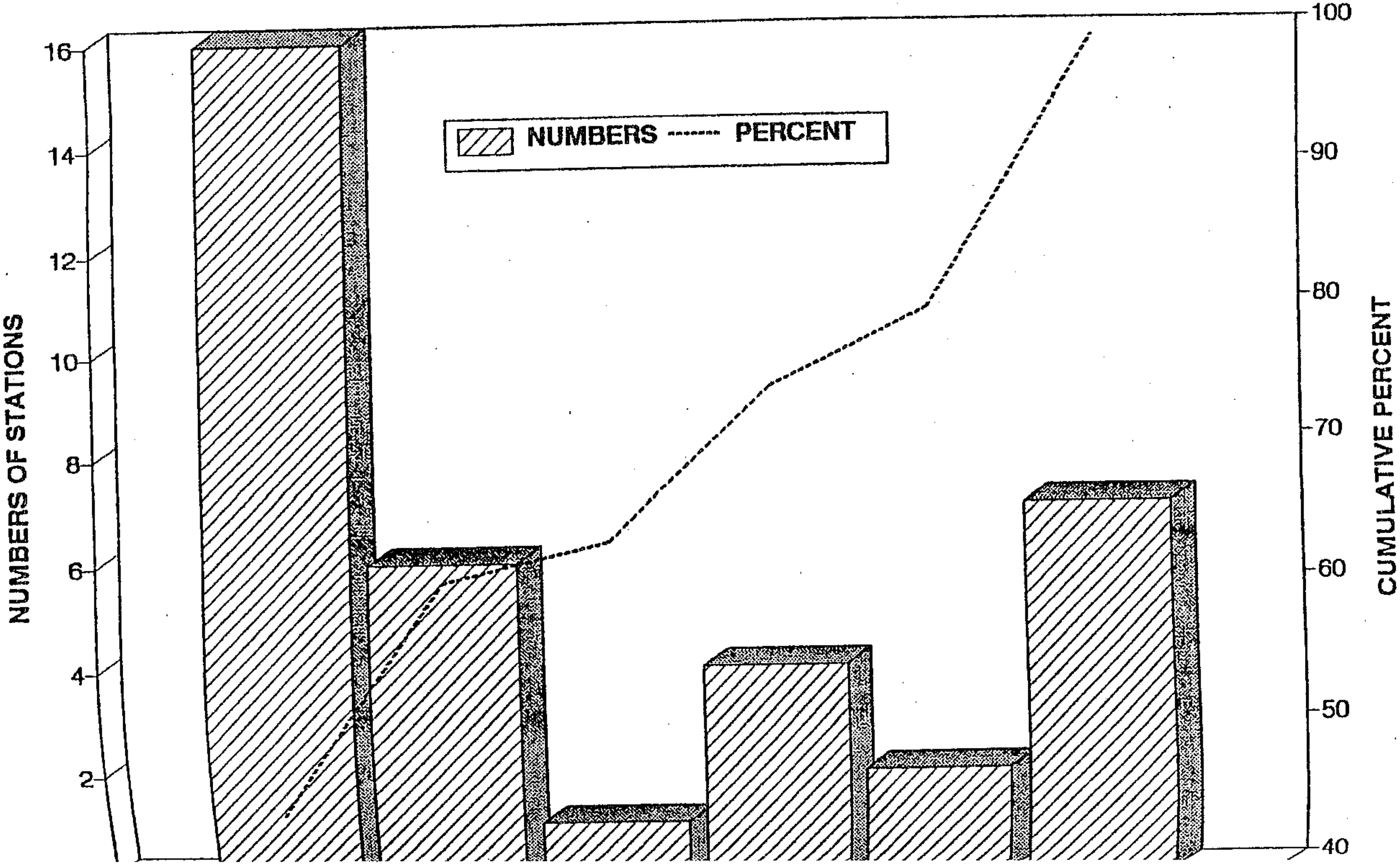
STRATIFICATION AND BOTTOM WATER TOTAL PETROLEUM
HYDROCARBON (TPH) SUMMARY TABLE
API LOUISIANA WETLANDS STUDY

STATION NUMBER	DISCH. CRITERIA	STRATI-FICATION PRESENT	STRAT. MAX. DIST. (FT) FROM DISCH.		MAXIMUM WATER TPH CONC. (ug/g)	DETECTABLE TPH MAX. DIST. (FT.) FROM DISCHARGE
31	2	Y	300		2.4	300
32	1	Y	50		8.1	50
33	2	Y	300		15	300
34	2	Y	50		*179	50
35	2	Y	50		8.6	50
36	2	N	0		<0.5	---
53	1	Y	1000	1/	<0.5	---
57	3	N	0		<0.5	---
58	1	N	0		4.6	50
59	3	Y	50		<0.5	---
62	2	Y	1000	2/	<0.5	---
65	2	N	0		<0.5	---
66	1	N	0		3.2	300
67	3	Y	300		3.0	50
69	2	N	0		<0.5	---
72	2	Y	500		2.5	50
82	1	N	0		<0.5	---
88	2	N	0		<0.5	---
97	2	N	0		<0.5	---
157	3	Y	1000	1/	<0.5	---
165	3	Y	300		<0.5	---
170	1	Y	1000	3/	<0.5	---
177	3	Y	1000	3/	<0.5	---
181	2	Y	50		<0.5	---
185	2	Y	500+		*11	300
186	3	Y	1000		31	50
211	1	N	0		<0.5	---
214	1	N	0		<0.5	---
217	2	N	0		<0.5	---
219	2	Y	50		<0.5	---
224	2	N	0		<0.5	---
235	2	N	0		<0.5	---
242	1	N	0		<0.5	---
243	1	N	0		<0.5	---
244	2	Y	1000	3/	<0.5	---
275	1	Y	150		<0.5	---

1/ ONLY @ 1,000 FT. LOCATION, NOT STRATIFIED NEAR DISCHARGE
2/ ONLY @ 300 FT. & 1,000 FT. LOCATIONS, NOT STRATIFIED NEAR DISCHARGE
3/ ALL STATIONS STRATIFIED

* EMULSION PROBLEMS, WATER CONTAINED LARGE AMOUNT OF SUSPENDED SOLIDS

MAX. EXTENT OF SALINITY STRATIFICATION NEAR DISCHAGES API LA. WETLANDS STUDY



extent of stratification from the discharge point where stratification was observed at one or more stations around the discharge.

Stratification was found at 20 of the 36 locations sampled. Of the 20 locations with stratification, 3 were stratified at all sampling locations: Stations 170 (low discharge) and Stations 177 and 244 (both moderate discharge). Three others, Stations 53 (low discharge), 62 (moderate discharge) and 157 (high discharge), were stratified only at locations away from the discharge .

The remaining 14 stations showed salinity stratification at varying distances from the discharges. Six stations (32, 34, 35, 59, 181 and 219) were stratified only at 15m (50ft) from the discharge. Of these, Stations 32 and 59 are low discharge rate stations and 34, 35, 181, and 219 are moderate rate discharge stations. Station 275 (low discharge) was stratified at a distance of 45m (150ft) from the discharge.

Four stations (31, 33, 67 and 165) were stratified at a distance of 90m (300ft) from the discharge. Stations 31 and 33 are moderate discharge rate stations, and Stations 67 and 165 are high discharge rate stations. Stations 72 and 185 (moderate discharge) were stratified at a distance of 150m (500ft) from the discharge, and only Station 186 exhibited stratification at the 300m (1000ft) distance. No data from beyond the stratified 150m (45ft) locations were collected at Stations 72 and 185 due to equipment malfunction and shallow water access problems, respectively.

At 16 stations no stratification was found. This included seven stations with low discharge rates , eight stations with moderate discharge rates and one station with a high discharge rate . Six stations were stratified at 15m (50ft) from the discharge. These stations included one each from the low and high discharge rate criteria group and four from the moderate rate criteria group. One moderate rate discharge station was stratified at the 45m (150ft) distance. At the 90m (300ft) distance, two stations each from the moderate and high rate discharge groups were stratified. Two stations with moderate rate discharges were stratified at the 150m (500ft) distance. Four stations were stratified at the 300m (1000ft) distance. Of these four stations, one each is a low and medium discharge criteria and two are high discharge criteria. Three stations were stratified at all sampling locations. They included one each of the low, medium and high discharge criteria.

F.6. Water Petroleum Hydrocarbons

The surface water data contained no samples with detectable (0.5 mg/l or greater) concentrations of TPH. Of the 36 stations sampled (Table 6), 25 had maximum bottom water TPH concentrations of less than 0.5 mg/l. The maximum values for bottom water TPH concentrations at the remaining 11 stations ranged from 2.4 to 179 mg/l. The maximum TPH values at Stations 34 (179 mg/l) and 185 (11 mg/l) were the results of high suspended solids in the samples. High winds and choppy seas precluded placement of the water sampler near the bottom without stirring up the sediment at those stations. Of the other nine stations with detectable bottom water TPH concentrations, the maximum values ranged from 2.4 mg/l at Station 31 to 31 mg/l at Station 186.

F.7. Sediment Petroleum Hydrocarbons

The bottom sediment sample data from the top 10 cm of cores taken at Stations 57, 88, 157, 165, 181 and 214 are presented, respectively, in Tables 7 through 12. The sediment TPH data for these stations are graphed in Figures 42 through 47, respectively. Figure 48 presents the average TPH data in a single graph for interstation comparison. For ease of reference, a naming convention was used on sediment sampling locations at a discharge station. All locations on the north side (north, northeast or northwest) were named with a negative distance and those on the south side with a positive distance from the discharge.

TABLE 7

SEDIMENT TOTAL PETROLEUM HYDROCARBON (TPH),
WATER CONTENT, LOSS ON IGNITION AND GRAIN SIZE DATA
STATION 57
API LOUISIANA WETLANDS STUDY

DIR. FROM DISCH.	DIST. FROM DISCH. (FT.)	TPH CONC. (ug/g)	WATER CONTENT % BY WT.	DRY BASIS LOSS ON IGNITION % BY WT.	GRAIN SIZE DATA SAND (%)	SILT (%)	CLAY (%)
N	-1000	355	63	8.3	12	3	36
N	-1000	508	66	9.3	12	57	31
N	-500	882	87	57.0	19	13	68
N	-500	912	85	40.7	13	69	18
N	-300	2185	78	17.4	12	63	25
N	-300	1181	78	16.0	11	56	33
N	-150	965	78	7.3	3	51	46
N	-150	2595	77	12.6	5	48	47
N	-50	5085	74	11.8	10	63	27
N	-50	4489	71	13.8	10	44	46
@	0	4721	74	13.9	18	47	35
@	0	10454	66	12.1	18	62	20
S	50	2856	56	46.4	6	66	28
S	50	1588	72	10.7	6	49	45
S	150	1450	71	9.6	7	57	36
S	150	1361	73	10.7	6	46	48
S	300	1022	74	9.9	6	60	34
S	300	1426	73	9.5	5	41	54
S	500	832	73	7.3	6	56	38
S	500	680	72	10.1	8	46	46
S	1000	644	73	11.3	7	46	47
S	1000	466	68	10.1	8	50	42

STATION CRITERIA

HABITAT = SALINE
CONFIGURATION = OPEN WATER
DISCHARGE CRITERIA = 3,001-6,000 BBL/DAY
STRATIFICATION = NONE

SEDIMENT TOTAL PETROLEUM HYDROCARBONS
STATION 57

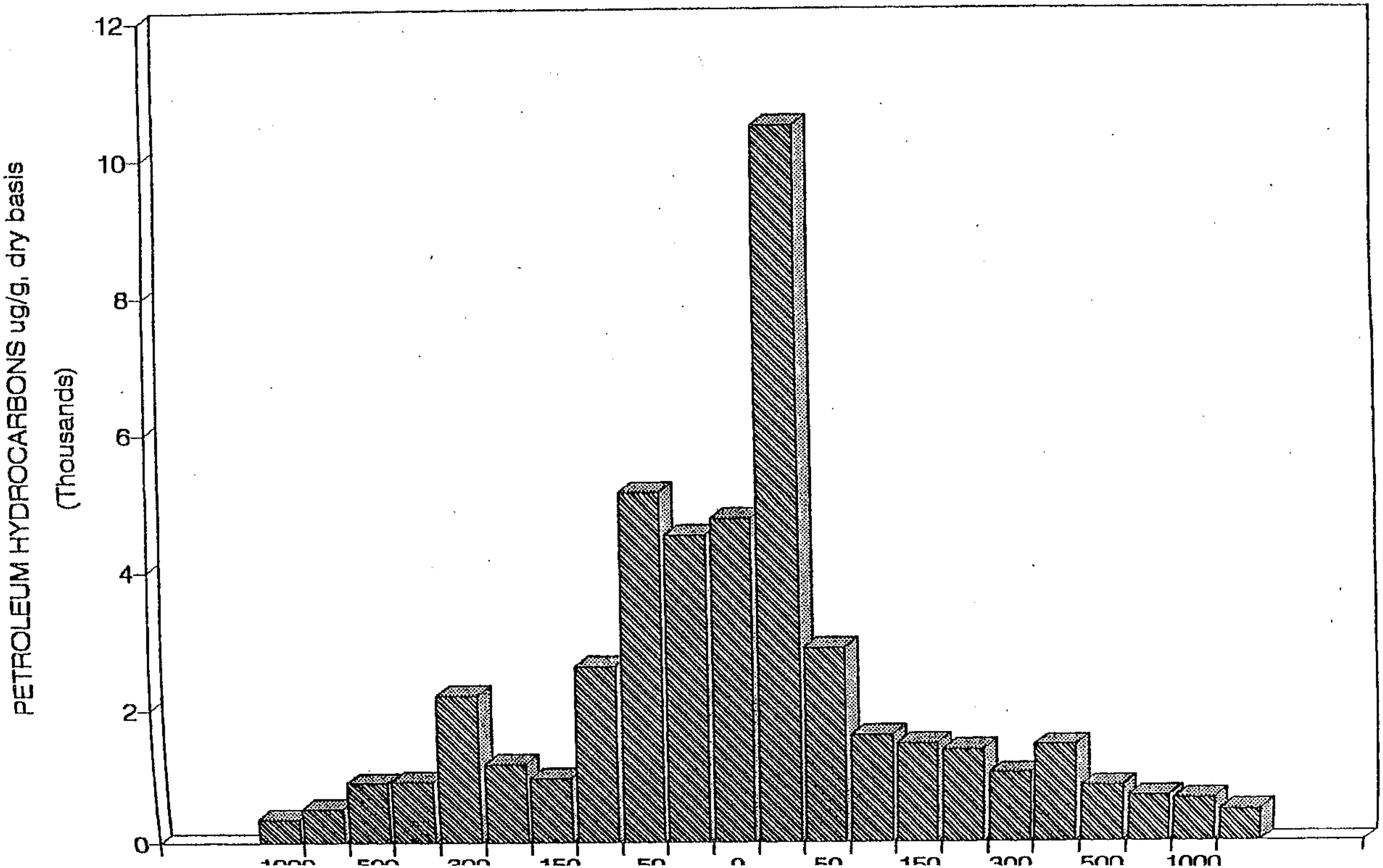


TABLE 8

SEDIMENT TOTAL PETROLEUM HYDROCARBON (TPH),
WATER CONTENT, LOSS ON IGNITION AND GRAIN SIZE DATA
STATION 88
API LOUISIANA WETLANDS STUDY

DIR. FROM DISCH.	DIST. FROM DISCH. (FT.)	TPH CONC. (ug/g)	WATER CONTENT % BY WT.	DRY BASIS LOSS ON IGNITION % BY WT.	GRAIN SIZE DATA SAND (%)	SILT (%)	CLAY (%)
N	-1000	145	57	7.9	23	52	25
N	-1000	958	58	5.5	36	36	28
N	-500	818	56	15.4	18	56	26
N	-500	561	45	6.0	11	57	32
N	-300	940	69	11.5	6	50	44
N	-300	783	63	31.6	7	49	44
N	-150	1313	75	13.7	8	64	28
N	-150	1303	76	13.7	6	75	19
N	-50	2879	75	5.9	7	58	35
N	-50	2538	75	13.8	7	48	45
@	0	2553	61	7.6	36	23	41
@	0	4795	73	12.0	13	54	33
S	50	1303	77	13.5	8	47	45
S	50	881	76	13.8	7	48	45
S	150	1094	79	14.1	12	48	40
S	150	1490	76	13.3	7	48	45
S	300	954	72	11.9	10	46	44
S	300	433	68	10.4	5	48	47
S	500	988	73	11.5	11	52	37
S	500	960	68	10.7	16	59	25
S	1000	531	73	12.3	12	51	37
S	1000	875	77	37.6	10	50	40

STATION CRITERIA

HABITAT = BRACKISH
CONFIGURATION = CANAL/OPEN WATER
DISCHARGE CRITERIA = 1,000-3,000 BBL/DAY
STRATIFICATION = NONE

Figure 43

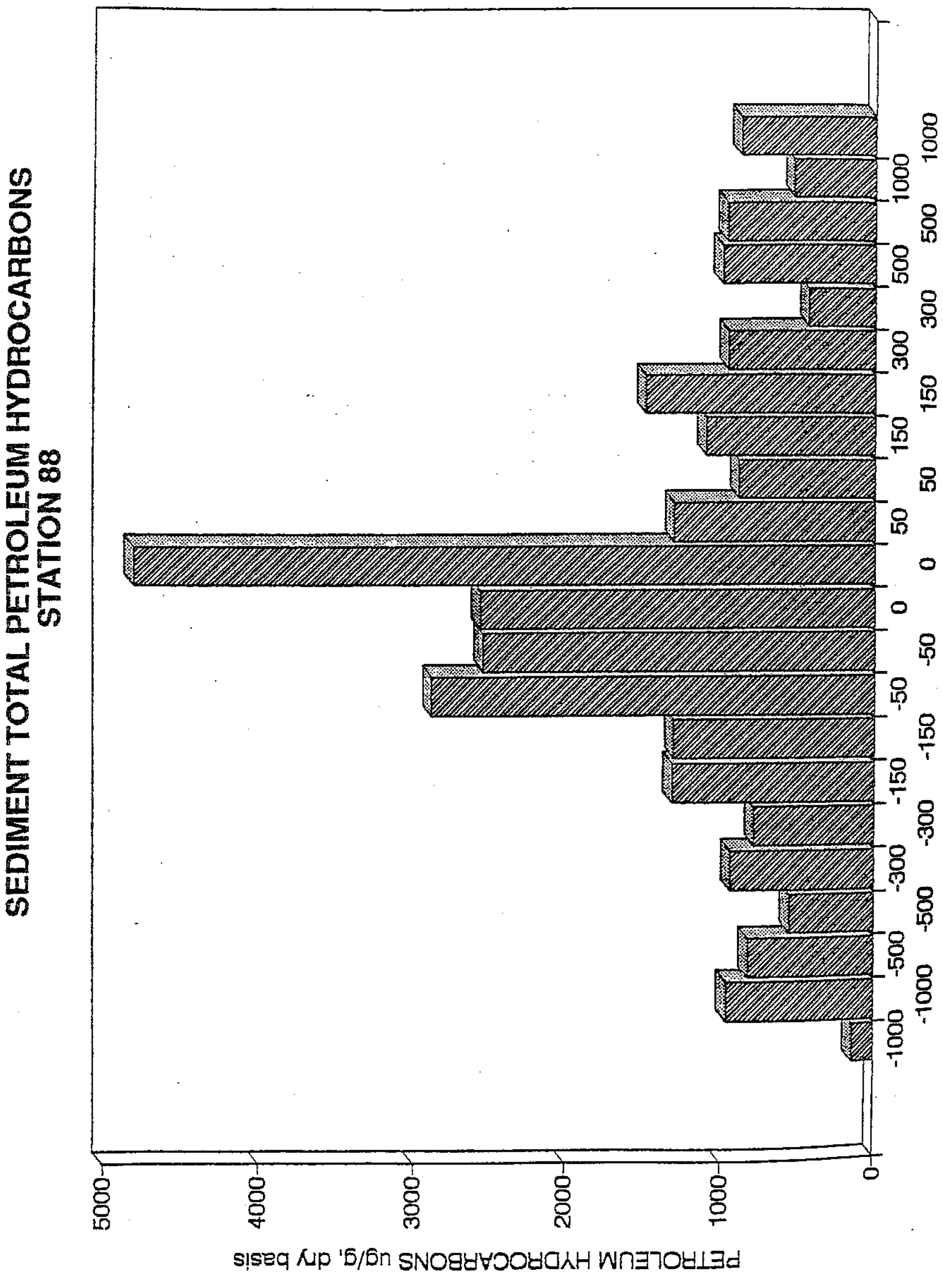

SEDIMENT TOTAL PETROLEUM HYDROCARBONS
STATION 88
PETROLEUM HYDROCARBONS ug/g, dry basis
0
1000
2000
3000
4000
5000
-1000
-1000
-500
-500
-300
-300
-150
-150
-50
-50
0
0
50
50
150
150
300
300
500
500
1000
1000

