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Final Environmental Impact Statement

(Final Statement to FEA-DES 77-9)

STRATEGIC PETROLEUM RESERVE

Capline Group Salt Domes

Iberia, Napoleonville, Weeks Island Expansion
Bayou Choctaw Expansion, Chacahoula,

Iberia, Iberville, and Lafourche Parishes, Louisiana

U.S. DEPARTMENT OF ENERGY

JULY 1978
VOLUME 4 OF 4

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Responsible Official:

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U.S. DEPARTMENT OF ENERGY
Washington, DC 20545

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VOLUME 4 OF 4

Volume IV

Appendix D	Oil-In-Brine
Appendix E	Oil and Brine Spill Risk Analysis
Appendix F	Cavern Stability
Appendix G	Technical Report—Capline Group Diffuser Site Study
Appendix H	Deep Well Injection of Brine
Appendix I	Hydrocarbons and Model to Calculate Ground-Level Concentrations
Appendix J	Thermal Effects of Displaced Oil and Brine
Appendix K	Comments Received

VOLUME IV TABLE OF CONTENTS

Page

APPENDIX D - OIL IN BRINE ANALYSIS D-1

APPENDIX E - OIL AND BRINE SPILL RISK ANALYSIS E-1

APPENDIX F - CAVERN STABILITY F-1

APPENDIX G - TECHNICAL REPORT - CAPLINE GROUP DIFFUSER SITE STUDY G.1-1

- G.1 INTRODUCTION G.1-1
- G.2 REGIONAL AND SITE SPECIFIC ENVIRONMENTAL SETTING . . . G.2-1
- G.3 IMPACTS OF BRINE DISPOSAL ON THE MARINE ENVIRONMENT G.3-1
- G.4 ALTERNATIVE DIFFUSER SITES G.4-1
- G.5 SUPPLEMENTARY DATA G.5-1
- G.6 REFERENCES G.6-1

APPENDIX H - DEEP WELL INJECTION OF BRINE H-1

APPENDIX I - I. ESTIMATES OF EMISSIONS FROM TANKER AND BARGE TRANSFERS AND MODEL USED TO CALCULATE DOWNWIND GROUND-LEVEL CONCENTRATIONS I-1

II. DESCRIPTION OF THE PHYSICAL AND CHEMICAL BASIS FOR EMISSIONS FROM MARINE VESSEL TRANSFER OF CRUDE OIL I-6

APPENDIX J - THERMAL EFFECTS OF DISPLACED OIL AND BRINE J-1

APPENDIX K - COMMENTS RECEIVED K-1

APPENDIX D

OIL IN BRINE MODEL STUDY

PART I GENERAL DISCUSSION AND USE OF EXISTING CAVERNS

PART II SOLUTION MINING AND USE OF NEW CAVERNS

PART III TESTIMONY OF GERARD FEDIDA: JOINT ENVIRONMENTAL PROTECTION AGENCY - CORPS OF ENGINEERS PUBLIC HEARING ON BRYAN MOUND BRINE DIFFUSER APPLICATION, MAY 2, 1978

APPENDIX D

PART I - GENERAL DISCUSSION AND USE OF EXISTING CAVERNS

D.1 INTRODUCTION

The storage of crude oil in the Strategic Petroleum Reserve Program will entail the contact of oil with brine solutions. This contact would result in the dissolving and entrainment of small concentrations of hydrocarbons in the brine through a number of physical phenomena. In order to assess the magnitude of oil concentrations discharged into the brine surface control facilities, a study was performed to determine the mechanisms of interactions between the oil and brine within a typical underground oil storage cavern. This appendix discusses the results of that study.

The primary cavern interactions which would distribute the oil into the brine are dissolution and dispersive reactions. Dispersive reactions require a physical energy input to the system to agitate the micro oil particles into the underlying brine. Dissolution occurs on the molecular level where the hydrocarbon solute dissolves into the brine solvent system. Although both of these reactions occur simultaneously during certain operational phases, the study indicates that principally dissolved components would be discharged to the surface brine control facilities.

Results of the study indicate that under a worst-case situation, the brine discharge would contain an estimated maximum 32 parts per million (ppm) of oil. However, this condition is not expected to occur. A more reasonable estimate of the dissolved oil-in-brine concentration discharged from a typical cavern during initial fill is approximately 16 ppm, and during approximately the later 10% of an individual cavern discharge and 6 ppm during the entire individual cavern discharge period for subsequent refills.

The sections which follow describe the oil/brine interactions within a storage cavern (Section D.2), dissolving reactions (Section D.3), dispersive reactions (Section D.4), expected concentration of oil-in-brine discharged to the surface brine control facilities (Section D.5), and conclusions (Section D.6).

D.2 OIL/BRINE INTERACTIONS IN A SALT SOLUTION-MINED STORAGE CAVERN

The following sections briefly describe the major interactions th[illegible] occur between the oil, brine, and raw water within a salt dome storage cavern. The interactions which occur during the operational phases of the storage program are illustrated schematically in Figure D-1 and are described herein as:

The initial oil fill and discharge of brine;
The long-term storage of oil in a quiescent state;
Raw water injection to displace oil;
Storage cavern conditions after oil is displaced; and
The second and subsequent refills.

D.2.1 Initial Oil Fill

The salt dome cavern, prior to the initial oil fill, is filled with brine. As crude oil injection begins, jetting (approximately 8 feet per second) causes turbulence at the oil-brine interface which produces an emulsion of oil and brine and affects solution of various hydrocarbons into the brine. Turbulence would be confined to approximately the upper 50 feet of the cavern. As cavern filling continues, interface turbu[illegible] would decrease as the interface descends. At a depth of approximately 50 jet diameters, the oil jet momentum would be one-tenth of its initial value and interface turbulence would have ceased (American Petroleum Institute, 1969).

The lighter, more soluble hydrocarbons diffuse across the oil-brine interface, while the heavier, less soluble components slowly begin to form a relatively dense and viscous refractory layer between the oil and brine. Thus, the major oil contamination of the brine occurs during the initial period of the filling phase while turbulence is high.

Dissolved and dispersed oil is expected to remain within the uppermost 100 feet of the brine column during initial fill due to a low rate of vertical diffusion. Consequently, during the early stages of fill the oil concentration of the discharged brine would be near zero. As the oi[illegible] brine interface approaches the bottom of the brine displacement tubing, oil concentration of the discharged brine would increase and average 16 ppm during the final stages of fill (Section D.5).

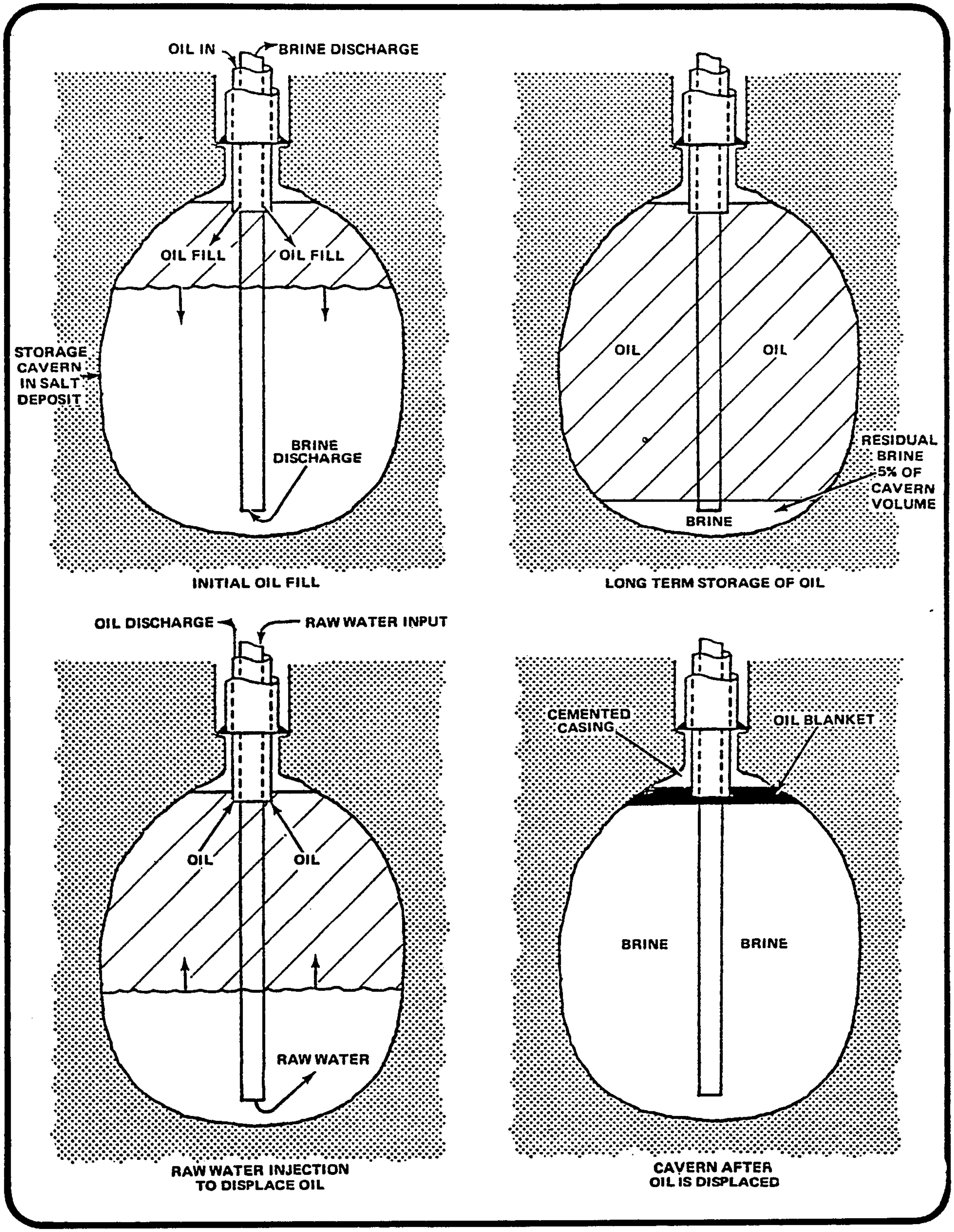


FIGURE D-1 Operational phases of oil storage program

D.2.2 Long-Term Oil Storage

During long-term oil storage, a brine layer is maintained at the bottom of the solution cavern and would amount to approximately 5 percent of the total cavern volume. The oil concentration within this brine is assumed to reach equilibrium during long-term storage. A refractory layer would form at the oil brine interface because of the loss of soluble hydrocarbons into the underlying brine and a consequent enrichment of heavier, relatively insoluble hydrocarbons. Any remaining small fraction of dispersed oil in brine would be expected to rise to the oil-brine interface contributing to the refractory layer or be absorbed by suspended particles and in turn settle to the bottom. The long-term storage is the only phase of the program where time allows the hydrocarbons to dissolve and establish equilibrium conditions with respect to the brine.

D.2.3 Injection of Raw Water and Displacement of Oil

The oil is displaced from the cavern by injection of raw water into the lower level, causing the upward displacement of oil. The raw water would dilute the residual brine solution in the bottom of the cavern may resuspend settled particles. The resultant dilution of both the brine and dissolved oil concentration would allow further dissolution of oil into brine. Initially, there would be turbulence at the oil-brine interface which may disperse some of the oil. The refractory layer at the oil-brine interface would effectively limit diffusion and dispersion When the crude oil is displaced from the storage cavern, an oil film would remain on the cavern walls. This oil film would, in time, partly dissolve into the brine and partly rise to the oil-brine interface as solution of the underlying salt progresses. For calculation purposes, in this report, this oil film was assumed to be totally dissolved, adding approximately 1.6 ppm to the oil-in-brine concentration.

The raw water being injected into the cavern would rise toward the surface due to its lower density and induce a circulation within the brine. This may result in an increase in the diffusion of oil into the now non-equilibrium system. As the interface rises within the cavern, the circulation would decrease in the upper brine column due to the rapid dilution of the raw water. The brine temperature within the cavern will eventually rise to approximately 150°F and an increase in salinity will occur as the dissolution of the cavern walls proceeds. The net effect is a decrease in oil solubility because the salinity factor has a greater influence than that of temperature (Section D.3). The dissolved oil concentration in the brine at the end of this operation is therefore the result of:

(1) the twentyfold dilution of the residual brine which had reached equilibrium oil concentrations at the bottom of the cavern,
(2) some dissolution of the oil layer on the cavern walls, and
(3) some small additional dissolution at the oil-brine interface during displacement.

D.2.4 Storage Cavern Conditions After Oil is Displaced

After the cavern is filled with water and the crude oil removed, a small amount of the crude oil would be retained as a blanket on top of the brine column. The oil blanket acts as a barrier between the solution cavern ceiling and the brine, thereby minimizing salt dissolution around the cemented casing. The oil at the oil-brine interface will be composed of a relatively dense, viscous layer and would only allow slow diffusion of the soluble hydrocarbon components. The additional oil concentration dissolved into the brine during this operation is judged to be minimal.

D.2.5 Second and Subsequent Oil Refill Phase

The oil-brine interface would now have had sufficient time for a dense refractory layer to form. This layer would reduce the diffusion and dissolution during subsequent refills. Throughout subsequent oil refills approximately 6 ppm of oil in brine (as calculated in Section D.5) will be discharged to the surface brine control facilities, providing the dense refractory layer continues to act as a barrier. In the event that the refractory layer is penetrated by the input jet of oil, reactions similar to those of the initial fill cycle would occur.

D.3 DISSOLUTION REACTIONS DURING CAVERN OPERATIONS

The solubilities of various hydrocarbons in water and in brine h been studied by a number of workers. The data illustrated in Figure D-2 indicate that for each homologous series of hydrocarbons, the logarithm of solubility in water is a linear function of hydrocarbon molar volume. The solubility of hydrocarbons as illustrated in Figure D-2 and listed in Table D-1 increase with a decrease in molar volume and molecular weight and an increase in branching and degree of unsaturation. The most soluble hydrocarbons are the low molecular weight aromatics (Price, 1973; McAuliff 1976).

Review of studies which were conducted to determine the saturation concentrations for oil in seawater and in freshwater, indicate that as the hydrocarbons dissolve, solubility rates decrease before equilibrium conditions are established (Price, 1973).

Equilibrium concentrations at standard temperature and pressure for four different crudes are listed in Table D-2. Equilibrium concentrations found by other researchers for crude oil in both freshwater and saltwater, range from 7 to 40 ppm with the preponderance of data ranging from 20 [illegible] ppm (McAuliffe, 1976; Frankenfeld, 1975; Candle, 1977; Anderson, 1974).

Selected data for the La Rosa and Murban crudes, presented in Table D-3, reveals the variations in equilibrium concentrations which can be expected. This data indicates that the hydrocarbon composition of a particular stored crude would effect the concentration of dissolved oil being discharged with the brine. For the purpose of calculating estimated oil concentrations in a brine discharge, the Middle East Murban crude was considered as a possible crude to be stored in the Strategic Oil Reserve Program.

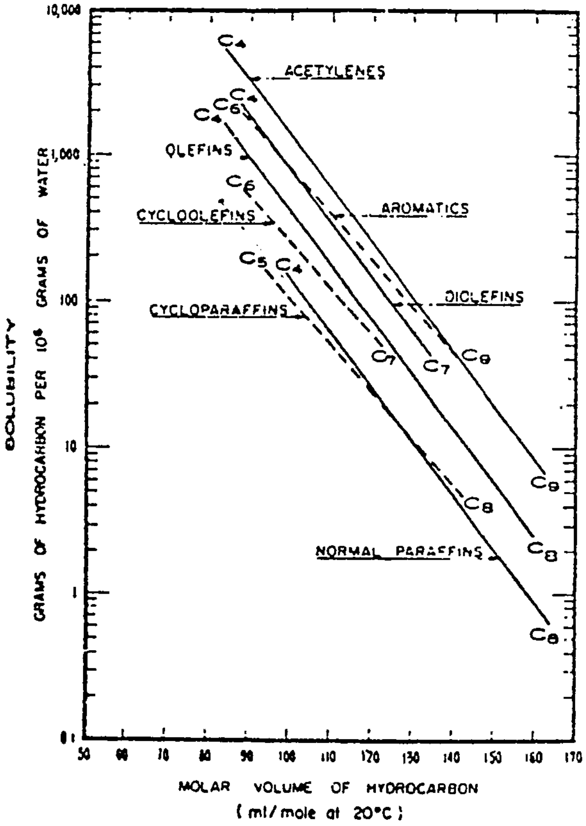
The equilibrium concentration of Murban crude in seawater with a salinity of 36 ppt is 27.9 ppm at standard temperature and pressure as shown in Table D-2.

As temperature and pressure change within the storage cavern, the resultant equilibrium concentrations can be expected to change. General hydrocarbon solubility studies indicate that as temperature and pressure increase, solubility and equilibrium concentrations increase. Increasing

TABLE D-1 Aqueous solubility values of individual compounds at 25°C (ppm).

COMPOUND	PRICE	MCAULIFFE
PENTANE	39.5	38.5
HEXANE	9.47	9.5
HEPTANE	2.24	2.93
OCTANE	0.431	0.66
NONANE	0.122	0.22
ISO PARAFFINS		
2,3 – DIMETHYLBUTANE	19.1	
2,2 – DIMETHYLBUTANE	21.2	
2 – METHYLPENTANE	13.0	
3 – METHYLPENTANE	13.1	
2,4 · DIMETHYLPENTANE	4.41	
2,2 – DIMETHYLPENTANE	4.40	
2,3 – DIMETHYLPENTANE	5.25	
3,3 – DIMETHYLPENTANE	5.94	
2,2,4 – TRIMETHYLPENTANE	1.14	
2,3,4 – TRIMETHYLPENTANE	1,36	
ISOPENTANE	48.0	
2 – METHYLHEXANE	2.54	
3 – METHYLHEXANE	2.65	
3 – METHYLHEPTANE	0.792	
4 – METHYLOCTANE	0.115	
BICYCLOPARAFFIN		
(4.4.0) BICYCLODECANE	.889	
NAPTHO–AROMATIC	88.9	
CYCLOPARAFFINS		
CYCLOPENTANE	160	156
METHYLCYCLOPENTANE	41.8	42
PROPYLCYCLOPENTANE	2.04	
PENTYLCYCLOPENTANE	0.115	
1,1,3 – TRIMETHYLCYCLOPENTANE	3.73	
CYCLOHEXANE	66.5	55.2
METHYLCYCLOHEXANE	16.0	14.0
1,4 – TRANSDIMETHYLCYCLOHEXANE	3.84	
1,1,3 – TRIMETHYLCYCLOHEXANE	1.77	
AROMATICS		
BENZENE	1740	1780
TOLUENE	554	515
M – XYLENE	134	
O – XYLENE	167	175
P – XYLENE	157	
1,2,4 – TRIMETHYLBENZENE	51.9	57
1,2,4,5 – TETRAMETHYLBENZENE	3,48	
ETHYLBENZENE	131.1	152
ISOPROPYLBENZENE	48.3	50
ISOBUTYLBENZENE	10.1	

SOURCE: PRICE, 1973.
McAULIFFE, 1969



SOURCE: McAuliffe, 1969 (3)

FIGURE D-2 Comparison of the solubilities in water at 25°C of various types of hydrocarbons, as functions of their molar volumes

TABLE D-2 Hydrocarbons dissolved in sea water* equilibrated with oil samples.

COMPOUND	SOUTH LOUISIANA CRUDE (1) ppm	KUWAIT CRUDE (1) ppm	VENEZUELA LA ROSA CRUDE (2) ppm	MIDDLE EAST MURBAN CRUDE (2) ppm
ALKANES				
ETHANE	.54	.23	2.011	.231
PROPANE	3.01	3.30	3.63	2.150
n BUTANE	2.36	3.66	1.88	2.880
ISOBUTANE	1.69	.90	.76	.800
n PENTANE	.49	1.31	.60	1.340
ISOPENTANE	.70	.98		1.030
CYCLOPENTANE + 2 METHYLPENTANE	.38	.59		
METHYLCYCLOPENTANE	.23	.190	.275	.355
HEXANE	.09	.290	.65	1.35
CYCLOHEXANE			.190	.410
METHYLCYCLOHEXANE	.22	.080	.160	.235
n HEPTANE	.06	.090	.100	.330
C_{16} n PARAFFIN	.012	.0006		
C_{17} n PARAFFIN	.009	.0008		
TOTAL $C_{12} - C_{24}$ n PARAFFINS	.089	.004		
AROMATICS				
BENZENE	6.75	3.36	3.30	6.080
TOLUENE	4.13	3.62	2.80	6.160
ETHYLBENZENE	1.56	1.58	.275	.825
M – P – XYLENE			.840	1.940
O – XYLENE	.40	.67	.350	1.010
TRIMETHYLBENZENE	.76	.73	.300	.750
NAPHTHALENE	.12	.02		
1 METHYLNAPHTHALENE	.06	.02		
2 METHYLNAPHTHALENE	.05	.008		
DIMETHYLNAPHTHALENE	.06	.02		
OTHER AROMATICS	021	.013		
TOTAL SATURATES	9.86	11.62	11.200	11.100
TOTAL AROMATICS	13.90	10.03	7.860	16.800
TOTAL DISSOLVED HYDROCARBONS	23.76	21.63	19.000	27.900

*Seawater (36 PPT) at Standard Temperature and Pressure

SOURCE: 1 ANDERSON, et. al., (1974)
2 MCAULIFFE (1976)

TABLE D-3 Relative aromatic components of crude and their effect on equilibrium concentrations*.

	MURBAN CRUDE (ABU DHABI)		LA ROSA CRUDE (VENEZUELA)	
	EQUILIBRIUM CONCENTRATIONS ppb	PERCENT COMPOSITION IN CRUDE	EQUILIBRIUM CONCENTRATIONS ppb	PERCENT COMPOSITION IN CRUDE
BENZENE	6,080	.13	3,300	.07
TOLUENE	6,160	.49	2,800	.22
TRIMETHYLBENZENE	750	.74	300	.30
TOTAL	12,990	1.36%	6,400	.59%

*In Seawater at Standard Temperature and Pressure

REF. MCAULIFFE, 1976

the salinity of the solvent yields a decrease in the hydrocarbon solubility and a reduction of the equilibrium concentrations. The following sections summarize the anticipated changes in cavern equilibrium concentrations of the oil in brine as a result of a temperature increase to 150°F, an increase in pressure to approximately 1500 psi and an increase in salinity to 310 parts per thousand.

D.3.1 Increased Temperature Effects on Equilibrium Concentrations

As illustrated in Figures D-3 and D-4 the temperature/solubility relationship is non-linear and until temperatures in excess of 257°F are reached significant increases in solubilities do not occur. The operating temperature for the caverns will be approximately 150°F. Published data indicate that for an increase of from 70°F to 150°F an equilibrium concentration increase of 1.5 is the maximum that can be reasonably expected (Price, 1973; Griswold, 1942). For model calculation purposes, a temperature multiplier of 1.5 has been utilized.

D.3.2 Increased Salinity Effects on Equilibrium Concentrations

The aqueous solubility of hydrocarbons is an inverse function of salinity (Price, 1973; Candle, 1977). Within the salt dome caverns brine concentrations will be in excess of 310 parts per thousand (ppt) (McAuliffe, 1969). The results of solubility experiments on discrete hydrocarbons listed in Table D-4 indicate that large reductions in hydrocarbons solubility can be expected with increases in salinity. Recent studies on a number of domestic crude oils (Table D-5) exhibit similar decreases in hydrocarbon solubility when compared over the smaller range of salinity. Based on these studies a salinity multiplier of 0.15 is reasonable and perhaps even conservative.

D.3.3 Increased Pressure Effects on Equilibrium Concentrations

The effect of increasing pressure on the solubility of hydrocarbons is to increase their solubility. As illustrated in Figure D-5, this effects is most significant for the lighter or lower molecular weight hydrocarbons such as methane and butane. Similar effects for larger hydrocarbon molecules could not be identified. The data as listed in

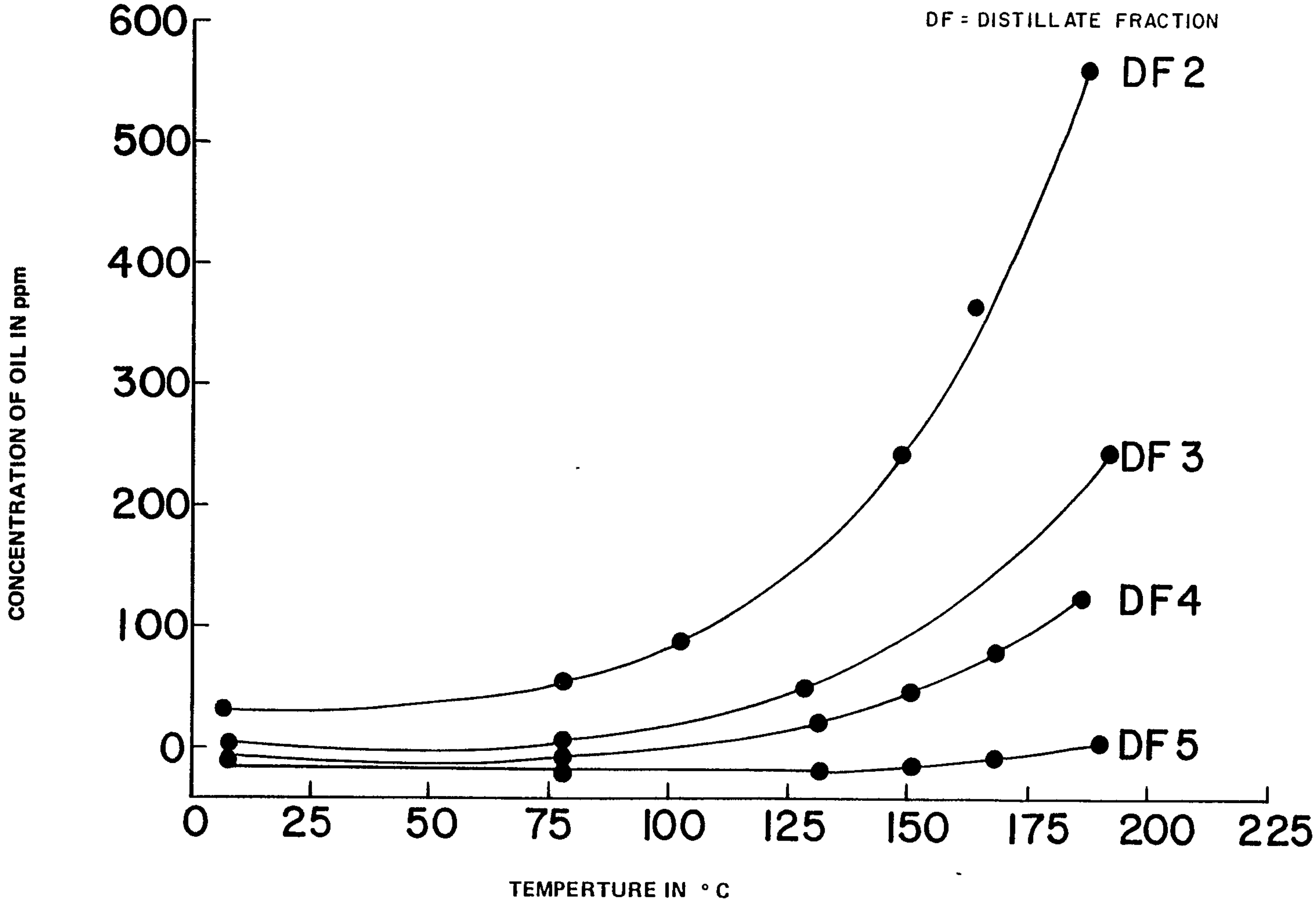
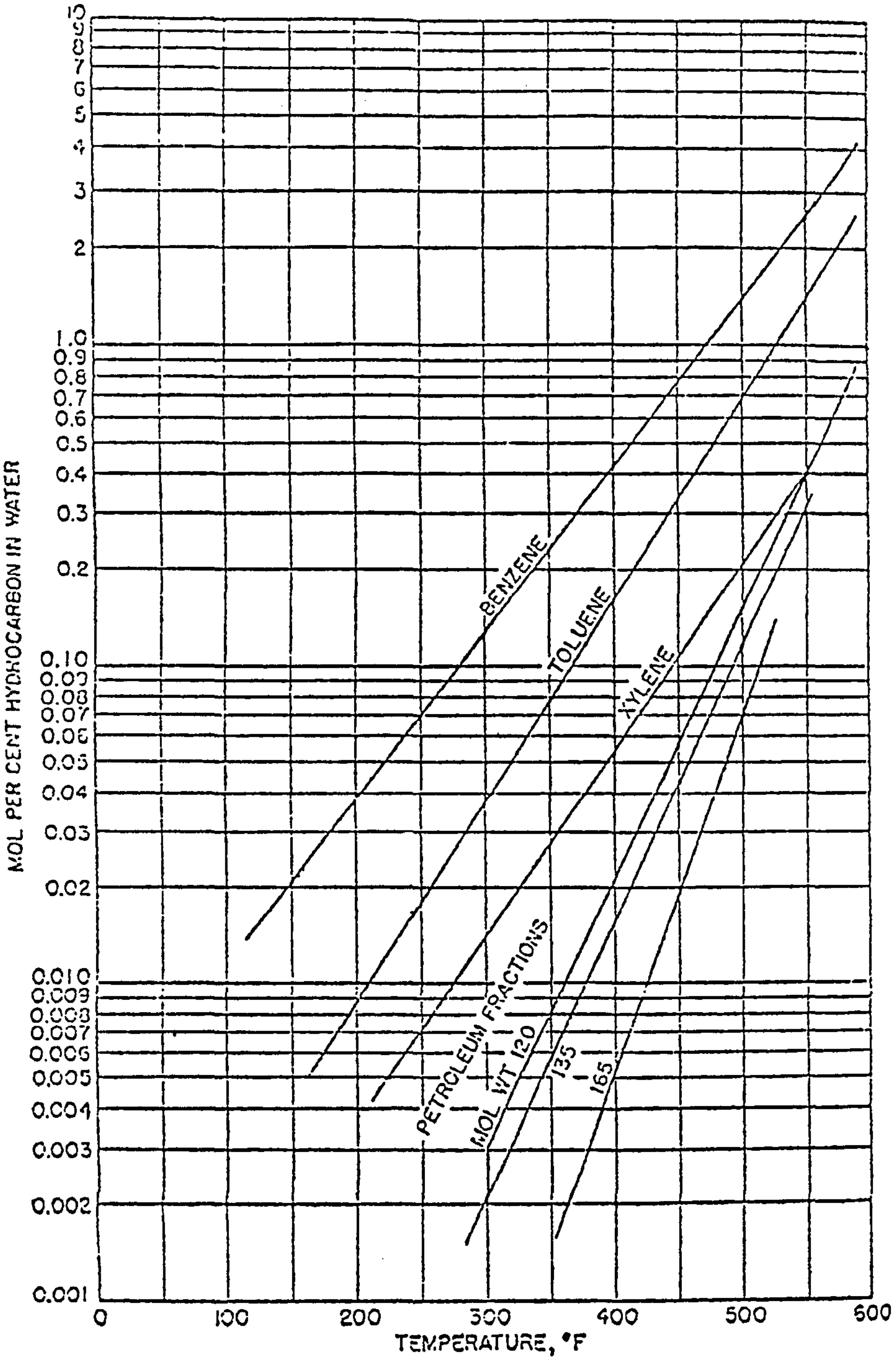


FIGURE D-3 The solubilities of the second (DF 2, [illegible]-193°C), third (DF 3, 193-232°C), fourth (DF 4, 232-316°C) and fifth ([illegible], 316-371°C) distillation fractions of the Ghawar Arabian crude oil in w[illegible] as a function of temperature [illegible] [illegible] pressure



SOURCE: Griswold, 1942 (8)

FIGURE D-4 Solubilities of hydrocarbons and petroleum fractions in water at total system pressure

TABLE D-4 Solubility of individual hydrocarbons in aqueous solutions at 25^{o}C as a function of NaCl concentration.

NaCl CONCENTRATION IN PPM	SOLUBILITY OF HYDROCARBON IN PPM			
	PENTANE	BENZENE	TOLUENE	METHYLCYCLOPENTANE
0	39.5	1740	544	41.8
1,002	36.8	1718	526	38.0
10,000	34.5	1628	490	36.3
SEA WATER * 34,472	27.6	1391	402	29.2
50,030	22.6	1194	359	27.0
125,100	10.9	593	182	12.7
199,900	5.91	388	106	5.72
279,800	2.64	214	53.8	3.36
358,700 **	2.01	134	37.2	1.89

* ARTIFICIAL SOLUTION

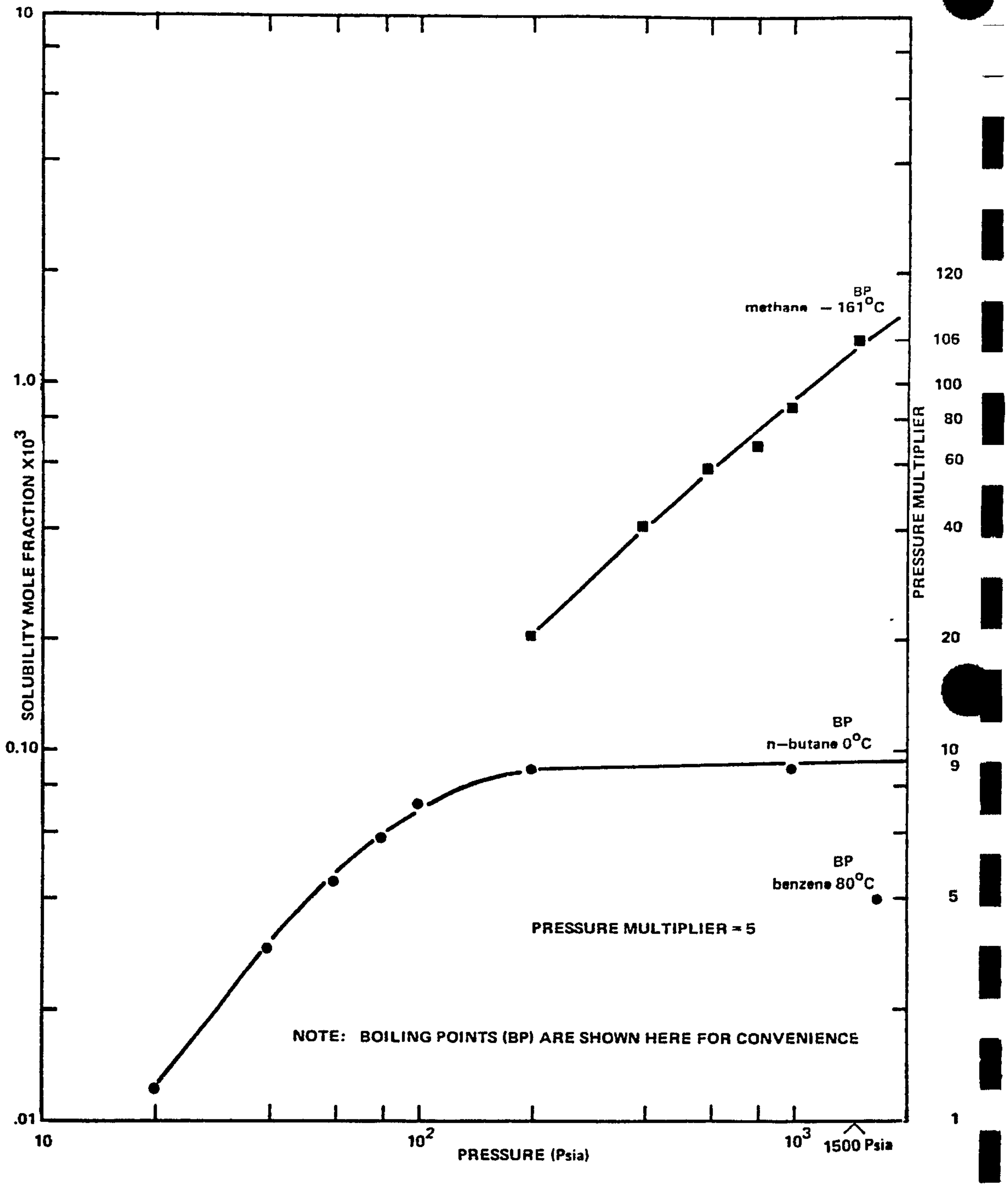
** SATURATED NaCl SOLUTION

SOURCE: Price, 1973

TABLE D-5 Dissolved oil content of brines equilibrated with various oils.