TABLE 9

SEDIMENT TOTAL PETROLEUM HYDROCARBON (TPH), WATER CONTENT, LOSS ON IGNITION AND GRAIN SIZE DATA
STATION 157
API LOUISIANA WETLANDS STUDY

DIR. FROM DISCH.	DIST. FROM DISCH. (FT.)	TPH CONC. (ug/g)	WATER CONTENT % BY WT.	DRY BASIS LOSS ON IGNITION % BY WT.	GRAIN SIZE DATA SAND (%)	SILT (%)	CLAY (%)
@	0	1031	60	5.9	2	53	45
@	0	2043	58	5.7	4	48	48
W	50	712	60	6.1	2	51	47
W	50	907	62	6.5	2	51	47
W	150	245	59	6.4	2	45	53
W	150	286	62	6.5	3	42	55
W	300	797	62	7.3	2	48	50
W	300	607	62	5.9	2	44	54
W	500	381	60	6.6	2	47	51
W	500	510	59	6.8	2	43	55
W	1000	618	58	6.4	4	46	50
W	1000	365	62	7.9	2	42	56

STATION CRITERIA

HABITAT = FRESH-INTERMEDIATE
CONFIGURATION = CANAL
DISCHARGE CRITERIA = 3,001-6,000 BBL/DAY
STRATIFICATION = ONLY AT 1000 FT. LOCATION

Figure 44

SEDIMENT TOTAL PETROLEUM HYDROCARBONS
STATION 157

TABLE 10

SEDIMENT TOTAL PETROLEUM HYDROCARBON (TPH),
WATER CONTENT, LOSS ON IGNITION AND GRAIN SIZE DATA
STATION 165
API LOUISIANA WETLANDS STUDY

DIR. FROM DISCH.	DIST. FROM DISCH. (FT.)	TPH CONC. (ug/g)	WATER CONTENT % BY WT.	DRY BASIS LOSS ON IGNITION % BY WT.	GRAIN SIZE DATA SAND (%)	SILT (%)	CLAY (%)
NW	-1000	<37	28	0.8	84	9	7
NW	-1000	158	30	1.7	62	23	15
W	50	3222	56	4.4	4	50	46
W	50	3445	60	4.6	2	58	40
W	150	15830	70	1.7	7	52	41
W	150	7383	66	6.1	2	63	35
W	300	7088	70	7.0	1	51	48
W	300	7680	70	7.2	1	54	45
W	500	88	38	3.3	22	38	40
W	500	<33	27	1.4	56	33	11
SW	1000	<42	40	3.0	2	53	45
SW	1000	111	27	0.8	85	9	6

STATION CRITERIA

HABITAT = FRESH-INTERMEDIATE
CONFIGURATION = CANAL
DISCHARGE CRITERIA = 3,001-6,000 BBL/DAY
STRATIFICATION = MAXIMUM OF 300 FT. FROM DISCHARGE

SEDIMENT TOTAL PETROLEUM HYDROCARBONS STATION 165

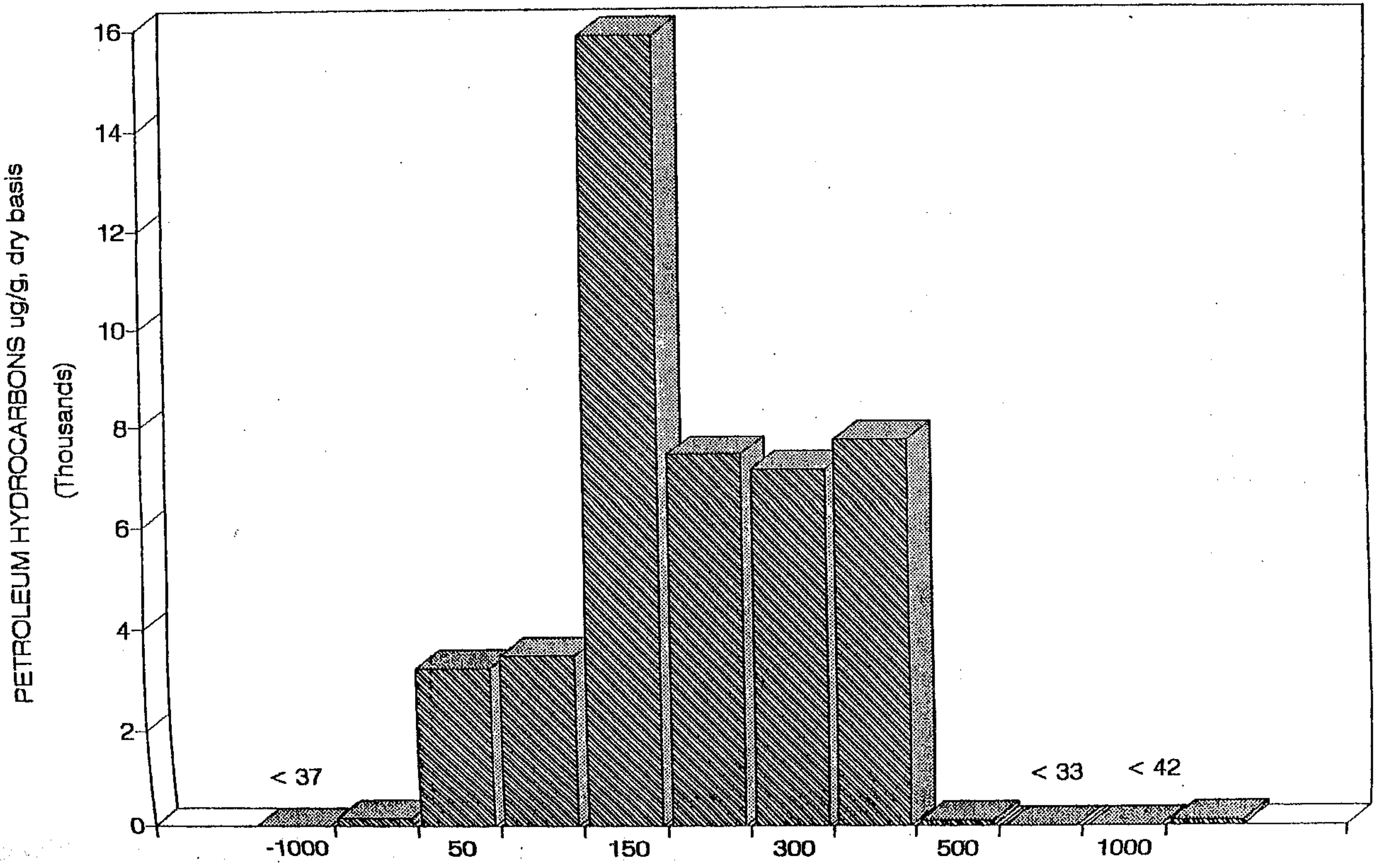


TABLE 11

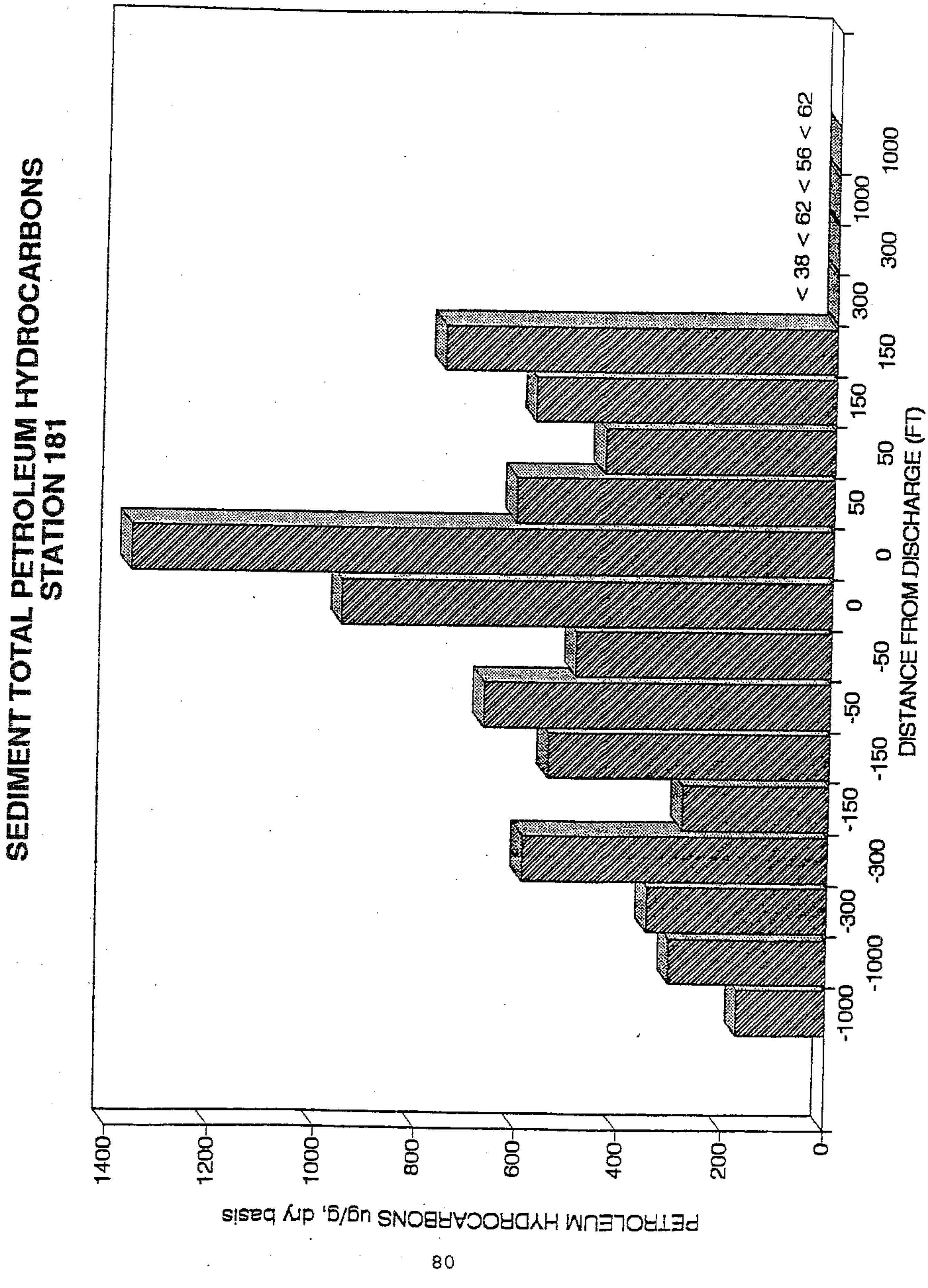
SEDIMENT TOTAL PETROLEUM HYDROCARBON (TPH),
WATER CONTENT, LOSS ON IGNITION AND GRAIN SIZE DATA
STATION 181
API LOUISIANA WETLANDS STUDY

DIR. FROM DISCH.	DIST. FROM DISCH. (FT.)	TPH CONC. (ug/g)	WATER CONTENTT % BY WT.	DRY BASIS LOSS ON IGNITION % BY WT.	GRAIN SIZE DATA SAND (%)	SILT (%)	CLAY (%)
NW	-1000	172	55	7.2	24	39	37
NW	-1000	303	64	8.6	25	35	40
NW	-300	348	76	10.8	4	59	37
NW	-300	591	74	10.1	4	36	60
NW	-150	282	72	10.0	4	36	60
NW	-150	542	73	10.4	2	38	60
NW	-50	672	73	10.4	3	37	60
NW	-50	493	73	11.1	2	38	60
@	0	957	71	10.9	8	37	55
@	0	1361	72	12.4	4	38	58
SE	50	615	71	11.0	8	37	55
SE	50	444	72	11.0	8	34	58
SE	150	579	65	8.2	1	27	72
SE	150	761	66	8.9	1	25	74
SE	300	<38	42	4.5	4	52	44
SE	300	<62	54	4.2	6	24	70
SE	1000	<56	39	3.3	25	40	35
SE	1000	<62	50	5.5	7	21	72

STATION CRITERIA

HABITAT = SALINE
CONFIGURATION = CANAL
DISCHARGE CRITERIA = 1,000-3,000 BBL/DAY
STRATIFICATION = MAXIMUM OF 50 FT. FROM DISCHARGE

Figure 46



SEDIMENT TOTAL PETROLEUM HYDROCARBONS
STATION 181
PETROLEUM HYDROCARBONS ug/g, dry basis
0
200
400
600
800
1000
1200
1400
DISTANCE FROM DISCHARGE (FT)
-1000
-1000
-300
-300
-150
-150
-50
-50
0
0
50
50
150
150
300
300
1000
1000
< 38 < 62 < 56 < 62

TABLE 12

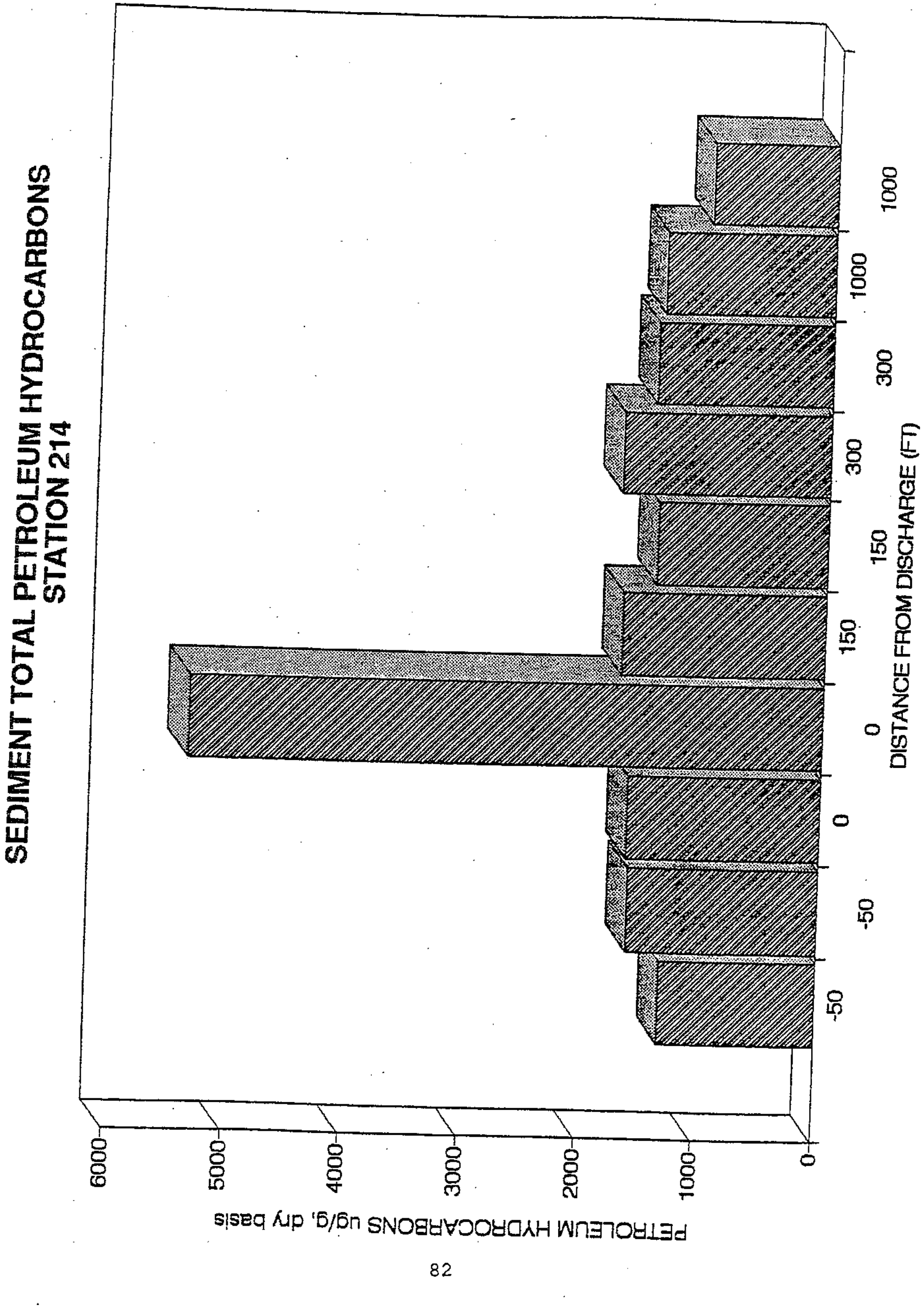
SEDIMENT TOTAL PETROLEUM HYDROCARBON (TPH),
WATER CONTENT, LOSS ON IGNITION AND GRAIN SIZE DATA
STATION 214
API LOUISIANA WETLANDS STUDY

DIR. FROM DISCH.	DIST. FROM DISCH. (FT.)	TPH CONC. (ug/g)	WATER CONTENT % BY WT.	DRY BASIS LOSS ON IGNITION % BY WT.	GRAIN SIZE DATA SAND (%)	SILT (%)	CLAY (%)
W	-50	1313	85	19.5	12	48	40
W	-50	1599	85	20.3	5	41	54
@	0	1622	81	17.9	5	48	47
@	0	5350	82	17.7	9	61	30
S	150	1705	83	21.7	5	45	50
S	150	1431	84	21.7	7	43	50
S	300	1739	81	18.8	3	47	50
S	300	1475	82	16.1	8	49	43
S	1000	1417	84	18.2	7	52	41
S	1000	1050	81	17.0	10	51	39

STATION CRITERIA

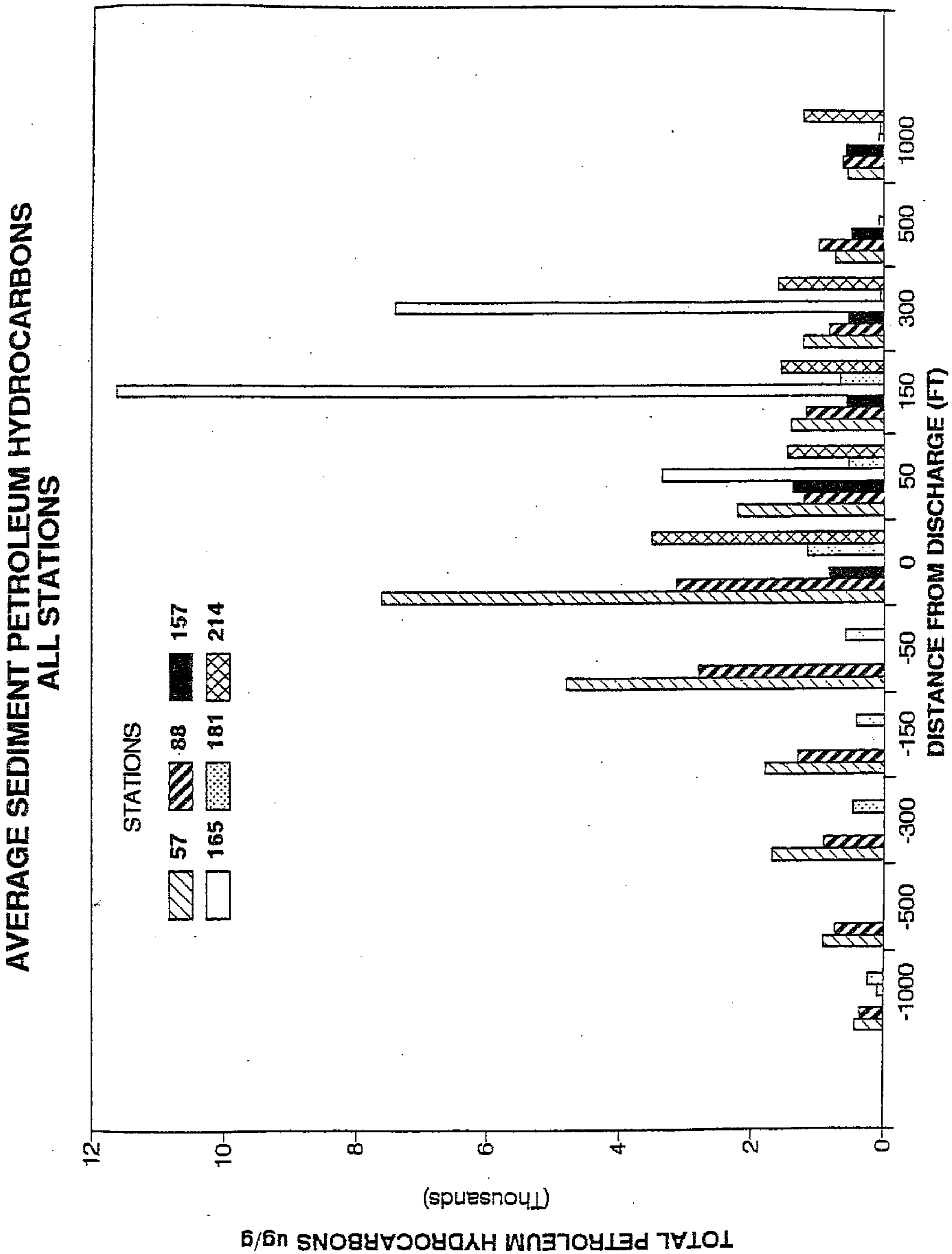
HABITAT = SALINE
CONFIGURATION = CANAL
DISCHARGE CRITERIA = 200-600 BBL/DAY
STRATIFICATION = NONE

Figure 47



SEDIMENT TOTAL PETROLEUM HYDROCARBONS
STATION 214
PETROLEUM HYDROCARBONS ug/g, dry basis
0
1000
2000
3000
4000
5000
6000
DISTANCE FROM DISCHARGE (FT)
-50
-50
0
0
150
150
300
300
1000
1000

Figure 48



AVERAGE SEDIMENT PETROLEUM HYDROCARBONS
ALL STATIONS
STATIONS
57
88
157
165
181
214
TOTAL PETROLEUM HYDROCARBONS ug/g
(Thousands)
0
2
4
6
8
10
12
DISTANCE FROM DISCHARGE (FT)
-1000
-500
-300
-150
-50
0
50
150
300
500
1000

TPH concentrations in the bottom sediment samples ranged from below detection limits to 15,830 ug/g (Station 165, 45m from the discharge). In samples from sites 300m (1,000ft) away from the discharges, TPH concentrations ranged from below detection limits to 958 ug/g (Station 88). At the 150m (500ft) sites, the concentrations ranged from less than the detection limit to 988 ug/g (Station 88). Samples from the 100m (300ft) distance ranged in concentrations from less than the detection limit to 7,680 ug/g (Station 165). The 45m (150ft) sites showed the widest range of concentrations, from 245 (Station 157) to 15,830 ug/g (Station 165). The 15m (50ft) and at discharge samples ranged in TPH concentrations from 444 (Station 181) to 5,085 ug/g (Station 57) and 957 (Station 181) to 10,454 ug/g (Station 57), respectively.

Station 57 (CF#2 TB-5) is an open water, saline habitat, high discharge criteria facility located in the Bay de Chene Field. Sediment TPH values (Table 7, Figure 42) showed high levels of sediment contamination, particularly within 150m (500ft) of the discharge. Sediment TPH concentrations ranged from 10,454 ug/g at the discharge to 355 ug/g at 300m (1000ft) away. Station 88 (TB-1), a moderate discharge rate facility, is located in the Delacroix Island Field. The discharge empties into the junction of a canal and a small bay bordered by brackish marsh. Like the previous station, high levels of TPH were found. Sediment TPH concentrations ranged from 4795 ug/g at the discharge to 145 ug/g at 300m (Table 8, Figure 43).

Station 157 (FAC.#12) is located on a canal in a washed out portion of fresh-intermediate marsh at the western edge of the Mississippi River Delta. This West Bay Field facility has a high discharge. Sediment TPH concentrations ranged from 2043 ug/g at the discharge to 365 ug/g at 300m (Table 9, Figure 44).

Station 165 (Delta Gathering Station) is located in a canal off an abandoned Mississippi River distributary in a fresh-intermediate marsh. The facility was a high discharge rate station. The highest sediment TPH concentrations in this study were found at the 45m (150ft) sampling location, not at the 15m (50ft) location (Table 10, Figure 45). No sample was collected at the discharge due to shallow water. TPH concentrations ranged from 15830 ug/g at 45m to below detection limits at 150 and 300m (500 and 1000ft). There were abrupt drops in sediment TPH beyond 90m (300ft). This corresponded with sampling locations outside of the shallow, bowl shaped basin that the discharge flowed into. It also corresponded to the extent of stratification at this station. Station 181 (LL&E 22-2D) is located in a canal bordered by a saline marsh. This station was a moderate discharge rate facility. The sediment TPH values ranged from 1361 ug/g at the discharge to less than the detection limit at 300m (1000ft) from the discharge (Table 11, Figure 46). The sharp drop between the 45m (150ft) and 90m (300ft) station south of the discharge corresponds to the change from a dredged oilfield access canal to a deep bayou with swift currents. Stratification was found at the 15m (50ft) sampling location.

Station 214 (Homeplace TB) is located in a dead-end canal bordered by a saline marsh. It was the only low discharge rate criteria station among the sediment sampling sites. Sediment TPH concentrations ranged from 5350 ug/g at the discharge to 1050 ug/g at 300m (1000ft) (Table 12, Figure 47). Except for one of the samples taken at the discharge, the TPH values are very similar and do not show a strong trend of decreasing concentration with distance.

Duplicate sediment samples collected at the same location showed a range of zero to 300% differences in TPH concentration. The highest variabilities between the duplicate sediment samples were found at the locations with the highest TPH concentrations. The high variability in TPH concentrations between samples but within sampling areas is evidence of the patchiness of the concentrations and that too few samples were analyzed to determine a representative value with any statistical confidence.

F.8. Sediment Loss on Ignition and Grain Size

The loss on ignition data (Tables 7-12) showed a different pattern with respect to sediment parameter variability. Stations 57 and 88 showed as much as a 35% difference in percent loss on ignition between duplicate cores taken at the same location and nearly as great a variation in cores collected as little as 15m apart. The variability in results evidences the need for more sample analysis to clearly define sample variability. The remaining four stations (157, 165, 181 & 214) all showed very little variation between both the duplicate cores taken at the same site and from other core locations within the station.

Sediment LOI and grain size data are shown graphically in Figures 49-54. The percent loss on ignition ranged from 7.3 to 57.0 at Station 57, 6.0 to 37.6 at Station 88, 5.9 to 7.3 at Station 157, 0.8 to 7.2 at Station 165, 3.3 to 12.4 at Station 181 and 16.1 to 21.7 at Station 214. Stations 57, 88 and 214 generally had higher percent loss on ignition than the three remaining sediment sampling stations.

Grain size data from the bottom sediment core samples showed differences in surface sediment composition among the stations. Sediments at Station 57 were predominantly clayey silts or silty clays with the sand sized fraction making up approximately 10% of the samples on average. At Station 88, clayey silts predominated with the sand fraction averaging approximately 13%. The core samples from Station 157 were all very uniform with respect to both grain size and LOI percentages. The soils were composed of nearly equal parts silt and clay with the sand fraction less than 5%.

The sediments at Station 165 showed large differences in grain size composition among the locations sampled. Locations within 100m of the discharge were clayey silts with the sand fraction constituting less than 5%. At greater distances from the discharge, the sampling locations ranged from sand to silty sand to

Figure 49

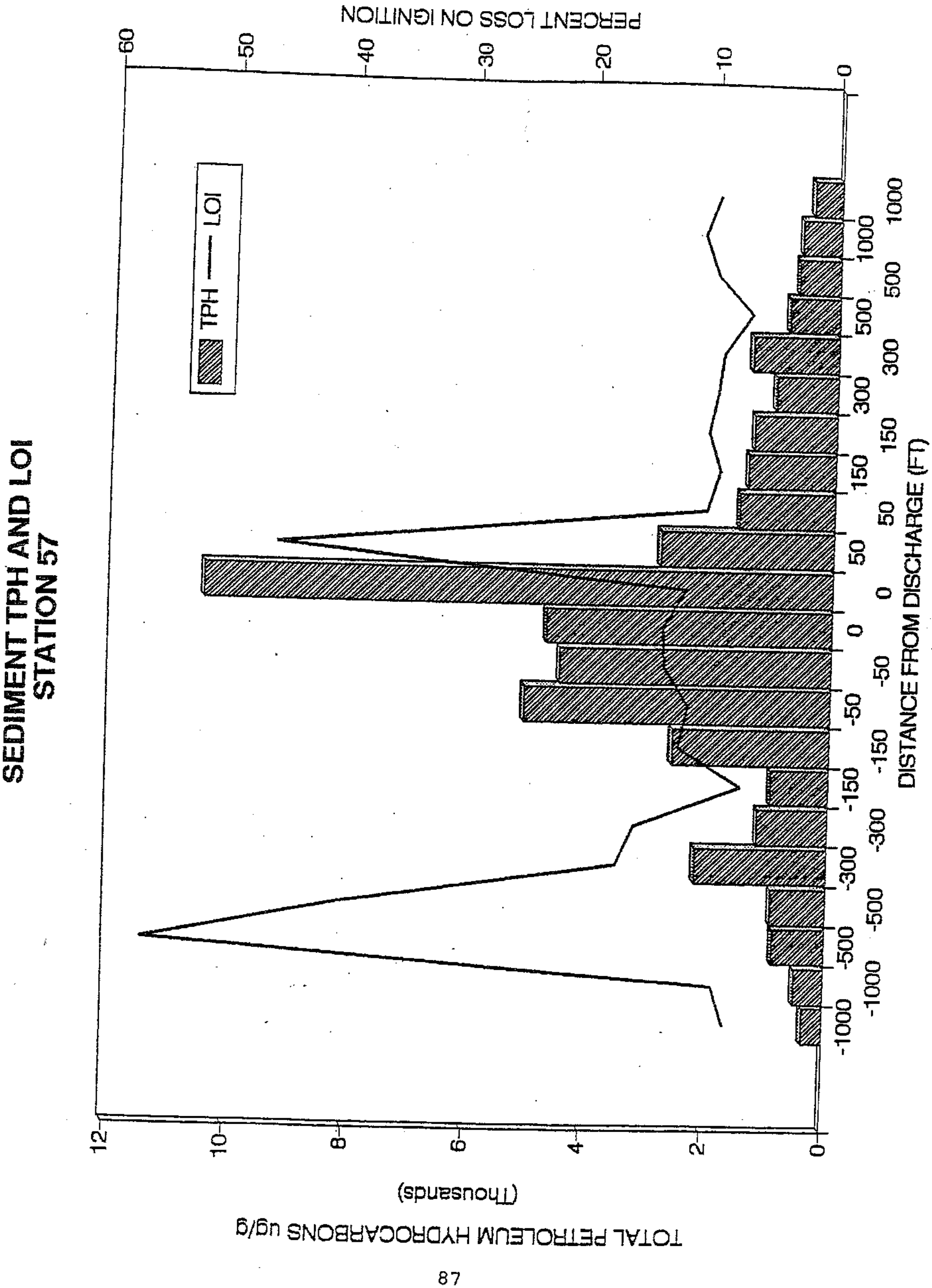

SEDIMENT TPH AND LOI
STATION 57
TPH
LOI
PERCENT LOSS ON IGNITION
0
10
20
30
40
50
60
TOTAL PETROLEUM HYDROCARBONS ug/g
(Thousands)
0
2
4
6
8
10
12
DISTANCE FROM DISCHARGE (FT)
-1000
-1000
-500
-500
-300
-300
-150
-150
-50
-50
0
0
50
50
150
150
300
300
500
500
1000
1000

Figure 50

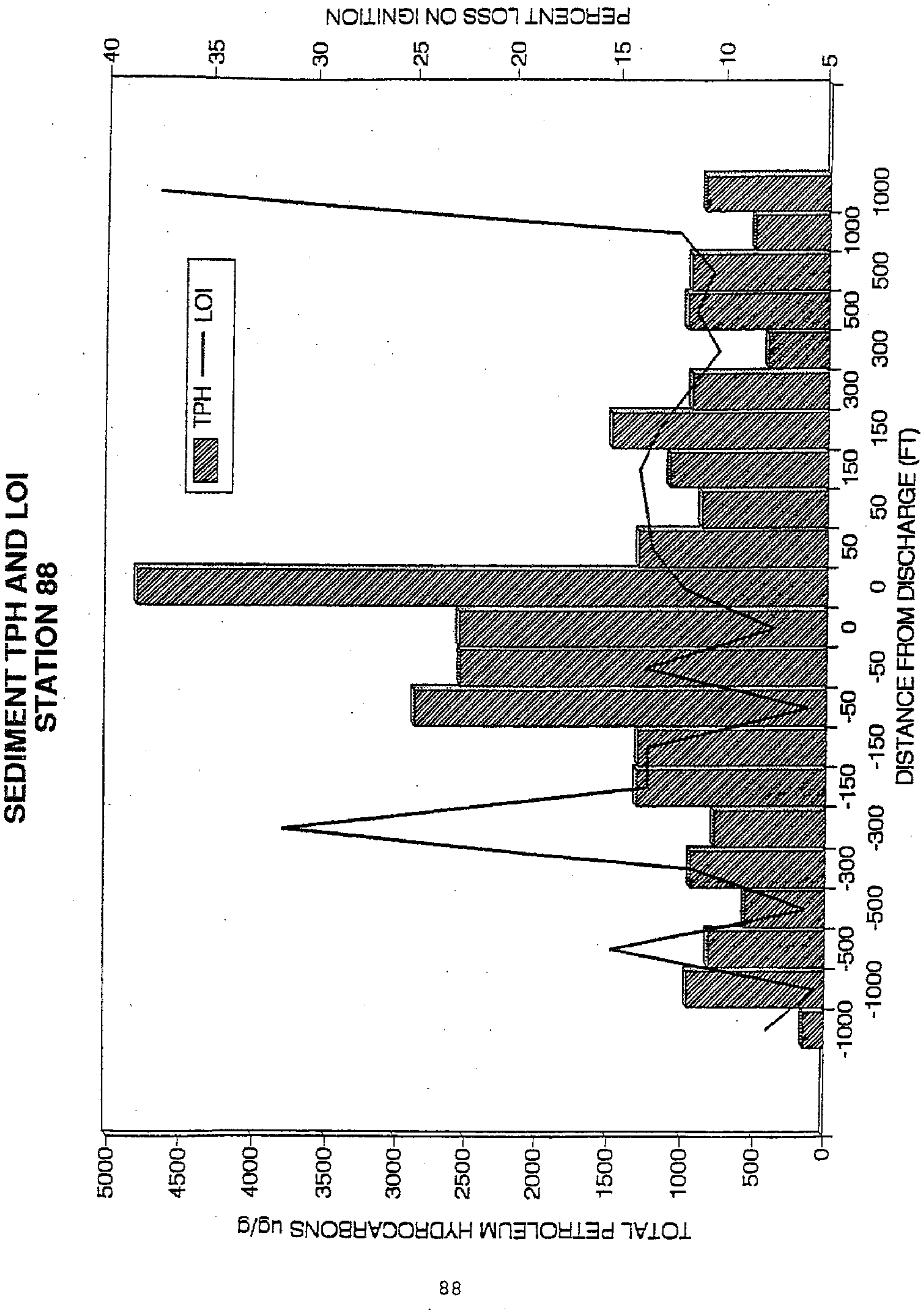

SEDIMENT TPH AND LOI
STATION 88
TPH
LOI
PERCENT LOSS ON IGNITION
40
35
30
25
20
15
10
5
TOTAL PETROLEUM HYDROCARBONS ug/g
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
DISTANCE FROM DISCHARGE (FT)
-1000
-1000
-500
-500
-300
-300
-150
-150
-50
-50
0
0
50
50
150
150
300
300
500
500
1000
1000