	BRINE ppt	GRAVIMETRIC mg/l
GULF COAST TEXAS CONDENSATE	1	9.64
	30	5.83
	100	2.45
GULF COAST TEXAS HIGH GRAVITY CRUDE	1	6.87
	30	4.03
	100	2.15
LOUISIANA MEDIUM GRAVITY CRUDE	1	6.16
	30	5.53
	100	3.68
EAST TEXAS MEDIUM GRAVITY CRUDE	1	11.49
	30	6.96
	100	3.11
EAST TEXAS LOW GRAVITY CRUDE	1	5.02
	30	3.96
	100	2.41
CALIFORNIA LOW GRAVITY CRUDE	1	0.40
	30	0.31
	100	0.60
CALIFORNIA MEDIUM GRAVITY CRUDE	1	9.64
	30	4.58
	100	3.87
ALASKA CRUDE	1	9.56
	30	7.83
	100	5.04
FLORIDA CRUDE	1	10.51
	30	7.51
	100	4.15

SOURCE: Caudle, 1977



SOURCE: Reference Petroleum Production Handbook

FIGURE D-5 Pressure effect on solubility

Table D-6 and shown in Figure D-5, taken at a temperature of 160°F to approximate cavern conditions, indicates a corresponding increase in solubility with pressure in addition to the importance of the hydrocarbons molecular size and boiling point. This data suggests that pressure has a diminishing effect on the solubility of the hydrocarbons as their molecular weights and boiling points increase (Price, 1973; McKelta and Wehe, 1962). For convenience, the boiling points of the hydrocarbons are also listed on Figure D-5. Since no data was located for pressure/solubility relationships for the higher boiling point hydrocarbons, a pressure multiplier of 5 was used for calculation purposes. The pressure multiplier of 5 is plotted on Figure D-5 in relation to the boiling point of benzene. The pressure multiplier factor of 5 appears to be a reasonable worst case assumption and only operating data or precise experimentation would provide closer approximations.

D.3.4 Calculations of Dissolved Oil Concentrations

Based on the preceding discussion, expected cavern equilibrium concentration for Murban crude can be computed as follows:

Seawater Equilibrium		Temperature Multiplier		Salinity Multiplier		Pressure Multiplier		
(27.9 ppm)	X	(1.5)	X	(0.15)	X	(5)	=	(31.4 ppm)

Allowing the cavern brine to reach equilibrium conditions, the concentrations of hydrocarbons will be roughly equivalent to that of seawater concentrations as determined by McAuliffe. Personal communications with McAuliffe on this subject reveals that 25-30 ppm would be a reasonable equilibrium concentration.

The equilibrium concentration would occur only during the long oil storage period. However, this concentration would ultimately be diluted by a factor of 20 by raw water during displacement of the oil (see Section 2 and 3). This dilution would lead to non-equilibrium conditions and a resumption of dissolution. During the relatively short periods between cessation of oil withdrawal and completion of cavern refill the entire volume of brine should not attain an equilibrium concentration of dissolved oil. Solution would be retarded by the refractory layer at the

TABLE D-6 Pressure effect on solubility.

SMOOTHED VALUES FOR THE SOLUBILITY OF
METHANE IN WATER IN THE VAPOR—LIQUID REGION

PRESSURE, psia	MOLE FRACTION $CH_4 \times 10^3$ 160° F*
200	0.203
400	0.407
600	0.599
800	0.780
1,000	0.945
1,250	1.133
1,500	1.308
2,000	1.608
2,500	1.861
3,000	2.094
3,500	2.309
4,000	2.516
5,000	2.888
6,000	3.221
7,000	3.519
8,000	3.782
9,000	4.007
10,000	4.211

*Temperature of the System

SOURCE: McKetta and Wehe (1962)

TABLE D-6 continued.

SOLUBILITY OF n–BUTANE IN WATER	
PRESSURE psia	MOLE FRACTION OF n–BUTANE X 10^3 160° F*
20	0.012
40	0.029
60	0.044
80	0.058
100	0.071
200	0.088
300	0.088
400	0.088
500	0.089
600	0.089
800	0.089
1,000	0.090
5,000	0.098
10,000	0.103

*Temperature of the System

SOURCE: McKetta and Wehe (1962)

brine/oil interface and downward diffusion of dissolved oil will proceed very slowly.

The dissolved oil concentrations contributed from the cavern wall (based on the dimentions of cavern number 4 at Bryan Mound) will be 1.6 ppm. This calculation was based on an estimated 50 micron oil film remaining on the wall during oil displacement and subsequent dissolution into the brine as the underlying salt is dissolved away. The oil film adhering to the cavern wall would be thick for heavy, viscous crudes but relatively thinner for the lighter more fluid crudes. An effective film thickness was calculated by considering the largest (in molecular volume) hydrocarbon which has a measurable solubility. Under cavern operating conditions, the largest normal paraffin which would dissolve in appreciable amounts is C_{10} (decane) which has a typical layer thickness of 50 microns. A molecular layer was estimated to remain on the cavern wall.

An analysis of the wall oil layer component to the brine (based on cavern number 4) indicates that for a millimeter wall layer, the oil in brine concentration would increase to 28.6 ppm. The latter concentration is roughly equivalent to the equilibrium concentration for the entire volume.

The amount of hydrocarbons which would dissolve from the oil-brine interface during oil fill and withdrawal and during non-oil storage periods is difficult to estimate due to the lack of experimental data. The rates of solubility as determined by Price (1973) were based on studies of hydrocarbons and brine solutions in test tubes. Under these conditions, Price observed that it required 2-4 days to achieve equilibrium conditions. Under these relatively slow rates and given the infinitely larger volumes of the cavern, it is reasonable to assume that only the brine close to the oil-brine interface would be affected by dissolved oil during oil filling and withdrawal phases. The dissolution of hydrocarbons during the oil withdrawal and refill phases should be reduced with the existence of the refractory layer at the oil-brine interface. This layer will develop as a result of lighter, more soluble hydrocarbons dissolving into the underlying brine leaving the heavier, relatively insoluble hydrocarbons at the interface. The resistance of this layer to dissolution would increase with time until practically all diffusion across the interface ceases.

The hydrocarbon concentration due to dissolution occurring during the period of non-equilibrium conditioned between oil withdrawal and cavern refill will be 3 ppm. This value is based on the assumption that the time between cessation of drawdown and completion of refill will be of such short duration so that only the volume of the uppermost 50 feet of brine will approach equilibrium. Assuming a 500 foot cavern height, a ten-fold dilution of the equilibrium concentration would occur; resulting in 3 ppm of oil dispersed within the brine column. This average value would change as a function of the cavern geometry and phase within the brine discharge cycle. The addition of this component to the total hydrocarbon concentration being discharged would be minor during first quarter of a cavern's discharge cycle and increase as the oil brine interface descends toward the bottom of the brine pipe. The near equilibrium concentration close to the oil brine interface would not be discharged due to cavern enlargement and diffusion during oil withdrawal and refill phases.

The total dissolved hydrocarbon concentration expected to be discharged is derived as follows:

(1)	Long-Term Storage Equilibrium Component	= 1.6 ppm	Assumes the residual 5% volume of brine attains equilibrium of 31.4 ppm and is diluted 20 times during oil withdrawal.
(2)	Wall Oil Component	= 1.6 ppm	The solution of the 50 micron oil film from the cavern wall's surface. (cavern geometry dependent)
(3)	Oil Withdrawal, Non-Storage Period and Refill, Non-Equilibrium Component	= 3.1 ppm	Assumes the upper most fifty feet of the cavern volume attains equilibrium concentrations and is diluted by the remaining brine volume. (cavern geometry dependent)
	Total dissolved hydrocarbon concentrations	= 6.1 ppm or 6 ppm	

D.4 DISPERSION REACTIONS

Whereas dissolution occurs on a molecular level, dispersive reactions occur on a particle level. This reaction requires a breakup of the oil into particles and dispersing them into the underlying brine. The energy for this reaction is produced during the initial oil injection where oil is jetted at a velocity of approximately 8 feet per second into the brine and micro particles dispersed into the upper area of brine. This agitation would diminish and eventually cease as the downward oil-jet momentum is balanced by the buffering force of the oil thereby limiting the depth of the turbulent zone.

Studies of the dispersion of oil in seawater under oil slick conditions indicate that the greatest amount of oil is dispersed in a particle size of 40 microns or less in diameter (Price, 1973). For illustrative purposes data for Bunker C, listed in Table D-7, show the distribution of particle sizes ranges from 10 to 80 microns.

The suspension time for oil particles in the brine would be very short because of the large density differential of the oil (sp.gr.approx. .85) versus the brine (sp.gr. 1.19). Studies of crude dispersions, Table D-8, in seawater illustrates the rate of floatation. With the greater density differential, as in saturated brine, the dispersed oil within the caverns would be expected to show even faster floatation rates.

Within the cavern, even under the most rapid fill rates, the dispersed particles would have several weeks in which to rise and coalesce at the oil/brine interface. This is believed to be sufficient time for the dispersed oil concentrations to decrease to values of less than 1 ppm. For calculation of oil in brine, a value of 1 ppm of dispersed oil is assumed to be discharged to the brine surface control facilities.

TABLE D-7 Distribution of particle size beneath an oil spill*.

	NO. AND VOL. OF PARTICLES IN 10–MICRON RANGE CENTERED AT							
	10u	20u	30u	40u	50u	60u	70u	80u
NUMBER	323	147	57	19	4	3	3	1
VOLUME	0.45	0.96	1.42	1.35	0.40	0.66	1.12	0.60

* BUNKER C OIL

SOURCE: The Fate of Oil Spilt at Sea

TABLE D-8 Settling time and dispersed oil particles*.

TIME OF SETTLING DAYS	OIL CONTENT PPM
0.01	31
0.02	10
0.04	4.5
0.33	2.5
1.0	4.6 **
1.1	1.5
2.2	2.7 **
147	0.6

SOURCE: THE FATE OF OIL SPILT AT SEA.

* TYPE OF CRUDE OIL NOT STATED
** REASONS FOR OIL CONTENT INCREASE NOT GIVEN

D.5 DISCHARGE OF THE OILY BRINE TO THE SURFACE CONTROL FACILITY

The discharge of brine containing hydrocarbons, as schematically illustrated in Figure D-6, will involve different scenarios dependent upon whether it is during initital fill or subsequent refills.

For initial fill, an assumption was made that the top 50 feet of brine became saturated with hydrocarbons (31.4 ppm) and this was diluted into the uppermost 100 feet yielding approximately 16 ppm (see Section D.2.1). This initially high hydrocarbon concentration would result from the fresh unweathered crude not having sufficient time to form a refractory layer before fill is completed. In subsequent fills the refractory layer will be present. The 16 ppm would exhibit a concentration gradient (0 to 31 ppm) when discharged; however, its average over the discharge period is expected to be about 16 ppm.

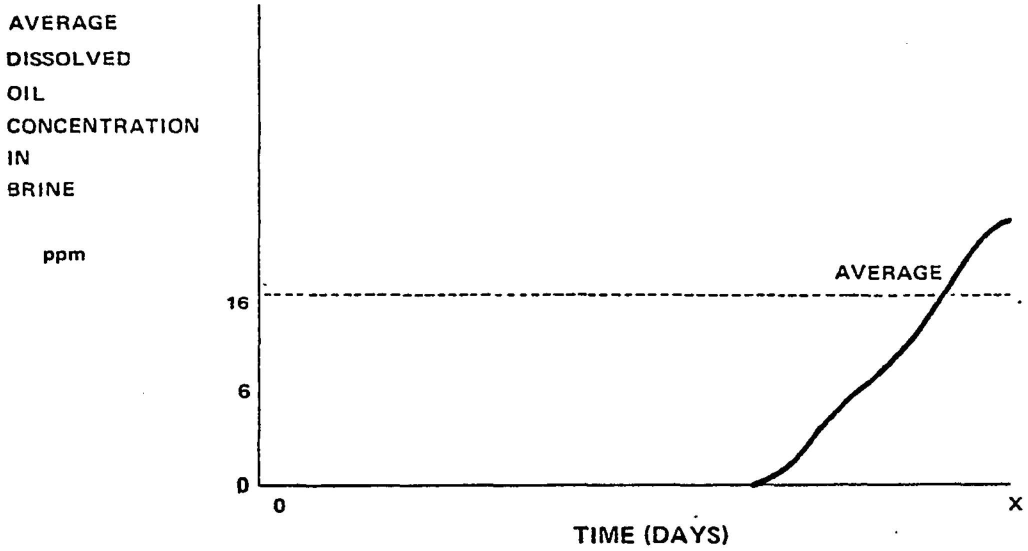
It is expected that low levels of oil averaging approximately 6 ppm would be discharged continuously during subsequent refills. Contingent upon differing cavern geometries, the oil concentration would vary from 4 to 15 ppm.

The only available data from similar operations are from the German oil storage facility at Etzel, Germany and the French oil storage facility at Manosque, France.

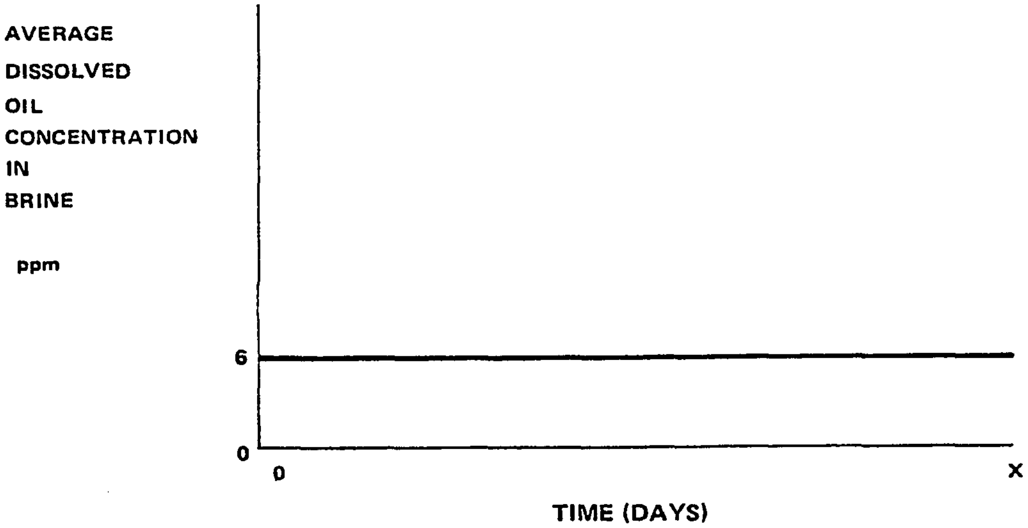
The Etzel data (Kavernen Bau - und Betriebs - BmbH, n.d.) indicate that the oil concentration of brine discharged from the brine control surface facility is less than 1 ppm.

The Manosque data (LOOP, Inc., 1975) indicate an oil concentration of 17 ppm in the brine discharged from the cavern to the surface facilities. Neither the duration of storage or type of crude were identified.

These data from the two operating oil storage facilities clearly indicate that with an expected eighty percent reduction of the oil concentration due to vaporization of light hydrocarbons such as butane, pentane and benzene (McAuliffe, 1969) and an additional reduction by oil skimming, the estimated oil concentration in the discharged brine of approximately 6 ppm appears reasonable for the proposed U.S. facilities.



INITIAL OIL FILL



SUBSEQUENT OIL FILL

FIGURE D-6 Schematic representation of oil in brine concentrations discharged from a typical cavern

D.6 CONCLUSIONS OF THE OIL BRINE STUDY

The major conclusion of this study is that there is insufficient time, turbulence and circulation within the cavern during oil fill and withdrawal phases, to allow the dissolved oil to reach equilibrium. Practical operating experience of mines in France (Part III) have substantiated these conclusions. Equilibrium concentrations for the thirteen crudes studied will not exceed approximately 31 ppm under the cavern operating conditions. Thus, during the time when the cavern is principally filled with non-equilibrium oil-brine concentrations of less than 31 ppm, dissolution and diffusion reactions will occur in the upper brine column.

The results of the study indicate that the dissolved oil in the brine discharged to the brine surface control facility is expected to average 16 ppm for the later stages of the initial oil fill of each cavern and average approximately 6 ppm for subsequent oil refills from a cavern of specific geometry. Differing cavern geometry effects the duration of the initial oil discharge and the concentration of the dissolved oil in subsequent discharges. The oil concentration in the brine will be principally composed of dissolved hydrocarbons rather than dispersed oil as is commonly found beneath oil slicks at sea. The dispersed oil component which is created during initial turbulent oil injection is quickly and naturally removed from the brine column due to its high buoyancy and less than 1 ppm would be expected in the brine discharge.

Studies of the effects on hydrocarbon solubility as a function of increasing the temperature of 150°F, pressure to 1500 psi and salinity to 310 ppt indicate that solubility changes of: 1.5 times would occur due to temperature increase, 5.0 times for pressure and 0.15 times for salinity. The net effect of these would be an increase in solubility of only 1.125 times in comparison to seawater equilibrium concentrations. Thus, cavern oil equilibrium concentrations will be very similar to values measured for the various crudes in seawater at standard conditions of temperature and pressure.

The oil film remaining on the cavern wall is not expected to appreciably affect the net oil concentrations of the brine due to the large dilution effect within the cavern and the estimated 50 micron thickness of the wall film.

At the start of filling operations the oil jet velocities should be controlled to limit the amount of turbulence during initial fill and the possible disruption of the refractory layer during the subsequent refills.

A refractory layer is expected to form at the oil brine interface which will reduce dissolution and to a degree dispersion reactions.

D.7 REFERENCES

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PART II - SOLUTION MINING AND USE OF NEW CAVERNS

D.1 Oil-In-Brine, Cavern Construction and Operation Effects

D.1.1 Cavern Construction and Initial Fill

The caverns at the proposed SPR storage sites are to be constructed by utilizing the leach-then-fill and/or leach/fill methods. Leach-then-fill is the primary method. It requires that the cavern to be leached to its design capacity before crude oil storage begins. This method has the advantage of less potential for oil-brine interactions than leach/fill does, but the disadvantage that the lengthy (2 year) leaching process must precede oil fill. The leach/fill method may be utilized to reduce the time required for initial oil storage. Leach/fill allows for storage of crude oil concurrently with all but the initial months of cavern leaching, but has a potential for higher hydrocarbon (HC) concentrations in the brine displaced from the caverns than the leach-then-fill method does. These higher HC concentrations would have a negative impact on air quality and on the brine disposal area.

D.1.1.1 Leach-Then-Fill Method

When the leach-then-fill method is utilized, caverns would be leached to their design capacity in a continuous operation. The resulting caverns would be approximately cylindrical in shape and have a maximum diameter of about 300 feet. Blanket oil (to restrict upward growth of the cavern roof) would be installed early in the leaching process and would remain in place for the duration of leaching operations.

At the conclusion of leaching of a cavern, oil fill would be initiated, displacing brine from the cavern. Initially, the displaced brine would have negligible HC concentrations. Brine with low HC concentrations would then be displaced for about two-thirds of the oil fill period. Finally, brine (near the oil-brine interface) with higher HC concentrations would be displaced. During the final stages of oil fill, HC concentrations are anticipated to average 16 ppm.

Brine displaced to the surface control facility (brine pond) would be retained for settling of insoluble material. A four hour retention time is planned, during which 50 to 100 percent of the hydrocarbons in in the brine would evaporate. The remaining hydrocarbons would be transported with the brine to the disposal area. Monitoring of HC concentrations in the brine is planned, both at the cavern wellheads and at the output of the surface control facility. Filling operations would be adjusted to maintain effluent HC concentrations below state standards (at a level of about 10 ppm). Filling would be curtailed if concentrations exceeded state standards.

D.1.1.2 Leach/Fill Method

The leach/fill procedure would permit crude oil to be stored about 1 MMB of available capacity is reached in a given cavity. With the designed cavern diameter, 1 MMB would occupy the upper 100 feet of the cavern. As with the leach-then-fill concept, the oil-in-brine would remain within the upper 100 feet of the brine column. Therefore, after a fill of 1 MMB of oil, the oil-in-brine would extend 200 feet below the top of the cavern. Additional fill would be added as space is leached.

With the leach/fill procedure the leach casings and zones of active leaching would precede oil fill by only a short vertical distance. Oil levels would be adjusted for optimum leaching configuration. The volume of brine in the cavern would be smaller than with leach-then-fill and the total elapsed time in which oil-brine activity could occur would be longer. Hence, total hydrocarbons dissolved in brine are likely to be higher for this method than leach-then-fill. Depending on casing depths and oil fill increments utilized, high concentrations of oil in brine could be released earlier using this method than for leach-then-fill. Continual monitoring of the hydrocarbon concentrations would be required to determine the appropriate criteria for leach and fill rates and schedules, to maintain concentrations below state standards.

D.1.2 Second and Subsequent Oil Refills/Withdrawals

Following displacement of stored oil during the first withdrawal, HC concentrations would be similar whether leach-then-fill or leach/fill procedures were used for cavern construction. The principal effects of subsequent fill/withdrawal cycles on the quantity of oil dissolved in brine would be 1) cavern enlargement during withdrawal, 2) the dilution of residual brine during refill, and 3) the dissolution of oil remaining on the cavern walls during withdrawal.

Assuming an initial cylindrical cavern of 10 MMB capacity, 1000 feet in height and 270 feet (average) in diameter, cavern enlargement would be experienced approximately as shown in Table D-9. Using fresh water as the displacement source, the cavern would grow from its initial 10 MMB capacity to about 18.6 MMB in size over the 5 cycles. As only 10 MMB of crude oil is planned to be stored during each fill, about 3/4 as much brine as oil would be contained in the cavern after the fifth oil fill. The cavern diameter could enlarge by as much as 50 feet and the area of the brine-oil interface would increase by 40 percent over 5 cycles. The refractory layer would then be spread over the larger area, and additional oil would be expected to enter the layer.

Cycling the cavern with 10 MMB of crude oil during each fill and withdrawal would have the effect of moving the brine-oil interface higher in the cavern with each cycle. Because brine is removed from the bottom of the cavern during oil fill, the high HC concentrations in brine (near the top of the brine) would be farther from the brine exit with each additional cycle.

Long-term storage of crude oil between withdrawals would cause increasing volumes of brine to reach equilibrium HC concentrations (31.4 pmm) prior to dilution during withdrawal. Accounting for dilution by displacement water, concentrations would increase 10-fold for 5 cycles.

Short-term dissolution would also occur in the interim between the initiation of a withdrawal and the completion of a refill; mostly occurring during the period of no activity prior to refill. Assuming the upper 50 feet of the brine reaches equilibrium HC concentration, the average HC concentration shown in Table D-9 would result. Average HC concentrations would increase in later cycles as the volume of the 50 foot thick layer becomes a greater portion of the cavern volume utilized for a 10 MMB refill.

Oil in brine resulting from residual oil on cavern walls entering solution during withdrawals is only slightly affected by cavern enlargement. As cavern volume increases, the surface area increases at a smaller rate, and the resulting average HC in brine concentrations would be less for later cycles. These concentrations are greatly affected by the thickness of the residual oil film and clingage thicker than the 50 microns assumed would greatly increase concentrations.

D.2 Summary

In summary, hydrocarbon concentrations of displaced brine during oil fill would be relatively high (due to turbulence and mixing early in the fill) during the latter stages of the initial fill. Following the initial fill, a dense refractory layer would form, lessening those effects during later fills. The later fills/withdrawals would be affected by the rate of cavern enlargement and the increasing distance from the brine withdrawal pipe to the refractory layer. The second fill would displace the least hydrocarbons due to the formation of the refractory layer and the small percentage of cavern enlargement. During subsequent fills, the effects of cavern enlargement would become more pronounced with HC concentrations approaching equilibrium conditions.

TABLE D-9 Fill/withdrawal cycle vs. cavern size relationship.

Fill Cycle	Withdrawal Cycle	Active Cavern Volume, MMB	Total Cavern Volume,[1] MMB	Residual Brine After 10 MMB Fill, MMB	Brine Dilution During Withdrawal	Long-Term Storage Equilibrium Concentration,[2] ppm	Oil Clingage on Cavern Walls,[3] bbl	Clingage Oil Concentration in Brine, ppm	Short-term Oil Dissolution[4] Ratio	ppm	Total Dissolved HC Concentration ppm
1	0	10.0	10.5	0.5	-	-	-	-	-	-	-
2	1	11.7	12.2	2.2	1:20	1.6	27	2.6	1:20	1.6	5.8
3	2	13.4	13.9	3.9	1:4.5	7.0	30	2.5	1:16.0	2.0	11.5
4	3	15.1	15.6	5.6	1:2.6	12.1	32	2.3	1:13.9	2.3	16.7
5	4	16.8	17.3	7.3	1:1.8	17.4	34	2.2	1:12.2	2.6	22.2
-	5	18.6	19.1	-	1:1.4	22.4	36	2.1	1:10.9	2.9	27.4

1) Including 0.5 MMB sump

2) Equilibrium concentration ÷ dilution

3) Assuming 50 micron thickness

4) Assuming only upper 50' of cavern reaches equilibrium concentration of 31.4 PPM

PART III

COMMENTS OF GERARD FEDIDA[a] CONCERNING STUDIES OF THE OIL CONTENT OF BRINES DISCHARGED FROM SALT CAVERNS AT MANOSQUE, FRANCE

I am Gerard Fedida, Manager of Projects at GEOSTOCK (Societe Franca[illegible]e De Stockage Geologique) at the time of this study and the coordinator of the group which wrote the reports on the content of oil in brines discha[illegible]e from salt caverns at Manosque, France.

My professional training in engineering was obtained at the Ecole Polytechnique and Ecole Nationale Superieure des Techniques Avancees in Paris, France. I have been associated with GEOSTOCK since 1973, and was formerly associated with C.G. Doris, a French offshore engineering firm.

GEOSTOCK is a subsidiary of four oil companies in France, and has specialized in performing design and management services in the implementation of the French strategic petroleum reserve and other underground hydrocarbon storage facilities. GEOSTOCK presently is the operator for approximately 90 million barrels of a variety of hydrocarbons, including LPG, gasoline, naptha and crude oil.

In November 1977, the Department of Energy (DOE) entered into a contract with Geostorage Inc., the American subsidiary of GEOSTOCK, for the following four studies related to the storage of crude oil in salt-solution caverns at Manosque, France:

1. A compilation of selected historical data and measurements of the oil content of brines taken during several years of facili[illegible]y operation;
2. Sampling and measurement of the oil content of brines from caverns which had contained crude oil for prolonged periods;
3. Sampling and measurement of the oil content of brines displace from caverns during normal fill operations; and
4. A compilation of selected historical temperature profiles made within certain caverns. This latter study has no direct bearing on my testimony and will not be discussed further.

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[a] Joint Environmental Protection Agency-Corps of Engineers Public Hear on Bryan Mound Brine Diffuser Application, May 2, 1978.

(Transparency No. 1)[a] The Manosque storage complex is located in the south of France, 55 miles northeast of Marseille.

Between 1968 and 1973, 18 cavities were leached in a massive salt formation. In a second phase of development currently underway, 18 new cavities are being created. The volume of these cavities ranges from 700,000 to 2.5 million barrels.

The facilities include two brine surge ponds for 1.2 million barrels capacity at Manosque, two 20" pipelines linking the site to brine lakes and refineries and VLCC facilities on the Mediterranean coast near Marseille, and the necessary pumping equipment and controls. Brine samples are periodically taken at the Rognac station here. The description of this complex is analogous to the general system description of the DOE complex appearing in the Bryan Mound final Environmental Impact Statement.

The two 20" pipelines mentioned above serve to carry excess brine and petroleum between Manosque and the petrochemical industries near Marseille. One of these pipelines is dedicated to brine and the other to petroleum; they are not used interchangeably.

(Transparency No. 2)[a] Each cavity is equipped with two concentric pipes. Hydrocarbons are pumped into a cavity through the annulus and brine is displaced through the suspended tubing (Transparency No. 3)[a] to the surface brine ponds, where most dissolved and dispersed hydrocarbons separate out. This method is virtually identical to the one in which DOE will operate its facilities. Any excess brine is pumped through 20" pipeline, mentioned earlier, to the brine lakes near Marseille. During drawdown cycles, the procedure is simply reversed.

Since inception of the project at Manosque, frequent samples of the brine in the 20" pipeline have been collected in order to monitor corrosion and oil content. For Part 1 of our study a total of 40 analyses were compiled for the period January 4, 1972, through November 25, 1976. These analyses represent both leaching under a hydrocarbon blanket and actual storage operations.

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[a] Transparencies No. 1, 2 and 3 were presented as part of Mr. Fedida's testimony but have not been included in this Appendix.

As noted earlier, the brine displaced from the various caverns initially flows into one of two 600,000 barrel capacity surface ponds which act as surge pits. Any film which forms on the ponds is periodically skimmed and disposed of.

(Transparency No. 4) (Table D-10) Each of the 40 samples, selected for this compilation, was withdrawn from the 20" pipeline at the Rognac pump station, which you will recall is located near Marseille.

All samples were analyzed using an infrared spectrometric method similar to the one recommended by Michael Gruenfeld, Environmental Protection Agency, Edison, New Jersey. This method involves a liquid-liquid extract of the brine with a suitable solvent such as Freon-113 or carbon tetrachloride, followed by a measurement of the infrared absorbance of the solution. Using this method the practical limit of detection is 0.5 parts per million (ppm).

Residence time of the brine in the ponds varied from one day to more than 3 weeks depending on the scale and type of operation at the time. Differences in residence time of brine in the ponds appear to have an insignificant effect on its oil content since most hydrocarbons either volatilize, or come out of solution and form a surface film, within a short time after the brine reaches the surface, due to the decrease in pressure.

Other parameters of simultaneous movements in the caverns were also compiled, such as brine temperature and density, distances between the oil/brine interface and the shoe of the brine displacement casing, and the spacing between the shoes of the oil injection and brine displacement casings. No relationship was established between these parameters and the concentration of oil in the brine samples, the distribution of which appears in transparency no. 4 (Table D-10).

The second part of our study required the collection and analysis of brine samples from caverns which had contained crude oil in quiescent storage for prolonged periods. The purpose of this task was to obtain data on the oil content of brines which approached equilibrium with the stored oil before the samples had undergone the separation effects of the surge ponds.

We selected four cavities which we felt were appropriate for this study. Two samples were collected at the wellhead of each cavern. The first sample was collected after the volume of brine standing in the tubing had been displaced to the surface. The second sample was collected after an additional few thousand barrels had been displaced.

The results of the analysis of these samples is presented in the next transparency (No. 5) (Table D-11). As you will note, brine from cavity ET, which had contained crude oil for 13 months, contained only 12.7 parts per million oil. You will recall that these samples were collected before any settling of the brine had taken place in the ponds. All samples exhibited a strong odor of hydrocarbons and degassing when they were collected. This is consistent with what is known about the solubility of hydrocarbons in brine, namely, that the light hydrocarbons, especially those like butane and propane are the more soluble, and solubility is pressure dependent. Therefore, when brine from beneath stored crude oil is produced to the surface, the reduction in pressure will cause dissolved hydrocarbons to volatilize.

Our final study regarding oil-in-brine, called for the sampling and analysis of brines displaced from cavities during normal fill cycles. A total of 24 samples were collected from the wellheads of five cavities for the purposes of this task. The results of the analyses of these samples is presented in the next transparency (No. 6) (Table D-12). As can be seen, the maximum oil content was only 9.4 ppm, before any settling in the surge ponds, which is within the range reported earlier for historical data of operational cavities.

All of the samples exhibited a hydrocarbon odor and most were obviously degassing.

All of the oil-in-brine analyses reported were made on samples obtained from a hydrocarbon storage facility which has been in operation for ten years. The samples were obtained from origins as different as the wellheads of static storage, the wellheads of operating storage and the effluent of a brine settling pond. These analyses show that the oil concentration is below 15 parts per million even in the worst case and averages four to five ppm.

TABLE D-10 Content of oil in brines displaced from caverns at Manosque, France.

OIL CONTENT (PPM)

OPERATIONAL CAVERNS (18 SAMPLES)		LEACHING OF NEW CAVERNS (22 SAMPLES)
0.0-13.8	RANGE	0-10
2.8	MEDIAN	2.6
4.6	AVERAGE	3.3

TRANSPARENCY NO. 4

TABLE D-11 Oil content of brine samples from cavities containing crude oil for prolonged periods.

(ALL SAMPLES COLLECTED AT THE WELLHEAD)

CAVITY	MINIMUM STORAGE TIME	TOTAL OIL CONTENT (PPM)	
		FIRST SAMPLE	SECOND SAMPLE
ET	13 MONTHS	12.7	9.3
A	3 WEEKS	9.4	3.8
D	3 WEEKS	6.1	1.7
F	3 WEEKS	2.2	1.6

TRANSPARENCY NO. 5

TABLE D-12 Oil content of brine displaced from cavities during normal fill operations.

(ALL SAMPLES COLLECTED AT THE WELLHEAD)

	TOTAL OIL CONTENT (PPM)		
CAVITY	START OF CAVERN FILL	END OF CAVERN FILL	RANGE
A	9.4	0.7	0.7-9.4
D	6.1	1.4	0.8-6.1
W	0.7	0.7	0.7-3
E	3	0.7	0.7-3
G	0.7	1.4	0.7-1.4

TRANSPARENCY NO. 6

APPENDIX E

OIL AND BRINE SPILL RISK ANALYSIS

APPENDIX E

OIL AND BRINE SPILL RISK ANALYSIS

E.1 Risk Analysis Introduction

This Appendix describes the oil and brine spill risks associated with development of the Capline Group of candidate SPR storage sites. Generalized environmental risks associated with facility use are described in Section E.2; calculated spill expectations associated with various facility operations are also presented. The methodology utilized in computing the spill expectations is given in Section E.3, Further description of the chance of cavern collapse and catastrophic release of oil (or brine) is provided in Appendix F.

Information presented in this Appendix, along with the description of existing environment and the expected oil or brine movements following an accidental release, is used in analyzing site specific impact potential in Section 4.0 of the EIS.

E.2 Oil and Brine Spill Risks Related to the SPR Program

A significant environmental hazard associated with development of the proposed SPR oil storage facilities is the risk of crude oil or brine spills. The risk of oil spills during cavern fill begins with offloading from VLCCs in the Gulf of Mexico and includes transport by tanker up the Mississippi River, offloading at the docks, pipeline transport to the storage sites, and terminal operations (including cavern storage). During withdrawal of the oil, essentially the same transportation modes are used. However, some of the oil is planned for delivery to the CAPLINE Pipeline for transport to refineries downstream. The remainder would be loaded onto small tankers at docks on the Mississippi River for transport to other ports. Oil would be left in the pipelines, and possibly in the surge tanks during standby storage, constituting a continuous exposure risk.

The risk of a brine spill is present during the cavern leaching operations when near-saturated brine is temporarily held in a reservoir at the storage site and piped to the Gulf of Mexico or deep injection wells for disposal. During cavern fill, oil would displace brine from the caverns into the brine reservoir, and then by pipeline to the Gulf of Mexico or deep salt water bearing sands.

The following sections summarize oil and brine spill hazards and loss expectations due to development and operation of each of the candidate SPR storage site groupings (including the early storage facilities).

E.2.1 Oil Spill Risks

E.2.1.1 Oil Spill Risk from Cavern Storage

The loss of oil from cavern storage systems to the surrounding environment requires two conditions to be present. First, the storage barrier, such as the cavern or a storage tank, must be breached and, second, there must be a driving force to initiate oil migration. During surface storage, the driving force is gravity; during salt cavern storage the force could be provided by inflow of overlying surface or ground waters, or by sudden decompression of the oil containing cavern (by shearing or rupture of pipelines).

Since the liquid column of petroleum that is needed to hydrostatically balance a column of water is taller than the water column, the petroleum would be lifted above the head of the water column. This difference is between 10 and 20 percent and provides a 400 to 800 foot differential column height for a cavern with the bottom 4000 feet below the surface. A cavern volume of 10 million barrels represents about 1300 acre-feet of storage. Either very tall dikes or a very large containment area would be required to contain a spill associated with collapse of a cavern. Thus, diking of the storage area to protect against cavern collapse is not practical.

The likelihood of a cavern collapsing has been evaluated as being a remote occurrence provided that contributory conditions are avoided or monitored (Appendix F). All four known instances of salt cavern collapse (Bayou Choctaw, Louisiana, 1954; Grand Saline, Texas, 1976; Belle Isle, Louisiana, 1973; Eminence, Mississippi, 1973) occurred during brine solution mining and are believed to have resulted from uncontrolled or accidental leaching of the salt near the top of the dome, rather than from structural failure of the cavern roof. Thickness of the cavern roof in each of these occurrences was less than 300 feet.

Spills from direct hit airplane crashes or acts of war are highly improbable and inestimable. Their effects would largely be confined to surface facilities and are more likely to result in a fire rather than a spill.

Oil Spill Expectation

It is not possible to place meaningful quantification to the likelihood of cavern collapse. Assuming the precautions discussed in Appendix F are carried out as planned, the chance of collapse seems remote. With sonar monitoring of the cavern walls during use, and following withdrawal expansion, it should be possible to detect any slabbing or cracking of the cavern roof arch, offering a further measure of protection.

In the event of collapse at any of the sites, ground water is present to displace oil to the surface. The inflow rates may vary between sites as aquifer conditions are not identical, but infiltration of stored petroleum into fluidized rock and soil may occur at any site if a storage cavity should collapse.

Non-catastrophic losses from storage through a crack, loss of seal around the cavern fill pipes, or improper filling is expected to be contained in the site diking system (wellheads and surge tankage), so that release to the environment should be avoided. Lateral failures between caverns should not pose any chance of oil release as long as the caverns are insulated within the dome.

The contribution of cavern collapse to oil spill losses is thus assumed to be zero under the constraints of proper design, construction and monitoring.

E.2.1.2 Oil Spill Risk During Marine Transportation

Casualty and operational spills from vessels may occur during transfer between VLCC and lighter, during transfer between lighter and the docks, and in lighter transit between the VLCC and the docks (or in the case of withdrawal, between the docks and open Gulf waters). Oil spills from vessels operating in coastal waters are a function of time of exposure (Section E.2). Spills resulting from transfer operations are a function of volume handled and direction of transfer (loading or offloading). All of the oil to be stored in the caverns would be delivered by tanker to the DOE docks for pipeline transport to the site. However, it is expected that only 40 percent of the oil in storage would be distributed by tanker, the rest going to the CAPLINE Pipeline at St. James. Each transport step involves a quantifiable risk of spillage into the environment, the estimation of which is based upon statistical patterns established for oil spills between 1969 and 1973 (Section E.2).

The quantities of oil which could be spilled during Capline Group marine operations, is given in Tables E-1 through E-8. As shown, considerably greater volumes of oil may be spilled during cavern fill operations than during withdrawal because of the relatively clumsy tanker-VLCC transfer operation and the greater quantity of oil transported. For a 333 million barrel Capline SPR grouping, approximately 69 percent (12,596.5 barrels) of the total oil spill expectation would occur from marine operations.

Spill size distributions which could occur for the several categories of oil spill modes are presented in Table E-9. Spills greater than 1000 barrels should not occur during transfer operations. Spills greater than 1000 barrels may occur up to 29 percent of the time from vessel casualties (average spill size of 1111 barrels); truly large spills, greater than 10,000 barrels, should occur only .75 percent of the time. Thus, from Tables E-1 through E-9, the number of large oil spills expected for operations during the lifetime of a 333 MMB storage system, is .19 percent (.27 spills expected, times .75 percent chance of large spill). This is equivalent to a recurrence interval of 11,580 years, or 2630 fill/withdrawal cycles, which is an extremely low probability.

E.2.1.3 Pipeline and Terminal Accidents

Oil spills from pipelines and terminals may occur while pumping oil to or from the sites and while oil is kept in lines and tanks during standby storage. Oil spills from pipelines are a function of pipeline length and time of exposure; oil spills at terminals are

TABLE E-1a Expected crude oil spill during cavern fill operations - proposed system - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Napoleonville		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Transfers	16.2	17.4	282	16.5	267	27.8	450	61.7	999	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.016	17.8	0.036	39.5	60,000
Mississippi River										
Vessel Casualty	428	0.510	218	0.484	207	0.815	349	1.81	774	60,000
Koch Transfers	27	---	---	---	---	4.57	123	4.57	123	500
DOE Transfers	27	3.48	94	3.30	89	0.99	27	7.77	210	500
Pipelines										
Pumping	1100	0.029	31.6	0.042	46,5	0.024	25.8	0.095	103.9	5,000
Terminals										
Koch	1100	---	---	---	---	0.0615	67.7	0.062	67.7	5,000
DOE	1100	0.047	51.7	0.0445	49.0	0.0135	14.9	0.105	115.6	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.075	37.5	0.167	83.3	3,000
Total										
Single Fill		21.52	711.9	20.43	691.4	34.37	1112.7	76.32	2,516	
Total										
5 Fills		107.6	3560	102.1	3457	171.9	5564	381.6	12,581	

TABLE E-1b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectation - proposed system - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Napoleonville		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Vessel Casualty	1111	0.0036	4.0	0.0036	4.0	0.001	1.2	0.0082	9.2	60,000
Mississippi River										
Vessel Casualty	428	0.324	139	0.324	139	0.097	41.4	0.745	319.4	60,000
Koch Transfers	80.6	-	-	1.49	120	-	-	1.49	120	500
DOE Transfers	80.6	1.49	120	-	-	0.44	36	1.93	156	500
Bull Bay										
Barge Casualty	428	0.003	1.3	-	-	-	-	0.003	1.3	20,000
Transfers	3.6	4.17	15	-	-	-	-	4.17	15	500
Pipelines										
Pumping	1100	0.008	8.8	0.014	15.6	0.004	4.6	0.026	29.0	5,000
Terminals										
Koch	1100	-	-	0.030	33	-	-	0.030	33.0	5,000
DOE	1100	0.030	33	-	-	0.009	9.9	0.039	42.9	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.075	37.5	0.167	83.3	3,000
Total										
Single Withdrawal		6.08	344.6	1.91	333.9	0.63	130.6	8.61	809.1	
Total										
5 Withdrawals		30.4	1723	9.5	1670	3.2	653	43.1	4,046	
Project Total										
5 Cycles		138.0	5283	111.6	5127	175.1	6217	424.7	16,627	

TABLE E-2a Expected crude oil spill during cavern fill operations - proposed system - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Napoleonville		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Transfers	16.2	17.4	282	16.5	267	27.8	450	61.7	999	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.016	17.8	0.036	39.5	60,000
Mississippi River										
Vessel Casualty	428	0.657	281	0.484	207	0.995	426	2.136	914	60,000
Nordix Transfers	27	3.48	94	---	---	3.38	91	6.86	185	500
DOE Transfers	27	---	---	3.30	89	2.18	59	5.48	148	500
Pipelines										
Pumping	1100	0.013	14.6	0.42	46.5	0.53	58.1	0.108	119	5,000
Terminals										
Nordix	1100	0.047	51.7	---	---	0.0455	50.1	0.093	102	5,000
DOE	1100	---	---	0.0455	49.0	0.0295	32.5	0.074	81.5	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.075	37.5	0.167	83.3	3,000
Total										
Single Fill		21.65	757.9	20.43	691.4	34.57	1222	76.65	2,671	
Total										
5 Fills		108.3	3790	102.1	3457	172.9	6110	383.3	13,357	

TABLE E-2b Expected crude oil spill during emergency oil withdrawal operations and total system spill expectation - proposed system - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Napoleonville		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Vessel Casualty	1111	0.0036	4.0	0.0036	4.0	0.001	1.2	0.0082	9.2	60,000
Mississippi River										
Vessel Casualty	428	0.418	179	0.324	139	0.097	41.4	0.839	359.4	60,000
Nordix Transfers	80.6	1.49	120	--	--	--	--	1.49	120	500
DOE Transfers	80.6	--	--	1.49	120	0.44	36	1.93	156	500
Bull Bay										
Barge Casualty	428	0.003	1.3	--	--	--	--	0.003	1.3	20,000
Transfers	3.6	4.17	15	--	--	--	--	4.17	15	500
Pipelines										
Pumping	1100	0.009	10.4	0.014	14.9	0.005	5.4	0.028	30.7	5,000
Terminals										
Nordix	1100	0.030	33.0	--	--	--	--	0.030	33.0	5,000
DOE	1100	--	--	0.030	33	0.009	9.9	0.039	42.9	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.075	37.5	0.167	83.3	3,000
Total										
Single Withdrawal		6.17	386.2	1.91	333.2	0.63	131.4	8.71	850.8	
Total										
5 Withdrawals		30.9	1931	9.5	1666	3.2	657	43.6	4254	
Project Total										
5 Cycles		139.2	5721	111.6	5123	176.1	6767	426.9	17,611	

TABLE E-3a Expected crude oil spills during cavern fill operations - alternative site grouping #1 - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Weeks Island Expansion		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Transfers	16.2	17.4	282	16.5	267	16.8	273	50.7	822	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.0097	10.8	0.029	32.5	60,000
Mississippi River										
Vessel Casualty	428	0.510	218	0.484	207	0.494	211	1.488	636	60,000
Koch Transfers	27	3.48	94	-	-	0.48	13	3.96	107	500
DOE Transfers	27	-	-	3.30	89	2.89	78	6.19	167	500
Pipelines										
Pumping	1100	0.031	34.0	0.023	25.7	0.024	26.2	0.078	85.9	5,000
Terminals										
Koch	1100	0.047	51.7	-	-	0.0065	7.2	0.054	58.9	5,000
DOE	1100	-	-	0.0045	49.0	0.039	42.9	0.084	91.4	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.0455	22.8	0.137	68.6	3,000
Total										
Single Fill		21.52	714.3	20.41	670.6	20.79	684.9	62.72	2,070	
Total										
5 Fills		107.6	3572	102.1	3353	104.0	3425	313.6	10,349	

TABLE E-3b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectation - alternative site grouping #1 - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Weeks Island Expansion		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Vessel Casualty	1111	0.0036	4.0	0.0021	2.4	0.0022	2.4	0.008	8.8	60,000
Mississippi River										
Vessel Casualty	428	0.324	139	0.191	81.8	0.196	83.9	0.711	304.7	60,000
Koch Transfers	80.6	1.49	120	--	--	--	--	1.49	120	500
DOE Transfers	80.6	--	--	0.88	71.2	0.90	72.8	1.78	144	500
Bull Bay										
Barge Casualty	428	0.003	1.3	--	--	--	--	0.003	1.3	20,000
Transfers	3.6	4.17	15	--	--	--	--	4.17	15	500
Pipelines										
Pumping	1100	0.009	9.5	0.008	8.9	0.009	9.1	0.025	27.5	5,000
Terminals										
Koch	1100	0.030	33	--	--	--	--	0.30	33	5,000
DOE	1100	--	--	0.018	19.6	0.018	20	0.036	39.6	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.046	50.1	0.138	95.9	3,000
Total										
Single Withdrawal		6.07	345.3	1.14	206.2	1.17	238.3	8.39	789.8	
Total										
5 Withdrawals		30.4	1726	5.7	1031	5.8	1191	42.0	3949	
Project Total										
5 Cycles		138.0	5298	107.8	4384	109.8	4616	355.6	14,298	

TABLE E-4a Expected crude oil spills during cavern fill operations - alternative site grouping #1 - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Weeks Island Expansion		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Transfers	16.2	17.4	282	16.5	267	16.8	273	50.7	822	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.0097	10.8	0.029	32.5	60,000
Mississippi River										
Vessel Casualty	428	0.657	281	0.484	207	0.580	248	1.721	736	60,000
Nordix Transfers	27	3.48	94	-	-	2.03	55	5.51	149	500
DOE Transfers	27	-	-	3.30	89	1.33	36	4.63	125	500
Pipelines										
Pumping	1100	0.018	20.2	0.031	33.6	0.031	34.5	0.080	88.3	5,000
Terminals										
Nordix	1100	0.047	51.7	-	-	0.0275	30.3	0.075	82.0	5,000
DOE	100	-	-	0.0445	49.0	0.0180	19.8	0.063	68.8	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.0455	22.8	0.137	68.6	3,000
Total										
Single Fill		21.66	763.5	20.41	678.5	20.86	730.2	62.95	2,172	
Total										
5 Fills		108.3	3817	102.1	3393	104.3	3651	314.8	10,861	

TABLE E-4b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectation - alternative site grouping #1 - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Weeks Island Expansion		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Vessel Casualty	1111	0.0036	4.0	0.0021	2.4	0.0022	2.4	0.008	8.8	60,000
Mississippi River										
Vessel Casualty	428	0.418	179	0.191	81.8	0.196	83.9	0.805	344.7	60,000
Nordix Transfers	80.6	1.49	120	---	---	---	---	1.49	120	500
DOE Transfers	80.6	---	---	0.88	71.2	0.90	72.8	1.78	144	500
Bull Bay										
Barge Casualty	428	0.003	1.3	---	---	---	---	0.003	1.3	20,000
Transfers	3.6	4.17	15	---	---	---	---	4.17	15	500
Pipelines										
Pumping	1100	0.009	10.4	0.008	9.3	0.009	9.5	0.026	29.2	5,000
Terminals										
Nordix	1100	0.030	33.0	---	---	---	---	0.030	33	5,000
DOE	1100	---	---	0.018	19.6	0.018	20.0	0.036	39.6	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.046	50.1	0.138	95.9	3,000
Total										
Single Wighdrawal		6.17	386.2	1.14	206.6	1.19	238.7	8.49	831.5	
Total										
5 Withdrawals		30.9	1931	5.7	1033	5.9	1194	42.5	4,158	
Project Total										
5 Cycles		139.2	5748	107.8	4426	110.2	4845	357.2	15,019	

TABLE E-5a Expected crude oil spills during cavern fill operations - alternative grouping #2 - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Bayou Choctaw Expansion		Iberia		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico												
Transfers	16.2	17.4	282	16.5	267	10.4	168	9.2	150	53.5	867	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.0060	6.6	0.0053	5.9	0.031	34.1	60,000
Mississippi River												
Vessel Casualty	428	0.510	218	0.484	207	0.303	130	0.272	117	1.569	672	60,000
Koch Transfers	27	---	---	2.11	57	---	---	1.87	50	3.98	107	500
DOE Transfers	27	3.48	94	1.19	32	2.07	56	---	---	6.74	182	500
Pipelines												
Pumping	1100	0.029	31.6	0.049	53.5	0.002	2.0	0.008	9.0	0.088	96.1	5,000
Terminals												
Koch	1100	---	---	0.029	31.9	---	---	0.025	27.5	0.054	59.4	5,000
DOE	1100	0.047	51.7	0.016	17.6	0.028	30.8	---	---	0.091	100.1	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.028	14.0	0.025	12.5	0.145	72.3	3,000
Total												
Single Fill		21.52	711.9	20.43	698.8	12.84	407.4	11.41	371.9	66.20	2,190	
Total												
5 Fills		107.6	3560	102.1	3494	64.2	2037	57.1	1859	331.0	10,950	

TABLE E-5b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectations - alternative site grouping #2 - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Bayou Choctaw Expansion		Iberia		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico												
Vessel Casualty	1111	0.0022	2.5	0.0036	4.0	0.0014	1.6	---	---	0.007	8.1	60,000
Mississippi River												
Vessel Casualty	428	0.198	84.9	0.324	139	0.126	53.9	---	---	0.648	277.8	60,000
Koch Transfers	80.6	0.91	73.6	---	---	0.58	47.0	---	---	1.49	120.6	500
DOE Transfers	80.6	---	---	1.49	120	---	---	---	---	1.49	120	500
Bull Bay												
Barge Casualty	428	0.003	1.3	---	---	---	---	---	---	0.003	1.3	20,000
Transfers	3.6	4.17	15	---	---	---	---	---	---	4.17	15	500
Pipelines												
Pumping	1100	0.005	5.9	0.014	14.9	0.003	3.5	0.003	3.4	0.025	27.7	5,000
Terminals												
Koch	1100	0.018	20.2	---	---	0.012	12.9	---	---	0.030	33.1	5,000
DOE	1100	---	---	0.030	33.0	---	---	---	---	0.030	33.0	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.028	14.0	0.025	12.5	0.145	72.3	3,000
Total												
Single Withdrawal		5.35	226.9	1.91	333.2	0.75	132.9	0.03	15.9	8.04	708.9	
Total												
5 Withdrawals		26.7	1135	9.5	1666	3.8	665	0.2	79	40.2	3,545	
Project Total												
5 Cycles		134.3	4695	111.6	5160	68.0	2702	57.3	1938	371.2	14,495	

TABLE E-6a Expected crude oil spills during cavern fill operations - alternative grouping #2 - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Bayou Choctaw Expansion		Iberia		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico												
Transfers	16.2	17.4	282	16.5	267	10.4	168	9.2	150	53.5	867	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.0060	6.6	0.0053	5.9	0.031	34.1	60,000
Mississippi River												
Vessel Casualty	428	0.657	281	0.502	215	0.391	167	0.272	117	1.822	780	60,000
Nordix Transfers	27	3.48	94	0.41	11	2.07	56	--	--	5.96	161	500
DOE Transfers	27	--	--	2.89	78	--	--	1.87	50	4.75	128	500
Pipelines												
Pumping	1100	0.013	14.6	0.050	55.4	0.013	14.2	0.008	9.0	0.084	93.2	5,000
Terminals												
Nordix	1100	0.047	51.7	0.006	6.1	0.028	30.8	--	--	0.081	88.6	5,000
DOE	1100	--	--	0.039	42.9	--	--	0.025	27.5	0.064	70.4	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.028	14.0	0.025	12.5	0.145	72.3	3,000
Total												
Single Fill		21.65	757.9	20.45	708.2	12.94	456.6	11.41	371.9	66.44	2294.6	
Total												
5 Fills		108.2	3790	102.3	3541	64.7	2283	57.1	1859	332.2	11,473	

TABLE E-6b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectations - alternative site grouping #2 - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Bayou Choctaw Expansion		Iberia		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico												
Vessel Casualty	1111	0.0022	2.5	0.0036	4.0	0.0014	1.6	---	---	0.007	8.1	60,000
Mississippi River												
Vessel Casualty	428	0.256	110	0.324	139	0.162	69.4	---	---	0.742	318.4	60,000
Nordix Transfers	80.6	0.91	73.6	---	---	0.58	47.0	---	---	1.49	120.6	500
DOE Transfers	80.6	---	---	1.49	120	---	---	---	---	1.49	120	500
Bull Bay												
Barge Casualty	428	0.003	1.3	---	---	---	---	---	---	0.003	1.3	20,000
Transfers	3.6	4.17	15	---	---	---	---	---	---	4.17	15	500
Pipelines												
Pumping	1100	0.006	6.5	0.014	15.6	0.004	3.9	0.003	3.4	0.027	29.4	5,000
Terminals												
Nordix	1100	0.018	20.2	---	---	0.012	12.9	---	---	0.030	33.1	5,000
DOE	1100	---	---	0.030	33.0	---	---	---	---	0.030	33.0	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.028	14.0	0.025	12.5	0.145	72.3	3,000
Total												
Single Withdrawal		5.41	252.6	1.91	33.9	0.79	148.8	0.03	15.9	8.13	751.2	
Total												
5 Withdrawals		27.1	1263	9.5	1670	3.9	744	0.2	79	40.7	3,756	
Project Total												
5 Cycles		135.3	5053	111.8	5211	68.6	3027	57.3	1938	372.9	15,229	

TABLE E-7a Expected crude oil spills during cavern fill operations - alternative grouping #3 - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Chacahoula		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Transfers	16.2	17.4	282	16.5	267	37.1	600	71.0	1,149.0	1,000
Vessel Casualty	1111	0.010	11.1	0.0095	10.6	0.0213	23.7	0.041	45.3	60,000
Mississippi River										
Vessel Casualty	428	0.510	218	0.484	207	1.087	465	2.081	890	60,000
Koch Transfers	27	3.48	94	-	-	1.78	48	5.26	142	500
DOE Transfers	27	-	-	3.30	89	5.63	152	8.93	241	500
Pipelines										
Pumping	1100	0.029	31.6	0.042	46.5	0.024	26.7	0.095	104.8	5,000
Terminals										
Koch	1100	0.047	51.7	-	-	0.024	26.4	0.071	78.1	5,000
DOE	1100	-	-	0.045	49.0	0.076	83.6	0.121	132.6	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.100	50.0	0.192	95.8	3,000
Total										
Single Fill		21.52	711.9	20.42	691.3	45.84	1475.4	87.79	2,878.6	
Total										
5 Fills		107.6	3559	102.1	3457	229.2	7377	438.9	14,393	

[a] 383 MMB total capacity distributed as follows:
200 MMB expansion capacity at Chacahoula dome
94 MMB early storage capacity at Bayou Choctaw
89 MMB early storage capacity at Weeks Island

TABLE E-7b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectations - alternative site grouping #3 - DOE/Koch terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Chacahoula		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Vessel Casualty	1111	0.0036	4.0	0.0036	4.0	0.0022	2.4	0.009	10.4	60,000
Mississippi River										
Vessel Casualty	428	0.324	139	0.324	139	0.194	82.9	0.842	360.9	60,000
Koch Transfers	80.6	1.49	120	-	-	-	-	1.49	120	500
DOE Transfers	80.6	-	-	1.49	120	0.89	72	2.38	192	500
Bull Bay										
Barge Casualty	428	0.003	1.3	-	-	-	-	0.003	1.3	20,000
Transfers	3.6	4.17	15	-	-	-	-	4.17	15	500
Pipelines										
Pumping	1100	0.009	9.5	0.014	14.9	0.007	7.5	0.030	31.9	5,000
Terminals										
Koch	1100	0.030	33	-	-	-	-	0.030	33	5,000
DOE	1100	-	-	0.030	33	0.018	19.8	0.048	52.8	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.100	50.0	0.192	95.8	3,000
Total										
Single Withdrawal		6.08	345.3	1.91	333.2	1.21	234.6	9.20	913.1	
Total										
5 Withdrawals		30.4	1727	9.5	1666	6.1	1173	46.0	4,566	
Project Total										
5 Cycles		138.0	5286	111.6	5123	235.2	8550	484.9	18,959	

TABLE E-8a Expected crude oil spills during cavern fill operations - alternative site grouping #3 - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Chacahoula		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Transfers	16.2	17.4	282	16.5	267	37.1	600	71.0	1,149.0	1,000
Vessel Casualty	1111	0.010	11.0	0.0095	10.6	0.0213	23.7	0.041	45.3	60,000
Mississippi River										
Vessel Casualty	428	0.657	281	0.484	207	1.273	545	2.414	1,033	60,000
Nordix Transfers	27	3.48	94	-	-	4.40	119	7.88	213	500
DOE Transfers	27	-	-	3.30	89	3.01	81	6.31	170	500
Pipelines										
Pumping	1100	0.013	14.6	0.042	46.5	0.049	53.4	0.104	114.5	5,000
Terminals										
Nordix	1100	0.047	51.7	-	-	0.059	65.5	0.106	117.2	5,000
DOE	1100	-	-	0.045	49.0	0.041	44.6	0.086	93.6	5,000
Storage Site	500	0.047	23.5	0.0445	22.3	0.100	50.0	0.192	95.8	3,000
Total										
Single Fill		21.65	757.9	20.42	691.3	46.05	1582.2	88.13	3,031.4	
Total										
5 Fills		108.3	3,789	102.1	3457	230.2	7911	440.6	15,157	

[a] 383 MMB total capacity distributed as follows: 200 MMB expansion capacity at Chacahoula dome
94 MMB early storage capacity at Bayou Choctaw
89 MMB early storage capacity at Weeks Island

TABLE E-8b Expected crude oil spills during emergency oil withdrawal operations and total system spill expectations - alternative site grouping #3 - DOE/Nordix terminal combination.

	Average Spill Size	Bayou Choctaw (Early Storage)		Weeks Island (Early Storage)		Chacahoula		Total Program Spill Risk		Maximum Credible Spill Size
		No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	No. Spills	Barrels	Barrels
Gulf of Mexico										
Vessel Casualty	1111	0.0036	4.0	0.0036	4.0	0.0022	2.4	0.009	10.4	60,000
Mississippi River										
Vessel Casualty	428	0.418	179	0.324	139	0.259	111	1.001	429	60,000
Nordix Transfers	80.6	1.49	120	-	-	0.89	72	2.38	192	500
DOE Transfers	80.6	-	-	1.49	120	-	-	1.49	120	500
Bull Bay										
Barge Casualty	428	0.003	1.3	-	-	-	-	0.003	1.3	20,000
Transfers	3.6	4.17	15	-	-	-	-	4.17	15	500
Pipelines										
Pumping	1100	0.009	10.4	0.014	15.6	0.010	10.6	0.033	36.6	5,000
Terminals										
Nordix	1100	0.030	33	-	-	0.018	19.8	0.048	52.8	5,000
DOE	1100	-	-	0.030	33	-	-	0.030	33	5,000
Storage Site	500	0.047	23.5	0.045	22.3	0.100	50.0	0.192	95.8	3,000
Total										
Single Withdrawal		6.17	386.2	1.91	333.9	1.28	265.8	9.36	985.9	
Total										
5 Withdrawals		30.9	1931	9.5	1670	6.4	1329	46.8	4,930	
Project Total										
5 Cycles		139.2	5720	111.6	5127	236.6	9240	487.4	20,087	

TABLE E-9 Expected brine spill[a] during leaching and fill operations.

	Leaching	Cavern Fill	Program Total 5 cycles + leach	Average Spill Size (BBL)
I. Proposed System				
Napoleonville				
- No. Spills	.016	.009	.061	
- Barrels	48.8	27.6	186.8	3000
Bayou Choctaw				
- No. Spills	-	.003	.015	
- Barrels	-	7.7	38.5	3000
TOTAL[b]				
- No. Spills	.016	.012	.076	
- Barrels	48.8	35.3	225.3	-
II. Alternative Group 1				
Weeks Island Expansion				
- No. Spills	.009	.003	.024	
- Barrels	45.3	17.2	131.3	5000
Bayou Choctaw				
- No. Spills	-	.003	.015	
- Barrels	-	7.7	38.5	3000
TOTAL[b]				
- No. Spills	.009	.006	.039	
- Barrels	45.3	24.9	169.8	-
III. Alternative Group 2				
Bayou Choctaw Expansion				
- No. Spills	.005	.002	.015	
- Barrels	16.2	4.7	39.7	3000
Iberia Dome				
- No. Spills	.008	.002	.018	
- Barrels	23.1	5.3	49.6	3000
Bayou Choctaw				
- No. Spills	-	.003	.015	
- Barrels	-	7.7	38.5	3000
TOTAL[b]				
- No. Spills	.013	.007	.048	
- Barrels	39.3	17.7	127.8	-
IV. Alternative Group 3				
Chacahoula				
- No. Spills	.072	.047	.307	
- Barrels	360.5	236.9	1545	5000
Bayou Choctaw				
- No. Spills	-	.003	.015	
- Barrels	-	7.7	38.5	3000
TOTAL[b]				
- No. Spills	.072	.050	.322	
- Barrels	360.5	244.6	1583.5	-

[a] Maximum credible spill 30,000 BBL

[b] Weeks Island early storage is non-contributing

a function of throughput handled. Average spill sizes are larger for complex terminals, such as at the St. James Terminal tank farm, than f[illegible] simpler terminals such as would be constructed at the storage sites. Spills from surface oil tanks are given less weight in impact considerations since dikes would be constructed of sufficient size to contain oil from completely filled tanks.

The quantities of oil which may be spilled from pipeline and terminal operation for the SPR program are given in Tables E-1 through E-8. There is a somewhat reduced amount of oil handling required during withdrawal, which results in lower oil spill expectation than during fill. For a 333 million barrel Capline SPR grouping, approximately 61 percent (10,800 barrels) of the total oil spill expectation would occur from terminal operations; approximately 4 percent (750 barrels) would occur from pipelines, assuming the pipelines are left filled throughout the project duration.

E.2.1.4 Oil Dispersion

The weathering of oil spilled into the environment involves two processes which reduce both the amount of oil and its ability to disperse. Immediately after release from confinement, the lighter fractions of oil tend to evaporate. The evaporation process reduces the fluid mass by 10-15 percent in one day, and up to 25 percent in three days under warm, Gulf coast weather conditions. Wind exposure also hastens evaporation. Weathering leaves denser, more viscous matter, until a consistency near that of tar is reached. The second process is direct decomposition by bacterial, chemical, and photochemical agents. These operate quite slowly in the natural environment; some oil may be deposited in sediments and escape direct decomposition.

Spreading of floating oil on water surfaces has been reported in a wide body of literature. As the water surfaces of greatest concern for the SPR sites are irregular land drainage, marsh, and river system, a single approach based upon average areal coverage has been utilized to estimate areas affected. An oil spill will spread until the average areal coverage is about 1-2 barrels per acre. Noting, although, that uniform coverage will not occur (the spills may be patchy with stretches of open water surface, or with sections with no more oil contamination than a surface sheen), typical coverage and average thicknesses parameters are:

100 bbl/acre - 0.16 inches - 4000 microns
10 bbl/acre - 0.02 inches - 400 microns
1 bbl/acre - 1.6 X 10^{-3} inches - 40 microns

For spills of 5000 barrels, 1-2 barrels/acre density may be reached in a few days. However, in spreading through an environment of small streams or marshy terrain, much of the oil may be removed as a coating at the waters' edge, and on foliage. Where tidal influences are effective, deposited coatings can be partially refloated and redeposited elsewhere, unless picked up by cleanup crews.

For spills which cannot be reached quickly (i.e. - a few minutes), motion of the water is a principal determinant in the spread of the oil. For offshore spills, wind is the principal determinant of oil slick movement, especially since it strongly influences surface currents in the Gulf offshore (5-20 mi) zone. Cleanup efforts for offshore spills, and for pipeline or vessel spills inland, in which standby equipment must be assembled, will have to be pre-planned as part of the countermeasure efforts (Section E.2.1.5).

For spills in waters with standby equipment available, it may be possible to control the spill before extensive surface spreading occurs. Such control is possible for transfer spills of 2-100 barrels where the current through the mooring does not exceed 1 knot. In stronger currents, boom underflow will likely limit full impoundment potential.

Spills which flow across the land before entering streams may be absorbed into the soil, or retained as a coating upon the vegetation. Soil pore moisture tends to retard oil absorption, so penetration can be expected to be greatest for dry, loose soils, and for gravelly soils with voids around the larger component particles. These absorptive conditions would be expected along very little of the planned pipeline right-of-way locatons except at plowed, planted, or dry agricultural land. The normal drainage patterns for agricultural land provided by standard ditching would afford a strong measure of protection for lands adjacent to pipeline rights-of-way. In the event of percolation of oil into soils, the decision on whether to dispose of the soil or to permit natural degradation to restore the soil productivity will depend greatly upon the contamination of runoff water drainage after surface removal of oil coatings was completed.

Damage parameters and spreading patterns may be utilized to estimate the general effects of oil spills from spillage expectations provided in Tables E-1 through E-8. Typical damage parameters (Dames & Moore, 1975) follow:

- 6 barrels of fresh floating oil may damage one acre of marine nursery productivity for one season.
- 25 to 60 barrels of oil may damage one year's bioproductivity of one acre of land or marsh, depending upon wetness and type.
- 60 to 120 barrels of oil may pollute one mile of beach.

E.2.1.5 Oil Spill Prevention and Control Measures

The candiate sites are planned to be diked against release of petroleum fluids to the environment from equipment failures, pipe ruptu etc., at the pump stations, wellheads, metering forms, and surge tankage. At some locations, the salt dome surface itself will require careful desi in diking, since downslope flow of leaking oil has been known to wash out diking.

Site diking can be expected to control leakage from partial cavern failures, such as loss of fill pipe integrity, internal cracking around the pipe, or overfill. However, it would not be feasible to provide diking sufficient for a total collapse of a cavern (10 million barrels or nearly 1300 acre-feet) because of the necessary height of the dikes and the remote chance of cavern collapse.

Shut-in procedures normal for terminals during hurricanes along the Louisiana Gulf coast involve closure of all systems, and filling of all emp tanks with water. Sea water or alternative sources of water to be used for cavern filling would be readily available for tank filling. Cleaning the water afterwards would present a problem, probably requiring a field oil/water separator unit and use of the brine settling pond for primary settling separation.

At the dock area, rapid deployment booms are the primary containment defense against transfer spills. On the docks, gutters, sumps and drip pans would be used to reduce low-level water contamination. Berthing skirts are not presently specified for the docks.

Exposure to large vessel spills is a result of potential vessel casualties. The average fill rate during refill corresponds to less than one vessel per day. However, the mode of refill by offloading VLCCs would tend to create peak traffic levels in ports. The CAPLINE Pipeline, delivering 1,200,000 B/D, would generate typical traffic levels of 4 to 5 vessels per day. VLCC traffic in the area would be about 1 to 2 per day generated by the proposed LOOP, Inc. (Louisiana Offshore Oil Port), and about 1 per week generated by the storage refill. Thus, VLCC traffic generated by the SPR project should not significantly increase traffic levels in coastal waters.