Figure 51

SEDIMENT TPH AND LOI
STATION 157

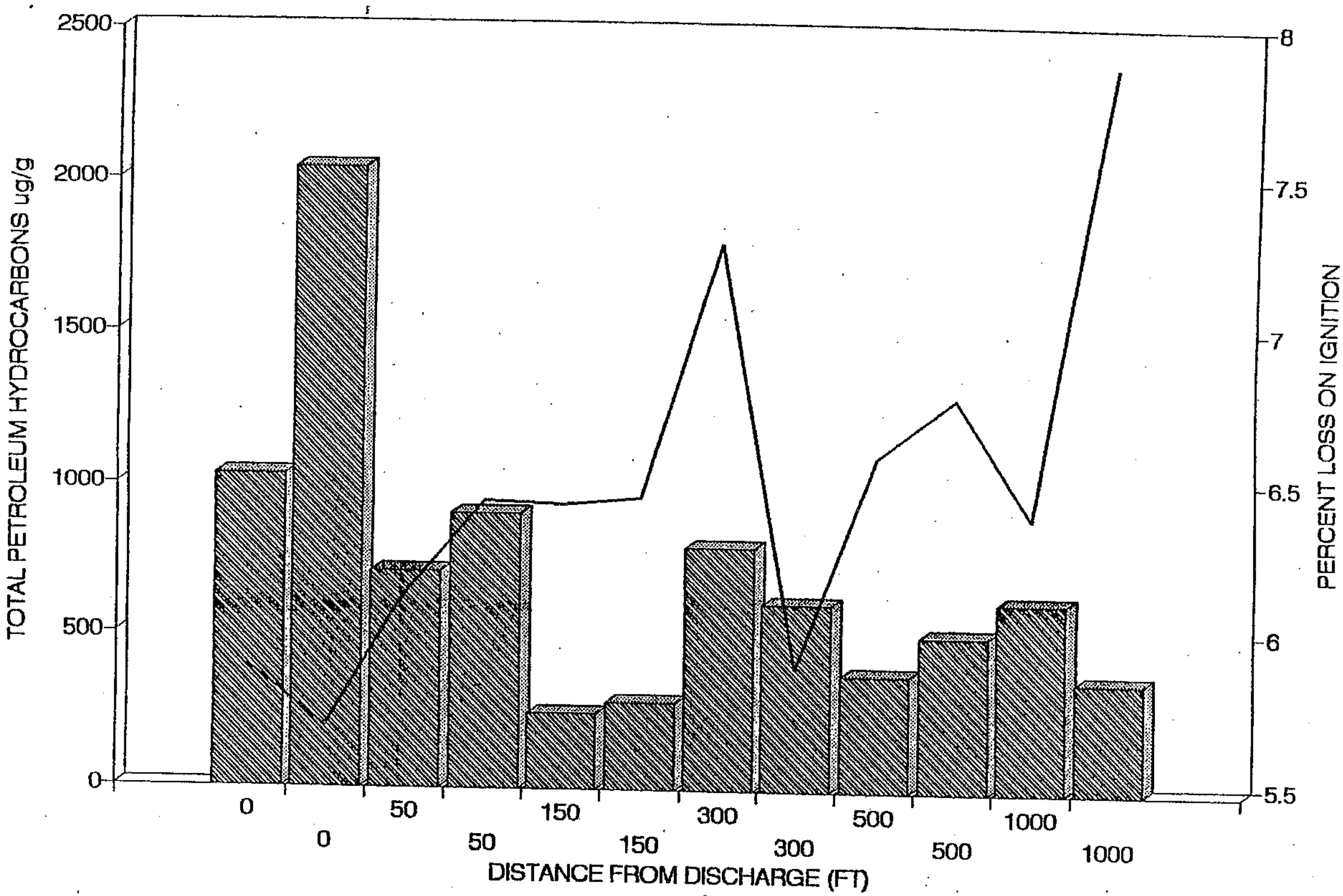


Figure 52

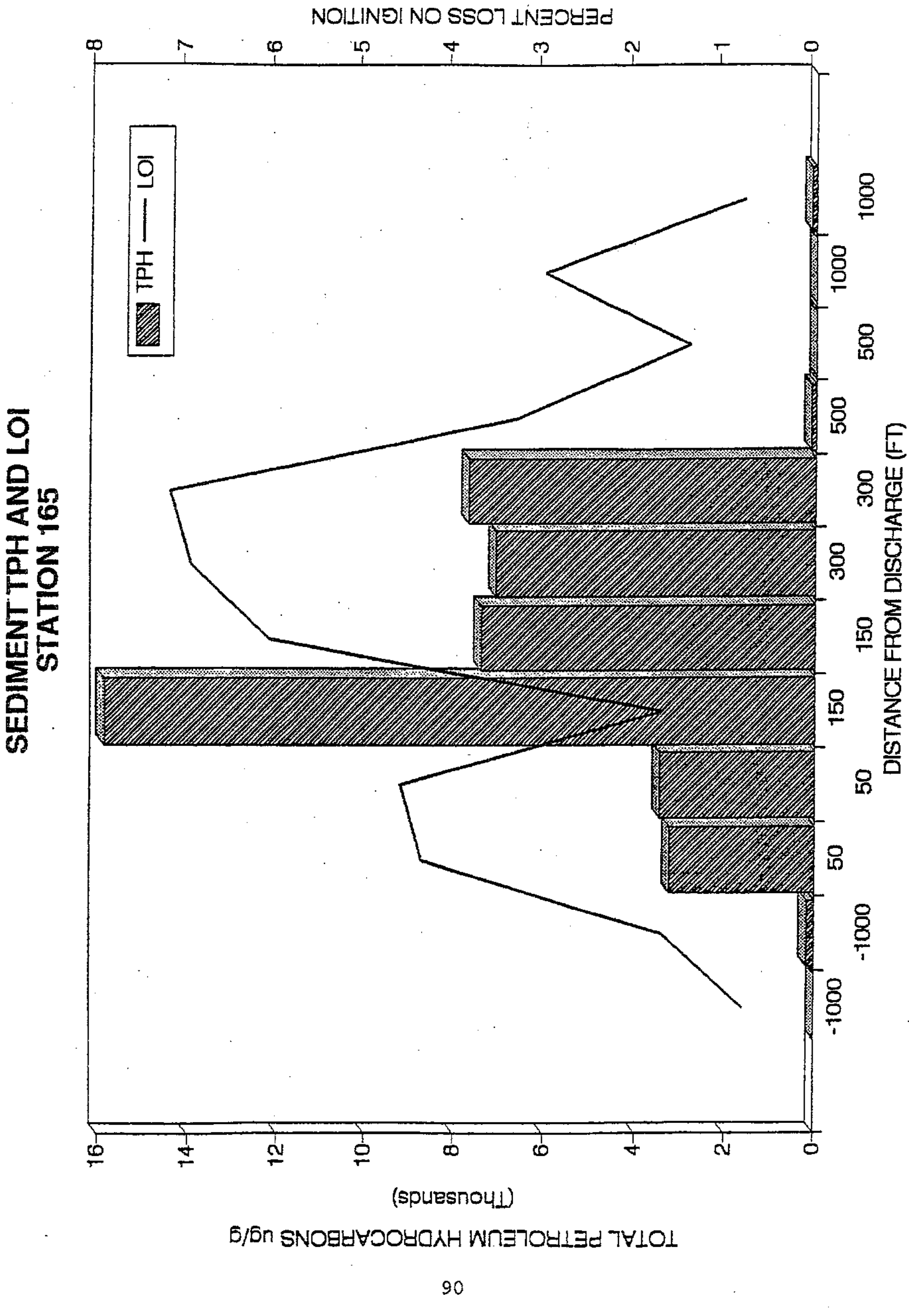
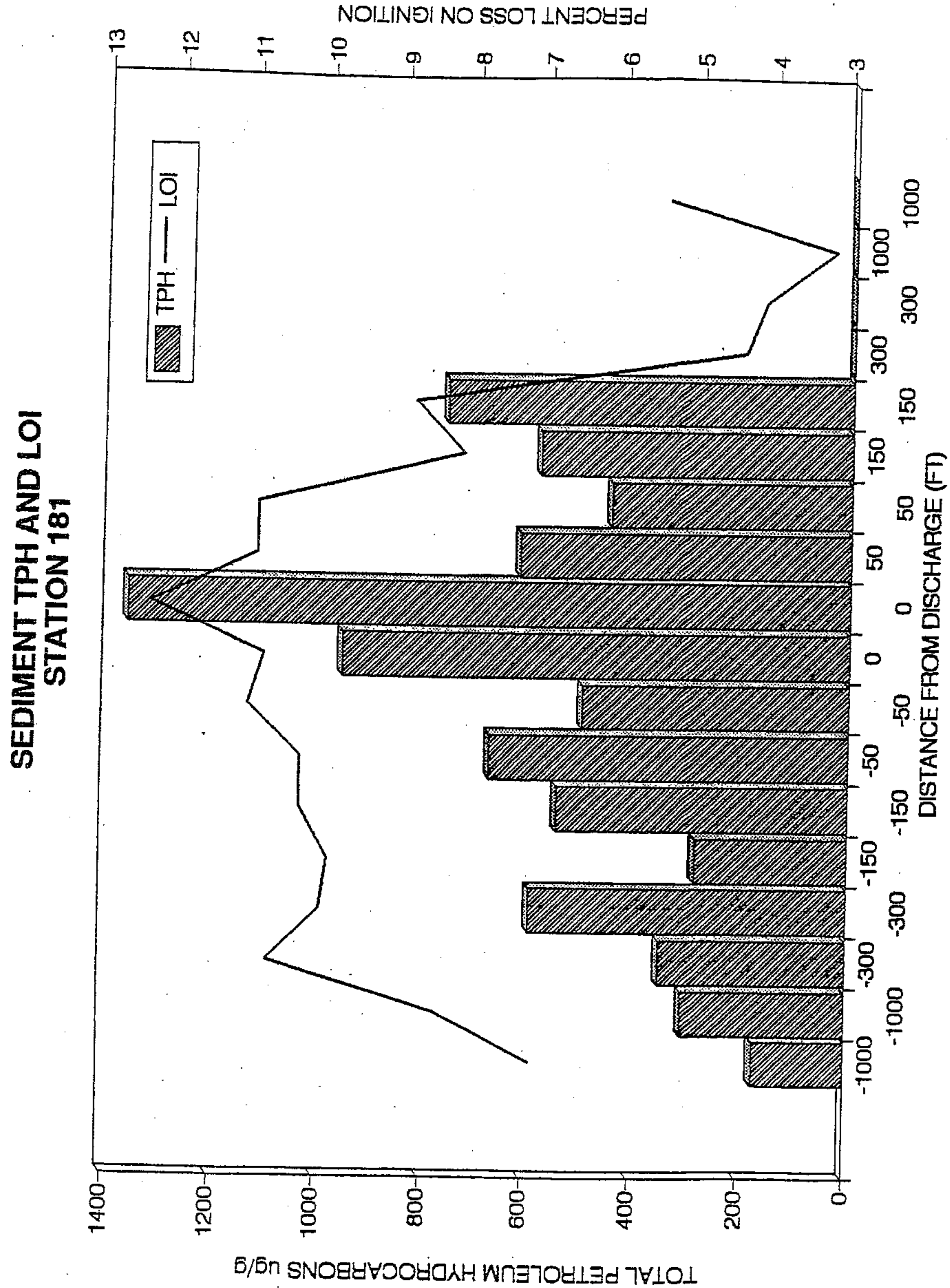
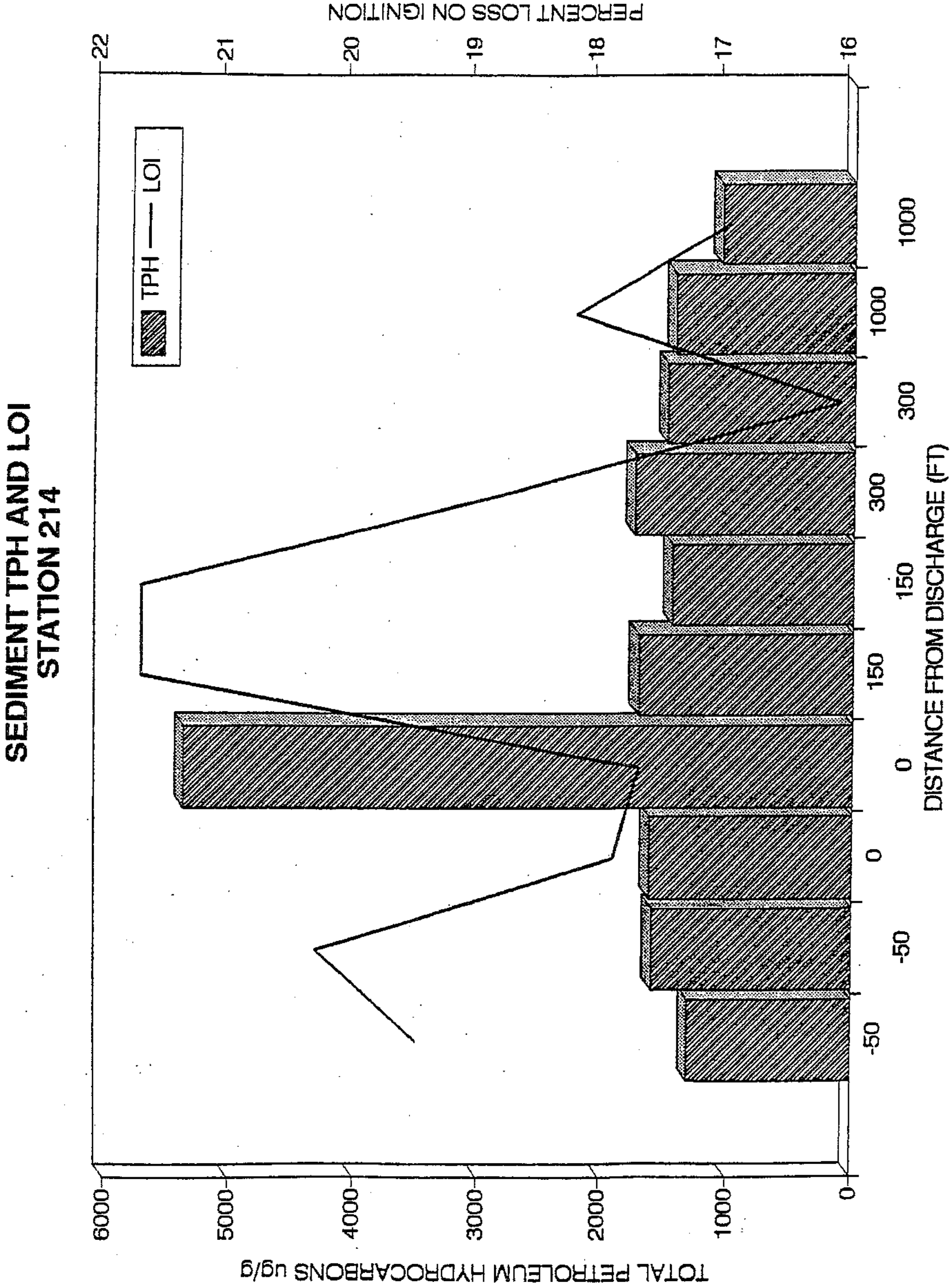

SEDIMENT TPH AND LOI
STATION 165
TPH
LOI
PERCENT LOSS ON IGNITION
TOTAL PETROLEUM HYDROCARBONS ug/g
(Thousands)
DISTANCE FROM DISCHARGE (FT)
-1000
-1000
50
50
150
150
300
300
500
500
1000
1000
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
6
7
8

Figure 53



SEDIMENT TPH AND LOI
STATION 181
TPH
LOI
PERCENT LOSS ON IGNITION
3
4
5
6
7
8
9
10
11
12
13
TOTAL PETROLEUM HYDROCARBONS ug/g
0
200
400
600
800
1000
1200
1400
DISTANCE FROM DISCHARGE (FT)
-1000
-1000
-300
-300
-150
-150
-50
-50
0
0
50
50
150
150
300
300
1000
1000

Figure 54



SEDIMENT TPH AND LOI
STATION 214
TPH
LOI
PERCENT LOSS ON IGNITION
22
21
20
19
18
17
16
TOTAL PETROLEUM HYDROCARBONS ug/g
6000
5000
4000
3000
2000
1000
0
-50
-50
0
0
150
150
300
300
1000
1000
DISTANCE FROM DISCHARGE (FT)

silty clay to clayey silt. Duplicate cores collected at 300m southwest of the discharge yielded a sand and a clayey silt at the same location. Samples from Station 181 had a higher percentage of clay than those of other stations. The soils at this station were silty clays or clayey silts with an average sand fraction of less than 10%. Like Stations 157 and 181, the sediments at Station 214 were relatively uniform silty clays or clayey silts with an average sand fraction less than 10%.

F.9. Water and Sediment ^{226}Ra and ^{228}Ra

Radionuclide samples were collected at Stations 57, 88, 157, 165, 181 and 214. Based on the discharge radionuclide criteria listed in the Methods Section, Station 214 had a discharge radionuclide criteria of Low = <200 pCi/l, Stations 57 and 165 were Moderate = 200-600 pCi/l and Stations 88, 165 and 181 were High = >600 pCi/l.

The radionuclide surface and bottom water and bottom sediment samples were collected 15m (50ft) up and down current of the discharge (Stations 57, 88 and 181) or only down current (Stations 157, 165 and 214) if the station was located in a dead-end canal. Three radionuclide water samples were lost in transit to the laboratory when their caps were broken. These samples were from Station 57 (down current, bottom water), Station 88 (down current, bottom water, QA/QC) and Station 157 (down current, surface water, QA/QC). Two other water sample containers leaked slightly but retained adequate volume to analyze. These samples were at Stations 88 (up current, surface) and 214 (down current, surface). Tables 13 and 14 present the water and sediment total ^{226}Ra and ^{228}Ra sample data. Figures 55 through 58, respectively, show water ^{226}Ra, water ^{228}Ra, sediment ^{226}Ra and sediment ^{228}Ra values, error factors and lower limit of detection (LLD) for each sample.