Along the pipeline routes, the primary spill preventive measures are regular inspection of pipeline routes, line pressure testing, and close monitoring of flow pressures and in-out volumes. In the event of line ruptures, the primary lines of containment of released oil are the affected waterways. Prevention of spilled oil from entering the bayous or rivers by response fast enough to contain the oil in the creeks and swales is unlikely, especially during periods of flood flow in those creeks. During low flow (or dry) periods, the movement of the oil could be retarded and partially absorbed along the stream bed. The generally sluggish flow of the streams is a factor helpful in the effectiveness of booms, and there are many access points for wheeled transport. Some of the marshy areas would require specialized transport vehicles, and cleanup of creek areas would likely require all-terrain transport.

Oil Spill Contingency Plans

A Spill Prevention Control and Countermeasure Plan (SPCC Plan) must be prepared by an operator of a nontransportation related oil facility that might be capable of discharging by accident, equipment failure, or operator error enough oil into navigable waters of the United States to create a visible sheen discoloration, subsurface sludge or emulsion, pursuant to the provisions of the Federal Water Pollution Control Act, Public Law 92-500. The strategic storage facilities, therefore, would be subject to the provisions of these regulations. Departments, agencies, and instrumentalities of the Federal government are subject to the regulations to the same extent as private operators. The SPCC outlines the method of operations, and measures and equipment used to prevent spills. It also describes available equipment to be used, and the planned program of response in the event of a spill.

Loading facilities for barges and tankers must also meet Coast Guard regulations (33 CFR 154) promulgated under Public Law 92-500. These regulations provide standards for design of hose connections, necessary emergency equipment, sumps, etc.; and for emergency shutoff switches, personnel training.

Transfer operations must meet Coast Guard rules (33 CFR 156) that define personnel requirements, lighting, communication, use of the equipment, and adherence to procedures. Barges and tankers used for oil transport must meet Coast Guard regulations for spill prevention equipment (33 CFR 155). The construction of tank vessels and their operation come under a large body of regulations, one of which is the Port and Waterway Safety Act (Public Law prescribes safety equipment requirements and safety zones, provides for the investigation of accidents and environmental quality of navigable waters, and regulates vessels carrying hazardous cargo in bulk. Regulation of tankers includes the right to inspect foreign registry vessels and prescribe minimum necessary safety and navigational equipment.

The Coast Guard may specify pilotage requirements for entry to U.S. waters. Inland Rules of the Road apply to the ICW; Western River Rules of the Road apply to the Mississippi River. The Coast Guard has the primary regulatory authority for vessel licensing, inspection, and enforcement of regulations.

In the event of a spill, the Coast Guard must be notified (18 CFR 610). Under the National Oil and Hazardous Materials Pollution Contingency Plan, a Regional Response Team headed by an On-Scene Coordinator (OSC) will take steps to assure that the best and most appropriate cleanup measures are taken. The operator of the facility involved in the spill is primarily responsible for cleanup efforts. The OSC may authorize the use of various cleanup agents, sorbents, or other chemicals, if they can assist in cleanup efforts without increasing ecological stress or damage. If the parties responsible for the spill do not or cannot undertake adequate cleanup (or if the spill should be large enough to warrant widespread concern), an emergency strike force may be organized to commit available manpower and equipment resources to the containment and cleanup effort.

If wastewater or treated wastewater should be discharged from a storage facility as a result of tanker operations or pipelines (or barging operation), then the Procedures for the National Pollutant Discharge Elimination System (NPDES) might apply to the facility (40 CFR 125, as amended), under Public Law 92-500, Sec. 402 and 405. Specifically, if flushing of the meter lines and cavern fill lines during standby is instituted, then it will be necessary to either discharge the flushing water, or to store it in the caverns. In view of the volume of the necessary flush water supply (about 5000 barrels per typical pipeline and 500 barrels per site line) and the rust inhibiting chemicals used to protect the pipes, storage of this waste in the caverns may be preferable to discharging it.

The complete SPCC Plan does not have to be prepared until the facility begins operation. The SPCC Plan will, however, be prepared within 6 months and implemented no later than one year after facility operation begins, pursuant to EPA regulations (40 CFR 112) as provided by Public Law 92-500. For purposes of the Environmental Impact Statement, it is sufficient to outline the elements of such a plan. The effectiveness of available cleanup methods and spill risk associated with storage are also discussed below.

Facility Spills

SPCC guidelines provide that where experience indicates reasonable potential for equipment failure, appropriate containment and/or diversionary structures or equipment to prevent discharged oil from reaching a navigable water course should be used, including:

1. Dikes, berms, and impervious retaining walls.
2. Curbing.
3. Culverting, gutters, or other drainage systems.

4. Weirs, booms, or other barriers.
5. Spill diversion ponds.
6. Retention ponds.
7. Sorbent materials.

In the vicinity of the sites, berms and sumps must be viewed as the primary line of defense against surface spills. The potential of heavy rain runoff filling berms and sumps makes them less reliable for an unmanned facility than for this one. For sites on a waterway, a sump at water level with a boom permitting underflow of water only, can provide effective retention of floating petroleum, while releasing rain waters. At docks, effective containment of spills by rapid deployment of booms is the primary defense against dispersion of spills.

The integrity of cavern storage remains a serious concern because of the potential for large petroleum releases into the environment. The primary method for monitoring cavern integrity is surveying (by sonar or other means) to check for cracks, slabbing, and other indicators of roof or wall weakening.

Loading and Unloading Spills

The SPCC plan for dock operations would involve a two-fold approach: 1) operation of the facility by a "Dock Operations Manual", which specifies the physical equipment, oil transfer procedures, emergency procedures, and inspection routine to detect faulty equipment, poor connections, errors and leaks; 2) response to a detected spill according to an "Oil Spill Contingency Manual", which deals with stopping the outflow, provisions for containment and cleanup, and guidelines for communication with local, state, and Federal response teams.

The elements of the preventive plan include:

1. Containment of Leakage - During cargo transfer, containment of leakage will be accomplished by using fiberglass spill prevention decks placed under loading manifolds, sump tanks of adequate capacity, portable drip-pans for any hose connections not over the spill prevention deck, and motor driven block valves, closed when not in use.

2. Emergency Shutdown Capability - This procedure shuts off all pumps and closes all valves. Activation switches are located at accessible locations on the dock, and a portable switch is placed on board the barge. The system must be capable of instantly stopping the barge pumps, and must also have a locked manual override to close the system during a power failure.

3. Personnel and Training - Adequate numbers of personnel must be on hand during operations to ensure safe operation, and to assist in emergency containment routines. Operators designated "persons in charge" should have at least 48 hours experience in transfer operations and pass oral qualification examinations. Any language barriers between boat and dock supervisors must be resolved.

4. Cargo Transfer Procedures - These specify the placement, linking, and handling of hoses and/or loading arms to avoid excessive wear, pulling strain, ruptures, kinking, and so forth. Use of quick-connect devices and latches is generally limited or proscribed. Important aspects include a transfer conference between the dock operator and the boat pump operator, and use of a checklist to ensure procedure compliance. From the standpoint of spill avoidance, and especially, large spills, inspection routines of the area on a regular, frequent basis are significant. Other regulations establish lighting standards, equipment specifications, record-keeping, and so forth.

5. Equipment Maintenance Program - Equipment service and life is documented; regular pressure and stress tests are conducted; bolt and coupling flanges, coupling seals, and gaskets, are examined for wear, abrasion, and so forth.

Staffing or having available competent, trained personnel for positions that are not permanent - i.e., which last only for a filling or emptying cycle - may be difficult. Training of personnel hired would have to be emphasized. During emptying cycles for strategic drawdown, it could be assumed that personnel would be available from the petroleum industry. Much of the regional labor pool in the area has some familiarity with petroleum-type equipment as a result of earlier drilling and oil field activities.

The elements of the cleanup plan would include:

1. Inspection for Leaks - The area must be lighted, and frequent regular inspections of the water must be made. If reliable automatic detection devices become available, provision would be made for their use.

2. Containment of Spilled Oil - The most effective spill containmen device is the rapid deployment boom. One boom should be located at each end of the dock to isolate the vessel involved; a boom or rubber air dam should be available to close off an entire slip when the site geometry permits. A skimming device, which can operate in the slip, should also be available at the site. For very small spills contained around a single vessel, sorbent material could be used, although a skimming device would be preferable. The skimmer should be able to deliver collected materials to a sump tank, either by direct hose from the mooring slip or from a holding tank.

3. Response Mobilization - Loading and unloading mishaps may occur in river current, protected waterways and mooring slips, and in the offshore waters of the Gulf. If oil should escape immediate booming because of current, wind, or wave conditions, guidelines for notifying and mobilizing additional response teams would be followed. Cleanup cooperatives and contractors are discussed below, since these teams are part of the regional response team for oil spills.

Transportation Spills

Spills of oil from vessels may occur as a result of casualties, i.e., collision, ground, structural or tankage failure, fire, explosion, ramming (collision with fixed objects), etc. Spills could also occur as a result of erroneous discharge - bilge, open valving, testing of discharge engines with improper valve setting, and so forth.

In the event of such mishaps or casualties, the site operator would notify the regional response team center, and the organizaton of the National Oil and Hazardous Materials Pollution Contingency Plan would be activated. If the site operator is unable to obtain sufficient assistance to clean up spilled oil, the On-Scene Coordinator may initiate action directl to implement spill cleanup. All vessel operators must have proof of abilit to assume financial liability for cleanup costs in order to obtain an operating certificate. Most operators have prior mutual aid arrangements, either directly or through insurors, for cleanup of spills.

Cooperatives of companies involved in oil production or transportation in the Gulf coastal area, and specifically the ICW have been formed. They maintain booms and shallow draft skimmers for use in bays and the ICW. Member companies have access to the equipment, but must supply the operating labor, beyond the supervisory skeleton crew that provides operational expertise. The equipment can be leased to nonmembers as well, but manpower must be obtained elsewhere. One cooperative is located at Venice (eastern Louisiana), Intracoastal City, Cameron (western Louisiana), and locations in the Beaumont, Galveston, and Freeport area. Large equipment for cleanup in bays is located at Grande Isle, Louisiana.

Another contractor operates in the Gulf Coast and can provide both equipment and manpower for cleanup. Other contractual services available in the area include wastewater processing, and disposal of oil contaminated materials. Some of these processors may act as salvors as well to reclaim oil. The Coast Guard has oil recovery equipment on the Gulf of Mexico primarily for ocean-going vessel salvage and spill containment. The Coast Guard could supply a submersible pump to facilitate emptying of a foundering oil vessel.

Pipeline Spills

For spills from ruptured pipelines, procedures similar to those for vessel spills are followed, with one important difference. The Environmental Protection Agency has lead responsibility instead of the Coast Guard. Control measures may be land-based, focusing on drainage paths of the oil into and along streams. However, in wetlands, the control efforts may be identical to waterway spills.

An important part of contingency planning is pre-identification of all drainage paths from every pipeline route, and the planning of primary points for spill dispersion control.

E.2.2 Brine Spill Risks

Brine and saline water spills may occur from the raw water supply and brine disposal pipelines and from the brine settling ponds. The brine lines would be constructed within the same right-of-way as the oil lines.

E.2.2.1 Brine Spill Risk from Cavern Storage

The mechanisms of brine fluid release from cavern storage are equivalent to those for petroleum, except for a major difference in density between the stored fluid and the inflowing water. The lower density of petroleum permits it to be lifted above the physical height corresponding to the water inflow pressure head. The density difference is opposite for brine lift. The specific gravity of the brine, containing up to 20 lbs salt per cubic foot, would be about 1.3, and will permit the inflow water to float on top, with mixing limited to a turbulent contact zone and slow diffusion beyond that zone. The inflow itself would not be able to flow out of the collapse pit unless an artisian head were present.

In the four historical instances of cavern roof collapse referenced previously, no release of brine was involved, even though water entered the collapse sinkholes.

Lateral migration of brines between cavities does not present a migration path for major releases of either brine or petroleum into the environment. Brine overfill can lead to escape of small amounts of brine from the cavern, and could contribute to failure of the seal around the fill pipe. However, brine forced up the oil section would not be expected to escape into the environment. It can be concluded that there is no reasonable chance of major brine spills from the cavern storage.

E.2.2.2 Brine Spills from Surface Storage

Most of the sites for leached storage capacity are planned with a partial impoundment of the brine for settlement. Evaluation of impoundment failure on a statistical basis is not applicable, since most impoundment failures in U.S. statistics involve poorly engineered or unengineered farm and mine impoundments. An estimation of the chance of breaching the impoundment by flood can be made, based upon the design resistance of the structure. However, breach of a brine impoundment by flood is of little concern - the flood mitigates both the salinity and any flow which would otherwise result from impoundment losses. As a general rule, considering the flat terrain involved near the sites, the environmental context of impoundment releases should be similar to those of pipeline ruptures near the site. At sites where the impoundment may be elevated slightly, (i.e., on the side of the mound for those sites in which the salt intrusion has created an elevation) local downslope flow damage and accompanying turbidity could result from loss of impoundment waters.

Surveillance procedures for monitoring the integrity of impoundment include regular inspections of earthworks for settlement, cracking, etc., and checking ground water in the vicinity for salinity migration.

The brine settling ponds to be constructed at the storage sites have design volumes ranging from 40,000 to 430,000 barrels. The probability of exposure to hurricanes is considered low for all site locations. The sites range from approximately two miles inland (Weeks Island) to approximately 40 miles inland (Chacahoula). The Weeks Island site has the highest probability of exposure to hurricanes (6 percent), due to its proximity to the coast. Protection from flooding will be provided by the perimeter dikes used to construct the ponds above natural ground elevations. The pond dikes would be designed to withstand 50 to 150 year flood recurrences. The chance of loss of ponded brine may be estimated to range from 4 to 50 percent in the event a greater flood should occur. Using a 50-year levee design and a 50 percent loss probability as worst case estimates, the chance of total loss of all brine would be 1 percent per year. However, brine would be in the pond only during leaching and cavern withdrawal (perhaps 12 years during the project lifetime). Also, during a destructive flood, the environmental impact of a brine release would be negligible because of dilution by flood waters.

E.2.2.3 Brine Spills from Pipelines

Spills may occur from brine disposal pipelines and from raw water lines. During leaching, the environment is simultaneously exposed to spills of fresh brackish water from the water supply line and to spills of brine from the brine disposal line. During cavern fill, exposure is to brine from the brine disposal line. During cavern withdrawal, exposure is to fresh to brackish water from the water supply line. Finally, dur standby storage, there would be exposure to saline water in the water supply line and brine in the brine disposal line.

Data for performance of brine lines in cross country fluid transport are available only for a few specific installations. Consequently, it has been necessary to apply spill risk parameters based upon data from the entire interstate pipeline network of crude oil lines. Although concentra e brines are more corrosive to steel lines than crude oil, it may be noted that crude oils contain a small amount of brine, and much of the pipeline network is exposed to saline water on the outside of the pipe as well as the inside. Consequently, there is a basis for performance comparison, assuming that design standards for corrosion control are comparable for the two applications.

Median and maximum credible spill sizes cannot be extrapolated from petroleum data, because they are closely correlated to the detection time interval for large ruptures and the testing interval for small leaks. Petroleum transfers are closely metered for inventory control as well as for leak detection, and detection intervals are short. Brine transfers are not inventory controlled, and, in the case of ocean disposal, not amenable to flow monitoring at the exit. Brine spills into the environme may go undetected for a longer period. In some cases, they may be found only by pressure tests on the line. As a result, average brine spill sizes must be projected to be much larger than oil spills.

Pressure and flow monitoring of an open disposal line extending to the ocean is not expected to be reliable for rapid detection of spills. It is unlikely that a rapid detection of ocean discharge upstream of the diffuser can be expected. The monitoring of water samples in the vicinit of the line for heavy brine plumes along the bottom would likely be the first line of ocean spill detection. However, it must be remembered that small leaks are of no concern in the ocean. The problem to be avoided is a smothering brine pool which lies on the bottom unmixed with seawater, after exit from the pipe. Diffusers are designed to set the heavy brine into the surrounding seawater for turbulent mixing. A small leak ahead of the diffuser would act in the same manner.

Calculated brine spill expectations from pipelines for the various Capline SPR groupings are provided in Table E-9. This table contains spill estimates for leaching, fill, withdrawal, standby storage, and for all project operations together.

Losses would be greatest for Alternative grouping #3 because of the larger storage volume to be created.

The percent chance of brine spills occurring during the project lifetime are:

	No Spills	One Spill	2 or More Spills
Bayou Choctaw early storage	98.7	1.3	Negligible
Weeks Island early storage	(Not a brine system)		
Napoleonville SPR	94.1	5.8	0.1
Weeks Island SPR expansion	97.6	2.4	Negligible
Bayou Choctaw SPR expansion	98.5	1.5	Negligible
Iberia SPR	98.2	1.8	Negligible
Chacahoula SPR	72.9	23.6	3.5

E.2.2.4 Brine Spill Risk from Aquifer Injection and Storage

The concern for brine spillage from aquifer injection stems from the injection pressures needed to place the brine into the aquifers. As a worst case, the pressure increases are hypothesized as breaking the permeability barrier overlying the aquifer (hydro-fracturing), permitting upward migration of brine or saline water into zones of potable or agricultural water withdrawal.

As the fluids percolate through the soils, they are expected to stratify in the soils according to density, rather than undergo rapid diffusion. Upward migration of the injected brine is unlikely because of the density involved. The prevailing migratory pressure for brine is downward, in contrast to petroleum fluids which would percolate upward in water-saturated media.

The deep aquifers near the domes are highly saline, as a result of natural leaching of the salt domes, while most of the near-surface ground waters, except where they intersect a piercement dome, are sources of fresh water, recharged by surface waters. Although in some areas, there is no longer a surplus of surface water for aquifer recharge, upward migration of saline waters has not been a problem in the areas being considered fo[illegible] water injection.

Injection situations in which water supply aquifers are separated from injection sands by a thin aquiclude will be avoided as a precaution. In the event of an upward fracture, the least concentrated brines would diffuse upward, displacing overlying waters of less salt content. Once such a process is detected, it would be arrested by cessation of injection. The pressure build-up in the injection formation would dissipate as the brine migrates outward.

If the quality of a ground water supply is not sensitive to changes of a few ppm of chloride content, then monitoring of the well systems for pressure and salt content would be sufficient to detect breakout migration from the injection sands before concentrated brine displacements into the upper aquifers can result.

E.2.2.5 Brine Dispersion

The motion of brine across land, in the soil, and within bodies of water, is identical to that of water in every respect except in contact with water. The mixing, or equalization of salt concentration, between brine and water by molecular diffusion alone is a very slow process. If brine flows quietly into a pond or the ocean away from shoreline turbulence, it will tend to stratify at the bottom of the water. Rapid mixing of brine and water requires energy of turbulence. A small leak of brine into a flowing stream can be quickly diluted to nearly negligible concentrations, whereas a leak into a small lake or pond may retain density stratification for several days.

The dispersion of brine in the ocean is expected to be accomplished by use of a multi-port, multi-jet diffuser (Appendix G). Each jet has sufficient energy to provide rapid flow mixing with the surrounding water, and is separated spatially from the next port to prevent density buildup. Salinity down-current (even with sluggish currents) of a properly operated diffuser should be reduced to 5 or 10 percent above ambient within a few hundred meters. Ocean salinity is on the order of 30 parts per thousand, and brine salinity is on the order of 300 ppt. Reduction of the salt content of the brine to 10 percent above ambient implies 100 to 1 diluti[illegible] with seawater.

Without a diffuser, studies by NOAA indicate that a brine plume could extend down-current on the Gulf floor for several kilometers, possibly posing a disruptive influence on benthos, especially shrimp. A large break in the brine line offshore could also produce such an effect. In the event that a dense plume is formed by a spill in coastal waters, it will slowly disperse after the source is plugged. It is doubtful that sufficient current energies are available in the Gulf, to disperse the concentration of the brine flow more rapidly than the diffuser would. Natural dispersion could be assisted with bottom jets if it were apparent that the plume would impact sensitive zones down-current. These sensitive zones which could be impacted would vary with the seasons and with changes in bottom currents.

Onshore, brine flows across soils would leave salt deposits in the ground, which will leach upward with upward migration of pore water during dry periods. Ruptures of buried brine lines may present an opportunity for brine to percolate into aquifers, in which the natural migration is downward. Large ruptures, however, would probably surface and flow over the land to local water courses. Partial containment of the brine in the pipeline trench by permeability limitations is not expected to occur.

For brine line spills onshore, the greatest risks would be those in which water supplies, agricultural land, or sensitive fresh water marine nursery zone, may be affected. In this context, however, salt water intrusions from hurricane surges have been experienced in much of the area which might be contacted by a brine line spill. The primary recovery mechanism after a brine spill is dilution of salt water and washout of salt deposits into the waterways, most of which can be expected to provide a flushing pathway into the Gulf of Mexico.

Intrusion of brine into ground waters underlying croplands could be more difficult to purge. During dry periods, salt is carried upward in (interstitial) soil pore water. For wet soils, the natural migration of the salt is downward. However, it may not move away, and could remain in a position to affect the root zones. One method of purging salt contamination from irrigated, or irrigable lands is downward leaching to deep drainage. A collection tile is installed at a depth of 8 to 10 feet, the land is flood irrigated, and the water in the drain tile is pumped out, carrying the leached salt with it. If a slight ground water surplus is available, recovery assistance by well point pumping may be sufficient. Otherwise, natural leachout by ground water movement toward the Gulf would be relied upon to produce eventual water quality recovery.

E.2.2.6 Brine Spill Prevention and Control

Detection of brine line spills is more difficult than oil spill detection because the system is open to the ocean through a diffuser, or to injection wells. Furthermore, a brine spill is much less readily noticed by casual observers. Primary preventive measures would include regular line leak checks, line inspection, and monitoring of ground water salinity. Large pressure changes accompanying major line ruptures would be readily detected, but partial losses would be very difficult to notice from operating parameter readouts. Regular line pressure checks are the only reliable method of detecting small leaks. Offshore, brine diffuser lines are open, and breaks would not be detectable by instrumentation. Monitoring of water salinity profiles near the diffuser and inshore of it is a possible method of detecting leaks.

The control of brine spills is opposite to that of oil; rather than containment, dispersion and dilution is desired. Dilution and flushing of saline waters to waterways discharging to the ocean is the basic mitigating measure. In some cases, this will require pumping of fresh water through affected areas to produce flushing. The drainage patterns for all portions of the line can be determined in the same manner as for oil lines, and in most instances, they will be identical. The pre-planned control points will differ, since the objective is to disperse saline brines rather than to contain them. Equipment needed for contingency action would be primarily water pumps and connecting lines, rather than booms and collection materials.

Legislative authority for action on brine spills into inland waters and land stems from the basic Federal Water Pollution Control Act, since a saline spill alters potable water quality and affects agricultural usage. It is assumed that procedures parallel to those for oils and toxic chemicals, such as pesticides, would be followed. However, guidelines specific to brine spills may eventually be promulgated by the Environmental Protection Agency. A response and inspection team would be expected to be formed in the event of a large discharge, and would also be empowered under the levels of the Act (92-500) to undertake or require restorative actions.

For brine spills offshore, the specific procedures to be implemented in the event of determination of a brine plume are not clear. The most concerned agencies for the adverse effects on offshore fisheries and benthos conditions would be the National Oceanographic and Atmospheric Administration and the state fisheries department. It would be necessary to determine a suitable inspection interval for offshore sampling, depending upon season, and also to evaluate methods or zones at which brine plumes might be jetted most effectively.

Other preventive measures for the brine system would include purging of the lines after use, close inspection of earthworks associated with brine impoundments (which may also serve as emergency oil sumps), and ground water monitoring in the vicinity of impoundments.

E.2.3 Related Risks

The statistical base used for projecting spill expectations includes spills from all causes, such as natural disasters and fires. Spills from cavern storage are not covered in the statistical basis, but the petroleum in storage is well protected from natural hazards. (See Appendix F for cavern roof collapse discussion).

The natural hazards affecting petroleum operations include hurricanes, tornados, floods, earthquake (limited to subsidence faulting and related foundation problems in the area of concern), and lightning-caused fires. Additional risks include fires, and external party causes, such as aircraft crashes, vandalism, sabotage, etc. The level of risk represented by these accident modes is assumed to be accounted for with ordinary preventive measures - security, fire control spray systems, shut-in during hurricanes, and standard safe operating principles for all components. Some natural hazards are so remote that they are not perceptible in the risk bases (such as meteorite impacts).

Underground salt storage caverns which have been designed with provision for adequate cavern control, roof strength, and operating safeguards, can be projected to be inherently more hazard free than surface storage. The natural hazard which has been indicated to be a potential problem is undetected leaching of the salt cavern roof by ground water percolation around the entry passages. This particular hazard would not be caused by a sudden natural event, but rather a gradual deterioration leading to a sudden failure. Furthermore, as indicated previously, the hazard has historically occurred only where the depth to salt was less than 300 feet and was preceeded by abnormal cavity behavior which would be detected by close monitoring.

E.3 Spill Risk Analysis Methodology

The analysis methodology used to compute expected oil (and brine) spill volumes is summarized in this section. Controlling parameters are: miles and time of exposure, for pipelines; volume of cargo and typical operation, for vessel transfers; volume throughput and facility size, for surface storage to terminals; and ton-miles (inland waterways) or travel time (coastal waters), for vessel casualties. As explained in Section E.2.1.1, data is not available to make a quantitative estimate of oil spill risks from cavern storage.

The statistical bases from which the characterization of risk exposure is made and the probability procedures for projecting spill size distributions, generally define an expected incident frequency and an average spill size. The projection of risk with regard to spill sizes, however, requires that a distribution of spill sizes and frequencies be determined. The probability distribution used here is the log-normal, because of its applicability to many natural random events (earthquakes, rainfalls). To complete the statistical characterization of a given mode of spill, the maximum credible spill size must be specified. The maximum credible spill is based upon extrapolation from the largest sizes of spills available in the data base and upon a realistic evaluation of program operating conditions. It presents a practical limit to the extrapolation, but does not imply that the spills larger than the credible maximum are impossible.

E.3.1 Marine Transportation

Oil spills associated with marine transportation of oil may be considered for the categories of transfer operations and vessel casualties.

E.3.1.1 Vessel Transfers

The bases for calculating spills for vessel transfer are selected frequency records and gross spillage rates for transfer operations as follows:

Frequency - 1 spill per 90 operations at docks and inland waters.
(selection of a typical value from several published sites)
- 1 spill per 18 operations between vessels offshore.
(mean for 1965-1973, world-wide data)

Spill Volume - 3×10^{-6} of cargo transferred, vessel to vessel.
2×10^{-6} of cargo transferred, dock to vessel.
1×10^{-6} of cargo transferred, vessel to dock.

The above frequency rate for offshore transfers is based upon a worldwide survey of transfer operations for the period between 1966-70 (J. J. Henry, 1973). This survey included single point mooring systems (SPM), lightering and 7-point mooring facilities. The frequency rate for onshore transfers is a median of those recorded for several U.S. facilities which experienced a spill every 60 to 133 transfers. Spill volume rates recorded in U.S. facilities range from 0.5 to 3×10^{-6}; foreign ports have experienced much higher rates. The above rates were selected on the basis of U.S. experience and are consistent with other published projections.

Th maximum credible spill size from transfer operations at the tanker docks is estimated to be 500 barrels. Because of higher pumping rates and less controlled docking conditions offshore, the maximum credible spill size for VLCC to tanker transfers is estimated to be 1000 barrels. Historically, a few large spills (5000 to 10,000 barrels) have occurred during transfer at terminals due to negligence. A routine of vigorous close inspection is expected to avoid spills of this type. Using a log-normal spill size distribution, the average spill sizes computed in Tables E-1 and E-2, and the maximum credible spill sizes indicated above, the chance of a spill of a particular size range occurring may be estimated as shown in Table E-10. At the docks, there is a 96.6 percent chance of a spill being less than 50 barrels; offshore, there is a 75.4 percent chance.

E.3.1.2 Vessel Casualty

Vessel casualty rates are based on estimates selected from various casualty records to provide a spillage model dependent upon the route length. In this regard, spillage for inland waters is based upon a ton-mile cargo exposure; in offshore waters, spillage is based upon a time exposure. Very large crude carrier (VLCC) casualty exposure offshore was not included in the analysis. The following spill rate parameters were chosen:

Frequency	- 1 spill per 7 billion ton-miles in inland waters.
	- travel in ballast weighted 50% in inland waters. (1 spill per 14 billion ton-miles)
	- 1 spill per 12.8 vessel years in offshore waters.
Mean Spill-	428 barrels in inland waters.
Size	1111 barrels in coastal waters.

Offshore spillage rates are based upon tankship casualty rates in worldwide coastal waters. It may be reasonable to use lower rates such as might apply to a dedicated fleet for lightering operations, but the rates used here are more conservative (yield higher spill estimates). The spill frequency in inland waters is based upon the composite for all U.S. waters for barges and tankships during the period of 1968-70 (Brobt, 1972). The average spill size, however, is based upon tankships for the years 1969 to 1973.

The maximum credible spill size assigned to tanker casualty losses is 60,000 barrels. Using a log normal distribution, the probability that a spill in coastal waters would be less than 500 barrels is 46.7 percent (Table E-3).

E.3.2 Pipelines

The basis for calculating pipeline spill risks is the spill rate frequency, which is 50 spills annually per 100,000 miles of pipeline. This estimate was derived in the LOOP Environmental Analysis (1975) for new crude lines. The mean spill size is considered to be 1100 barrels for the large lines involved (DOT Office of Pipeline Safety annual summaries, 1969-73).

SPR pipelines should not involve exposures unusual to Louisiana and Texas. These areas also provide a large portion of the risk exposure comprising the U.S. pipeline failure base statistics. Thus there is no reason to anticipate other than the projected pipeline failure risk. Principal pipeline hazards include soft, saturated soils, saline water and less-than-average exposure to other construction activities. The mix of pipe sizes should also be representative of the base. The basic exposure parameter for pipelines is length and time of use, rather than throughput, which is consistent with the fact that many of the causes of failure are external to the use of the line.

The maximum credible spill for the pipeline can be judged from various combined static and pumping losses. The maximum pumping rate would be about 1388 barrels per minute to handle two million barrels per day. A 36-inch line would contain 6700 barrels per mile. The leak detection capability would vary with the size of the leak. However, a state-of-the-art system has been assumed, with some allowances for operator hesitation:

Break Severity	Loss Description		Volume of Oil Loss
Total break:	1 mile of line + 10 minutes pumping	=	20,590 barrels
10 percent break:	1 mile of line + 1 hour pumping	=	15,030 barrels
2 percent break:	1 mile of line + 12 hours pumping	=	26,690 barrels

These situations are contrived by assuming worst conditions. The metering system should be able to react to a cumulative difference of 600 barrels in one hour or more, but it could be set for lower sensitivity to avoid unnecessary shutdowns due to line operating pressure surges. A maximum credible spill of 10,000 barrels has been assumed. Suction could be applied to the pipeline from the terminal to minimize oil loss after shutdown. From Table E-3 it is estimated that 30 percent of all pipeline spills would release less than 500 barrels of oil.

For brine pipeline spills, the leak detection system would be substantially less sensitive. Consequently, average spill size is taken to be 5000 barrels and maximum credible spills are estimated to be 30,000 barrels. The basis for spill frequency is assumed to be the same as for oil pipelines.

E.3.3 Terminals

Average spill sizes different from the historical average are proj[illegible]d for the SPR terminals on the cavern sites, and at single purpose pipeline stations and docks. Where existing standard terminals (e.g., St. James) are used, historical average spill size (1083 barrels 1969-73, sometimes rounded to 1100 barrels) is applied. There are several reasons for alteri[illegible]g the estimate for the SPR terminals. An average U.S. terminal has an exposure which could be based either on capacity or throughput. To the extent that certain types of terminals tend to have similar capacity-to-throughput ratios (i.e., from 10 days for a transportation terminal to 100 days for a storage depot), the exposure selection is not critical. An above ground SPR terminal has a ratio measured in hours, while the caverns themselves have a ratio measurable in years.

Sufficient data has not been analyzed to determine whether throughpu capacity, or a combination thereof, is the best parameter for estimating terminal spillage rates. The basis selected here is throughput, which is the most conservative estimate for terminals with minimum storage exposur such as those proposed for the storage program. The assumed basis for terminal exposure is as follows:

Frequency - 1 spill per 2 billion barrels throughput
Spill Size - 1100 barrels at the CAPLINE terminal
- 500 barrels at the storage terminals.

The frequency is estimated on the basis of spill data for all U.S. terminals during the period 1969-70; the average spill size is taken from 1969-73 data. Because of the low capacity-to-throughput ratio indicated above, the throughput exposure which has been applied to SPR terminals may be conservative (high).

The maximum credible spill event selected for analysis of terminal spill expectation is 5000 barrels. Though larger spills have occurred, t[illegible]e have been the result of negligence and a lack of facility and monitoring. (Even if the entire contents of a storage tank should be lost, the contai[illegible]ment levees are designed to contain all the oil released). From Table E-[illegible], it is estimated that 71.5 percent of the spills from storage site facilitie would be less than 500 barrels.

E.4 REFERENCES

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APPENDIX F

CAVERN STABILITY

APPENDIX F
CAVERN STABILITY

F.1 INTRODUCTION

Petroleum hydrocarbons have been stored in solution mined cavities in salt domes in the United States since 1951. By 1975, at least 196,298,000 barrels of hydrocarbons and products were stored in Texas, Louisiana, and Mississippi salt domes. These hydrocarbons and products include propane, butane, ethane, ethylene, burning fuel oil, natural gasoline, natural gas liquids, and crude oil condensate. Large amounts of crude oil have not been stored in the U.S. to date, but there is no reason to suppose that crude oil storage is any different from storage of other hydrocarbons, or brine with respect to cavern stability.

Solution mining of salt from domes in the U.S. has been practiced for many years. Current operations include hundreds of wells on at least 20 salt domes in Alabama, Louisiana, and Texas, run by 16 different operators.

French and German crude oil storage programs in leached caverns in salt domes were initiated in 1967 and 1970, respectively. By December 1976, at least 63 MMB of crude oil was in storage in France. German capacity stored by the same time was 22 MMB. The longest experience with storage of crude oil in a leached cavity in a salt dome is a 3 MMB cavity in Germany, which has been filled for 6 years.

There are no recorded collapses of caverns containing hydrocarbons in the storage examined to date. This includes the 25 years of experience in the United States and also includes hydrocarbons stored in cavities leached for salt mining, and thus not specifically designed for hydrocarbon storage.

F.2 STRUCTURAL STABILITY OF SALT

The use of salt domes for petroleum storage is attractive because of both the relative low cost of such bulk storage and the extreme geological stability of rock salt masses. Containment is usually very good in salt domes, because existing or incipient cracks and fissures are small and tend to seal themselves because of the plasticity of salt.

All cavities in salt exhibit some closure due to the well known characteristics of rock salt to flow under stress (Waiversik et al., 1976; U.S. Depar of Interior, 1962). Overburden pressure increases with depth in any salt dome therefore, deeper levels are more "tight" than upper levels, and leaks are less likely to occur at deeper levels. The more direct effect of cavity depth is to determine the average geostatic stress in the salt surrounding the cavity. This in turn controls the pressure difference between the cavern fluid and walls, which is a major factor in determining cavern stability (Dreyer, 1972, 1974; Albrechs and Langer, 1974; Serata and Gloyng, 1960). A room and pillar mine operated at atmospheric pressure is a far more severe test for stability of underground openings in salt than a filled storage cavity with controlled stress differences. In summary, a limited amount of creep closure or slabbing is anticipated in any dome storage cavity.