Nine of the eighteen water samples contained values of total ^{226}Ra above the LLD. The LLD for ^{226}Ra in the water samples ranged

TABLE 13

Ra226 & Ra228 ACTIVITY IN WATER SAMPLES
API LOUISIANA WETLANDS STUDY

STATION NUMBER	SAMPLE TYPE	DISTANCE FROM DISCHARGE (FT)	TOTAL Ra226 (pCi/L)	TOTAL Ra226 ERROR +/- (pCi/L)	Ra226 LOWER LIMIT OF DETECTION (pCi/L)	TOTAL Ra228 (pCi/L)	TOTAL Ra228 ERROR +/- (pCi/L)	Ra228 LOWER LIMIT OF DETECTION (pCi/L)	SUM OF Ra226 & Ra228 (pCi/L)
57	SURFACE	50	0.2	0.2	0.3	1.6	1.7	2.8	1.8
57	SURFACE	-50	0.2	0.2	0.2	2.6	1.4	2.1	2.8
57	BOTTOM	-50	0.5	0.2	0.2	2.4	1.4	2.1	2.9
88	SURFACE	50	0.1	0.2	0.3	0.2	2.0	3.3	0.3
88	BOTTOM	50	0.2	0.2	0.3	1.7	2.0	3.3	1.9
88	SURFACE	-50	0.0	0.6	1.0	3.5	6.1	9.9	3.5
88	BOTTOM	-50	1.2	0.4	0.3	0.3	2.3	3.9	1.5
157	SURFACE	50	0.2	0.1	0.1	0.0	1.5	2.8	0.2
157	BOTTOM	50	1.2	0.4	0.3	0.3	2.3	3.9	1.5
165	SURFACE	50	1.6	0.3	0.1	0.0	1.4	2.8	1.6
181	SURFACE	50	0.2	0.2	0.2	0.4	1.6	2.6	0.6
181	BOTTOM	50	0.4	0.3	0.3	1.0	1.7	2.8	1.4
181	SURFACE	-50	0.0	0.2	0.3	0.0	1.6	2.8	0.0
181	BOTTOM	-50	0.2	0.2	0.2	0.4	1.6	2.6	0.6
181	BOTTOM	-50	0.2	0.2	0.3	0.2	2.3	3.9	0.4
214	SURFACE	50	1.5	0.3	0.1	0.0	1.4	2.4	1.5
214	SURFACE	50	0.7	0.5	0.5	0.0	5.3	9.5	0.7
214	BOTTOM	50	0.3	0.2	0.2	0.2	1.6	2.6	0.5

NOTE: ERROR = +/- 2 STANDARD DEVIATIONS (95% C.I.) LOWER LIMIT OF DETECTION = UPPER LIMIT OF 99% C.I.

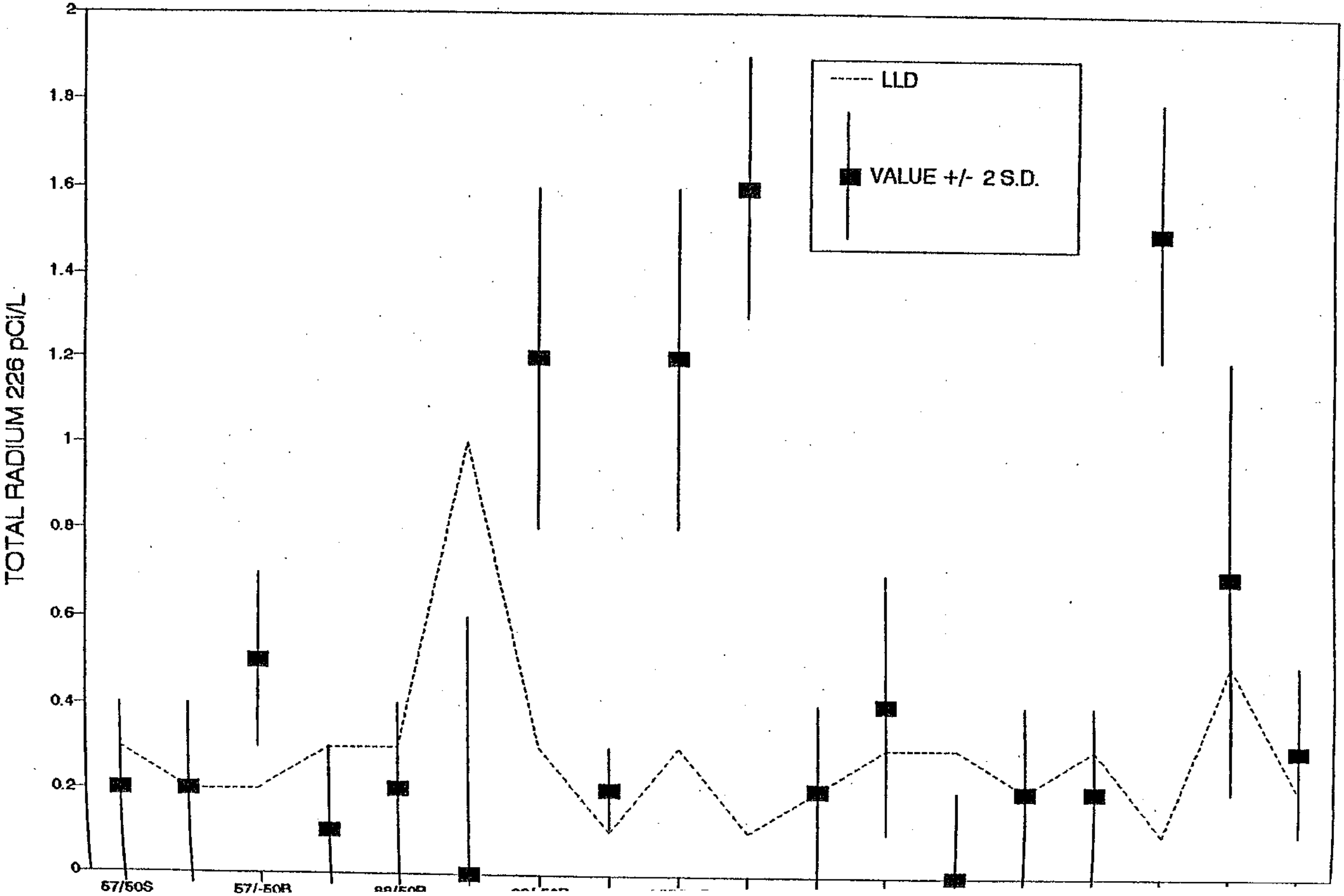
TABLE 14

Ra226 & Ra228 ACTIVITY IN SEDIMENT SAMPLES
API LOUISIANA WETLANDS STUDY

STATION NUMBER	DISTANCE FROM DISCHARGE (FT)	TOTAL Ra226 (pCi/gm)	TOTAL Ra226 ERROR +/- (pCi/gm)	TOTAL Ra226 LOWER LIMIT OF DETECTION (pCi/gm)	TOTAL Ra228 (pCi/gm)	TOTAL Ra228 ERROR +/- (pCi/gm)	TOTAL Ra228 LOWER LIMIT OF DETECTION (pCi/gm)	SUM OF Ra226 & Ra228 (pCi/gm)
57	50	0.6	0.2	0.1	0.6	0.6	0.9	1.2
57	-50	6.3	0.6	0.1	3.9	0.8	0.9	10.2
88	50	0.3	0.1	0.1	0.3	0.6	1.0	0.6
88	-50	0.9	0.2	0.1	0.9	0.7	1.0	1.8
157	50	0.8	0.2	0.1	0.5	0.8	1.2	1.3
165	50	1.7	0.3	0.1	2.0	0.8	1.1	3.7
181	50	0.1	0.1	0.1	0.0	0.6	1.1	0.1
181	-50	1.2	0.3	0.1	1.2	0.8	1.1	2.4
181	-50	0.3	0.1	0.1	0.0	0.6	1.1	0.3
214	50	0.1	0.1	0.1	0.0	0.7	1.1	0.1

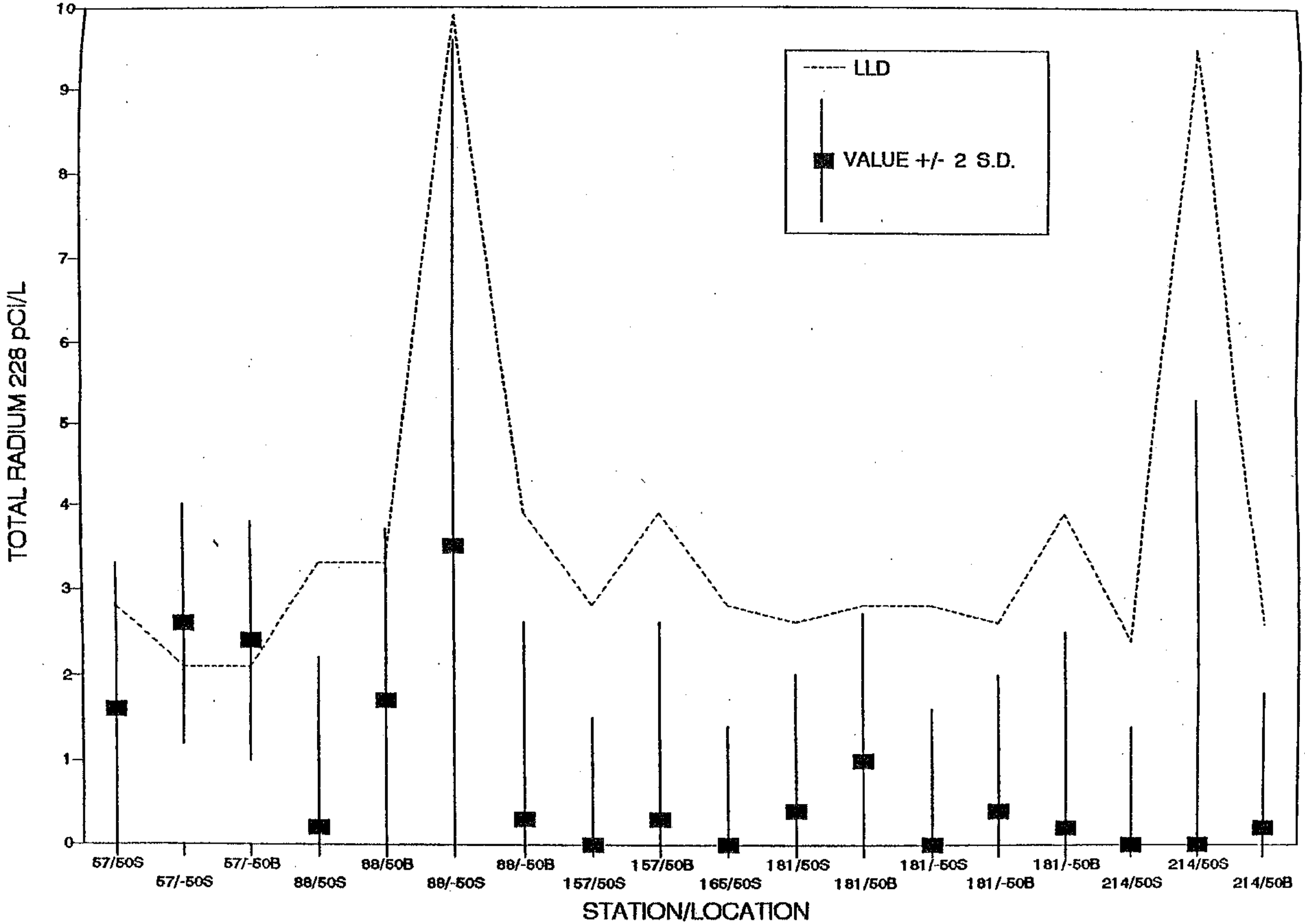
NOTE: ERROR = +/- 2 STANDARD DEVIATIONS (95% C.I.) LOWER LIMIT OF DETECTION = UPPER LIMIT OF 99% C.I.

WATER SAMPLE RADIUM 226 ACTIVITY
API LOUISIANA WETLANDS STUDY

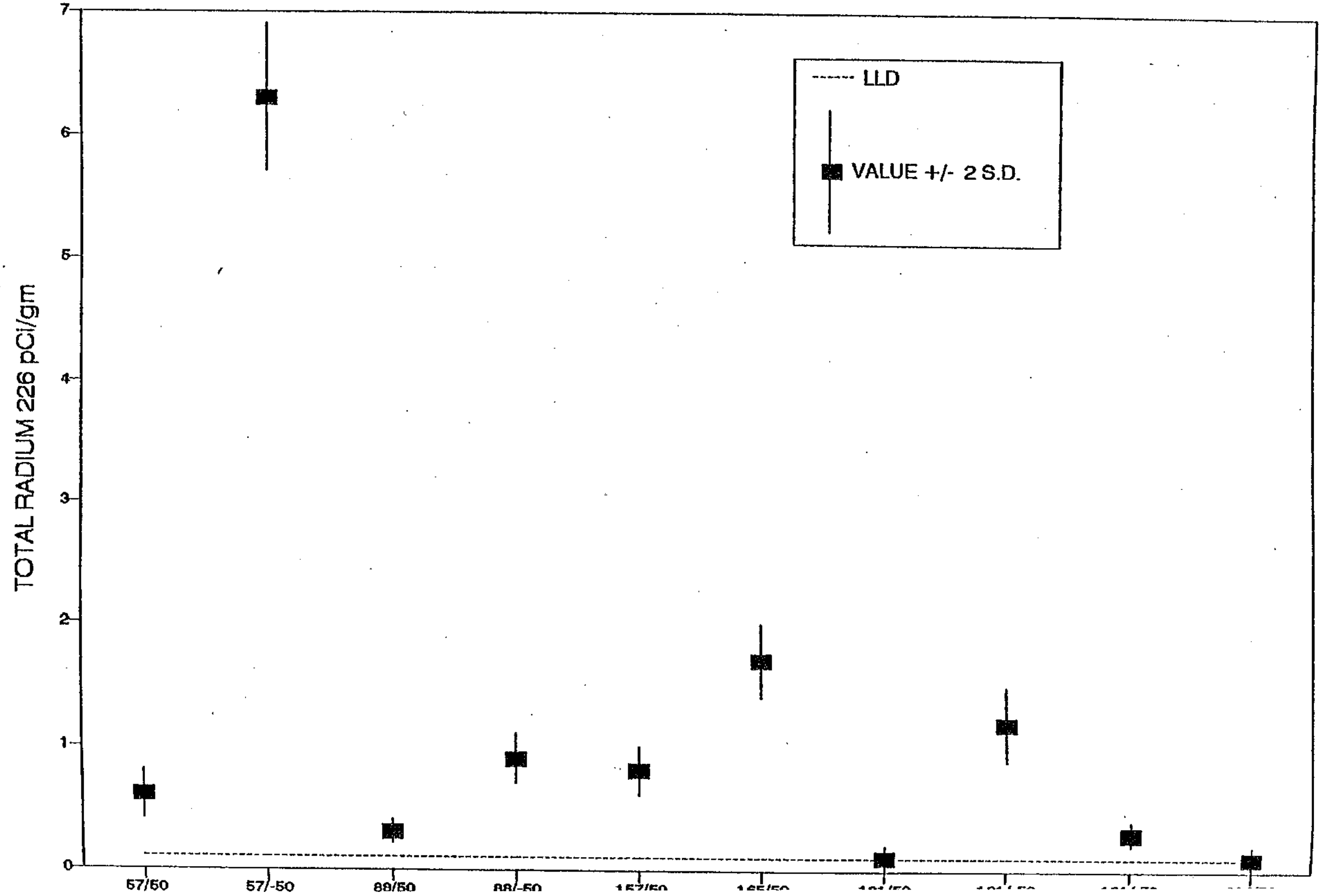


STATION/LOCATION

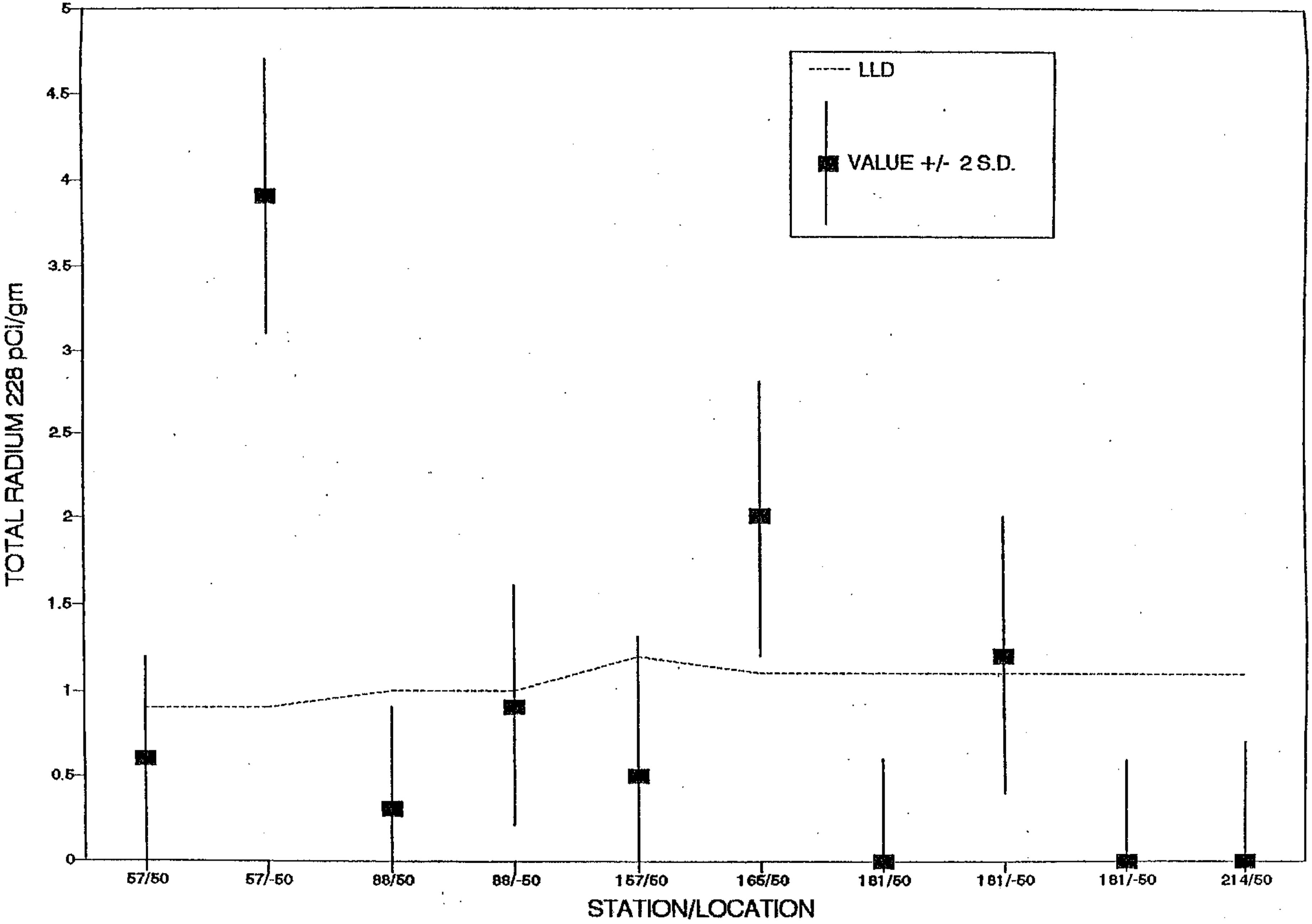
WATER SAMPLE RADIUM 228 ACTIVITY
API LOUISIANA WETLANDS STUDY



SEDIMENT SAMPLE RADIUM 226 ACTIVITY
API LOUISIANA WETLANDS STUDY



SEDIMENT SAMPLE RADIUM 228 ACTIVITY
API LOUISIANA WETLANDS STUDY



between 0.1 and 0.4 pCi/l except for the two samples that had leaked in transit. The LLD for those samples were 1.0 (Station 88) and 0.5 pCi/l (Station 214). The values that exceeded the LLD ranged from 0.2 (Station 157, surface, down current) to 1.6 pCi/l (Station 165, down current, surface). Five of the nine samples above the LLD were bottom water samples.