Another factor which determines cavern stability is the quality of the salt. In general, salt at shallow depths and near the top surface of domes tends to be more anisotropic and to contain zones of impurities. "Shear zone" effects tend to be minimized for relatively deep cavities in shallow domes. For example, solution cavities at shallower depths in the Bayou Choctaw dome display a preferred dissolution direction as compared to cavit s at greater depth. The implication is that this domal salt has a definite anisotropic character and the tendency is toward decreasing influence as cavities are created at greater depths in the dome, probably because salt becomes more pure. At great depths in domes, the salt may again be less pure; however, storage cavities probably will never be created at such depths because of creep closure effects. The shallow levels in the room and pilla salt mines of south Louisiana also display a greater range in quality of salt (pure to impure) than deeper levels. Slabbing of salt in the room and pillar mining operations in south Louisiana domes is common, but the danger can be minimized by "scaling" off the obvious loose slabs on the mine walls and roof.

Slabbing of salt or of impurities into cavities appears to be a minor problem for properly maintained Gulf Coast dome cavities, compared to bedded salt cavities (Jaron, 1969). Gulf Coast domes contain salt that is relatively free of shale or anhydrite stringers, which are zones of weakness that could cause salt slabbing. The relatively pure salt enables the uniform dissolution of salt and the formation of regular caverns, except where occasional stringers of impurities are found.

Cavities constructed at greater depths would appear to have advantages in at least two regards as compared to cavities at shallower depths: better quality and "tighter" salt. An adequate pressure difference must be maintained for deeper cavities, otherwise collapse could become severe (Brown and Sessen, 1959).

When a storage system of multiple cavities is created in salt domes, attention must be given to the coupling effects between neighboring cavities (Chao, 1974). A primary concern is the wall thickness between cavities necessary to maintain system stability. This system design concern is somewhat similar to that involved in designing supporting pillars for room and pillar mining.

Either physical or numerical modeling of typical appropriate portions of the storage system walls can be used to obtain a measure of safe wall thickness (Dreyer, 1974). Realistic material properties again must be available before confidence can be placed in minimum wall thickness determination. In the case of Gulf Coast salt domes, we have empirical data from conventional salt mines, which span several years.

Parametric numerical studies have indicated effects of varying spacing of underground openings near the ground surface (Bank and Ottoriani, 1974). Similar studies can be readily performed for deeper storage cavities. Chao (1974) reported on measurements of long term creep closure of cavity systems, and found that his field data and "conventional" FEM predictions did not coincide. He noted that multiple cavity interaction, e.g., creep interference, increased with the passage of time.

F.3 CLOSURE OF SALT DOME CAVERNS

Three major modes of closure of caverns in salt domes are possible "creep" closure, "slabbing," and general collapse. "Creep" closure (described above) is an active process in any salt cavity where stress differentials exist. For a fluid filled cavity under pressure, the hydrostatic pressure may equal lithostatic stress at one interval, while it exceeds lithostatic stress above and is less than lithostatic stress at greater depths. This situation would suggest that plastic "creep" of the salt would enlarge the cavern near the top, while the cavern would close slightly at depth. Total enlargement or closure due to "creep" is not expected to represent a significant fraction of the volume of the proposed cavities.

"Slabbing" has also been described above and is the result of anisotrop properties of sheared or impure salt. The proposed cavities are not expec e to encounter a significant problem due to slabbing because of their desig d depth and the purity of the salt at the designed cavern intervals. If slabbing is excessive in the shallow mine cavities to be converted, roof bolting of slabs may be required. This has not been a very serious problem in the previous mining oeprations.

Obviously, if "creep" closure becomes extreme, or if roof "slabbing" is excessive and continuous, then a progressive failure mode might eventu l occur which could result in a partial, and eventually general, collapse of a cavern. Either of these failure modes would be detectable early, and appropriate precautionary measures could be taken to prevent more serious failure of the cavern (i.e., roof bolting to prevent slabbing in a conventionally mined cavity).

General collapse of a storage cavity is the worst case failure that possible; however, <u>it is not suggested in this report to be a real possib</u> In the final stages of general collapse a surface sinkhole could apparently occur within a matter of several hours to a few days for a brine filled cavern. A plausible speculation of the sequence is that the salt roof over the cavity fails first, followed by the next layer of material above that and so on until the ground surface is reached and a characteristic sinkhole develops (Terzaghi, 1970). It is also possible that this process could s before it reaches the surface, in which case there would not be surface subsidence.

Surface subsidence in the case of all of the proposed storage sites would not be expected to directly affect any area offsite. Subsidence bowls from a "worst case" (but still not a real possibility) cavern collapse should not exceed tens of feet for the shallowest mines, and even less for deeper solution mined cavities.

The worst environmental effects of a general collapse would probably occur from the dispersion of the stored oil. The following discussion considers several possible paths of oil dispersion following a general collapse.

The general collapse of a storage cavern in salt is not analogous to debris falling into an empty hole and causing a "sinkhole" at the surface. These caverns are always full of a nearly incompressible fluid, brine or oil, which would be displaced volume for volume by falling salt caprock, and overlying sediment.

If the entire column of sediment above a cavern is lowered into the cavern in a manner analogous to a piston in a cylinder, and if the fluid in the cavern was completely displaced by percolation through the sediments of the "piston" rather than compressed, there would be a surface depression equal in volume to the original cavern filled but not overflowing with the displaced fluid.

This is a simplified case which assumes that the imperfect packing of falling particles, adsorption, absorption, dissolution, and trapping of the displaced fluid do not occur. In reality, these five mechanisms reduce the amount of oil that would continue to rise through the cone of influence and emerge on the surface. With these mechanisms, oil would probably reach the surface as small seeps, and as the sediments settles into the place formerly occupied by the oil, a small surface depression would form. Multiple depressions would appear as a wide area of shallow subsidence filled with oil.

Another possibility is that subsidence occurs without surface emergence of oil. Using the piston and cylinder model again with the assumption that the oil percolates up through water saturated sediments that have zero empty pore space, there is a volume for volume displacement of oil and the combined volume of the oil and saturated sediments remains constant. If the oil moves up from the saturated layer into the empty pores of an unsaturated layer, the volume of the unsaturated layer would remain constant as long as the oil only fills empty space. Oil would not emerge on the surface until all of the pore space near a potential seep was filled with oil. This would permit the possibility of an oil "slick" to form on top of the water table surface in the unsaturated layer.

F.4 SUMMARY

Cavern design concepts developed for the proposed cavities for the SPR program have incorporated the experience of hundreds of brine well operations,rock salt mine operations, and 25 years' experience with storing hydrocarbons in salt domes in the U.S. With use of appropriate construction techniques and constant monitoring of the caverns' integrity, the general collapse of a storage cavern is discounted as an unrealistic possibility. "Creep" closure and "slabbing" in storage cavities should present no environmental hazards, based on industrial experience with use of mined cavities in Gulf Coast salt domes.

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APPENDIX G

TECHNICAL REPORT
CAPLINE GROUP DIFFUSER SITE STUDY

Executive Summary

The Department of Energy (DOE), in implementing the Strategic Petroleum Reserve (SPR) Program, proposes to utilize for oil storage, caverns in the Capline Group of salt domes, on the Gulf Coast of Louisiana. If either the Weeks Island or Chacahoula oil storage site is selected for development, offshore brine disposal is proposed during either the solution mining operation or cavern refills. The brine discharge would have salinities ranging from 230 ppt to 264 ppt and maximum temperatures at the diffuser head in the range of 115° to 120°F. The proposed Weeks Island and Chacahoula brine diffuser sites are located about 9 and 24 nautical miles, respectively, offshore the entrance to Atchafalaya Bay, Louisiana, in approximately 21 and 33 feet of water. The alternative Weeks Island site is located almost 20 nautical miles off the entrance to Atchafalaya Bay, while the alternative Chacahoula site is located about 18 nautical miles off the Isles Dernieres in almost 20 feet of water.

This report was prepared to assist DOE's examination and assessment of potential environmental impacts associated with the option of brine disposal in the Gulf and to support the application for a discharge permit. This report is based on both historical data and site-specific investigations undertaken in the Gulf of Mexico.

The continental shelf in the vicinity of the proposed diffuser sites is covered by sediments varying from silty sands to silts or clays with some sand. Sediments are coarser nearshore and become finer with distance from the coast. Numerous shoals are present within the 30 foot contour. Depths range from about 16 feet at the Weeks Island site to over 30 feet at the Chacahoula site. The slope of the shelf to the 60 foot contour (30 miles offshore) is approximately 0.03 percent. Water temperatures are cooler in the nearshore zone. Currents are westerly and generally parallel to the coastline and isobaths. Current velocities normally range from 0.2 to 0.4 knots (0.3 to 0.7 ft/sec).

Predictive modeling for the proposed diffuser in the Capline series indicates that the discharged brine plume would remain near the bottom, thus minimizing its effect on mid-depth and surface waters. One series of model runs was performed using estimated magnitudes and directions of tidal and wind-driven currents based on historical data. Additional plume analyses were conducted using *in situ* current meter data collected at the proposed sites. Approximately 13 days of observed currents collected were used as input in a second series of model runs. Outputs were taken on the 13th day corresponding to discreet periods of the tidal cycle. The 1 ppt excess isohaline at the Weeks Island and Chacahoula sites would, under normal current conditions, cover an average of about 480 and 1420 acres, respectively. During an 8-day slack in the longshore tidal currents, this area would increase to about 2900 and 4600 acres.

A heat flow model was evaluated and analyzed to estimate the potential for excess temperatures at excess salinity profiles around the diffuser. This was accomplished by assuming 90°F seawater temperatures (worst case summer maximum) and brine temperatures at the diffuser head varying from 90°F to 150°F. Considering a worst case condition of 90°F Gulf waters and a brine discharge of 150°F, the excess temperature at the 3.0 ppt excess isohaline (about 40 acres at Weeks Island and 120 acres at the Chacahoula site) would be less than 0.5°F. When ambient temperatures in these coastal waters are less than 90°F, the excess temperatures at any isohaline would be greater, but the maximum temperature at these points would be less.

The water chemistry in the vicinity of the proposed diffuser sites is seasonally dependent on the freshwater discharge of the Mississippi and Atchafalaya Rivers. Hydrocarbons and trace metals, with the exception of mercury, are normally within the ranges expected for coastal waters. Heavy metal concentrations are usually greater in the interstitial waters than in the overlying water column. Zooplankton (chaetognaths) had significantly higher concentrations of trace metals than either the shrimp or the fish. Dissolved oxygen (DO) in the northern Gulf averages about 8.0 ppm; however, periodically the bottom waters become anoxic. In general, nutrients, heavy metals, hydrocarbon levels, and suspended matter were higher at Weeks Island than Chacahoula, due to the former site being closer to shore.

The major impact of the brine discharged into the Gulf would be the localized increased concentration of several chemical species, notably sodium and chloride in the immediate vicinity of the diffuser. Many of these constituents, in particular the trace metals, would be diluted to near ambient levels within a small area around the diffuser. Upon discharge, precipitation of various chemical species may occur; settling out of these particulates could impact the local benthic community. It has been estimated that the reduction of the DO from ambient at the 20 ppt excess isohaline, as a result of increased temperature and salinity, would be approximately 0.6 mg/l. No modification in the pH is anticipated. During the operational phase, brine discharge would have an estimated hydrocarbon content of 6.0 ppm, an order of magnitude greater than ambient. Local mixing and dispersion mechanisms would rapidly reduce these concentrations to ambient levels.

The biological assemblages at both sites are diverse and productive, but their components differ in several aspects. The phytoplankton communities at the sites are very similar, but the composition at the Weeks Island site is strongly influenced by the freshwater input to the Gulf from the nearby Atchafalaya River; the phytoplankton at the Chacahoula site has a greater proportion of marine species. Cell density and productivity at the Weeks Island site is relatively higher than at the Chacahoula site. Both sites attain maximum values for biomass, productivity, and chlorophyll a in the early spring; distinct minima occur during the summer months.

Bioassay studies have indicated that plankton entrained in the brine plume at the diffuser would be subjected to severe physiological (mainly osmotic) and temperature stress and, therefore, these plankton would undergo a temporary reduction in productivity and standing stock.

Since the residence time of the plankton in the plume area would be in terms of only a few hours, it is expected that no long-term or major impacts would be reflected in the plankton community for either of the sites. Since the plume will remain near the bottom, only those organisms associated with this lower portion of the water column or the benthic sediments would be affected.

Ninety-five taxa of benthic invertebrates were collected at the Weeks Island site, of which 29 taxa were unique to that site. In contrast, 98 taxa were collected at Chacahoula, of which 34 were unique to the site. Species diversity was always greater at the Chacahoula site. The density of organisms at the Weeks Island site ranged from 165 to 1410/m^2, while at Chacahoula the range was from 48 to 1585/m^2. In general, the polychaetes dominated, with the molluscs and crustaceans codominating.

Many species of benthic invertebrates live within the immediate vicinity of the diffuser sites where extreme salinities and temperatures would be expected. During an 8-hour day slack period, the area enclosed in the 4 ppt excess isohaline would be 30 acres at the Weeks Island site and 50 acres at the Chacahoula site. Assuming total mortality in this area, about 2.1 x 10^6 and 3.6 x 10^6 benthic invertebrates would be killed per acre, respectively, at Weeks Island and Chacahoula, but would vary depending on season. Little or no substantial adverse impacts to benthic organisms would occur outside the nearfield area. The younger developmental stages of many benthic invertebrates would be expected to be impacted the most. Fairly rapid recovery of the benthic community could be anticipated following termination of brine discharge.

Major fisheries in the Louisiana coastal waters include shrimp, menhaden, oysters, and blue crabs. Commercial landings in these waters in 1976 consisted of 1.2 billion pounds valued at $138 million. Of this, shrimp was leading species in value, followed by menhaden and oysters. Eight commercial species were collected at Weeks Island and seven at Chacahoula. The sport fisheries in these waters provide a large industry. The total number of invertebrate taxa was greater at the Weeks Island site than at Chacahoula, especially the commercial species. Thirty-six species of fish and a greater density was collected at Weeks Island, while 30 species were collected at Chacahoula.

The majority of the nekton would be expected to avoid the brine discharge in the vicinity of the diffuser where extreme salinities and temperatures would be expected. Nekton entering this region would be subjected to temporary osmotic and temperature stress. Bioassay studies have indicated that brine concentrations of about 36.5 ppt are lethal to embryonic white shrimp, while sublethal effects may occur below this concentration. Larval fish may be slightly more tolerant of high salinities than are embryonic white shrimp. Gulf menhaden larvae are known to metamorphose at salinities approaching 40 ppt, while the larval spotted seatrout are reported to have a 2-hour LC$_{50}$ of about 41 ppt. The planktonic larvae and eggs of fish and shrimp entrained in the plume where temperature and salinity values approach or exceed their upper tolerance limits would suffer lethal and sublethal impacts.

LIST OF TABLES

Table		Page
G.1-1	Projected brine disposal data by modes for the Capline Group.	G.1-8
G.1-2	Summary of diffuser characteristics	G.1-9
G.2-1	Long-term monthly average and extreme air temperatures for the Weeks Island - Chacahoula area.	G.2-2
G.2-2	Long-term near monthly precipitation, New Orleans, Louisiana.	G.2-3
G.2-3	Mean monthly wind speed and direction, Weeks Island - Chacahoula area, 1952-1971.	G.2-5
G.2-4	Monthly percent frequency of observed wind speeds, Bayou Lafourche area, 1952-1971.	G.2-7
G.2-5	Monthly variation of "fastest-mile" winds for New Orleans, Louisiana.	G.2-9
G.2-6a	Particle size characteristics - Weeks Island site.	G.2-16
G.2-6b	Particle size characteristics - Chacahoula site.	G.2-17
G.2-7	Monthly temperature and salinity averages for the Weeks Island and Chacahoula sites.	G.2-23
G.2-8	Offshore wind and wave data collected at East Cameron Block No. 328, October 20-25, 1977.	G.2-29
G.2-9	Offshore wind and wave data collected at Eugene Island Block No. 361, December 20-25, 1977.	G.2-31
G.2-10	Progressive vector summary.	G.2-42
G.2-11	Organic carbon and nutrients means and ranges in the water column for the proposed Weeks Island and Chacahoula brine diffuser sites, September 1977.	G.2-52
G.2-12	Major ion concentration means and ranges (ρ/Kg) for the proposed Weeks Island and Chacahoula brine diffuser sites, September 1977.	G.2-53
G.2-13	Dissolved metals (ppb) in surface and bottom waters in the LOOP study region.	G.2-55

LIST OF TABLES (continued)

Table		Pag
G.2-14	Concentration of trace metals in the dissolved and particulate phase of the water column and in pore (means and ranges) from the proposed Weeks Island and Chacahoula brine diffuser locations.	G.2-56
G.2-15	Concentration of trace metals in sediments (means and ranges) from the proposed Weeks Island and Chacahoula brine diffuser locations.	G.2-58
G.2-16	Heavy metal contents of selected organisms - proposed Weeks Island and Chacahoula brine diffuser sites.	G.2-60
G.2-17	Gas chromatograph hydrocarbon concentrations (means and ranges) in water samples and sediments from the proposed Weeks Island and Chacahoula brine diffuser sites.	G.2-62
G.2-18	Hydrocarbon concentrations in organisms collected from the proposed Weeks Island and Chacahoula brine diffuser sites.	G.2-71
G.2-19	Phytoplankton taxa observed during May 1973 to March 1974.	G.2-80
G.2-20	The quantitative distribution of phytoplankton species in the surface and bottom waters at the Weeks Island and Chacahoula brine diffuser sites from September to December, 1977.	G.2-82
G.2-21	Chlorophyll concentrations at the Weeks Island site for four months - September to December, 1977.	G.2-87
G.2-22	Chlorophyll concentrations at the Chacahoula site for four months - September to December, 1977.	G.2-88
G.2-23	A list of the zooplankton collected during the LOOP (1975) study.	G.2-89
G.2-24	Average number of zooplankton (#/m^3) identified at the Weeks Island and Chacahoula brine diffuser sites during September - December, 1977.	G.2-92
G.2-25	The percentage composition of the zooplankton comprising the four dominant species at the Weeks Island and Chacahoula brine diffuser sites during September - December, 1977.	G.2-[illegible]

LIST OF TABLES (continued)

Table		Page
G.2-26	Benthic infauna collected by ponar grab sampler in Louisiana coastal waters during the LOOP study.	G.2-99
G.2-27	Summary comparison of benthic macroinvertebrate infauna collected at the Weeks Island and Chacahoula brine diffuser sites, September - December, 1977.	G.2-101
G.2-28	Summary of benthic macroinvertebrates collections at the Weeks Island survey site (September - December, 1977).	G.2-102
G.2-29	Summary of benthic macroinvertebrate collections at the Chacahoula survey site (September - December, 1977).	G.2-106
G.2-30	Average annual harvest of major commercial fish and shellfish for Louisiana (1963-1967).	G.2-111
G.2-31	Migratory behavior of coastal organisms.	G.2-112
G.2-32	Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site (September - December, 1977).	G.2-115
G.2-33	Summary of trawl catches of invertebrates and fish collected at the Chacahoula survey site (September - December, 1977).	G.2-117
G.2-34	Threatened or endangered reptiles and mammals reported in the northern Gulf of Mexico.	G.2-125
G.3-1	Summary of parameters used in brine discharge calculations (for a bottom diffuser).	G.3-4
G.3-2	Specific water quality criteria - State of Louisiana.	G.3-34
G.3-3	Proposed EPA numerical criteria for water quality.	G.3-36
G.3-4	Preliminary analysis of brine in various salt domes on the Gulf Coast.	G.3-37
G.3-5	Water quality data from sampling stations in the Capline Group.	G.3-39

LIST OF TABLES (continued)

Table		Pag[illegible]
G.3-6	Free component concentrations at the various excess salinity contours as predicted by modeling.	G.3-40
G.3-7	Salinity ranges for benthic invertebrates in the northwestern Gulf of Mexico having a recorded occurrence in salinities above 45 ppt.	G.3-57
G.3-8	Salinity preference of postlarvae of brown and white shrimp.	G.3-63
G.3-9	Average mortality of 1 hour posthatch larval spotted seatrout to short term exposure to salt dome brine (based on 4 replicates).	G.3-70
G.3-10	Salinity tolerances of some coastal Louisiana fishes.	G.3-72
G.5-11	Water temperature (°C) data for the proposed Weeks Island brine diffuser site, September through December, 1977	G.5-2
G.5-2	Water temperature (°C) data for the proposed Chacahoula brine diffuser site, September through December, 1977.	G.5-[illegible]
G.5-3	Salinity (ppt) data for the proposed Weeks Island brine diffuser site, September through December, 1977.	G.5-4
G.5-4	Salinity (ppt) data for the proposed Chacahoula brine diffuser site, September through December, 1977.	G.5-5
G.5-5	Dissolved oxygen (mg/l) data for the proposed Weeks Island brine diffuser site, September through December, 1977.	G.5-6
G.5-6	Dissolved oxygen (mg/l) data for the proposed Chacahoula brine diffuser site, September through December, 1977.	G.5-7
G.5-7	Data for dissolved heavy metals, nutrients, and major ionic species from water column and underlying pore waters - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.	G.5-8
G.5-8	Data for relative dissolved and particulate heavy metal burdens - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.	G.5[illegible]

LIST OF TABLES (continued)

Table		Page
G.5-9	Data for heavy metal content of suspended particulates and bottom sediments - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.	G.5-10
G.5-10	Data for surface sediment (0-5 cm) metal contents and metal iron ratios - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.	G.5-13
G.5-11	Data for heavy metal content of selected organisms - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.	G.5-13
G.5-12	Data for gas chromatographic hydrocarbon concentrations and distributions in sediment samples from the proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.	G.5-14
G.5-13	Gas chromatographic hydrocarbon concentrations in water samples from the proposed Weeks Island and Chacahoula brine diffuser sites.	G.5-15
G.5-14	GCMS data for #816/station CR3, hexane fraction (sediment).	G.5-17
G.5-15	GCMS data for #816/station CR3, benzene fraction (sediment).	G.5-20
G.5-16	GCMS data for #818/WR3, hexane fraction (sediment).	G.5-23
G.5-17	GCMS data for #823/station C-2, benzene fraction (sediment).	G.5-25
G.5-18	GCMS data for #2002/surface water station C-5, hexane fraction.	G.5-28
G.5-19	GCMS data for #2025/deep water station W-2, benzene.	G.5-32
G.5-20	GCMS data for Weeks Island shrimp, hexane fraction.	G.5-34
G.5-21	GCMS data for Weeks Island shrimp, benzene fraction.	G.5-36

LIST OF TABLES (continued)

Table		Pag
G.5-22	Benthic macroinvertebrates collected at the Weeks Island site, September, 1977.	G.5-38
G.5-23	Benthic macroinvertebrates collected at the Weeks Island site, October, 1977.	G.5-44
G.5-24	Benthic macroinvertebrates collected at the Weeks Island site, November, 1977.	G.5-50
G.5-25	Benthic macroinvertebrates collected at the Weeks Island site, December, 1977.	G.5-56
G.5-26	Benthic macroinvertebrates collected at the Chacahoula site, September, 1977.	G.5-62
G.5-27	Benthic macroinvertebrates collected at the Chacahoula site, October, 1977.	G.5-67
G.5-28	Benthic macroinvertebrates collected at the Chacahoula site, December, 1977.	G.5-73
G.5-29	Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, September 17, 1977.	G.5-78
G.5-30	Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, October 14, 1977.	G.5-80
G.5-31	Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, November 12, 1977.	G.5-82
G.5-32	Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, December 15, 1977.	G.5-84
G.5-33	Summary of trawl catches of invertebrates and fish collected at the Chacahoula survey site, September 19, 1977.	G.5-85
G.5-34	Summary of trawl catches of invertebrates and fish collected at the Chacahoula survey site, October 15, 1977.	G.5-86
G.5-35	Summary of trawl catches of invertebrates and fish collected at the Chacahoula survey site, December 4, 1977.	G.5-88

LIST OF TABLES (continued)

Table		Page
G.5-36	Invertebrates characteristic of the offshore Louisiana coastal region based upon trawl samples.	G.5-90
G.5-37	Fish characteristic of the Louisiana coastal region based upon trawl samples.	G.5-92

LIST OF FIGURES

		Page
G.1-1	Coastal Louisiana showing proposed offshore brine disposal sites	G.1-2
G.1-2	Region of the proposed Weeks Island and Chacahoula brine diffuser sites including the sampling grids of the September to December 1977 survey	G.1-3
G.1-3	Projected variation in brine disposal rates - Weeks Island	G.1-6
G.1-4	Projected variation in brine disposal rates - Chacahoula	G.1-7
G.1-5	Proposed Weeks Island brine diffuser site sampling stations	G.1-12
G.1-6	Proposed Chacahoula brine diffuser site sampling stations.	G.1-13
G.2-1	Climatology of wind persistence for Burrwood, Louisiana giving the occurrence frequency of winds that persisted in the given directions over the indicated durations in hours.	G.2-6
G.2-2	Anticipated configuration of the Atchafalaya Delta shoreline by the year 2020.	G.2-12
G.2-3	Typical hydrographic profiles in the coastal Louisiana Gulf of Mexico: a) Summer, b) Winter.	G.2-20
G.2-4	Summer vertical cross-sectional observations of temperature, salinity and density in the coastal Louisiana Gulf of Mexico.	G.2-21
G.2-5	Winter vertical cross-sectional observations of temperature, salinity and density in the coastal Louisiana Gulf of Mexico.	G.2-22
G.2-6	Speed histograms and directional plots of currents measured as the proposed Weeks Island site, October 13-31, 1977	G.2-26
G.2-7	Speed histograms and directional plots of currents measured at the proposed Chacahoula site, October 14 to November 3, 1977.	G.2-27
G.2-8	Speed histogram and directional plot of currents measured at the proposed Weeks Island site, December 15, 1977 to January 7, 1978.	G.2-30

LIST OF FIGURES (continued)

		Page
G.2-9	Velocity scatter plot, proposed Weeks Island site, October 13 to 31, 1977.	G.2-33
G.2-10	Velocity scatter plot, proposed Weeks Island site, December 15, 1977 to January 7, 1978.	G.2-34
G.2-11	Velocity scatter plot, proposed Chacahoula site, October 14, to November 3, 1977.	G.2-35
G.2-12	Averaged velocity stick diagram, proposed Weeks Island site, October 13 to 31, 1977.	G.2-38
G.2-13	Averaged velocity stick diagram, proposed Weeks Island site, December 15, 1977 to January 7, 1978.	G.2-39
G.2-14	Averaged velocity stick diagram, proposed Chacahoula site, October 14 to November 3, 1977.	G.2-40
G.2-15	Progressive vector diagrams, proposed Weeks Island site, October 13 to 31, 1977.	G.2-44
G.2-16	Progressive vector diagrams, proposed Weeks Island site, December 15, 1977 to January 7, 1978.	G.2-45
G.2-17	Progressive vector diagrams, proposed Chacahoula site, October 14 to November 3, 1977.	G.2-46
G.2-18	Mean dissolved oxygen values at the Weeks Island and Chacahoula brine diffuser sites.	G.2-49
G.2-19	Gas chromatographic trace of station CR-3 sediment: proposed Chacahoula site.	G.2-63
G.2-20	Gas chromatographic trace of station WR-3 sediment. Proposed Weeks Island site.	G.2-64
G.2-21	Gas chromatographic trace of station W-5 sediment. Proposed Weeks Island site.	G.2-65
G.2-22	Gas chromatographic trace of station WR-3 water collected at mid-depth, proposed Weeks Island site.	G.2-67
G.2-23	Gas chromatographic trace of station W-2 surface water, proposed Weeks Island site.	G.2-68
G.2-24	Gas chromatographic trace of station W-5 surface water, proposed Weeks Island site.	G.2-69

LIST OF FIGURES (continued)

		Page
G.2-25	Gas chromatographic trace of hexane extract of station CR-3 water (mid-depth) and station C-5 water, proposed Chacahoula site.	G.2-70
G.2-26	Gas chromatographic trace of hexane fraction of croaker collected at the proposed Weeks Island and Chacahoula sites.	G.2-72
G.2-27	Gas chromatographic trace of whole white shrimp collected at the proposed Weeks Island site.	G.2-73
G.2-28	Gas chromatographic trace of whole white shrimp collected at the proposed Chacahoula site.	G.2-74
G.2-29	Gas chromatographic trace of the tail portions of white shrimp from the proposed Weeks Island site.	G.2-75
G.2-30	Average phytoplankton cell densities at the proposed Weeks Island and Chacahoula brine diffuser sites during September-December, 1977.	G.2-84
G.2-31	Average surface chlorophyll concentrations (mg/m^3) at the proposed Weeks Island and Chacahoula brine diffuser sites, September-December, 1977.	G.2-86
G.2-32	Average zooplankton concentrations (#/m^3) at the proposed Weeks Island and Chacahoula brine diffuser sites during September-December, 1977.	G.2-97
G.2-33	Shipwrecks in the region of the proposed diffuser sites.	G.2-127
G.3-1	Regions of analysis for the MIT Model.	G.3-2
G.3-2	Idealized non-tidal current cycle.	G.3-6
G.3-3	Bottom concentrations versus area for various runs at Weeks Island for output time 4.	G.3-8
G.3-4	Bottom concentrations versus area for various runs at Chacahoula for output time 4.	G.3-9
G.3-5	Bottom concentrations versus area for base case calculations at Weeks Island (run 5) for output times 1, 2, 3, 4.	G.3-10

LIST OF FIGURES (continued)

		Page
G.3-6	Bottom concentrations versus area for calculations with a 16-day cycle at Weeks Island (run 14) for output times 1, 2, 3, 4.	G.3-11
G.3-7	Bottom concentrations versus area for base case calculations at Chacahoula (run 18) for output times 1, 2, 3, 4.	G.3-12
G.3-8	Bottom concentrations versus area for calculations with a 16-day current cycle at Chacahoula (run 19) for output times 1, 2, 3, 4.	G.3-13
G.3-9	Contours of excess salinity concentration (ppt) at various distances from the center of the diffuser for the proposed Weeks Island site using observed currents at T = 0 hrs.	G.3-15
G.3-10	Contours of excess salinity (ppt) at various distances from the center of the diffuser for the proposed Weeks Island site using observed currents at T = 3 hrs.	G.3-16
G.3-11	Contours of excess salinity (ppt) at various distances from the center of the diffuser for the proposed Weeks Island site using observed currents at T = 9 hrs.	G.3-17
G.3-12	Contours of excess salinity (ppt) at various distances from the center of the diffuser for the proposed Weeks Island site using observed currents at T = 18 hrs.	G.3-18
G.3-13	Contours of excess salinity (ppt) at various distances from the center of the diffuser for the proposed Chacahoula site using observed currents at T = 0 hrs.	G.3-19
G.3-14	Contours of excess salinity concentrations (ppt) at various distances from the center of the diffuser for the proposed Chacahoula site using observed currents at T = 3 hrs.	G.3-20
G.3-15	Contours of excess salinity concentrations (ppt) at various distances from the center of the diffuser for the proposed Chacahoula site using observed currents at T = 6 hrs.	G.3-21
G.3-16	Contours of excess salinity concentrations (ppt) at various distances from the center of the diffuser for the proposed Chacahoula site using observed currents at T = 9 hrs.	G.3-22

LIST OF FIGURES (continued)

Page

G.3-17 Weeks Island current velocity vectors at depths of 11 and 14.5 feet corresponding to the snapshot times for the plume model output. G.3-23

G.3-18 Chacahoula current velocity vectors at depths of 16 and 21 feet corresponding to the snapshot times of the plume model output. G.3-24

G.3-19 Schematic model for brine temperature analysis. G.3-26

G.3-20 Schematic model of mixing zone relationships for brine plume temperature analysis. G.3-28

G.3-21 Temperature rise (ΔT) versus salinity rise (ΔC) correlation. G.3-32

G.3-22 Distribution of several organisms which may be encountered in the waters at the proposed Weeks Island and Chacahoula diffuser sites. G.3-47

G.3-23 Salinity record in the vicinity of the proposed Weeks Island brine diffuser site, 1963 and 1964, showing the brine concentration at which phytoplankton are stressed or growth is inhibited. G.3-50

G.3-24 Salinity record in the vicinity of the proposed Chacahoula brine diffuser site, 1963 and 1964, showing the brine concentration at which phytoplankton are stressed or growth is inhibited. G.3-51

G.3-25 Excess salinity versus duration of exposure for drifting planktonic species entrained in the brine plume. G.3-53

G.3-26 Excess salinity versus duration of exposure at indicated grid points. G.3-58

G.3-27 Idealized brine plume and analysis region shoreward and alongshore from the diffuser. G.3-59

G.3-28 Salinity record in the vicinity of the proposed Weeks Island brine diffuser site, 1963 and 1964, showing the brine concentrations at which white shrimp eggs, larvae and postlarvae are stressed or killed. G.3-66

LIST OF FIGURES (continued)

		Page
G.3-29	Salinity record in the vicinity of the proposed Chacahoula brine diffuser site, 1963 and 1964, showing the brine concentrations at which white shrimp eggs, larvae, and postlarvae are stressed or killed.	G.3-67
G.3-30	Excess salinity versus duration of exposure for drifting planktonic species entrained in the brine plume.	G.3-69
G.5-1	Reconstructed gas chromatogram for GCMS analysis of sediment sample 816, hexane fraction, station CR-3.	G.5-16
G.5-2	Reconstructed gas chromatogram for GCMS analysis of sediment sample 816, benzene fraction, station CR-3.	G.5-19
G.5-3	Reconstructed gas chromatogram for GCMS analysis of sediment sample 818, hexane fraction, station WR-3.	G.5-21
G.5-4	Reconstructed gas chromatogram for GCMS analysis of sediment sample 823, benzene fraction, station C-2.	G.5-24
G.5-5	Reconstructed gas chromatogram for GCMS analysis of surface water hexane fraction, station C-5.	G.5-27
G.5-6	Reconstructed gas chromatogram for GCMS analysis of deep water, benzene fraction, station W-2.	G.5-30
G.5-7	Reconstructed gas chromatogram for GCMS, analysis of white shrimp, hexane fraction, proposed Weeks Island site.	G.5-31
G.5-8	Reconstructed gas chromatogram for GCMS analysis of white shrimp, benzene fraction, proposed Weeks Island site.	G.5-33

APPENDIX G

TECHNICAL REPORT
CAPLINE GROUP DIFFUSER SITE STUDY

G.1 INTRODUCTION

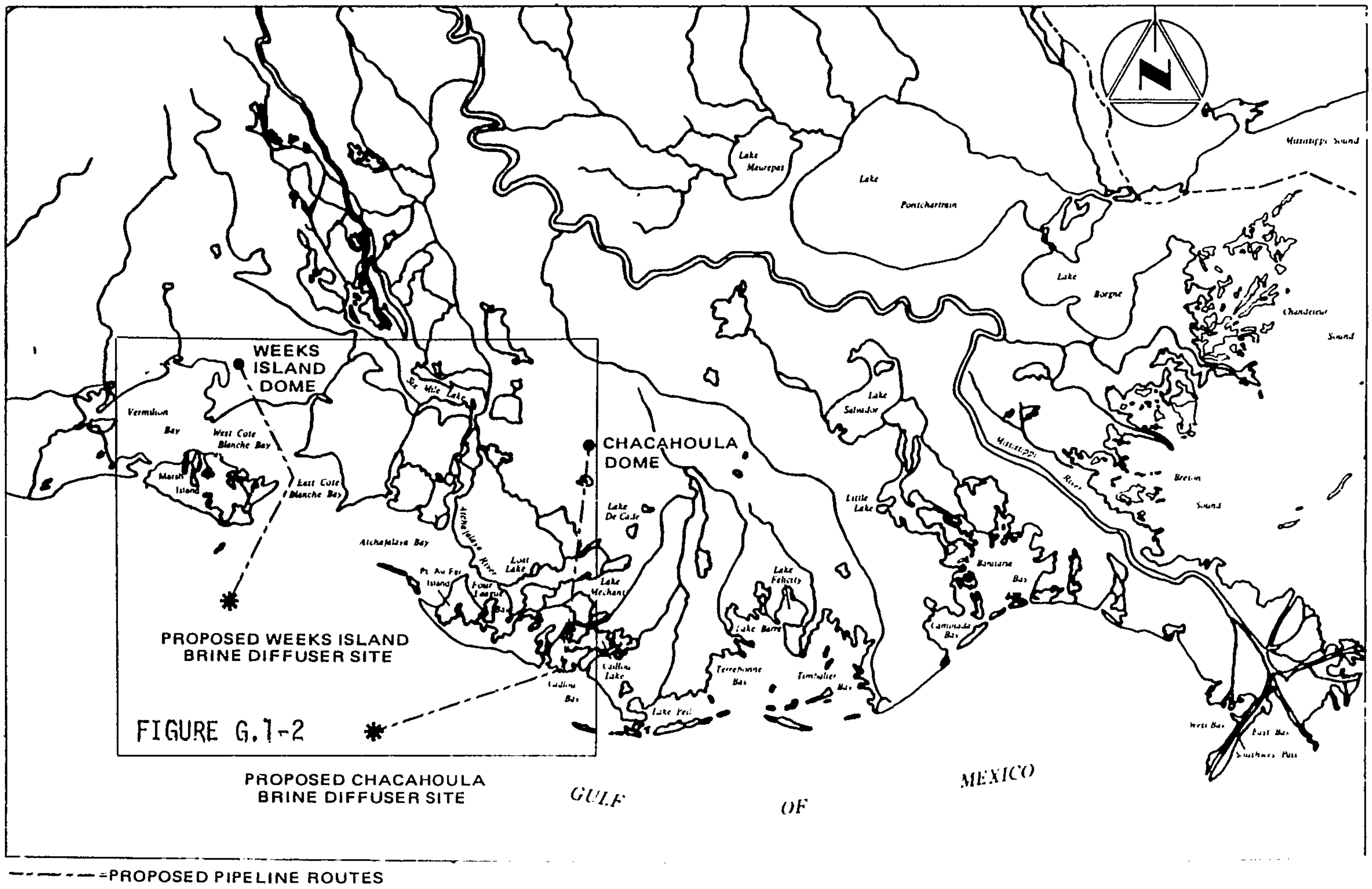
G.1.1 Background

This appendix presents a description of two proposed brine diffuser sites and an analysis of the physical, chemical, and biological effects of brine disposal in the Gulf of Mexico. The brine would result from the leaching of salt domes to form caverns, and from the subsequent use of those caverns for crude oil storage, thereby displacing the remaining brine. If either the Weeks Island or Chacahoula site is selected for development, offshore brine disposal is proposed to be utilized (Figure G.1-1).

Brine from the Weeks Island storage site would be transported through a pipeline which would pass under 27.9 nautical miles (32.1 statute miles) of bay and Gulf waters and would be discharged at a peak rate of 39 cubic feet per second. Use of an alternative location requiring 41.4 nautical miles (47.6 statute miles) of offshore pipeline is also addressed. At Chacahoula, the proposed diffuser site would require 20.5 nautical miles (23.6 statute miles) of offshore pipeline. Brine would be discharged at a peak rate of 90 cubic feet per second. An alternative site would require 19.4 nautical miles (22.3 statute miles) of offshore pipeline.

Since large quantities of brine would be produced as a result of solution mining and must subsequently be disposed, the impact of this disposal on the biology and water quality of the Gulf of Mexico is one of the most critical issues identified in the programmatic Environmental Impact Statement (FES 76-2).

One of the objectives of this appendix, therefore, is to support the Capline Group Final EIS with an assessment of the environmental effects of a brine disposal operation at the Weeks Island and Chacahoula disposal areas (Figure G.1-2). This assessment has been based on field studies which were conducted at both the proposed Weeks Island and Chacahoula brine diffuser sites during the months of September through



IGURE G.1-1. Coastal Louisiana showing proposed [illegible]shore brine disposal sites.

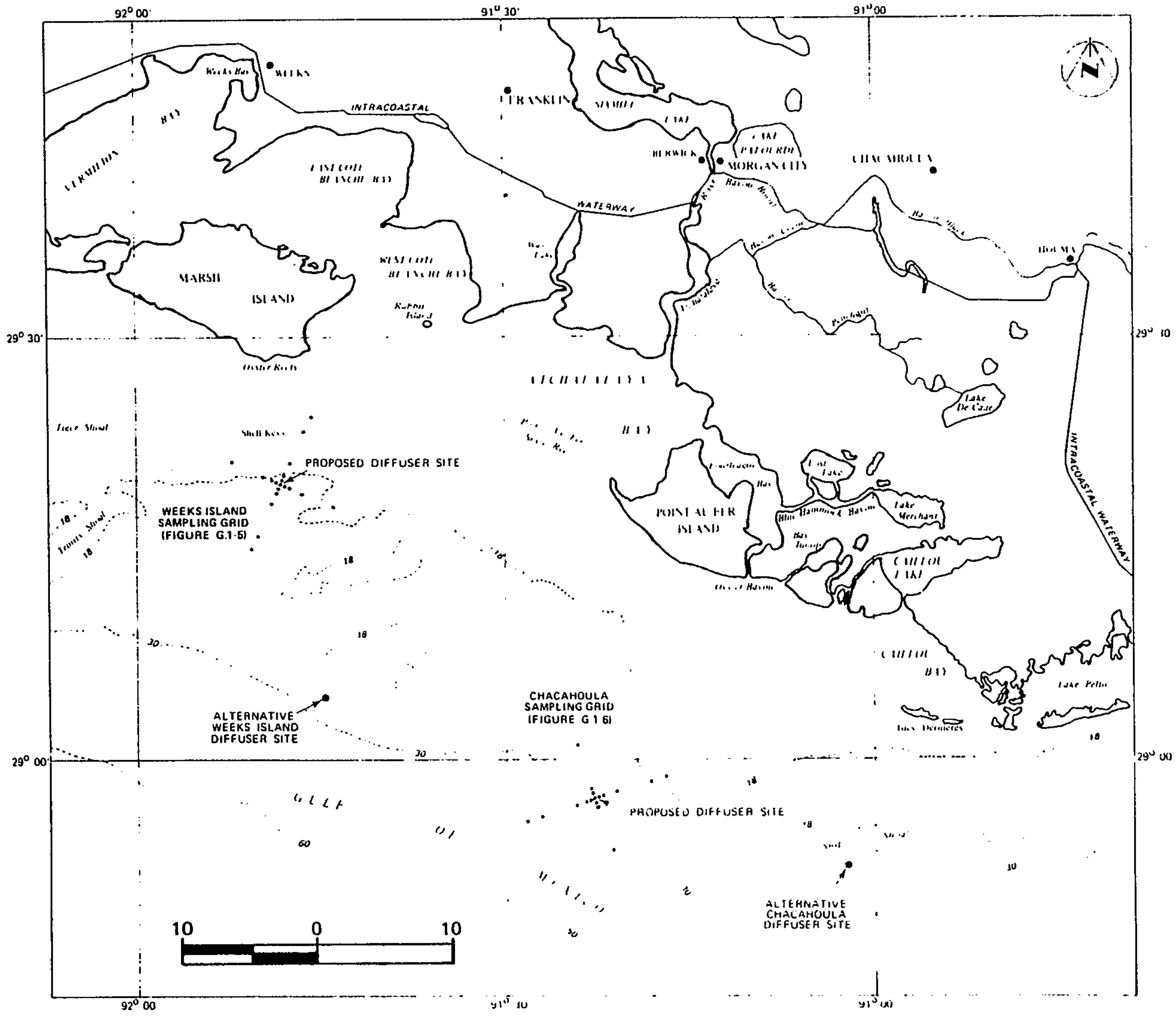


FIGURE G.1-2. Region of the proposed Weeks Island and Chacahoula brine diffuser sites including the sampling grids of the September to December 1977 survey.

December, 1977. Because of the limited time period, these studies are more appropriately termed a preliminary baseline characterization; the baseline studies have continued during 1978 at the alternative diffuser sites. Monitoring studies would be initiated at the diffuser sites during operation.

Another objective of this study is to provide DOE with information that, along with other studies, can be used to select an environmentally appropriate location, configuration, and size for a brine disposal diffuser system for the Louisiana offshore region within a reasonable distance of the dome storage sites under consideration. This information will be used to support applications to the Environmental Protection Agency for brine disposal permits.

G.1.2 Operational Brine Disposal Requirements

It has been proposed for the Strategic Petroleum Reserve (SPR) program that the early storage phase capacity of the Capline Group (183 MMB) be expanded by 117 MMB to a total storage volume of 300 MMB. The actual increase in group storage capacity could range from 91 MMB resulting from expansion of the Weeks Island salt dome cavern (274 MMB total Capline Group capacity) to 200 MMB for development of storage at the Chacahoula salt dome (383 MMB total). This additional capacity would be obtained by constructing new leached caverns, for which each barrel of space created would require the introduction of seven barrels of water and the disposal of a like amount of brine. Technical studies have determined that new leached space and initial fill of new capacity in the Capline Group may require the disposal of from 640 MMB to 1400 MMB of brine over a period of 4 to 5 years. This period includes the construction of the caverns by leaching and the initial fill period when crude oil is pumped into the newly formed caverns, displacing the remaining brine to the surface for disposal.

After the initial fill of new caverns, all storage caverns would be operated as a single system. Once the caverns are filled with oil, however, no further brine disposal or water supply will be required unless a foreign oil supply interruption occurs. Then, according to

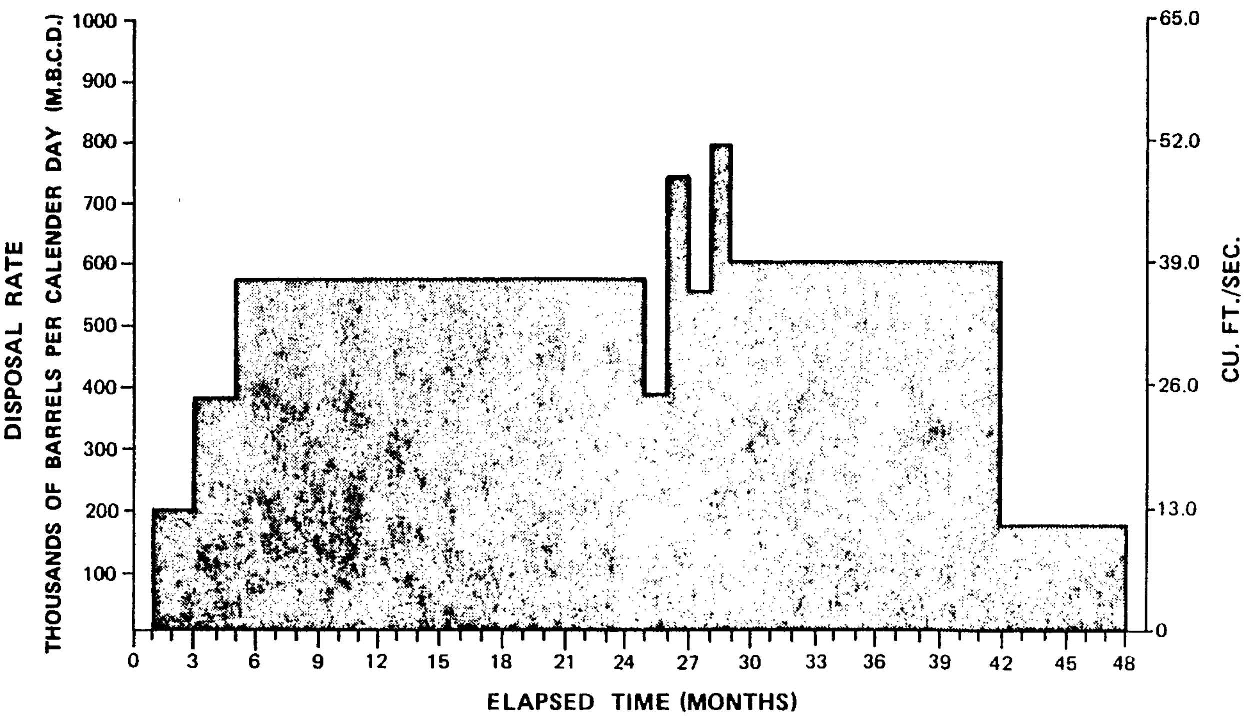
SPR program requirements, the oil will be withdrawn from the caverns by displacement with raw water within approximately a 150-day period. Resumption of normal foreign oil supplies would then initiate a second cycle; that is, the caverns would be refilled with oil, and this oil would displace the saturated brine. The refill period and its associated brine disposal would require from 12 to 24 months. Subsequent crude oil withdrawals and refills of the Capline Group capacity could each displace an additional 91 MMB to 200 MMB of brine to the Gulf (Gulf disposal would not be utilized for early storage capacity).

The range of projected disposal rates, durations, and total brine disposal volumes for the expansion of the Capline Group is presented graphically on Figure G.1-3 for Weeks Island and Figure G.1-4 for Chacahoula and is summarized in Table G.1-1. The maximum values of discharge (600 to 1250 MBCD) in this table represent leaching of the expansion capacity for a duration of about 4 years. During oil refill periods, lesser amounts of brine would be discharged into the Gulf from the diffuser. Over the projected 22-year life of the SPR, a maximum of five fill/ withdrawals are planned, displacing up to 450 MMB of brine from Weeks Island or 1000 MMB from Chacahoula.

G.1.3 Brine Diffuser Design Criteria and Plume Characteristics

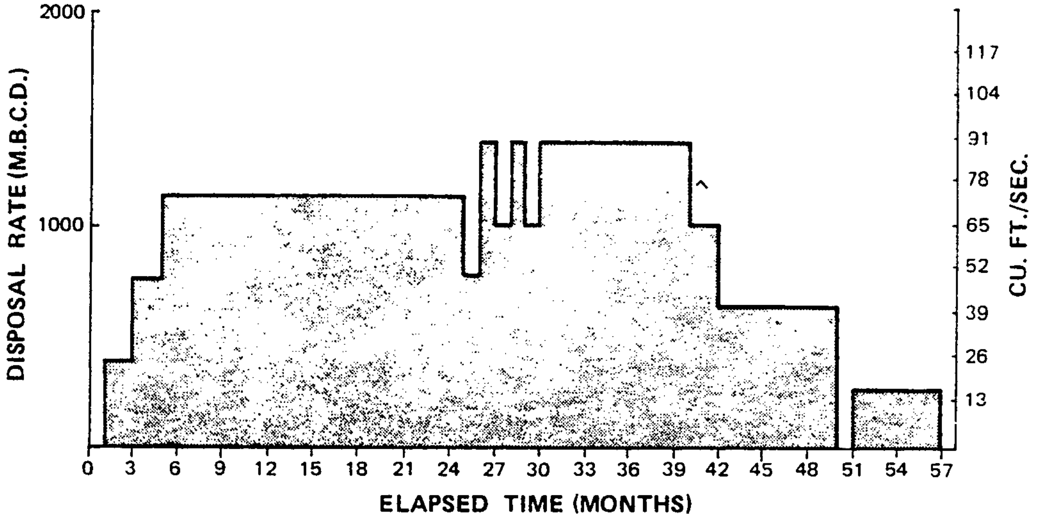
Design criteria for the offshore brine diffusers were based on environmental considerations and operational requirements (U.S. Department of Commerce, 1977a). Proposed and alternative locations based on those criteria are shown for each diffuser on Figure G.1-2. The proposed pipeline and diffuser characteristics are also summarized in Table G.1-2.

As discussed in Section G.1.2, brine plumes would occur from two separate activities. The initial discharge would result from solution mining of the salt dome to form caverns for oil storage. This discharge would occur over a period of 4 to 5 years, have a salinity of 230 ppt to 260 ppt and a temperature near ambient. The second discharge would occur when crude oil is pumped into the brine-filled completed caverns. The displaced brine would be discharged over a period of about 2 years, have a salinity



SOURCE: U.S. Dept. of Commerce, 1977a

FIGURE G.1-2 Projected variation in brine disposal rates-Weeks Island.



SOURCE: U.S. Dept. of Commerce, 1977a.

FIGURE G.1-4. Projected variation in brine disposal rates-Chacahoula.

TABLE G.1-1 Projected brine disposal data by modes for the Capline Group.

Site	Capacity (MMB)	Mode	Disposal Rate (MBCD)	Duration (months)	Brine Volume (MMB)	Salt Mass (millions of short tons)
Weeks Island	91	Leach	570 to 600	50-60	640	34.5
	91	Initial Fill	190	16	91	4.9
	91	Refills	190	16	91	4.9
Chacahoula	200	Leach	1250	50-60	1400	75.8
	200	Initial Fill	350	19	200	10.8
	200	Refills	350	19	200	10.8

TABLE G.1-2 Summary of diffuser characteristics.

	Weeks Island Proposed	Weeks Island Alternative	Chacahoula Proposed	Chacahoula Alternative
Latitude	29° 19.5' N	29° 04.5' N	28° 57.1' N	28° 52.0' N
Longitude	91° 48.2' W	91° 44.6' W	91° 22.75' W	91° 02.5' W
Offshore Pipeline Length	27.9 nm (32.1 mi)[a]	41.4 nm (47.6 mi)	20.5 nm (23.6 mi)	19.4 nm (22.3 mi)
Distance Offshore	10 nm from entrance to Atchafalaya Bay	22 nm from entrance to Atchafalaya Bay	23 nm from Point Au Fer Island	12 nm from Isles Dernieres
Water Depth	21 Feet	21 Feet	33 Feet	20 Feet
Diffuser Length	2000 Feet	Same as Proposed	3420 Feet	Same as Proposed
Orientation	Normal Isobaths	Same as Proposed	Normal Isobaths	Same as Proposed
Number of Ports	34	Same as Proposed	58	Same as Proposed
Orientation of Port Risers	90° to Bottom	Same as Proposed	90° to Bottom	Same as Proposed
Height of Risers Above Bottom	0-5 Feet	Same as Proposed	0-5 Feet	Same as Proposed
Port Exit Velocity	25 Feet per second	Same as Proposed	25 Feet per second	Same as Proposed

[a] nm = nautical mile
1 nautical mile = 1.151 statute miles

of approximately 264 ppt, and a temperature at the diffuser ports of about 120°F.

The MIT Transient Plume Model (U.S. Department of Commerce, 1977a), was used to develop the brine plume characteristics used in this study. For this study, the plume is considered to result from a worst case, 8-day slack period in the long-shore nontidal current component. An 8-day slack period is a conservative estimate of expected conditions; current data taken in the area generally indicate a maximum slack period of 2 days. For comparison of average and worst case conditions, the following table was derived from curves of bottom concentration versus bottom area covered (U.S. Department of Commerce, 1977a):

	WEEKS ISLAND		CHACAHOULA	
Isohaline (PPT above ambient)	8-Day Slack (acres)	Average Conditions (acres)	8-Day Slack (acres)	Average Conditions (acres)
1	2900	500	4600	1400
2	400	250	1300	450
3	100	40	200	125
4	30	--	50	--

Under average conditions of wind and current, high salinities would be limited to the bottom area in the immediate vicinity of the diffuser. Surface salinities would be essentially unaffected. During an 8-day slack period, when currents may fall as low as 1 centimeter per second, a broader area near the diffusers would experience excess salinities, and surface salinities would be increased slightly (up to 1.0 ppt).

G.1.4 Scope of Work for Baseline Characterization

Biological samples and physical and chemical measurements of the marine environment at the Weeks Island and Chacahoula brine disposal sites were taken in order to correlate existing environmental conditions with the predicted physical extent of the brine discharge as predicted by the MIT model (U.S. Department of Commerce, 1977a) and its chemical composition, and to predict potential areas of impact with regard to this discharge. A description of the methods and materials is presented below in conjunction with the scope of work.

G.1.4.1 Geographical Area Covered

G.1.4.1.1 Cruises

Cruises were conducted once a month at the proposed Weeks Island and Chacahoula diffuser sites between September and December, 1977. The first was for reconnaissance, for intensive sampling of biota, water, and sediment, and for deployment of current meters. Subsequent cruises were for retrieval of instrumentation data tapes and for less intensive biological sampling.

G.1.4.1.2 Oceanographic Station Arrays

For each sampling grid (Figures G.1-5 and G.1-6), the locations of disposal site stations and control stations were determined by considering the spatial extent of the brine plume as predicted by the MIT model and available knowledge of the prevailing coastal currents. Each grid was designed to extend beyond the predicted plume exposure in the near and far-fields. Near-field stations would be in direct contact with the brine effluent during initial jet mixing near the diffuser ports. Far-field stations were located within the region that would be affected, but would lack the intense exposure to brine that may be characteristic of the near-field stations. Control stations were established to delineate ambient conditions beyond the far field.

Water and sediment chemistry sampling was done only during the first cruise and samples were taken at selected stations within the grid (W2, W5, W8, W10, W15, WR3, C2, C5, C8, C10, CR3). Current meters and wave and tide gauges were deployed at the proposed diffuser sites (W5, C5). Benthic sampling was conducted at all stations, weather permitting, on each cruise.

Transects were established for each sampling region for plankton tows and for demersal fish and macroinvertebrate trawls.

G.1.4.2 Topical Coverage

G.1.4.2.1 Biological Oceanography

Major emphasis with regard to marine biology was placed on determining the species composition, abundance and diversity of the benthic community

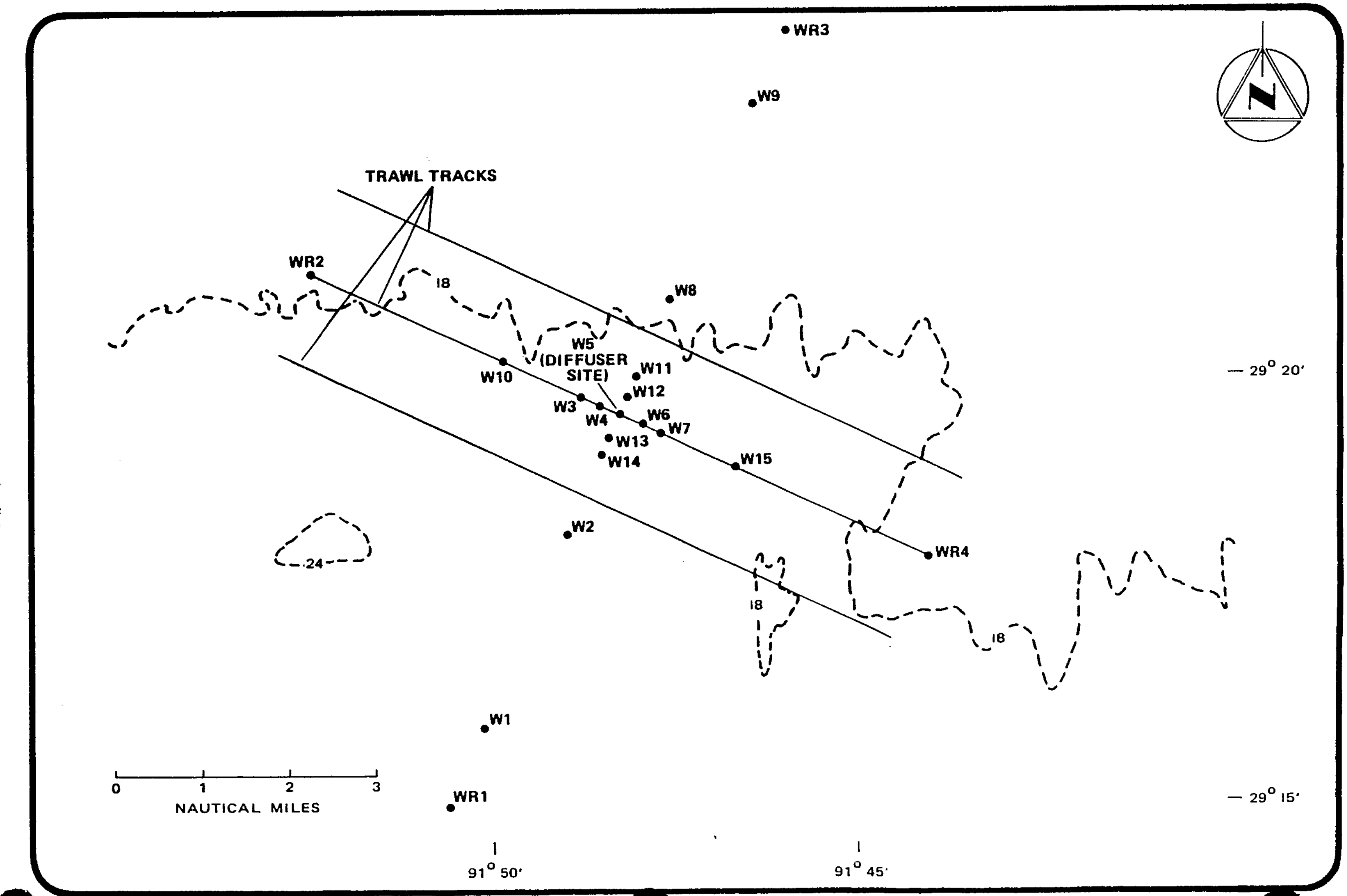


FIGURE G.1-5. Proposed Weeks Island brine diffus[illegible]ite sampling stations (depth contours in feet).

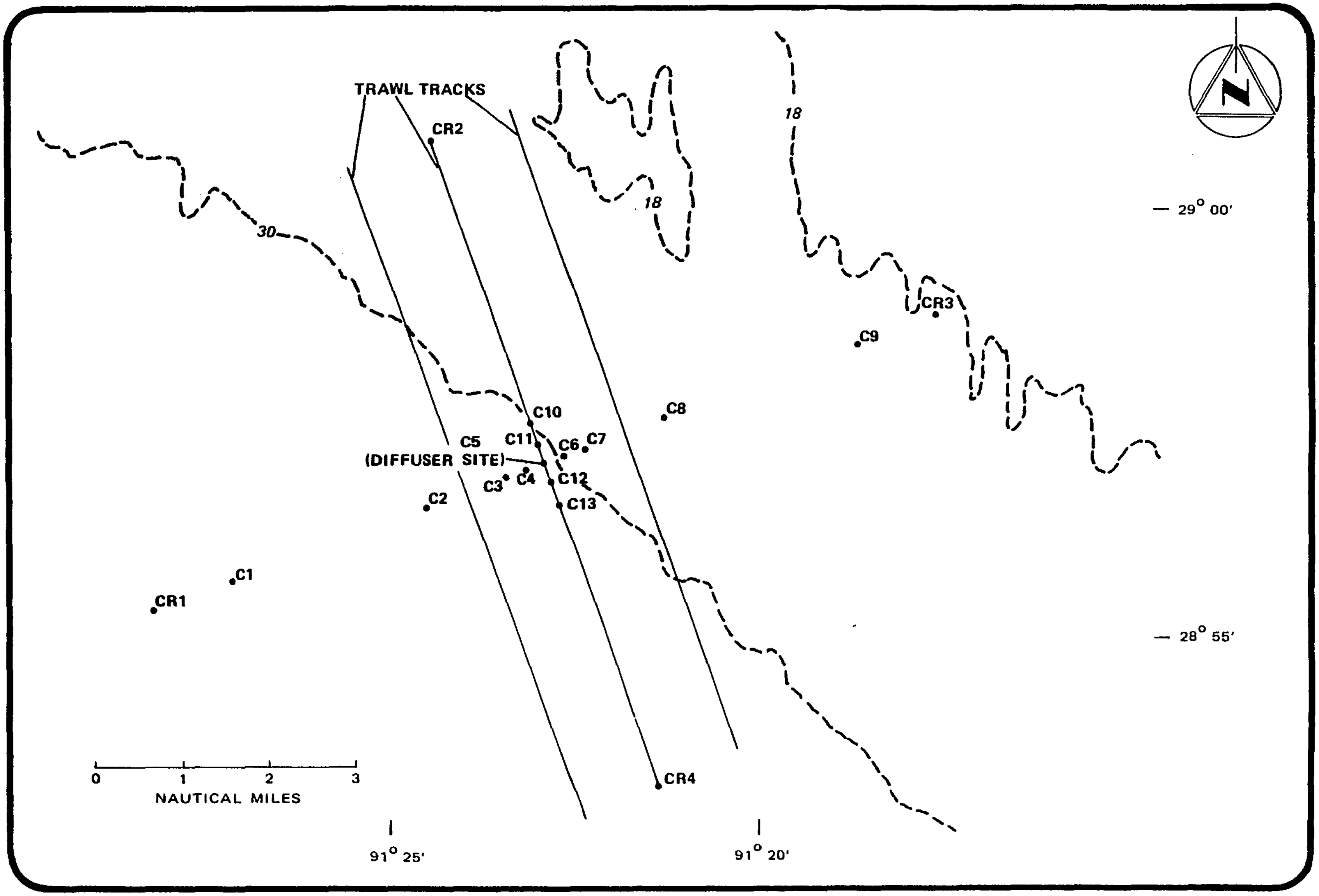


FIGURE G.1-6. Proposed Chacahoula brine diffuser site sampling stations (depth contours in feet).

at each diffuser site. Similar information was sought for the plankton and nekton communities, but these data were of a qualitative nature due to the communities' large temporal and spatial variability. In addition, adverse weather conditions at times necessitated changes in sampling location approach, and equipment, and in the number of samples taken.

G.1.4.2.1.1 Benthic Sampling

Among sites, benthic sampling was concentrated at the Weeks Island proposed site. At that site, 19 stations were occupied, compared to 17 at the Chacahoula proposed site (Figures G.1-5 and G.1-6). During a given cruise, sampling priority was placed on the Weeks Island proposed site in those instances where weather conditions limited sampling activity.

At both proposed sites, sampling was concentrated in the near-field. Replicate samples were collected at all stations when possible.

Benthic samples were taken by Peterson Grab (0.1 m^2). The organisms were separated from the sediment by washing the samples with a low pressure high volume flow of water through a 600 micron mesh sieve. Organisms from all samples collected during all cruises were preserved in 5 percent buffered formalin and later identified in the laboratory to the lowest practical toxonomic level. These data were used to characterize species composition, abundance, and density. Underwater photography to record epifaunal distributions and visible characteristics of the sediment surface was attempted but was unsuccessful due to low visibility.

To relate benthic communities to the substrate characteristics, one subsample of associated sediment was taken from each benthic sample and analyzed for particle size distribution and percent organic matter (loss on ignition).

Bathymetric data consisted of recording sample station depths with a precision depth recorder (PDR). The PDR was operated in transit between sampling stations to determine if there were significant anomalies between observed and charted depths.

G.1.4.2.1.2 Demersal Fish and Macroinvertebrates

An otter trawl (0.5 inch mesh wings, 0.125 inch mesh cod end) was used to sample demersal fish populations and epibenthic macroinvertebrates at each diffuser site. Three trawls were taken at each site (Figures G.1-5 and G.1-6); one transect crossing the diffuser location; and the remaining two paralleling and on each side of the first. Organisms taken by the otter trawl were sorted, identified, and counted and a representative number of each species was measured.

From the September cruise, tissue from one shrimp species and one fish species was collected at each site and assayed for trace metals (Fe, Mn, Zn, Pb, Ni, Cu, Cd, and Al) and high molecular weight hydrocarbons.

G.1.4.2.1.3 Plankton

Phytoplankton and zooplankton were sampled during each cruise. For phytoplankton, twenty liter water samples were collected at the end of each otter trawl transect (Figures G.1-5 and G.1-6) from the surface and near the bottom with an 8-liter Alpha bottle and concentrated on a 35 micron mesh screen. Samples were washed down into glass containers and preserved with a 5 percent solution of buffered formalin.

Zooplankton samples were collected during each trawl and consisted of a 3-minute surface tow using a metered 0.5 m conical net with a 202 micron mesh. Samples were rinsed off the net and preserved in a solution of 5 percent buffered formalin.

At the water/sediment chemistry stations, for each cruise, surface water samples were collected for chlorophyll a and phaeophytin to be determined by fluorimetry. Planktonic organisms were identified to the lowest practical taxonomic unit and the results were reported as species composition, abundance, and distribution and were correlated with the chlorophyll and nutrient indicators of production.

For the first cruise only, sufficient zooplankton biomass was reserved for chemical assay of trace metals as previously described for shrimp and fish; no hydrocarbon analyses were attempted.

G.1.4.2.2 Physical Oceanography

The physical oceanographic effort consisted primarily of monthly shipboard determinations of the salinity, temperature, and dissolved oxygen and monthly data retrieval and instrument servicing of wave and tide gauges and current meters.

G.1.4.2.2.1 Waves and Tides

Base wave and tide gauges were deployed at both disposal sites. The gauges were self-recording, requiring only periodic visits to retrieve recorded data.

G.1.4.2.2.2 Currents

Continuous, direct, Eulerian current measurements were taken at both sampling regions, using Endeco current meters. All meters were deployed on a taut mooring with subsurface flotation buoy and surface marker buoy(s) at diffuser sites. Where depth allowed, each meter array consisted of a near-bottom and a near-surface current meter. The current meter data was provided to NOAA in a format that was used directly in runs of the MIT plume model.

G.1.4.2.2.3 Salinity, Temperature and DO Fields

Determination of local temperature, salinity, and dissolved oxygen fields were made by in situ readings from surface and bottom at each water/sediment chemical sampling station utilizing a Hydrolab temperature/salinity/depth/dissolved oxygen probe.

G.1.4.2.3 Chemical Oceanography

With the exception of chlorophyll and phaeophytin analyses previously discussed under Plankton, chemical oceanography was a one-time effort conducted on the initial cruise. Chemical assays of the biota for hydrocarbons and trace metals have been discussed in detail under Biologic Oceanography. The remaining chemical effort was directed toward water and sediment samples taken at designated chemical stations.

G.1.4.2.3.1 Sediments

For the first cruise only, two sediment samples were collected at each chemical station with push cores taken by divers. One sample was reserved for chemical analysis of bulk properties; the other sample was reserved for chemical analysis of pore water. No replicate measurements were made.

Each pore water sample was analyzed for the following: the micronutrients, phosphate, reactive silicate, and nitrate and nitrite nitrogen;

the six bulk ions, Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_4^{2-}, and Cl^-; and the seven trace metals, Fe, Mn, Zn, Pb, Ni, Cu, and Cd. Note that this suite of metals differs slightly from that determined for the biota.