Two of the eighteen water samples contained values of ^{228}Ra above the LLD. The LLD for the ^{228}Ra samples ranged between 2.1 and 3.9 pCi/l , again except for the two samples that leaked. The LLD for those samples were 9.9 and 9.5 pCi/l, respectively. The two values above the LLD were from the up current surface (2.6 pCi/l) and bottom (2.4 pCi/l) samples at Station 57.

The LLD for ^{226}Ra in the sediment samples was 0.1 pCi/gm. Eight of the ten sediment samples analyzed had values above 0.1 pCi/gm. The values for ^{226}Ra ranged from 0.3 pCi/gm at Stations 88 (down current) and 181 (up current) to 6.3 pCi/gm at Station 57 (up current). Only the sample from up current at Station 56 exceeded 2.0 pCi/gm.

The LLD for ^{228}Ra in the sediment samples was approximately 1.0 pCi/gm. Seven of the ten sediment samples analyzed had values below the LLD. The three samples with values higher than the LLD were from up current at Station 57 (3.9 pCi/gm), down current at Station 165 (2.0 pCi/gm) and up current at Station 181 (1.2 pCi/gm).

G. DISCUSSION

G.1. General

The stations were sampled in late 1989 and provided a wide variety of settings in which to examine the relationship between PW discharges and the water column in coastal Louisiana. Those settings include fresh-intermediate, brackish and saline habitats; both canals and open bays as receiving water bodies; low, moderate and high discharge rates and multiple discharges in the same field.

The fresh-intermediate marsh discharges sampled were all from areas with relatively high freshwater inflows from the Mississippi or Atchafalaya Rivers. None of these stations was located in open water. Stations 82 (Delta Duck Field), 157 (West Bay) and 165 (West Delta/SE Black Bay) were located in canals off active or inactive Mississippi River Delta distributaries. Stations 185 and 186 (Weeks Island Field) were located on canals near the transition between brackish and fresh-intermediate marsh on the northeast shore of Vermilion Bay. These two stations were located furthest from Mississippi River distributaries and high river freshwater inputs.

Stations 242 (Bayou Sale Field) and 243 (Belle Isle Field) were located on bayous receiving freshwater from the Wax Lake Outlet of the Atchafalaya River. During the months of February to June, these sites normally receive greater freshwater flows than the rest of the year due to high spring flows on the Mississippi River (USACOE, 1981). All the sampling occurred during October, November and early December when river levels are at the late summer/early fall lows or beginning to rise from the yearly low flow.

While most of the information on long-term salinity trends in coastal Louisiana comes from the Barataria Basin, it is generally applicable to other basins. In the brackish and saline habitats, lowest salinities occur in the spring. The highest salinities occur during the later summer and early fall (Conner and Day, 1987). Both seasonal salinity lows and highs may be modified by the timing of Mississippi River floods, severe tropical storms and hurricanes (Gosselink, 1984).

G.2. Currents

Current velocity and direction data vary widely between the surface and bottom and close to and away from the discharge structure. Surface and mid-depth velocities were higher than bottom velocities. Current velocities in the top 0.3m (1ft) of the water column were often affected by ambient wind speed and direction. The shallower sampling locations around a station usually had lower current velocities than deeper locations. In some cases this trend was obscured due to velocity changes associated with tidal stage changes or wind shifts which can drastically alter water level during sampling.

At open water stations, the 15m (50ft) down current sampling location's current velocities and directions were often affected by the pilings supporting the production facility. Even at low current velocities, turbulence was evident near the structures. Current velocities and directions would fluctuate markedly over short periods of time (minutes). This turbulence may aid in mixing the discharge with the water column. In the canal configuration, sampling was parallel to the facility, so current readings were not affected by turbulence around the structure.

G.3. Produced Water Hydrocarbons and Salinity

The produced water TPH and salinity data presented in Table 3 do not provide a long-term data set to determine "average" inputs to coastal Louisiana. The data do provide a "snapshot" of the discharges to be used in conjunction with other data to determine how far the discharge remained detectable in the water column at the time of sampling. A range of factors at each site such as discharge rate, discharge TPH concentration, receiving water body configuration, current velocity, water column suspended solids concentration, sediment particle size and the dynamics of these factors determine the extent of water column and sediment hydrocarbon contamination. Hydrologic and water quality data collected in this study will be used in the future to model the dispersion plume of PW discharges in shallow water coastal habitats.

The TPH concentrations of the PW discharges in this study ranged from 1.7 (Station 165) to 119 mg/l (Station 242) and averaged 28.2 mg/l, with a S.D. of 23.5 mg/l (Table 3). Total hydrocarbons in PW samples analyzed by IR or GC and reported by Neff et al. (1989) ranged from 20 to 48 mg/l. Other studies of PW from platforms in the Gulf of Mexico such as Jackson et al. (1981) and Lysyj (1982) reported ranges of means from 11 to 106 mg/l TPH using IR. The TPH values reported in this study generally fall within the ranges cited in spite of differences in analytical methods.

Kraemer and Reid (1984) reported salinities of PW discharges from 28 oil and/or gas wells in the U. S. Gulf of Mexico Region ranging from 7.5 to 235 ppt. This is very similar to the 10- to 227-ppt range of the discharges sampled in study. The mean and S.D. of PW salinities from their study was 87 ppt and 60 ppt, respectively. This compared with a mean of 141 ppt and a S.D. of 47 ppt from this study. Boesch and Rabalais (1989b) reported PW salinities 100-140 ppt from discharges in the Bayou Sale, Lafitte and Golden Meadow Fields. Different discharges in each of these fields were sampled during this study.

G.4. Water Column Hydrocarbons

Dilution of the discharge TPH concentration to below detectable levels (0.5 mg/l) occurred within 300m (1000ft) of the discharge. Table 6 shows 11 of the 36 stations with detectable bottom water hydrocarbon concentrations in one or more samples. Excluding the two samples which contained high suspended sediment concentrations, the highest levels of bottom water TPH (31 mg/l) occurred at 15m (50ft) from Station 186. Five other stations had detectable TPH concentrations at the 15m distance. The samples were from Stations 32 (8.1 mg/l), 35 (8.6 mg/l), 58 (4.6 mg/l), 67 (3.0 mg/l) and 72 (2.5 mg/l). Three stations (Stations 31, 35 and 66) had TPH concentrations of 2.4, 15 and 3.2 mg/l at the 90m (300ft) distance. No bottom water samples from the 300m (1000ft) distance had detectable levels of TPH. As stated in the Results Section, none of the surface water samples contained detectable levels of TPH.

Comparison of water column TPH data collected in this study with other studies of PW discharges in coastal habitats is difficult due to differences in methodology. Boesch and Rabalais (1989b) reported the concentrations of a number of specific hydrocarbons and classes of hydrocarbons analyzed by GC/MS in near surface water samples collected in the vicinity of a PW discharge in the Bayou Sale Field. Their results showed trace to below detection limit concentrations of volatile, polyaromatic and saturated hydrocarbons both at the discharge and 500m (1600ft.) from the discharge. No bottom water TPH sample data were collected in their study. While analytical techniques used in their study were more sensitive to low levels of hydrocarbons, the TPH by IR analytical method is suitable for a broad scale survey such as this study. This is due to the relative ease of sample preparation and reduced analytical cost for large numbers of samples taken at numerous locations.

G.5. Salinity Stratification

Determination of which sampling locations around a station were stratified due to the PW discharge was obvious in many cases.

The PW was warmer and much more saline than the rest of the water column. It also formed a sharp boundary off the bottom.

Stations 58 and 66 in the Queen Bess Field had the highest water column, nondischarge-related salinities. The bottom salinities at these stations in lower Barataria Bay ranged from 20-24 ppt during our sampling. By contrast, the bottom salinities at the sampling locations where stratification occurred ranged from 28 ppt to >40 ppt, even in low salinity habitats. The stratified layer was also 1-4°C warmer than the rest of the water column. Where present, the stratified layer on the bottom ranged from 15 to 75cm deep, (0.5-2.5ft) with most locations exhibiting a less than 30cm (1.0ft) layer. If no stratification was observed at any sampling location, the assumption was made that no stratification was present although no measurements were made at the discharge or closer than the 15m (50ft) sampling stations.

Stratification was evident at 20 of the 36 sites sampled. Sixteen sites showed no stratification. The stratification at two stations at the 300m (1000ft) distance did not appear related to the PW discharges. Station 53 in the Dog Lake Field was not stratified near the discharges or at any other sampling locations other than the 300m (1000ft) location in the up current direction. Additionally, stratification at this location, which was in a separate canal leading into Hackberry Lake, was between 0.3 and 1.0m (1 and 3ft) below the surface as opposed to near the bottom of the water column.

Stratification at Station 157 in the West Bay Field occurred only 300m (1000ft) west of the outfall in the main channel between the field and the much deeper, more saline Tiger Pass which connects directly with the Gulf of Mexico. At this sampling point salinity ranged from 0.9 ppt at the surface to 13.7 ppt at the bottom. This area is also heavily influenced by Mississippi River discharge, and the fresh, highly turbid river water was evident in the area.

There were three stations with stratification at all sampling locations, Stations 170 and 177 in Four Isle Dome Field and Station 244 in Rabbit Island Field. In both fields, area-wide salinity stratification was observed during sampling. In neither case did the stratification appear to be related to the discharges.

All sampling locations around Stations 170 and 177 in the Four Dome Isle Field were stratified, but there was no sharp boundary between the overlying water and the higher salinity bottom water. The salinities increased gradually from approximately 9 ppt at the surface to 15 ppt at the bottom. The other station in the Four Isle Dome Field (Station 181), sampled on the previous day, did show the typical sharply bounded salinity stratification layer 15cm (6 in) off the bottom at the 15m (50ft) sampling location.

Station 244 in the Rabbit Island Field, in the open waters of western Atchafalaya Bay, is the closest to the Gulf and is the most exposed of all the stations sampled. The station has no land between it and the Gulf of Mexico. It is also located in an area strongly influenced by freshwater from the Lower Atchafalaya River and Wax Lake Outlet. All of the sampling locations around the discharge were stratified. While bottom salinities were 12-13 ppt, the surface salinities were 1-3 ppt. Although salinity increased with depth, the sharpest change in salinity occurred between 1-2m (3-7ft) above the bottom. The surface waters were highly turbid even though winds and waves were calm, indicating freshwater and suspended sediment input from the Lower Atchafalaya River and Wax Lake Outlet. The stratification observed at this station appeared to be related to the area-wide freshwater inputs, not the discharge.

In several cases, multiple discharges in the same field were sampled. These included the six stations (Stations 31, 32, 33, 34, 35 and 36) in the Golden Meadow Field, five (Stations 65, 211, 214, 217 and 224) in the Lake Washington Field, four (Stations 57, 59, 62 and 67) in Bay De Chene Field, three (Stations 170, 177 and 181) in Four Isle Dome Field and two each in Queen Bess (Stations 58 and 66), Lafitte (Stations 69 and 72) and Delacroix Island (Stations 88 and 97) Fields. With the exception of Stations 170 and 177 in the Four Isle Dome Field, all the discharges sampled within a field were located over 1km (0.6mi) apart. Stations 170 and 177 were located approximately 800m (2700ft) apart. Based on the maximum produced-water-related stratification distances recorded in this study, it is unlikely that the stratified area from one discharge overlaps that of other discharges.

Table 15 presents comparison data for salinity stratification near PW discharges in coastal Louisiana. The table lists location, discharge rate, station configuration, water depth, current velocity and discharge stratification distances. The sites include nine stations from this study located in the same fields as those from the chosen literature.

Boesch and Rabalais (1989a) examined several OCS PW discharges into Louisiana coastal waters. They reported salinity stratification at two of the three sites that they studied. At the Bayou Rigaud site on Grand Isle, stratification was found within 100m of one discharge canal and no stratification was found at a second discharge approximately 1km (0.6mi) away. The discharge rates at Bayou Rigaud sites were 105,000 and 40,000 bbl/day, respectively.

The stratification at their Port Fourchon site extended approximately 1 km from the discharge. No salinity data were reported for the East Timbalier Island site.

Where present, the salinity stratification in their study resembled that found at most of the stratified stations in this study. The PW-related stratified layer they found was sharply bounded and had a salinity of between 28-36 ppt, similar to the 28

TABLE 15

COMPARISON OF STRATIFICATION
DISTANCES FROM PRODUCED WATER DISCHARGES

LOCATION	REFERENCE*	DISCHARGE RATE (BBL/DAY)	STATION CONFIGURATION	WATER DEPTHS (FT.)	CURRENT VELOCITIES (FT./S)	STRATIFICATION DISTANCE (FT.)
Bayou Rigaud (Conoco)	/1	105,000	2 Way Bayou	13-23	Swift	330
Bayou Rigaud (Exxon)	/1	45,000	2 Way Bayou	13-20	Swift	0
Pass Fourchon (Chevron)	/1	45,000	Dead End Canal/Bayou	8-10	Weak	3,280
Bayou Sale (SWD-1)	/2	2,500	2 Way Canal	7-10	Strong	1,640
Bayou Sale (Sta. 242, CF#2)	/3	200-600	2 Way Bayou	12-17	>1.0	0
Lafitte (CF#8)	/2	3,676	2 Way Canal	3-7	———	1,640
Lafitte (Sta. 69, CF#10)	/3	1,000-3,000	2 Way Canal	5-7	0.1-0.3	0
Lafitte (Sta. 72, CF#4)	/3	1,000-3,000	2 Way Canal	3-7	0.1-0.3	>500
Golden Meadow (TB-7)	/2	2,845	2 Way Canal	7-10	Imper-ceptible	<300
Golden Meadow (TB-8)	/2	1,427	2 Way Canal	6-10	Strong	0
Golden Meadow (Sta. 31, TB-12)	/3	1,000-3,000	2 Way Canal	7-10	0.01-0.28	300
Golden Meadow (Sta. 36, TB-10)	/3	1,000-3,000	2 Way Canal	5-9	0.02-0.23	0

*Reference: /1 Boesch and Rabalais (1989a)
/2 Boesch and Rabalais (1989b)

TABLE 15 (Cont.)

COMPARISON OF STRATIFICATION
DISTANCES FROM PRODUCED WATER DISCHARGES

LOCATION	REFERENCE*	DISCHARGE RATE (BBL/DAY)	STATION CONFIGURATION	WATER DEPTHS (FT.)	CURRENT VELOCITIES (FT./S)	STRATIFICATION DISTANCE (FT.)
Golden Meadow (Sta. 32, TB-13)	/3	200-600	Open Water	6	0.00-0.28	50
Golden Meadow (Sta. 33, TB-5)	/3	1,000-3,000	2 Way Canal	6.5-8	0.00-0.55	300
Golden Meadow (Sta. 34, CF#3)	/3	1,000-3,000	2 Way Canal	8	0.00-0.85	50
Golden Meadow (Sta. 35, CF#6)	/3	1,000-3,000	Open Water	5-6.5	0.02-0.18	50

*Reference: /1 Boesch and Rabalais (1989a)
/2 Boesch and Rabalais (1989b)
/3 This Study

to >40 ppt range in this study. The major difference between the two was the 1 km (0.6 mi) distance from the discharge that stratification was found at the Port Fourchon site. Only 1 (Station 186) of 36 discharges in our study was stratified by PW past 300m (1000ft). That station had a discharge rate of 3,001-6,000 bbl/day compared to the 45,000-bbl/day rate at the Port Fourchon site. Station 186 in the Weeks Island Field discharged into a 1.0-1.5m (3-5ft) deep two-way canal bordering Weeks Bay. The Port Fourchon discharges were located in 2.5-3.0m (6-10ft) deep dead-end canal off Pass Fourchon. Boesch and Rabalais (ibid.) attributed the 1 km (0.6 mi) distant PW-related stratification to the low tidal flows and less energetic mixing in the dead-end pass. They also noted that salinity stratification had been absent at the Port Fourchon site during an earlier October, 1987 sampling of the same area.

As described in the Literature Review Section, Boesch and Rabalais (1989b) studied PW discharges in the Bayou Sale, Lafitte and Golden Meadow Fields. The Bayou Sale site sampled (SWD-1) had a 2500-bbl/day discharge rate. Their data show stratification extending as much as 500m (1640ft) from the discharge. They also reported that conductivity differences between the surface and bottom waters could be detected as far as 1000m (3300ft) from the discharge. The salinity of the surface water was 0.0-0.3 ppt and the maximum bottom salinity in the stratified layer was 3.3 ppt. The water depths were 2-3m (7-10ft).

Station 242, the Bayou Sale Field discharge (CF#2) that was sampled in this study, was located in Lone Oak Bayou approximately 1.5km south-southwest of SWD-1. The discharge rate criterion for the station was low (200-600 bbl/day). None of the sampling locations around the discharge was stratified, and surface and bottom salinities were a uniform 0.1 ppt. Bottom depths ranged from 4-5m (12-17ft). Current velocities were high and generally exceeded 30 cm/sec (1 ft/sec) except in the bottom 0.5m (1.5ft) of the water column. The strong current velocities noted during our sampling could prevent any discharge stratification from forming.

The Lafitte Field site sampled by Boesch and Rabalais (ibid.) (CF#8) is located approximately 3.4km (2.0mi) southeast of our Station 69 and 5.5km (3.4mi) south of Station 72. The discharge rate of the facility was 3676 bbl/day. They reported detectable stratification 500m (1640ft) from the discharge. The surface water salinities were 5.8-5.9 ppt and the maximum bottom salinity in the stratified layer was 10.9 ppt. Water depths were 1-2m (3-7ft).

No detectable stratification was found at Station 69 (CF#10). The discharge rate criterion was moderate (1000-3000 bbl/day). Surface salinities ranged from 7.4-8.1 ppt, and bottom salinities ranged from 7.9-9.0 ppt. Current velocities at both the surface and bottom were 3-9 cm/sec (0.1-0.3 ft/sec). Water depths were 1.5-2.0m (5-7ft).

Stratification extending at least 150m (500ft) from the discharge was found at Station 72 (CF#4). Discharge rate criterion for the station was moderate. Surface salinities ranged from 6.9-7.2 ppt. Bottom water salinities not influenced by the discharge were 7.1-7.7 ppt. Bottom water salinities at the discharge to at least 150m (500ft) ranged from 28.0-34.5 ppt. The 300m (1000ft) location was not sampled due to equipment problems. It is likely that the stratification at 150m (500ft) extended well beyond 150m (500ft). Current velocities were similar to those at Station 69. Water depths were 1-2m (3-7ft).