Each bulk properties sample was homogenized and divided into four subsamples. One subsample was used to determine particle size composition; one was used for analysis of total inorganic carbon, total organic carbon, and adenosine triphosphate (ATP). A third subsample was analyzed for the biologically available, acid-leachable fraction of metals, and the fourth was assayed for solvent extraction-gas chromatographic determination of hydrocarbons. The sediment suite of metals was the same as for the biota, except for the addition of Cr.

G.1.4.2.3.2 Water

Surface and bottom samples were taken at each chemistry station. Samples were filtered through a 0.45 micron membrane filter. The suspended biologically available particulate fraction (leachable) and the suspended refractory fraction were analyzed for Fe, Mn, Zn, Pb, Ni, Cu, and Cd plus particulate organic carbon.

Filtered water was analyzed for the six bulk ions and 8 trace metals (Cd, Cu, Pb, Ni, Hg, Zn, Fe, and Mn) plus dissolved organic carbon, dissolved hydrocarbons, and nutrients.

G.1.5 Presentation Format

Section G.2 of this technical report contains the results of the above field work together with a description of the pre-discharge baseline environmental characteristics of each diffuser site and a discussion of the potential impact of the disposal of brine at these sites on the important marine resources in the area can be found in Section G.3.

G.2 REGIONAL AND SITE SPECIFIC ENVIRONMENTAL SETTING

G.2.1 CLIMATOLOGY AND METEOROLOGY

G.2.1.1 Climate

The area around the proposed diffuser sites (Figure G.1-1) has a marine climate largely influenced by the characteristically warm waters of the Gulf of Mexico which temper extremes of summer heat, shorten winter cold spells, and provide abundant moisture and rainfall.

The Bermuda high, an extensive semipermanent high pressure cell centered in the Atlantic Ocean, dominates the spring and summer weather conditions at the sites. The prevailing southeasterly winds bring moist air to the area, with the result that humidities are high and convective shower activity occurs almost daily. Coastal circulation is affected by sea breezes during the afternoon and evening hours.

Although the region is south of the mean winter storm track, occasional intrusions of polar air can cause sudden drops in temperature and sometimes snowfall. The cold airmasses also tend to lower sea-surface temperatures and are important in the formation of advection-radiation fog, which is prevalent in the area, especially during winter and spring.

G.2.1.2 Meteorological Data

G.2.1.2.1 Temperature

Summer temperatures for the area average in the mid-80's; winter temperatures are usually in the 60's.

Table G.2-1 presents long-term monthly average and extreme temperatures based on marine observations between 1952 and 1971. The annual mean temperature is 74.3°F. July and August are the warmest months, with mean temperatures of 84°F; January and February, the coldest months, have mean temperatures of 63°F. The highest and lowest recorded temperatures are 100°F and 30°F, respectively.

G.2.1.2.2 Precipitation

Table G.2-2 summarizes long-term, mean monthly and extreme precipitation for New Orleans, Louisiana. The largest amount of rainfall occurs during the summer months in association with either local thunder-

TABLE G.2-1 Long-term, monthly average and extreme air temperatures for the Weeks Island - Chacahoula area, 1952-1971.

Month	Mean °F	Minimum °F	Maximum °F
January	63.2	30	84
February	63.8	32	85
March	66.1	37	88
April	71.4	46	91
May	77.4	58	94
June	82.0	67	99
July	84.1	70	100
August	84.0	70	100
September	81.9	62	99
October	76.7	52	99
November	69.8	39	90
December	65.5	36	90
Annual	74.3	30	100

SOURCE: U.S. Dept. of Commerce, 1972.

TABLE G.2-2 Long-term mean monthly precipitation, New Orleans, Louisiana.

Month	Normal Total[a]	Maximum Monthly[b]	Year	Minimum Monthly[b]	Year	Maximum Daily[b]	Year
January	3.84	12.62	1966	0.54	1968	4.77	1955
February	3.99	10.56	1959	1.02	1962	5.60	1961
March	5.34	19.09	1948	0.24	1955	7.87	1948
April	4.55	8.78	1949	0.33	1965	4.35	1953
May	4.38	14.33	1959	0.99	1949	9.86	1959
June	4.43	8.87	1962	1.12	1952	4.19	1953
July	6.72	11.46	1954	3.45	1951	4.30	1966
August	5.34	11.77	1955	2.00	1952	3.06	1969
September	5.03	16.74	1974	0.24	1953	6.50	1971
October	2.84	6.45	1959	0.00	1952	2.58	1960
November	3.34	14.58	1947	0.21	1949	6.38	1953
December	4.10	10.77	1967	1.46	1958	3.94	1952
Annual	53.90	19.09	March 1948	0.00	Oct. 1952	9.86	May 1959

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[a] Period of Record: 1931-1960

[b] Period of Record: 1946-1971

SOURCE: U.S. Dept. of Commerce, 1971.

storms or an occasional tropical storm. Winter precipitation generally results from frontal activity and falls as slow, steady rainfall; it may occur at any time of day and continue intermittently for several days.

The mean annual precipitation is 53.9 inches. The maximum 24-hour precipitation was 14.01 inches in April 1927 (U.S. Dept. of Commerce, 1971).

Frozen precipitation in the area is rare; over the 25-year period (1946-1971) the mean annual snowfall was 0.2 inches. In February 1895, an unusual storm dumped 8.2 inches of snow on New Orleans (U.S. Dept. of Commerce).

G.2.1.2.3 Wind Speed and Direction

G.2.1.2.3.1 Surface Winds

The mean annual wind speed at the diffuser sites is 11.5 knots (13.2 mph) (Table G.2-3). In the spring and summer, the Bermuda high usually controls surface winds at the sites. In autumn, there is a transition from a tropical wind regime to a modified continental wind regime. Accordingly, the winds shift to easterly and northerly directions, and these winds show the highest average wind speeds and greatest frequency of occurrence for the area. Winds in the autumn can be in excess of 33 knots.

G.2.1.2.3.2 Slack Wind and Persistence

Due to the coupling effects of surface winds and currents, periods of slack winds (wind speed $\leq$ 5 knots) are of importance to brine disposal.

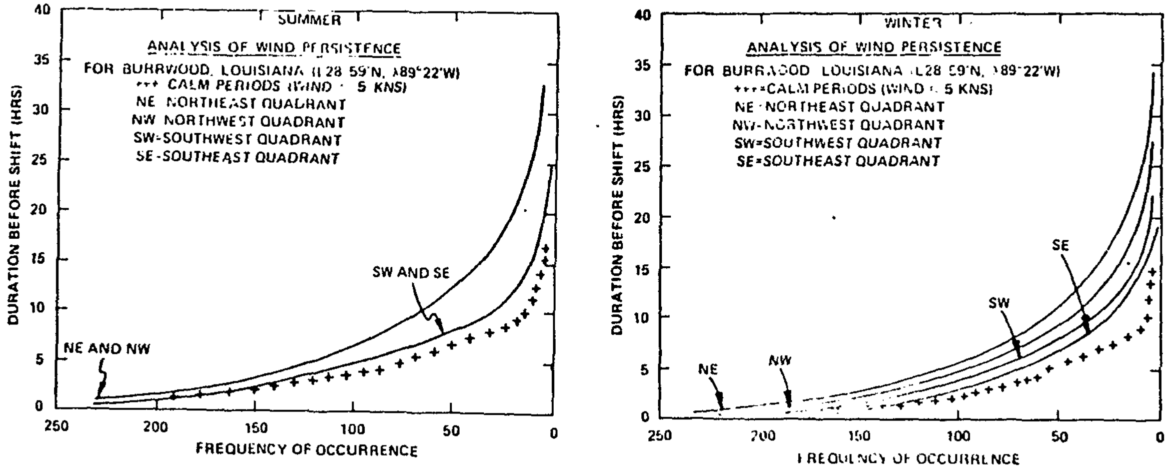
Figure G.2-1 is a climatological record of wind persistence produced from a 15-year record (1948-1963) of hourly wind data observed at Burrwood, Louisiana, the closest primary coastal meteorological station to the area. The frequency of occurrence of slack wind periods lasting for more than 12 hours is low. More than half of the observations had a slack wind period of less than 5 hours, indicating that these periods can occur often but in most cases prevail for only a short time.

Table G.2-4 presents a monthly percent frequency distribution of wind speed categories based on marine observations in the Bayou Lafourche area. Winds with speeds of 3 knots or less occur most frequently between May and September.

TABLE G.2-3 Mean monthly wind speed and direction, Weeks Island - Chacahoula area, 1952 - 1971.

Month	Wind Speed (knots)	Direction
January	13.3	N
February	13.3	E
March	12.9	SE
April	12.4	SE
May	10.4	SE
June	9.0	SE
July	8.1	SE
August	8.5	SE
September	11.4	E
October	11.9	NE
November	13.1	N
December	13.4	E
Annual	11.5	SE

SOURCE: U.S. Dept. of Commerce, 1972.



SOURCE: U.S. Dept. of Commerce, 1977a

FIGURE G.2-1 Climatology of wind persistence for Burrw[illegible] Lo[illegible]iana, vi[illegible]

TABLE G.2-4 Monthly percent frequency of observed wind speeds - Bayou Laforche Area, 1952-1971

	Wind Speed (knots)					
Month	0-3	4-10	11-21	22-33	34-37	48+
Jan	5.3	36.9	46.5	10.2	1.1	0.0
Feb	4.2	38.1	46.6	10.1	1.0	*
Mar	6.6	37.3	46.3	8.8	1.0	0.1
Apr	5.9	39.7	47.3	6.5	0.6	
May	10.3	48.1	38.3	3.1	0.1	0.0
June	14.4	55.3	28.3	1.8	0.2	0.0
July	17.0	59.8	22.2	0.9	0.1	0.0
Aug	15.6	58.3	24.8	1.2	0.1	0.1
Sept	9.0	45.0	39.0	6.1	0.8	0.1
Oct	6.4	42.8	44.0	6.3	0.5	*
Nov	5.5	37.6	46.3	9.8	0.9	0.0
Dec	4.4	37.5	46.8	10.4	0.9	0.0

* Data not available

Source: U.S. Dept. of Commerce, 1972

The table below shows monthly cummulative frequency categories and wind speeds for the area:

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FREQUENCY OF OCCURRENCE	WIND SPEED (KNOTS)											
01% ≤	0	0	0	0	0	0	0	0	0	0	0	0
05% ≤	3	4	2	2	1	1	1	1	1	1	1	4
25% ≤	7	6	6	6	5	4	4	4	5	6	7	6
50% ≤	12	12	11	11	9	8	7	7	9	11	12	12
75% ≤	18	18	17	17	15	12	10	11	16	16	18	18
95% ≤	28	28	27	25	21	20	19	19	25	24	28	28
99% ≤	35	35	35	30	25	25	22	24	33	30	33	33

Of the total observations, only 25% were of wind speeds 6 knots or less. Slack wind periods occurred most often between May and September.

G.2.1.2.3.3 Extreme Winds

Table G.2-5 summarizes the "fastest mile" (sustained) wind speeds in New Orleans for a 12-year period (1960-1971). Offshore, winds in excess of 175 knots (301.2 mph) are estimated to have occurred during hurricanes (U.S. Dept. of Commerce, 1972).

The table below gives estimated extreme winds for return periods from 5 to 50 years:

Mean Recurrence Interval (Years)	5	10	25	50
Maximum Sustained Wind (Knots)	85	95	110	120

G.2.1.2.4 Hurricanes

June to October is the tropical cyclone season. Between 1899 and 1971, 45 tropical storms have penetrated the Weeks Island-Chacahoula area with an average northward movement of about 10 knots; eighteen of these storms were of hurricane intensity (U.S. Dept. of Commerce, 1972).

Tropical cyclone and hurricane frequencies recorded in the area between 1899-1971 are given below:

TABLE G.2-5 Monthly variation of "fastest-mile" winds for New Orleans, Louisiana, 1960-1971.

Month	Speed (mph)	Direction[a]	Year
January	33	28	1966
February	43	26	1970
March	37	18	1969
April	35	07	1960
May	31	23	1962
June	48	05	1971
July	32	07	1969
August	42	33	1969
September	69	09	1965
October	40	17	1964
November	30	31	1969
December	32	17	1969
Annual	69	09	1965

---

[a] Direction in terms of degrees from true North; i.e., East-09; South-18; West-27; North-36.

SOURCE: U.S. Dept. of Commerce, 1971.

	Total No. 1899 - 1971	Average No. Years Between Occurren
Tropical Cyclones (winds > 34 knots)	45	1.6
Hurricane (winds > 64 knots)	18	4.1

In recent Gulf history, Hurricane Camille (August 1969) with estimated winds of 175 knots (201.5 mph), was the most severe.

G.2.2 PHYSICAL OCEANOGRAPHY

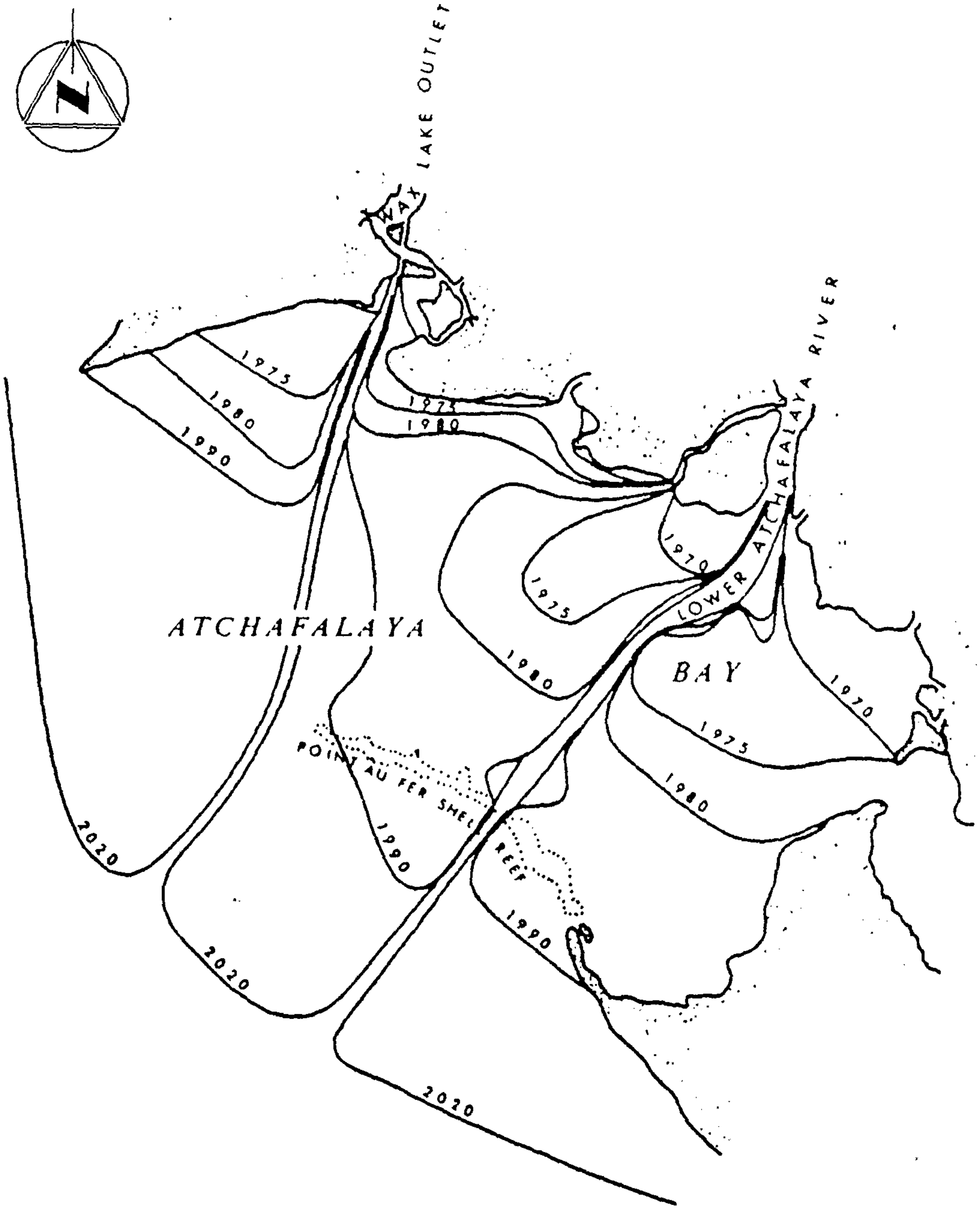
G.2.2.1 Nearshore Features

G.2.2.1.1 Regional Description

The coastal area of Louisiana in which the Weeks Island and Chacahoula brine diffusers would be located is endowed with a unique variety of dynamic environments including coastal bays, estuaries, lakes, marshlands, barrier islands and cheniers (stranded beaches) (Figure G.1-2). Within this area, O'Neil (1949) and Morgan and Larimore (1957) have defined two distinct morphological provinces: an eastern portion extending from Vermillion Bay to Mississippi Sound which consists of a delta plain characterized by a highly irregular shoreline; and a western portion which possesses a more regular shoreline and represents an area of marginal deltaic sedimentation. Along this latter section, mud flats which have been developed by the westward longshore drift of previously deposited deltaic sediments alternate with the growth of sand beaches. These areas and their periods of alternation correspond to changes brought about by the flow of the Mississippi River and its distributaries.

Since the early 1950's it has been observed that the Atchafalaya River, with its shorter path and steeper gradient, has been slowly capturing a significant portion of the Mississippi River discharge during high water stages. This aspect represents a continuation of the normal shifting patterns of the lower river channel and alternation in the growth and erosion of various subdelta complexes. Since 1953 flow into the Atchafalaya River has been artificially regulated by the U.S. Army Corps of Engineers to receive approximately 30 percent of the total Mississippi discharge together with the total flow volume of the Red River. Consequently, the Atchafalaya River is actively building a new delta complex in the Gulf of Mexico west of the Mississippi River delta area (Figure G.2-2).

An extensive study of the shelf waters immediately west of the Mississippi River delta was conducted in conjuction with the Louisiana Offshore Oil Port (LOOP) (LSU, 1975) Study program. A hydrographic study of the waters immediately to the west of the LOOP study area and



SOURCE: Shlemon, 1972.

FIGURE G.2-2. Anticipated configuration of the Atchafalaya Delta shoreline by the year 2020.

south of Timbalier Bay has been sponsored by the Gulf Universities Research Consortium (GURC) and is described by Oetking (1974a).

The dominant offshore bathymetric feature in the region is the Gulf Coast Geosyncline. The axis of this geosyncline generally corresponds with the trend of the present shoreline of the Gulf Coast states. The stratigraphic record indicates that this geosyncline has been gradually subsiding since the Cretaceous period because of the voluminous deltaic sedimentation and deposition. Continued subsidence of this area is indicated by the slope of the natural levees in the region which tilt toward the Gulf of Mexico.

The continental shelf adjacent to the Mississippi delta is to a large extent very narrow and at the delta is almost nonexistant where the Mississippi River has prograded across it. To the east or west of the delta the continental shelf of Louisiana widens markedly to more than 200 km off the coasts of Florida and Texas. The continental shelf west of the delta is noncarbonate in origin and has many isolated seaknolls and seamounts which are thought by some investigators to be surface expressions of salt domes (Shepard, 1937; Carsey, 1950; Moore and Curray, 1963; Ewing and Antoine, 1966).

G.2.2.1.2 Diffuser Sites

Atchafalaya Bay and Marsh and Point Au Fer Islands are the dominant nearshore features at the Weeks Island and Chacahoula sites (Figure G.1-2). The Bay is approximately 20 miles long in an east-west direction, averages 7 miles in width, and is generally less than 7 feet deep. The outer boundary of this bay is formed by Point au Fer Shell Reef, once an oyster-producing area. Oyster productivity on the reef has been destroyed by increasing amounts of freshwater and sediment from the Atchafalaya River basin. A submarine extension of additional reefs trend northwestward for 14 miles to Rabbit Island. Beyond these reefs, water depths increase very gradually such that the 3- and 100-fathom contour lines lie 10 and 115 miles, respectively, offshore.

Water depth at the Weeks Island site is approximately 20 feet, and at the Chacahoula site approximately 30 feet. Three large shoals lie offshore of Atchafalaya Bay in the vicinity of the proposed Weeks Island

and Chacahoula diffuser sites. Ship Shoal lies offshore in the eastern portion of the study area. This shoal is about 7 miles long, trends in an east-west direction, and has a water depth of 9 to 12 feet. Numerous oil rigs are positioned along the shoal.

Trinity Shoal is in the western section of the diffuser area about 20 miles south of the west end of Marsh Island (Figure G.1-2). Trinity Shoal along its major axis is about 20 miles and trends in a west-southwest and east-northeast direction; water depth ranges from 11 to 18 feet. The shoal is fairly steep on its south side where the 5- and 10-fathom curves are only about 5 miles apart. In calm weather, Trinity Shoal is discernable by high turbidity and in stormy weather by breaking seas, but because of its greater depth, waves do not break as heavily on Trinity Shoal as on Ship Shoal (U.S. Department of Commerce, 1977a). Strong tidal rips have been reported 15 miles southwest of Ship Shoal.

Tiger Shoal is located just south of Marsh Island, inshore of Trinity Shoal, and is bisected by the safety-fairway of Southwest Pass. Water depths on Tiger Shoal are generally less than 12 feet.

G.2.2.2 Sediments

G.2.2.2.1 Regional Stratigraphy

Recent nearshore sediments of central coastal Louisiana and adjacent to the diffuser sites consist of a thick blanket of terrigenous silt and clay (Uchupi and Emery, 1968). The continental shelf west of the Mississippi delta grades from sand inshore to silt and clay offshore. These sediments were derived from two sources: 1) a deltaic environment laid down by former Mississippi distributaries or 2) offshore sediments transported westward by littoral currents which formed cheniers (stranded beach ridges) behind a zone of newly developed mudflat marsh.

The Mississippi deltaic plain is a composite of various active and inactive deltaic complexes which stretch 180 miles across southeastern Louisiana, resulting from the migration of the main Mississippi River channel and its distributaries. Several cycles of sedimentation, marsh development, and beach ridge formation can be traced in the shallow subsurface of central and western Louisiana (Coleman and Smith, 1964).

The Quaternary stratigraphy of Atchafalaya Bay generally consists of three distinct deltaic complexes. About 40 feet of Maringouin-age prodeltaic clays form the base of the deltaic sequence. These sediments in turn are overlain by about 20 feet of the Bayou Salé lobe of the Teche deltaic complex. Near the top of this sequence is an ancient shell reef which is almost 5 miles wide (Frazier, 1967). Capping the Teche sediments are Lafourche-age deltaic deposits which increase in thickness from a few feet near the present shoreline to about 10 feet under Shell Reef off Point au Fer. Within this unit have been found two thin but extensive shell-mud layers.

Comparison of aerial photographs of the Atchafalaya Bay area taken in 1952 and 1968 shows a general shoreline retreat, however, accretion related to the growing delta has been noticed 60 miles to the west. Accretion is occuring because colloidal clays from the Atchafalaya River are carried into the Gulf, and flocculate out of suspension upon contact with saline waters, and settle to the bottom as a gelatinous mass (Thompson, 1951). During storms the clays are resuspended and transported further westward by the longshore drift and are subsequently redeposited. As more coarse-grained sediments are deposited in the lower Atchafalaya delta, the shoreline retreat should terminate and significant accretion will likely occur (Shlemon, 1972).

Bottom sediment samples collected at the Weeks Island site and at Chacahoula (Figure G.1-2 and Table G.2-6) show that the bottom sediments at the Chacahoula site are predominantly silty sands with little (10%) clay. Water depths at Chacahoula ranged between 19 and 46 feet. Sediments taken at the two Chacahoula stations (CR1, CR4) located farthest offshore and in deeper waters (46 and 35 feet, respectively) consisted mostly of sandy silts.

Bottom sediments at the Weeks Island site were much finer than those taken at Chacahoula and consisted predominantly of silt with high or nearly equal proportions of clay and sand (Table G.2-6). Water depths at Weeks Island were more uniform than at Chacahoula and varied

TABLE G.2-6a Particle size characteristics - Weeks Island site.

Station No.	Water Depth (feet)	Percent Sand (>0.06 mm)	Percent Silt (<0.06 mm, >0.002 mm)	Percent Clay (<0.002 mm)
W-1	23	73	18	9
W-2	22	19	43	38
W-3	18	16	49	35
W-4	18	23	55	22
W-5	18	31	56	13
W-6	18	18	62	20
W-7	18	23	57	20
W-8	15	22	58	20
W-9	13	31	30	39
W-10	18	23	54	23
W-11	17	25	48	27
W-12	17	18	60	22
W-13	18	14	59	27
W-14	20	14	54	32
W-15	19	24	53	23
WR-1	23	73	13	14
WR-3	15	6	33	61

TABLE G.2-6b Particle size characteristics - Chacahoula site.

Station No.	Water Depth (feet)	Percent Sand (>0.06 mm)	Percent Silt (<0.06 mm, >0.002 mm)	Percent Clay (<0.002 mm)
C-5	33	18	70	12
C-6	32	66	31	3
C-7	32	61	34	5
C-8	28	62	34	4
C-10	32	51	45	4
C-11	32	52	44	4
C-12	33	52	39	9
CR-1	46	24	64	12
CR-2	25	61	35	4
CR-3	19	63	34	3
CR-4	38	22	69	9

from 15 to 23 feet. The two Weeks Island sediment stations (W1 and WR1) located farthest offshore and in the deepest water (23 feet) were predominantly sand.

Differences in sediment characteristics between the two sites can be attributed to the transport of sediment by the Atchafalaya River through Atchafalaya Bay and the adjacent offshore area to the area of the diffuser. The coarsest fraction of the sediment load generally settles out of suspension and is deposited first nearshore, with progressively finer fractions being deposited further offshore. This distribution pattern is reflected in the sediment map prepared by Uchupi and Emery (1968). Some sediment is also distributed in the area from the reworking and resuspension of previously deposited deltaic sediments by the water currents or by storm waves.

The Weeks Island site lies in the path of fine-grained sediment transported westward from the Atchafalaya Delta. This sediment is being deposited to the west of Marsh Island. Divers have observed high turbidity in the water column at Weeks Island, and analysis of bottom sediments samples from this site indicated a high percentage of silt and clay.

Sediments in the vicinity of the Chacahoula diffuser site are predominantly sand, with a high proportion of silt but very little clay. Depth contours at the Chacahoula are evenly spaced, paralleling the coastline in a WNW-ESE direction and gently dipping to the SSW, which suggests the currents follow these contours. Because the predominant westward drift of the current along this section of the Louisiana coast is less affected by nearshore shoals, the current sweeps across the inner shelf with the clay-sized fraction in suspension but the sand-sized fraction remaining undisturbed.

G.2.2.3 Water Temperature and Salinity

G.2.2.3.1 Regional

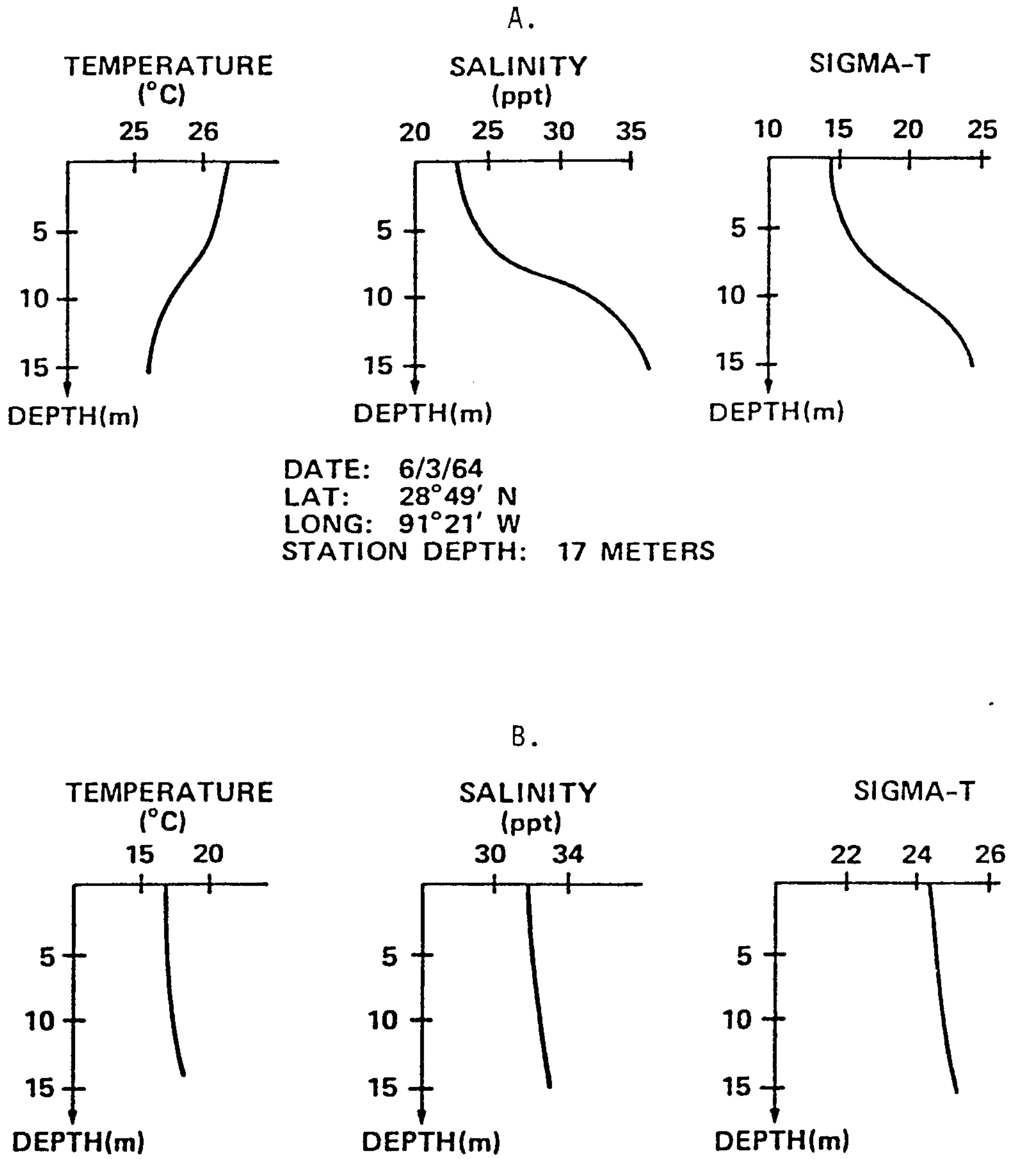
Coastal Louisiana salinity distributions are mainly influenced by the freshwater inflow from the Mississippi and Atchafalaya Rivers (Gagliano et al., 1970b; Nowlin and McLellan, 1967). Geyer (1950) reported that salinity within 5 to 6 miles of the Louisiana coast can vary from 15 to 35 ppt as a result of variations in the seasonal discharges of the Mississippi and Atchafalaya Rivers.

In the region of the proposed diffuser site, during the summer (Figure G.2-3a), typical salinities increase from a surface value of 23 ppt to slightly over 36 ppt in the upper 50 feet with a strong halocline at 23 to 26 feet. Temperatures are nearly isothermal, ranging from 77 to 79°F. The density (sigma-t) profile indicates strong stratification with a pycnocline at 23 to 26 feet. The typical winter profile (Figure G.2-3b) shows cooler temperatures (61 to 66°F) and nearly isohaline conditions; salinities range from 32 ppt at the surface to 34 ppt at 49 feet. Similarly the density (sigma-t) shows virtually no stratification (U.S. Department of Commerce, 1977a).

Summer and winter vertical cross sections of coastal Louisiana (Figures G.2-4 and G.2-5) show that during both seasons, fresher, less dense water, probably from the Mississippi River system, appears at the surface. The stong vertical density gradient during the summer would tend to inhibit vertical salt diffusion while the strong horizontal stratification would lead to a strong westerly baroclinic current that would enhance advection. The reduction of horizontal and vertical density gradients during the winter would tend to enhance vertical diffusion and inhibit advection.

G.2.2.3.2 Diffuser Vicinities

Bottom and surface water temperatures measured at both sites during September and December 1977 showed nearly isothermal conditions but temperatures progressively decreasing during the winter months. Average monthly surface water temperature (Table G.2-7) at Weeks Island ranged from 81.1°F (27.3°C) in September to 54.9°F (12.7°C) in December. Bottom water temperature closely parallelled surface water temperatures and ranged from 80.8°F (27.1°C) in September to 57.6°F (14.2°C) in December. The average water temperatures at Chacahoula were slightly warmer than those at Weeks Island and ranged from 82.8°F (28.2°C) in September to 63.5°F (17.5°C) in December at the surface and from 82.0°F (27.8°C) to 63.3°F (17.4°C) at the bottom.

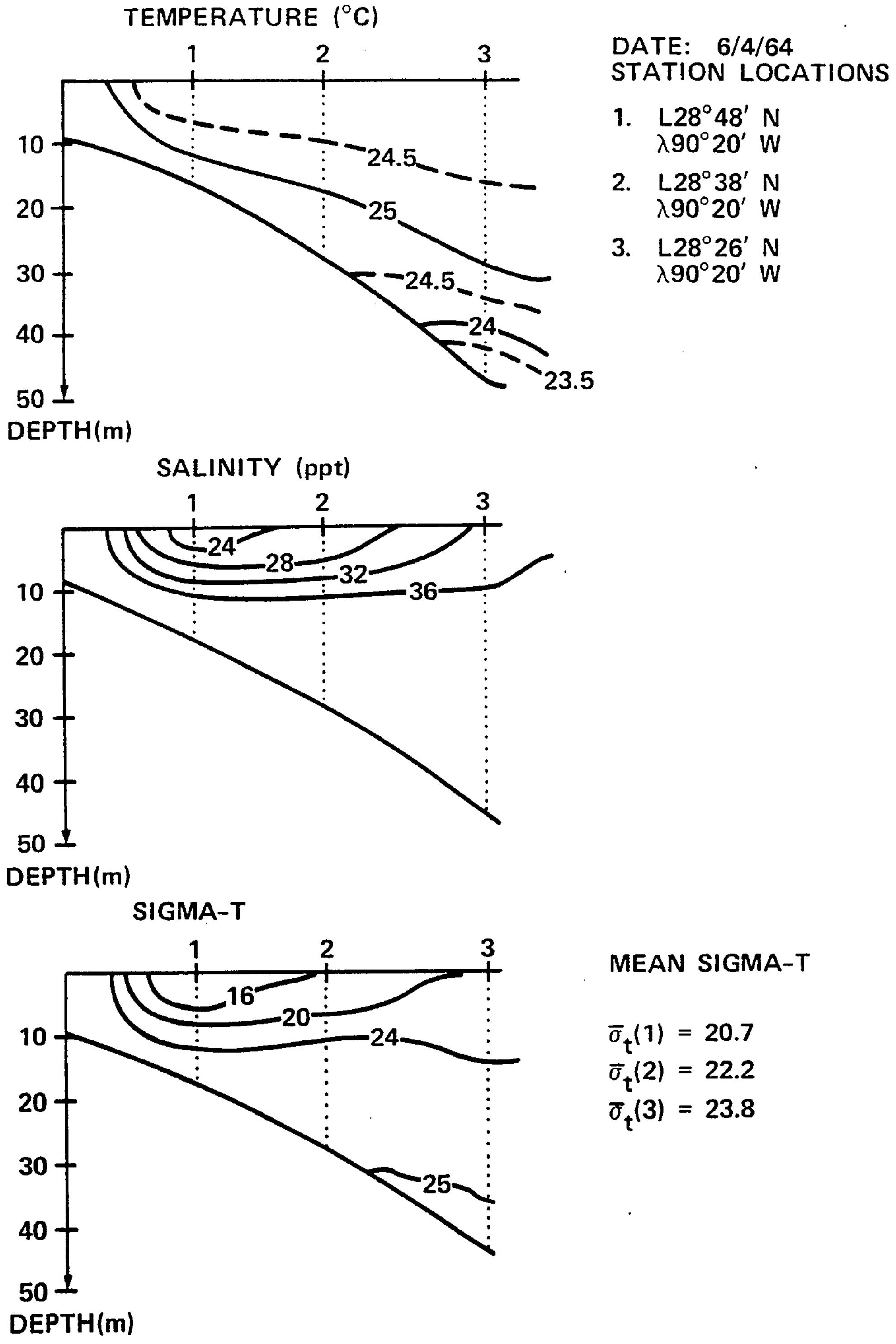


DATE: 6/3/64
LAT: 28°49′ N
LONG: 91°21′ W
STATION DEPTH: 17 METERS

DATE: 12/13/69
LAT: 28°43′ N
LONG: 91°18′ W
STATION DEPTH: 17 METERS

SOURCE: U.S. Dept. of Commerce, 1977a.