Boesch and Rabalais (ibid.) also examined two discharges in the Golden Meadow Field. The discharges were TB-7 and TB-8 and had discharge rates of 2845 and 1427 bbl/day, respectively. They found salinity stratification only at the TB-7 discharge. Surface salinities ranged from 9.2-10.3 ppt and bottom salinities away from the discharge of 9.3-10.4 ppt. At the discharge, bottom salinities were 11.3 ppt. Water depths ranged from 2-3m. No detectable stratification was found near the TB-8 discharge.

Station 31 (TB-12) is located 1.4 km west of TB-7. The discharge criterion for this station was moderate (1000-3000 bbl/day). Stratification was found at the 15m (50ft) and 90m (300ft) sample locations but not the 45m (150ft) location. Surface salinities were 15.1-15.9 ppt, and bottom salinities not influenced by the discharge were 15.0-16.1 ppt. Bottom salinities at the 15m and 90m locations were 19.3 and 18.5 ppt, respectively. Current velocities ranged from <1 cm/sec to 9 cm/sec (0.01-0.28 ft/sec). Water depths ranged from 2-3m (7-10ft).

Station 36 (TB-10) is another discharge located in the vicinity of the Boesch and Rabalais study sites. It is located 2.4km (1.5mi) northwest of TB-7 and 1.8 km (1.1mi) north of Station 31 (TB-12). The discharge criterion for this station was moderate. No stratification was found at any of the locations sampled. Surface and bottom salinities ranged from 14.1-15.4 ppt. Current velocities ranged from <1 cm/sec (0.02 ft/sec) to 23 cm/sec (0.76 ft/sec). Water depths were 1.5-3m (5-10ft).

The four other stations in the Golden Meadow Field sampled during our study were Stations 32, 33, 34 and 35. Stations 32 and 35 were open water stations located in Catfish Lake, 4.8-5.0 km (3.0-3.1mi) east of Stations 31 and 36. Stations 33 and 34 were located in canals east of Catfish Lake, approximately 7.6km (4.7mi) east of Stations 31 and 36. Stratification was found at a distance of 15m (50ft) from the discharge at Stations 32, 34 and 35. Stratification was found at a distance of 45m (300ft) from Station 33.

The bottom water stratification associated with PW discharges observed in this study was localized within 300m (1000ft) of the discharge in most cases. At only three of 36 sampling stations was produced-water-induced stratification observed beyond 150m (500ft). These distances are substantially shorter than the 1000m (3280ft) maximum stratification distance reported by Boesch and Rabalais (1989a). The Port Fourchon discharge in their OCS produced water study had a discharge rate possibly one or more orders of magnitude higher than the discharges sampled in this study. This factor and the dead-end nature of the receiving water body could explain the difference in the extent of stratification.

The non-OCS discharge study sites (Boesch and Rabalais, 1989b) had similar discharge rates and receiving water body configurations and were located in the same fields as a number of those from this study. The extent of stratification at these sites in their study ranged from 0-500m (0-1640ft). At comparable sites from our study they ranged from 0 to >150m (0 to >500ft). Based on the results from the other sites sampled in our study, it is possible that the >150m (>500ft) stratification could have extended to 300m (1000ft) but would be unlikely to extend significantly beyond that distance. Differences in tidal stage, meteorological conditions, water column salinity, water temperature and the salinity content of the discharges during sampling all could account for the remaining differences in the extent of stratification.

G.6. Sediment Hydrocarbons

The sediment TPH data collected in this study were limited both in numbers of stations sampled and distance from the discharge that samples were collected. The data were collected to correlate bottom sediment TPH with sediment parameters, such as grain size and LOI, the extent of discharge-related salinity stratification and water column TPH. Other studies such as Armstrong et al. (1979), Neff et al. (1989) and Boesch and Rabalais (1989a; 1989b) have reported the concentrations of various classes of hydrocarbon compounds in coastal sediments near PW discharges. They have, more importantly, addressed the impacts of these hydrocarbon concentrations on benthic populations. Both of these tasks are beyond the scope of this study.

Figures 48 through 54 show no apparent relationship between the hydrocarbon and the organic content that the LOI data represent. Likewise, the effective grain size and LOI data were regressed individually against the TPH data. The resulting graphs were scatter plots with no statistically significant regression correlations and are not presented in this report. Neff _et al_. (1989) found a similar lack of relationship between THP concentrations and percent silt/clay at their Lake Pelto sampling location. Both TPH concentrations and sediment parameters showed high variability between replicates and between sampling locations within a station. This variability is likely to obscure any relationship present between sediment parameters and hydrocarbon uptake.

As discussed under Water Column Hydrocarbons, comparisons between sediment TPH data collected in this study and others should be made understanding that there are differences in sampling and analytical methodology. For example, bottom sediment samples in this study were collected from the top 10 cm (0.5 ft) of cores. Neff _et al_. (1989) and Boesch and Rabalais (1989a) used only the top 2-3 cm (1 in) in their studies. Additionally, sediment TPH extraction procedures were different in each study.

The TPH by IR method used for the sediment and water hydrocarbon detection should provide reasonably good agreement with the total hydrocarbon by gas chromatography/mass spectrometry methods (GC/MS) used in other studies. Neff _et al_. (1989) reports total hydrocarbons by summing saturated and aromatic hydrocarbon fractions analyzed by GC/MS. When comparing produced water samples analyzed by GC/MS with those analyzed by IR (the method used in our study), they found good agreement in the total hydrocarbon concentrations.

Boesch and Rabalais (1989b) provide a comparison table listing sediment TPH and distance data from that study, from their own work (1989a) and those of Armstrong _et al_. (1979) and Neff _et al_. (1989). They list values of total alkanes and polyaromatic hydrocarbons for various distances from discharges in the studies cited. They also divide selected station data into near discharge, moderate contamination and background levels. After summing the two hydrocarbon fractions to approximate total hydrocarbon levels, the near discharge concentrations taken from samples within 20m (65ft) of the discharges ranged from 59-1204 ug/gm. The TPH concentrations of the 15m (50ft) locations at Stations 57, 88, 165 and 214 all fell outside this range. Stations 157 and 181 had 15m (50ft) sampling location hydrocarbon concentrations of between 400 and 800 ug/gm and did fall within the near discharge range.

The moderate contamination levels in their table ranged from 5.2-260 ug/gm. These concentrations were lower than the values at the 300m (1000ft) locations sampled in this study, except for a few below detection limit values associated with hydrologically distinct samples areas.

The limited TPH sediment data collected in this study show TPH to range from less than detectable to 1417 ug/g at a distance of 300m (1000ft) from the discharge. Of the 17 samples taken at this distance from the discharge at six stations, eight samples had concentrations higher than 500 ug/g. Six additional samples had concentrations between 100 and 500 ug/g, and three samples had concentrations below the detection limits. These data show significantly elevated concentrations of TPH (500 ug/g) 300m (1000ft) from the source in at least one of the duplicate samples in four of the six stations sampled.

Where sediment TPH at or within 300m (1000ft) of the discharge approached background concentrations as defined by Boehm and Requejo (1986) for the coastal Gulf of Mexico, 10-50 ug/g, unique circumstances existed. At both stations, sampling locations with low TPH concentrations were located in waterways adjacent to the one in which the discharge was located. In both cases, this nearby waterway was deeper than the canal receiving the discharge and with stronger current.

The PW discharges sampled in this and other studies are never the only source of petroleum hydrocarbons in their vicinity. Numerous oil wells, compressor platforms, pump stations and other facilities as well as spills from vessels and pipelines provide additional possible sources of hydrocarbons. The pattern of generally decreasing sediment TPH concentrations with distance from the discharge does indicate that PW from the facilities are the primary source of the hydrocarbons.

G.7. Water and Sediment Radionuclides

Water and sediment ^{226}Ra and ^{228}Ra data were collected at the same six stations as the sediment hydrocarbon data. The purpose of the sampling was to generate radionuclide data from the close proximity of selected discharges. No attempt was made to closely define an area of elevated radionuclide activity around the discharges.

Eight of the eighteen water samples analyzed had ^{226}Ra activities less than or equal to the lower level of detection (LLD). The activities of ten samples with higher than LLD values ranged from 0.2 ± 0.1 pCi/l to 1.6 ± 0.3 pCi/l. Of these ten samples, four had higher activities than the 0.59 pCi/l background level reported by Hanan (1981) for a single surface water sample from Grand Bay in the Mississippi River Delta. Those four samples were from the upstream bottom water at Station 88 (1.2 ± 0.4 pCi/l), the downstream surface water at Station 165 (1.6 ± 0.3 pCi/l) and two from the downstream surface water at Station 214 (1.5 ± 0.3 and 0.7 ± 0.5 pCi/l).

Hanan (ibid.) reported ^{226}Ra activities ranging from 1.41 ± 0.18 to 1.90 ± 0.13 pCi/l for water samples collected near a produced water discharge in the Grand Bay Field near the mouth of the Mississippi River. The four samples listed above fall within this range.

Only 2 of 18 water samples analyzed had ^{228}Ra activities above the LLD. The two samples were from upstream surface (2.6 ± 1.4 pCi/l) and bottom (2.4 ± 1.4 pCi/l) at Station 57.

Station 214 was the only station sampled belonging to the low radionuclide discharge criteria group ($^{226+228}Ra$ = <200 pCi/l), yet it had one of the highest ^{226}Ra activities of the stations sampled. Stations 57 and 165 were moderate radionuclide criteria ($^{226+228}Ra$ = 200-600 pCi/l) stations. Station 165 had the highest ^{226}Ra activity in the sample data set. Stations 88, 157 and 181 all belonged to the high radionuclide criteria group ($^{226+228}Ra$ = >600 pCi/l).

In the last column of Table 13, the activity of both the ^{226}Ra and ^{228}Ra in water samples is summed. These values range from 0.0-3.5 pCi/l. The primary drinking water standard (EPA, 1980) for naturally occurring $^{226+228}Ra$ is ≤5.0 pCi/l. All the samples had lower activities than the standard.

Water column radionuclide activities were elevated above background levels in the vicinity of some discharges. No pattern is apparent as to which stations have higher activities. Some high radionuclide criteria discharges have low water column activities (Station 181). The low radionuclide criteria discharge sampled (Station 214) had the second highest activity of all the samples. The open water stations had both elevated (Station 88) and below background (Station 57) activities in some samples. The canal stations showed a similar pattern with both below background (Station 181) and elevated (Station 165) radionuclide activities.

Sediment ^{226}Ra activities ranged from 0.1 ± 0.1 pCi/gm to 6.3 ± 0.6 pCi/gm in the samples from the six discharge stations. Eight of the ten samples had activities higher than the LLD.

Hanan (ibid.) found sediment ^{226}Ra activities of 1.00 ± 0.06 pCi/gm to 5.17 ± 0.15 pCi/gm at sampling locations within 20m (65ft.) of a the PW discharge he examined. Although the minimum values in our samples are well below those of his samples, the maximum values are similar. The control station values he reported from two control cores ranged from 1.05 ± 0.04 pCi/gm to 1.46 ± 0.07 pCi/gm.

Only three of ten sediment samples had ^{228}Ra activities greater than the LLD. Those values ranged from 1.2 ± 0.8 pCi/gm and 3.9 ± 0.8 pCi/gm.

The sediment radionuclide data show two of ten samples with elevated ^{226}Ra levels, relative to the control station values reported by Hanan. The small number of samples reported here and the limited scope of the sampling preclude broad generalizations about radionuclide accumulation in the sediments near the discharges sampled. From the limited sampling and literature data available for comparison, the stations sampled do not show high levels of sediment radionuclides near the discharges. A few samples do have radionuclide activities higher than reported background levels.

H. CONCLUSIONS

The PW discharges sampled in this study cover a wide range of discharge rates, PW salinities, hydrocarbon concentrations, marsh habitats and receiving water body configurations. With the exception of the high-volume inshore coastal OCS discharges, they are typical of many other facilities located in coastal Louisiana.

Current velocities and direction varied widely between the surface and bottom waters and between sampling locations around the discharge. Surface and mid-depth velocities were generally higher than bottom velocities. The current velocity of the top 0.3m (1ft) of the water column was often affected by ambient wind speed and direction. Currents flowing through the support pilings of the open water discharges produced downcurrent turbulence throughout the water column at many of these facilities. This may aid in the mixing of the discharge with the water column and reduce the extent of stratification at these stations.

No detectable (<0.5 mg/l) TPH levels were found in the surface water samples collected around the discharges. Dilution of the produced water TPH concentrations decreased to below LLD within 300m (1000ft.) of the discharge. Less than half of the stations sampled had any detectable TPH concentrations in the bottom water samples.

Salinity stratification was found at 20 of 36 produced water discharge stations sampled. Three of the twenty stations exhibited area-wide stratification which was the result of large freshwater inputs not related to the discharges. Two additional stations showed salinity stratification at 300m (1000ft) distance, but not at sample locations closer to the discharge. Stratification at these stations did not appear to be related to the PW discharges.

Bottom water salinity stratification associated with PW discharges observed in this study, when present, was localized within

300m (1000ft) of the production facility. Discharge-related stratification extending 150m (500ft) was found at only three stations. Current velocity, water depth and bottom topography were the major factors affecting if and to what extent PW-related stratification occurs near the discharges.

The limited sediment TPH data collected in this study show high levels (below detection limits to 958 ug/g) of sediment contamination 300m (1000ft) from the discharges sampled. Where sediment TPH levels approached background concentrations of 10-50 ug/g for coastal Gulf of Mexico sediments (Boehm and Requejo, 1986) within 300m of the discharge, it was due to changes in hydrologic factors such as water depth and current velocities.

The PW discharges sampled in this and other studies are not the only source of petroleum hydrocarbons in the areas sampled. The pattern of generally decreasing sediment hydrocarbon concentrations away from the discharge, however, does indicate that PW is the primary source of the sediment hydrocarbons.

Water column radionuclide activities, which ranged from 0.0 to 3.5 pCi/l $^{226+228}$Radium, were elevated above background levels at a distance of 15m (50ft) from the discharge at some stations. None of the samples exceeded the primary drinking water standards of 5.0 pCi/l $^{226+228}$Ra activity.

Two of ten sediment samples contained ^{226}Ra of 1.7 and 6.3pCi/gm, both above the control station values (1.05 $\pm$ 0.04 pCi/gm to 1.46 $\pm$ 0.07 pCi/gm) reported by Hanan. From the limited data presented here and available for comparison from Hanan (1981) who sampled a single discharge station and a single control station, sediment radionuclide levels measured in this study are generally low and do not appear to be accumulating to high levels near the discharges.

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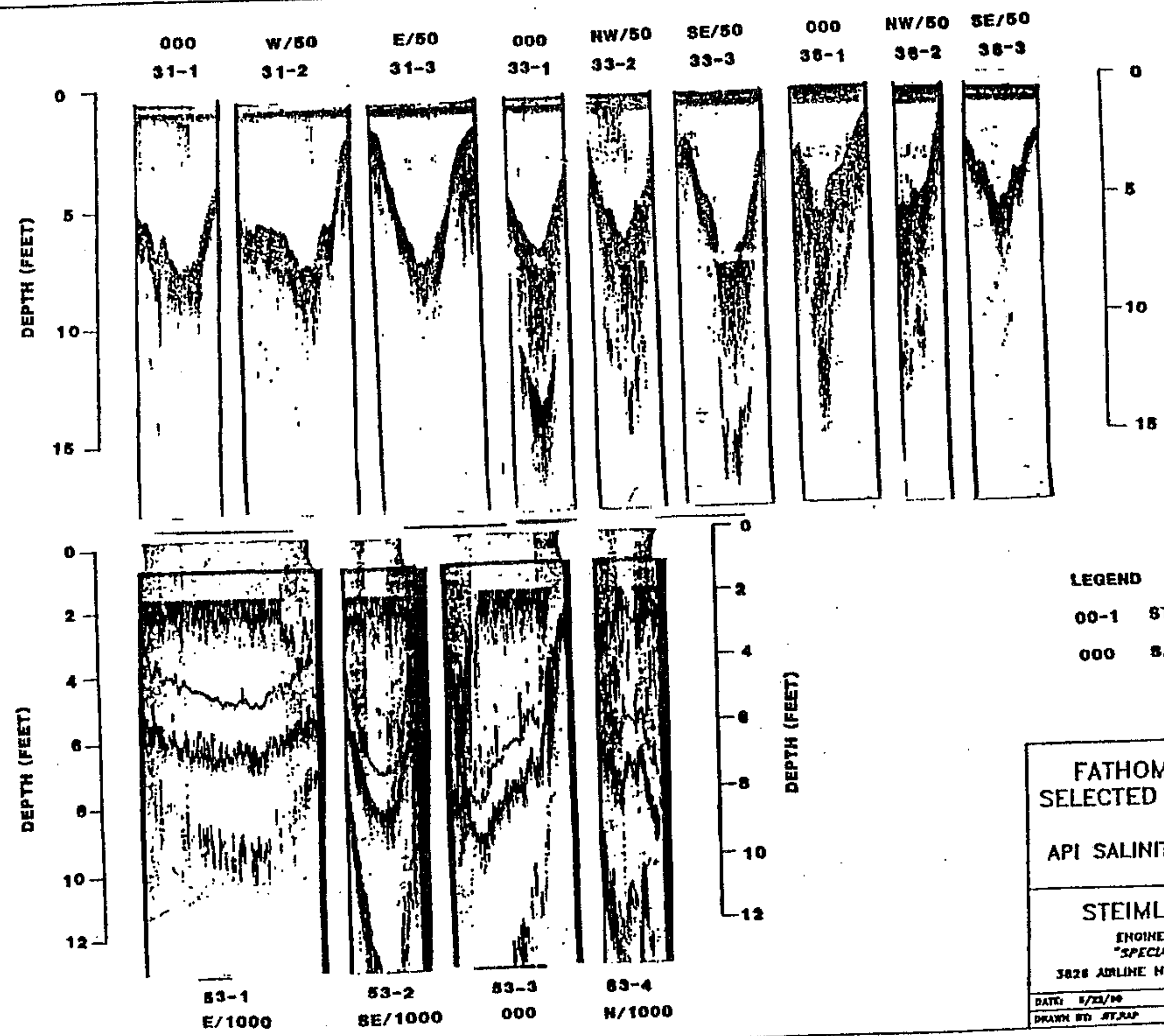
APPENDIX A

FATHOMETER PROFILES



LEGEND

00-1 STATION TRANSECT

000 SAMPLE LOCATION

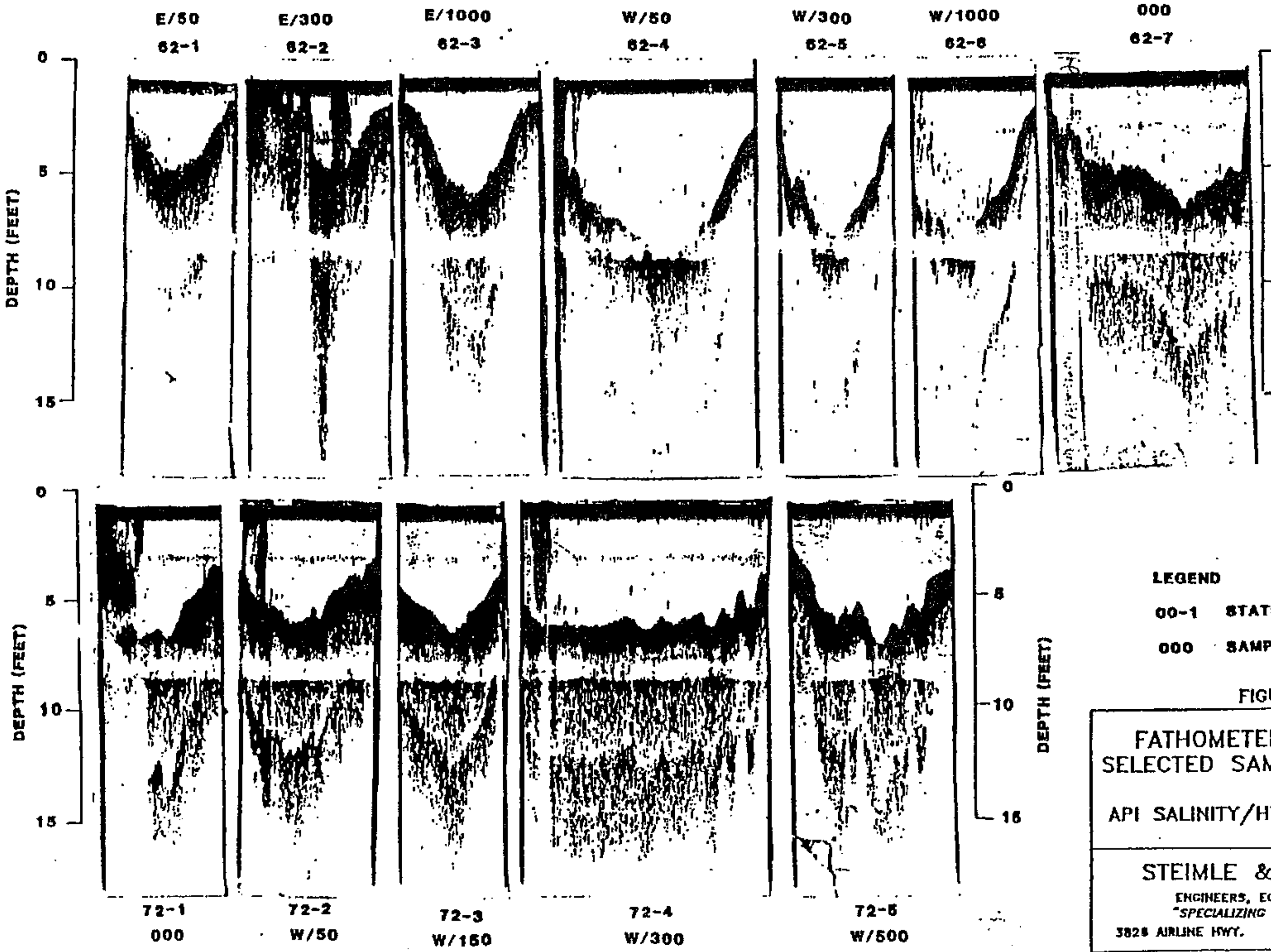
FIGURE A-1

FATHOMETER PROFILES OF SELECTED SAMPLING LOCATIONS

API SALINITY/HYDROCARBON STUDY

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3828 AIRLINE HWY. METAIRIE, LA 70001

DATE:	JOB NO.	
DRAWN BY: JT,RAP	CHECKED BY: MFR	SCALE: N.T.S.



LEGEND

00-1 STATION TRANSECT

000 SAMPLE LOCATION

FIGURE A-1 (CONT.)

FATHOMETER PROFILES OF SELECTED SAMPLING LOCATIONS

API SALINITY/HYDROCARBON STUDY

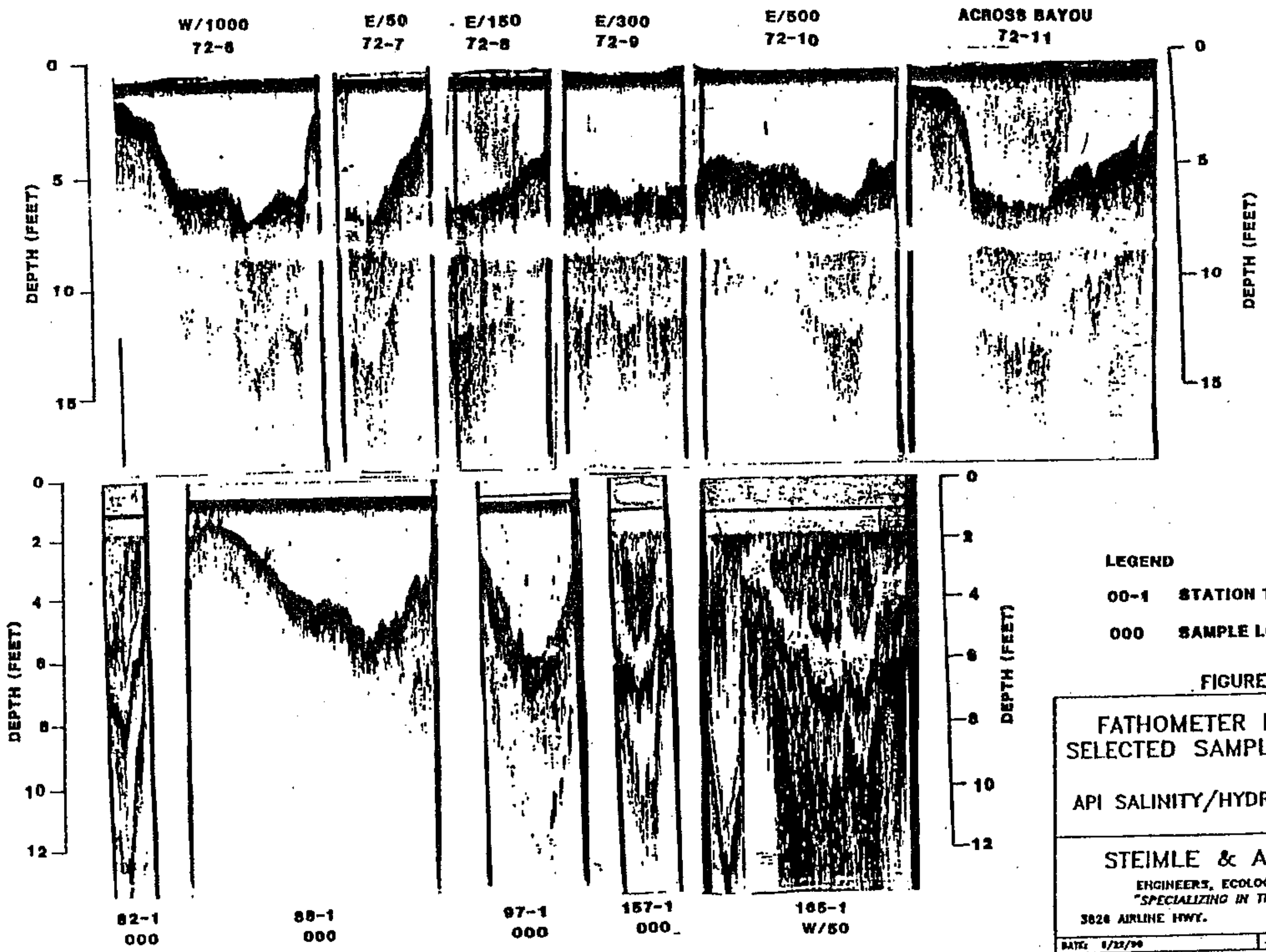
STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS

"SPECIALIZING IN THE ENVIRONMENT"

3828 AIRLINE HWY. METAIRIE, LA 70001

DATE: [illegible]	JOB NO. [illegible]	
DRAWN BY: [illegible]	CHECKED BY: [illegible]	SCALE: N.T.S.



LEGEND

00-1 STATION TRANSECT

000 SAMPLE LOCATION

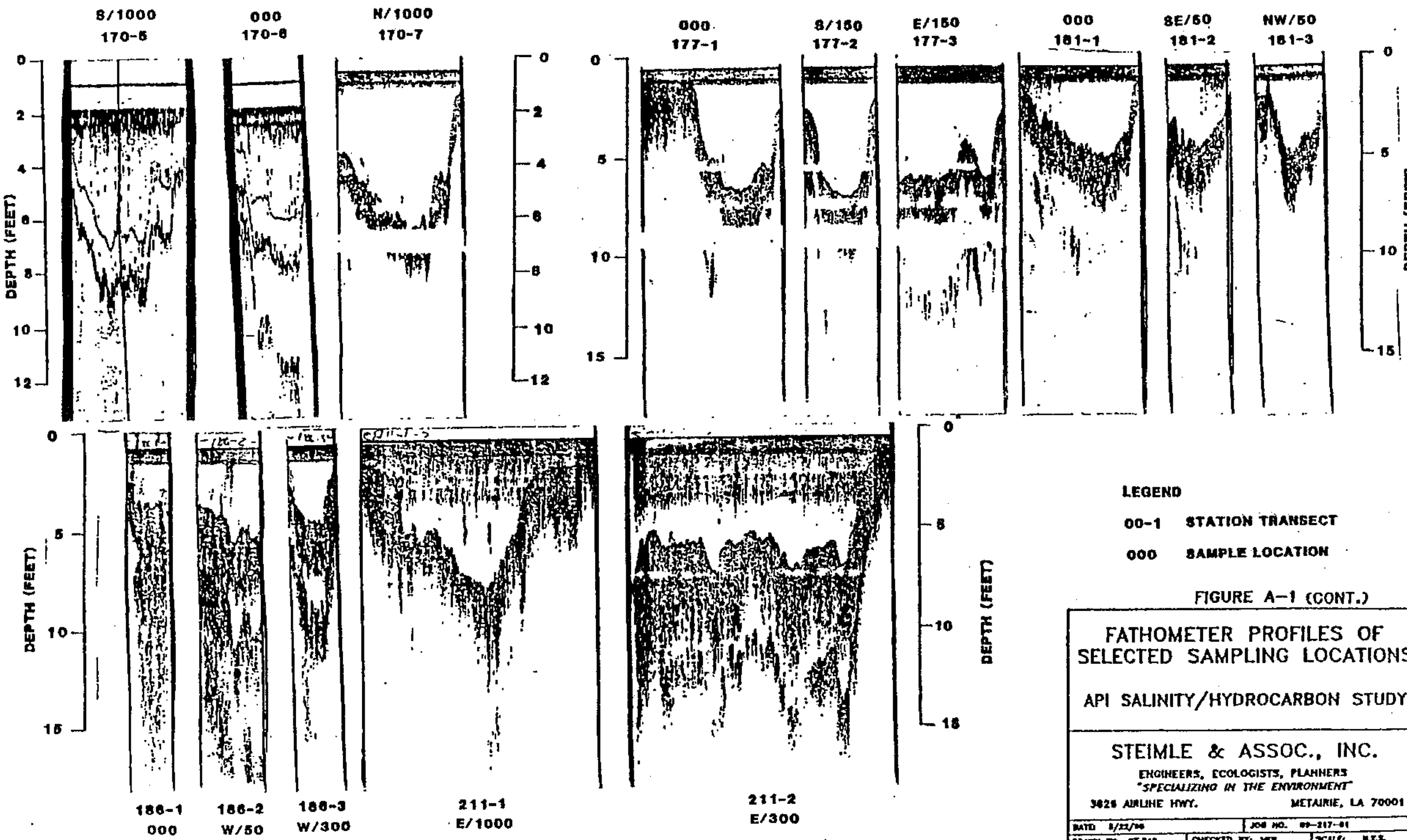
FIGURE A-1 (CONT.)

FATHOMETER PROFILES OF SELECTED SAMPLING LOCATIONS

API SALINITY/HYDROCARBON STUDY

STEIMLE & ASSOC., INC.
ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"
3828 AIRLINE HWY. METAIRIE, LA 70001

DATE: [illegible]/22/90 | JOB NO. [illegible]
DRAWN BY: [illegible] | CHECKED BY: MFR | SCALE: N.T.S.



LEGEND

00-1 STATION TRANSECT

000 SAMPLE LOCATION

FIGURE A-1 (CONT.)

FATHOMETER PROFILES OF SELECTED SAMPLING LOCATIONS

API SALINITY/HYDROCARBON STUDY

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"

3828 AIRLINE HWY. METAIRIE, LA 70001

DATE 8/22/90	JOB NO. 89-217-01	
DRAWN BY: AT,RAP	CHECKED BY: MFR	SCALE: N.T.S.

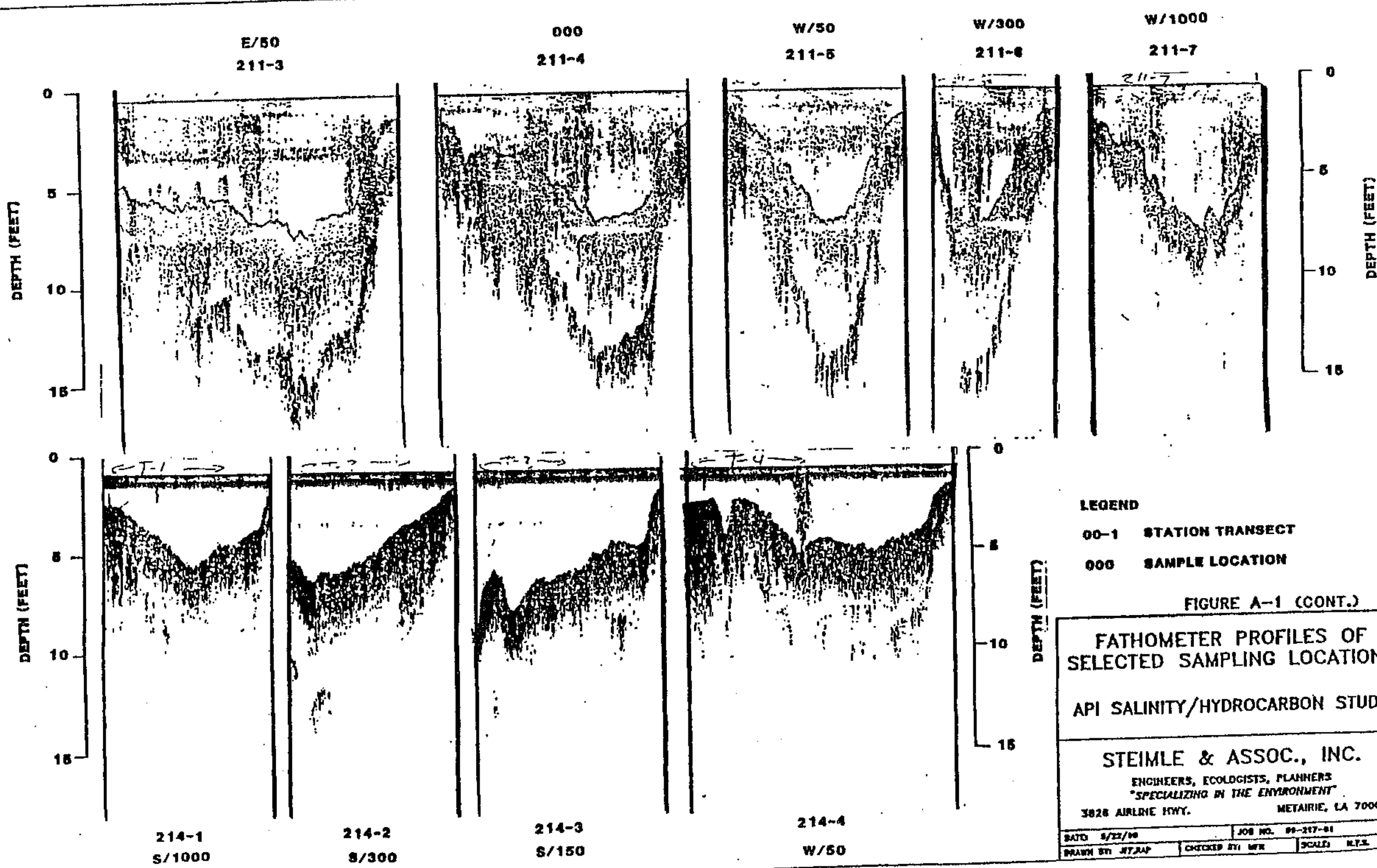


FIGURE A-1 (CONT.)

FATHOMETER PROFILES OF SELECTED SAMPLING LOCATIONS

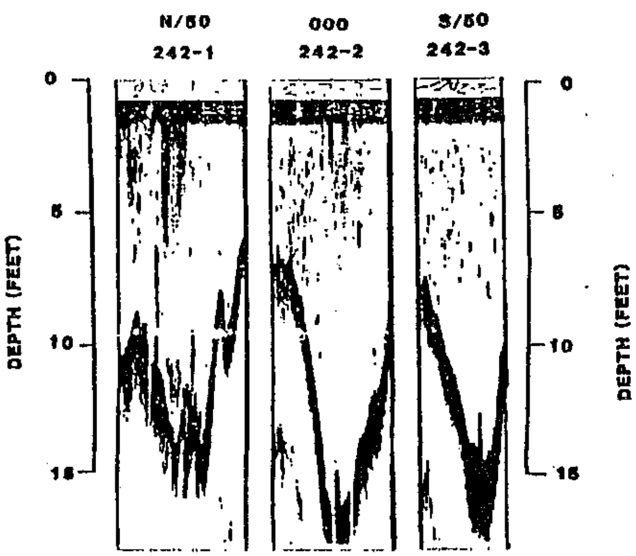
API SALINITY/HYDROCARBON STUDY

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS
"SPECIALIZING IN THE ENVIRONMENT"

3828 AIRLINE HWY. METAIRIE, LA 70001

DATE: 5/22/90	JOB NO. 90-217-01	
DRAWN BY: JTJ/AP	CHECKED BY: MFR	SCALE: N.T.S.



LEGEND

00-1 STATION TRANSECT

000 SAMPLE LOCATION

FIGURE A-1 (CONT.)

FATHOMETER PROFILES OF SELECTED SAMPLING LOCATIONS

API SALINITY/HYDROCARBON STUDY

STEIMLE & ASSOC., INC.

ENGINEERS, ECOLOGISTS, PLANNERS

"SPECIALIZING IN THE ENVIRONMENT"

3826 AIRLINE HWY. METAIRIE, LA 70001

DATE: [illegible]		JOB NO. [illegible]
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