FIGURE G.2-3. Typical hydrographic profiles in the coastal Louisiana Gulf of Mexico: (A) summer, (B) winter.



DATE: 6/4/64
STATION LOCATIONS

1. L28°48′ N
   λ90°20′ W
2. L28°38′ N
   λ90°20′ W
3. L28°26′ N
   λ90°20′ W

MEAN SIGMA-T

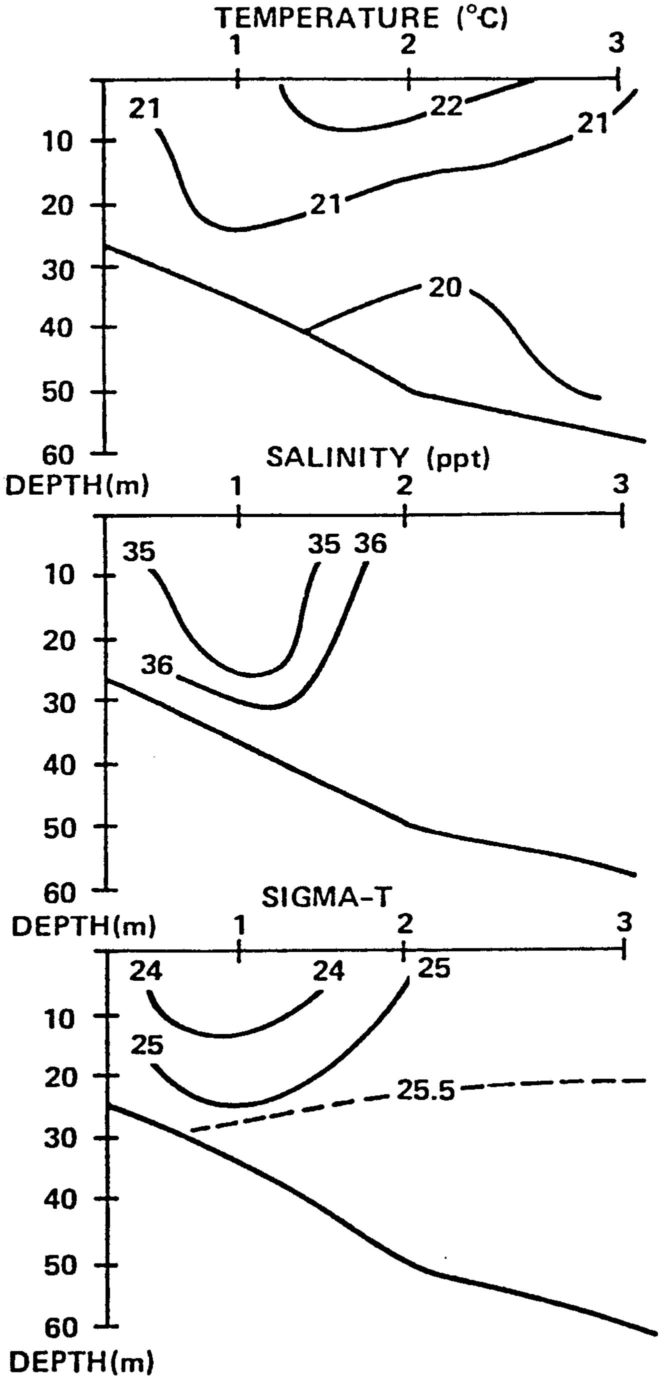
$\bar{\sigma}_t(1) = 20.7$

$\bar{\sigma}_t(2) = 22.2$

$\bar{\sigma}_t(3) = 23.8$

SOURCE: U.S. Dept. of Commerce, 1977a.

FIGURE G.2-4. Summer vertical cross-sectional observations of temperature, salinity, and density in the coastal Louisiana Gulf of Mexico.



DATE: 3/29/35

STATION LOCATIONS

1. L28°45′ N
   λ92°17′ W
2. L28°32′ N
   λ92°15′ W
3. L28°18′ N
   λ92°14′ W

MEAN SIGMA-T

$\bar{\sigma}_t(1) = 24.35$

$\bar{\sigma}_t(2) = 25.34$

$\bar{\sigma}_t(3) = 25.37$

SOURCE: U.S. Dept. of Commerce, 1977a.

FIGURE G.2-5. Winter vertical cross-sectional observations of temperature, salinity, and density in the coastal Louisiana Gulf of Mexico.

TABLE G.2-7 Monthly temperature and salinity averages for the Weeks Island and Chacahoula sites.

	WEEKS ISLAND		CHACAHOULA	
Temperature (°C)	Surface	Bottom	Surface	Bottom
September	27.3	27.1	28.2	27.8
October	20.3	21.5	21.6	21.1
November	17.4	17.3	--	--
December	12.7	14.2	17.5	17.4
Salinity (ppt)				
September	--	--	--	--
October	15.7	21.9	27.8	28.3
November	26.2	27.1	--	--
December	--	--	--	--

Between September and December 1977, the increase in salinity values measured at the Weeks Island site reflects the decrease in surface runoff from the Atchafalaya and Mississippi Rivers. In October a distinct halocline occurred between the surface and bottom, but this halocline dissipated by November; at the Chacahoula site nearly isohaline conditions occurred during October.

G.2.2.4 Waves and Tides

Waves experienced in the area are a combination of local wind-generated waves and swell entering from open water. Wave direction generally corresponds to wind direction and changes according to the season of the year. Between March and August, waves travel in a northwesterly direction, while in the fall and winter the waves shift more to the west. When strong northers are present, the waves can travel offshore. Wave heights range from 0 to 20 feet, with the smallest waves occurring in the summer. Data obtained at drilling platforms 15 miles offshore from Atchafalaya Bay indicate that 95 percent of the time, waves do not exceed 4 feet (Horrer, 1951).

Significant wave heights measured at Sabine Pass, Texas and at Bayou Lafourche, Louisiana (U.S. Department of Commerce, 1972) have been used to estimate wave expectations for the diffuser sites. Significant wave heights (average of the highest one-third) are similar in both areas and are closely related to wind speed. On the average, a significant wave height of 42-43 feet will occur in deep water once every 50 years and a height of 30-31 feet will occur every 5 years. During a storm, individual waves may be much greater than the significant wave height.

Tide records measured at the two diffuser sites indicate that the area has a mixed tide, that is, successive high and low levels are different. The ranges of tides at the Chacahoula site varied from 0.1 feet to 2.7 feet for the period October 14 to November 1, 1977. Tide records at the Weeks Island site indicated a range from 0.1 feet to 3.6 feet and averaged 1.6 feet for the period October 13 to November 16, 1977.

G.2.2.5 Currents

G.2.2.5.1 Regional Historical Data

Current patterns within the area of the brine diffusers would be the most significant factor in determining dispersal of brine. The driving forces of wind stress, local runoff, and density stratification combine to shape the behavior of nearshore waters along the Louisiana coast. Wave-driven currents predominate in controlling nearshore circulation and beach drift, while density gradients and vertical mixing of brackish and fresh waters will assume important roles at tidal passes and estuaries.

Gulf surface currents in the central Louisiana region have a westerly net annual flow paralleling the shore, with speeds averaging from 0.2 to 0.4 knots. Shallow water, wind driven currents and barotropic slope currents, both which parallel isobaths, contribute to the generally westward current (U.S. Department of Commerce, 1977a). Currents vary seasonally, controlled by regional wind conditions. An easterly surface flow (0.4 knots) has been found in the summer and a westerly surface flow (0.82) has been found to persist during the winter and spring. Bottom currents were onshore and easterly during the summer and westerly, onshore and offshore, respectively, during the winter and early spring (Oetking, 1974b).

Superimposed on the above currents is a rotary tidal current which seldom exceeds 0.3 knots. Generally the tide heights in nearshore central Louisiana Gulf ranges from 1.5 to 2.0 feet and the tide wave moves from west to east. When the moon is at its maximum declination, the tide is diurnal and of greatest range. When the moon is over the equator, the tidal range is lowest and several days of semidiurnal tides may occur (U.S. Department of Commerce, 1977a).

G.2.2.5.2 Observed Currents

A speed histogram and directional plot from *in situ* current measurements in October (Figures G.2-6 and G.2-7) show that bottom currents consistently had somewhat lower speeds than the near-surface currents. This difference suggested that a vertical shear exists between the

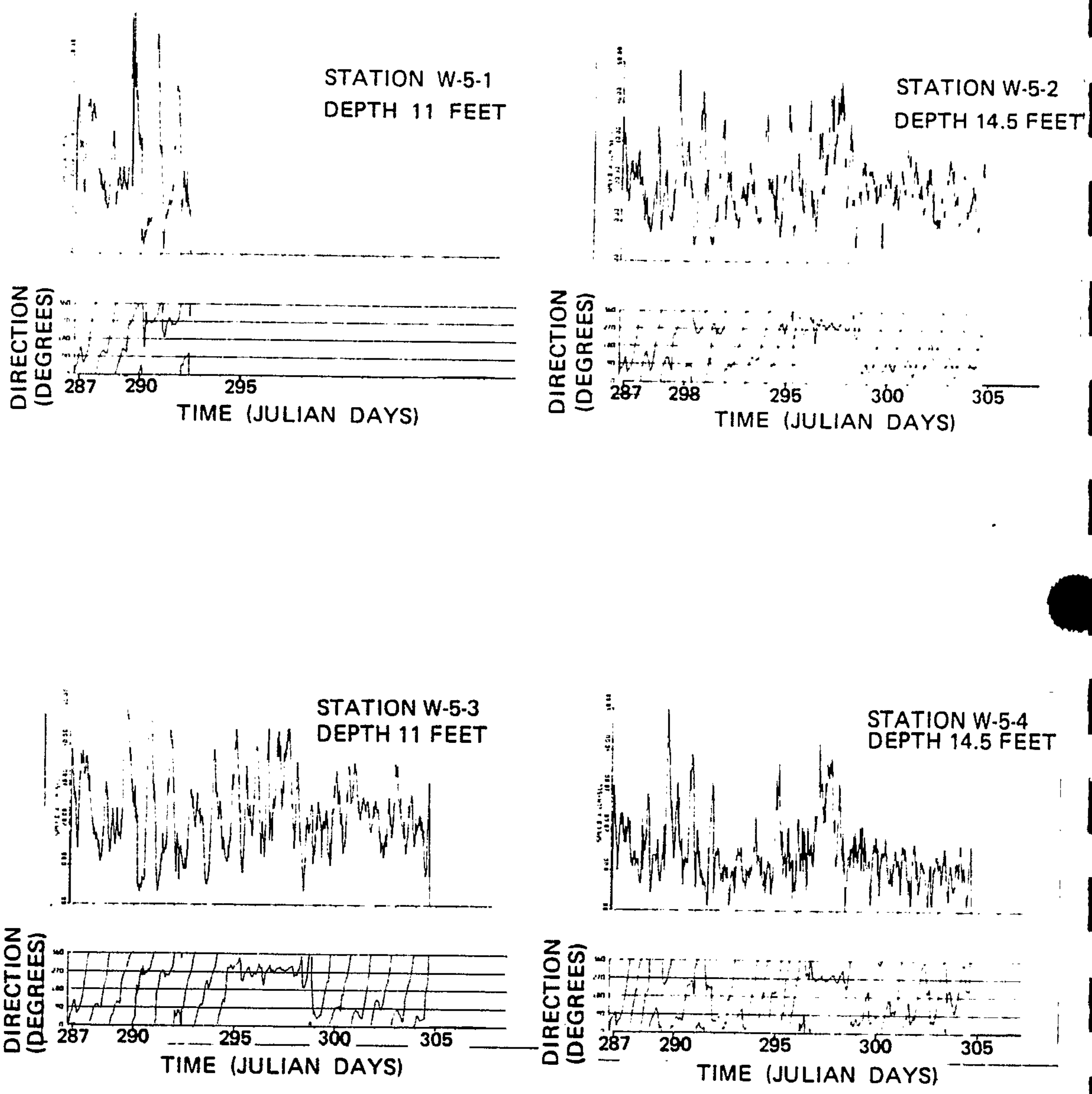


FIGURE G.2-6. Speed histograms and directional plots of currents measured a the proposed Weeks Island site, October 13-31, 1977.

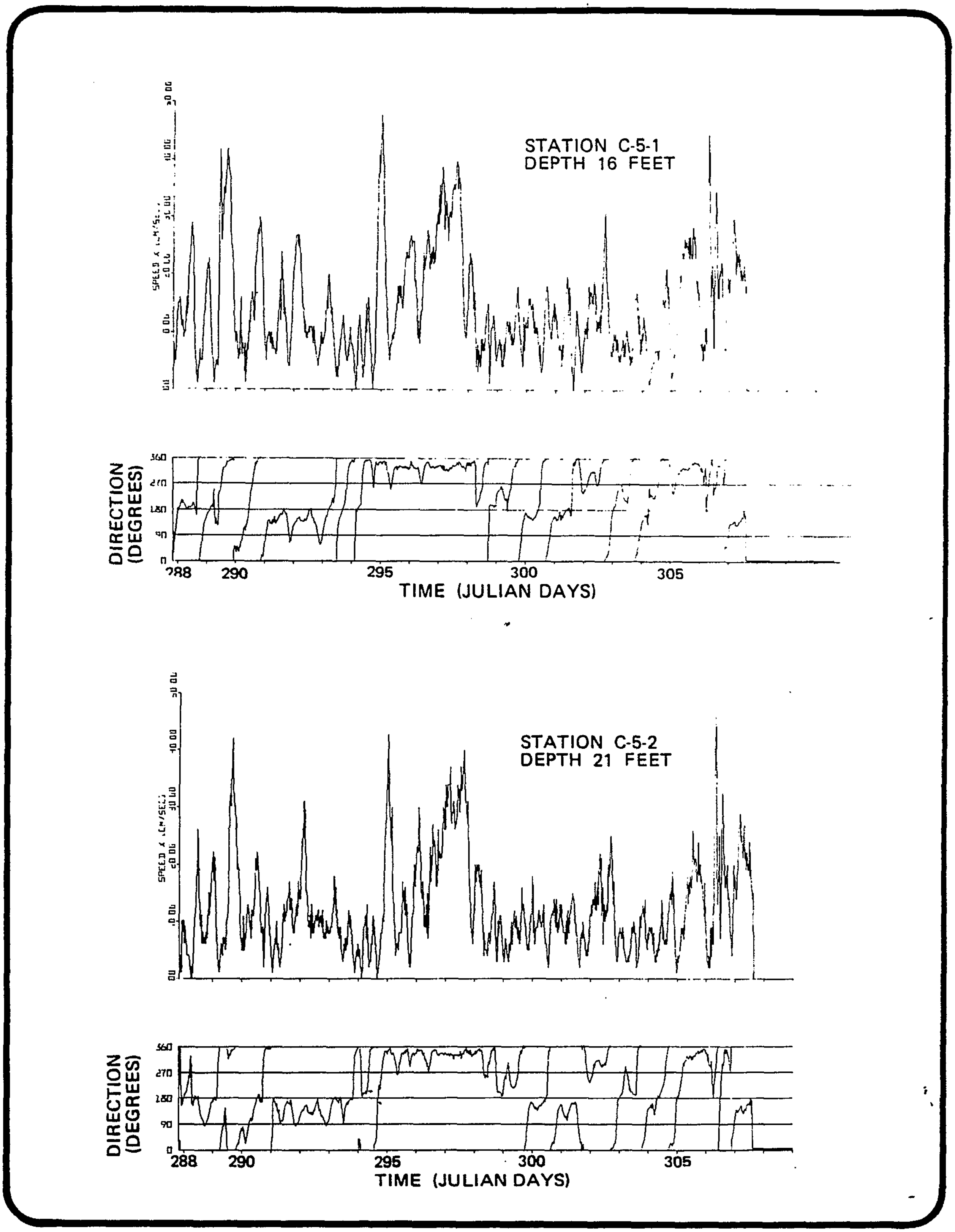


FIGURE G.2-7. Speed histograms and directional plots of currents measured at the proposed Chacahoula site, October 14 to November 3, 1977.

surface and bottom waters. Generally, current speeds ranged from 0-50 cm/sec, but most commonly they ranged between 0-30 cm/sec. A rotary tidal effect was apparent throughout most of the record but was most strongly reflected in the upper currents. In addition, a strong northwesterly current was measured from October 21 to 24 (Julian calendar days 294-297).

Wind and wave data collected from an offshore platform (Table G.2-8) shows easterly and southeasterly winds ranging from 5-45 knots during this time interval. Wave heights ranged from 4-6 feet and corresponded to the direction of the wind.

Analysis shows that the current speeds in December-January (Figure G.2-8) ranged from a maximum of 83 cm/sec to a minimum of 2 cm/sec and were slightly higher than those found during the October interval.

A rotary current was noted during the first 4½ days of the study. The easterly-southeasterly flow during the next 2 days (Julian days 354-356) corresponds to the period of maximum current speeds Winds during this interval (Table G.2-9) generally were from the northwest at speeds ranging from 5-55 knots. An 8-day period (Julian days 357-364) of predominantly northward flow, for which there is only partial meteorological data, was followed by a slightly irregular but tidal-dominated flow pattern for the remainder of the current record (Julian days 365-07).

G.2.2.5.2.1 Alongshore-Onshore Velocity Scatter Diagrams

Scatter plots developed to present half-hourly alongshore-onshore velocities (Figures G.2-9, G.2-10, and G.2-11) can be visually assigned an approximate principal axis corresponding to the mean direction of current flow. The extent of scatter in the diagrams between measurements at the same depth represents differences in speed, and the existence of a "hole" around the zero speed point may indicate high measured speeds at low flow conditions, that is, high starting speeds or wave-induced contamination in the measurements (Beardsley et al, 1977). Likewise, the presence of a band without any speed and direction measurements

TABLE G.2-8 Offshore wind and wave data collected at East Cameron Block No. 328, October 20-25, 1977.

		Wind		Waves		
Date	Time	Speed (Knots)	Direction	Height	Direction	Period
October 20, 1977 (Julian Day 293)	0000	0	E	0	E	
	0400	10	E	1	E	4.3
	0800	15	E	1	E	4.3
	1200	15	SE	1	SE	4.5
	1600	20	SE	1	SE	4.7
	2000	25	SE	1	SE	4.4
October 21, 1977 (Julian day 294)	0000	27	E	1	E	4.7
	0400	27	E	1	E	4.7
	0800	25	E	3	E	4.2
	1200	25	E	3	E	4.6
	1600	33	SE	4	SE	5.4
	2000	33	SE	4	SE	5.7
October 22, 1977 (Julian day 295)	0000	30	E	6	E	3.8
	0400	23	E	6	E	5.5
	0800	23	E	5	E	4.7
	1200	27	SE	5	SE	5.0
	1600	15	SE	6	SE	5.6
	2000	15	SE	6	SE	6.1
October 23, 1977 (Julian day 296)	0000	30-35	E-SE	5	ESE	5.0
	0400	43	SE	5	SE	4.5
	0800	40	SE	9	SE	4.6
	1200	13	SE	9	SE	6.0
	1600	13	SE	10	SE	6.0
	2000	13	SE	8	SE	6.1
October 24, 1977 (Julian day 297)	0000	20-25	E	6	E	4.1
	0400	20	E-SE	7	ESE	3.8
	0800	5-10	E	12	E	3.9
	1200	5-10	SE	8	SE	3.1
	1600	5-10	N-NE	7	NNE	4.8
	2000	5-10	N	6	N	6.0
October 25, 1977 (Julian day 298)	0000	5	N	NO DATA	NO DATA	NO DATA
	0400	5	N	NO DATA	NO DATA	NO DATA
	0800	5	NE	NO DATA	NO DATA	NO DATA
	1200	5	N	NO DATA	NO DATA	NO DATA
	1600	5	N	NO DATA	NO DATA	NO DATA
	2000	5	NW	NO DATA	NO DATA	NO DATA

Source: Transworld Drilling Co., 1977.

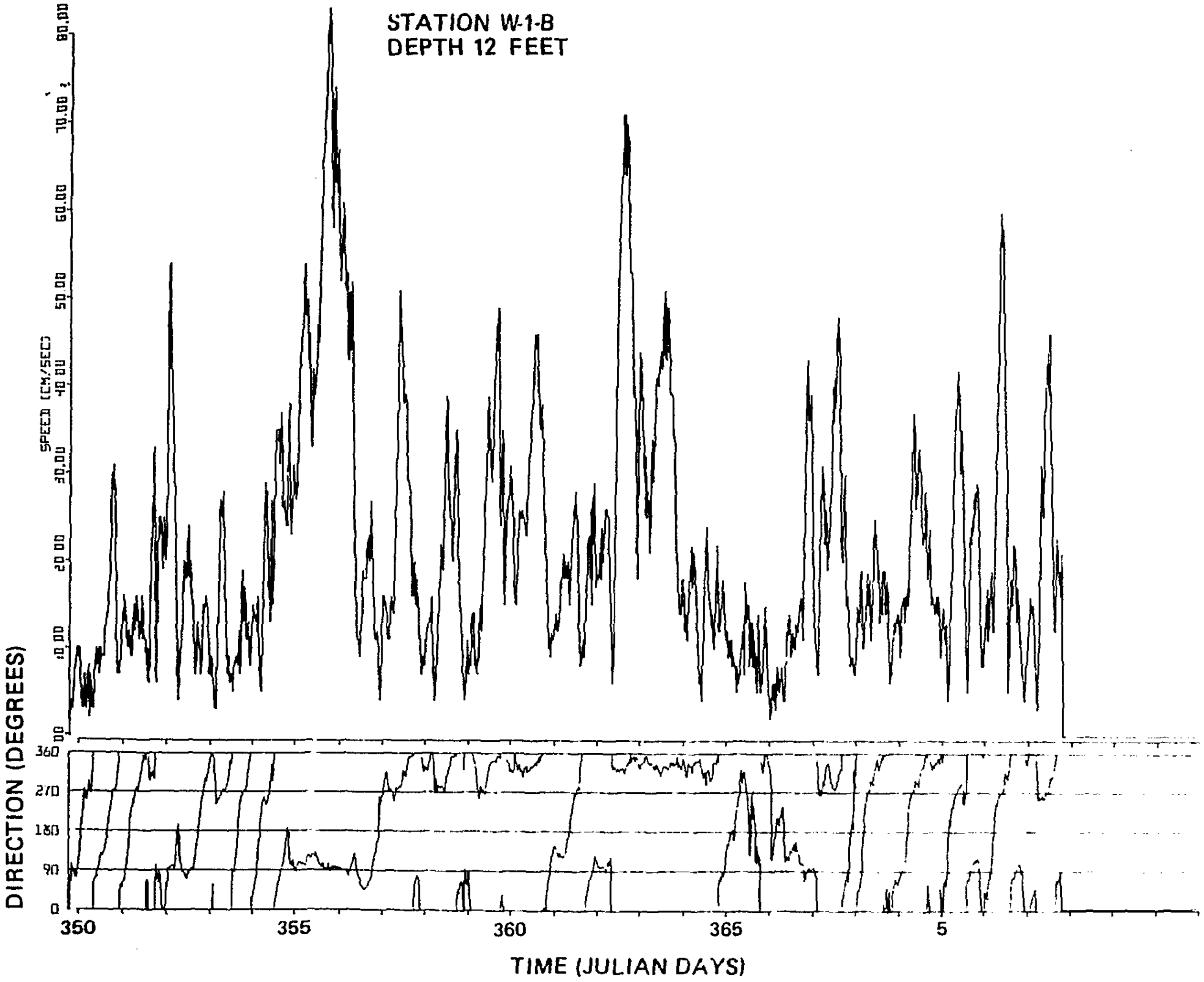


FIGURE G.2-8. Speed histogram and directional plot of currents measured at the proposed Weeks Island site, December 15, 1977 to January [illegible] 1978.

TABLE G.2-9 Offshore wind and wave data collected at Eugene Island Block No. 361, December 20-25, 1977.

Date	Time	Wind Speed (Knots)	Wind Direction	Waves Height	Waves Direction	Waves Period
December 20, 1977 (Julian day 354)	0000	15-19	SSW	5	SSW	
	0400	24-30	SSE	5-7	SSE	
	0800	30-35	N.	7-9	N	
	1200	35-40	N	10-11	N	
	1600	40-44	N	13-15	N	
	2000	40-44	N	15-16	N	
December 21, 1977 (Julian day 355)	0000	44-50	NNW	16-17	NNW	
	0400	40-45	NW	16-19	NW	
	0800	40-45	NW	18-19	NW	
	1200	40-44	NW	20	NW	
	1600	48-55	NW	18	NW	
	2000	46-50	NW	19	NW	
December 22, 1977 (Julian day 356)	0000	26-32	NW	10	NW	
	0400	16-22	N	6	N	
	0800	15-20	NE	5	NE	
	1200	4-10	S	6	S	
	1600	4-10	SE	6	SE	
	2000	16-18	S	6	S	
December 23, 1977 (Julian day 357)	0000	30	S	6	S	5.8
	0400	30-35	SW	9	SW	6.0
	0800	33-35	SW	9	SW	5.5
	1200	30	SW	8	SW	6.3
	1600	30	SE	7	SE	6.0
	2000	30	SE	7	SE	5.8
December 24, 1977 (Julian day 358)	0000	30-35	SE	7	SE	5.0
	0400	30	S	9	S	5.5
	0800	30	S	8	S	5.7
	1200	28-30	S	8	S	6.0
	1600	30-40	SE	9.5	SE	5.7
	2000	30-35	SE	9.5	SE	6.1
December 25, 1977 (Julian day 359)	0000	14-22	SW	8-11	SW	5.1
	0400	28-30	W	9-11	W	5.3
	0800	18-22	N	7	N	5.6
	1200	21	NW	8	NW	6.2
	1600	30	NW	8	NW	6.9
	2000	38-42	NW	8-10	NW	7.3

TABLE G.2-9 continued.

Date	Time	Wind		Waves		
		Speed (Knots)	Direction	Height	Direction	Period
December 26, 1977	0000	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	0400	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	0800	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	1200	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	1600	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	2000	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
December , 1977	0000	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	0400	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	0800	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	1200	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	1600	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
	2000	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA

Source: Transworld Drilling Co., 1977.

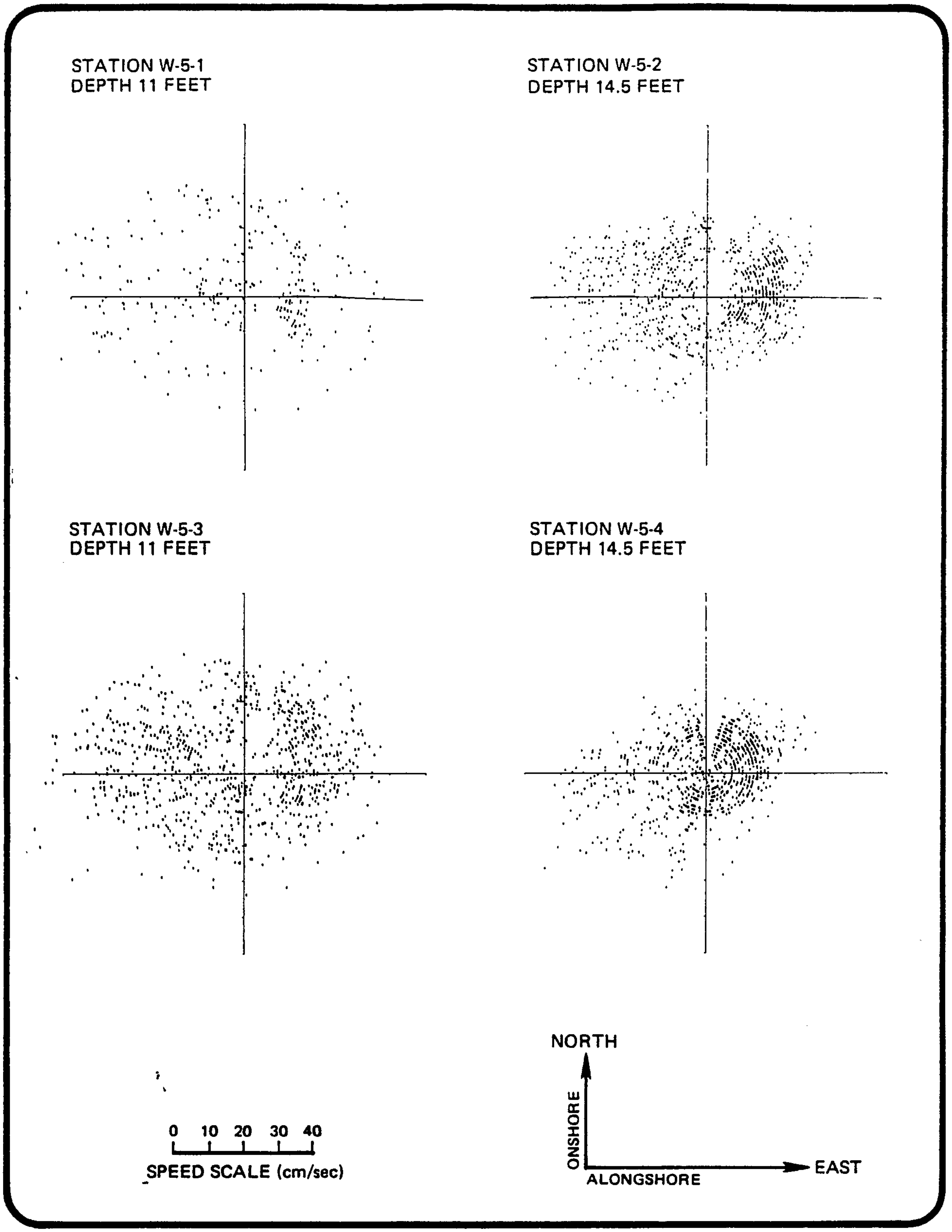


FIGURE G.2-9. Velocity scatter plot, proposed Weeks Island site, October 13 to 31, 1977.

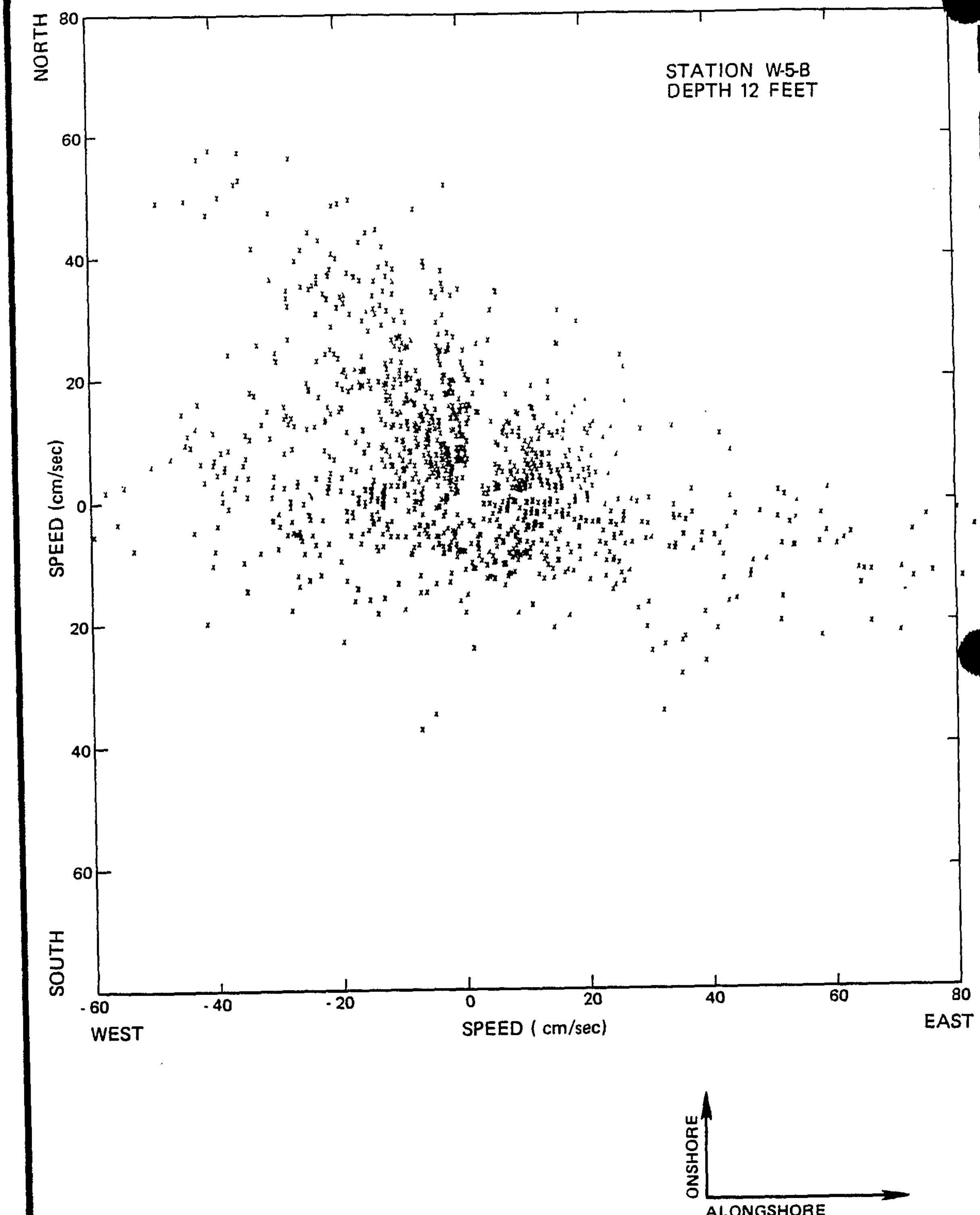


FIGURE G.2-10. Velocity scatter plot, proposed Weeks Island site, December 1
1977 to January 7, 1978.

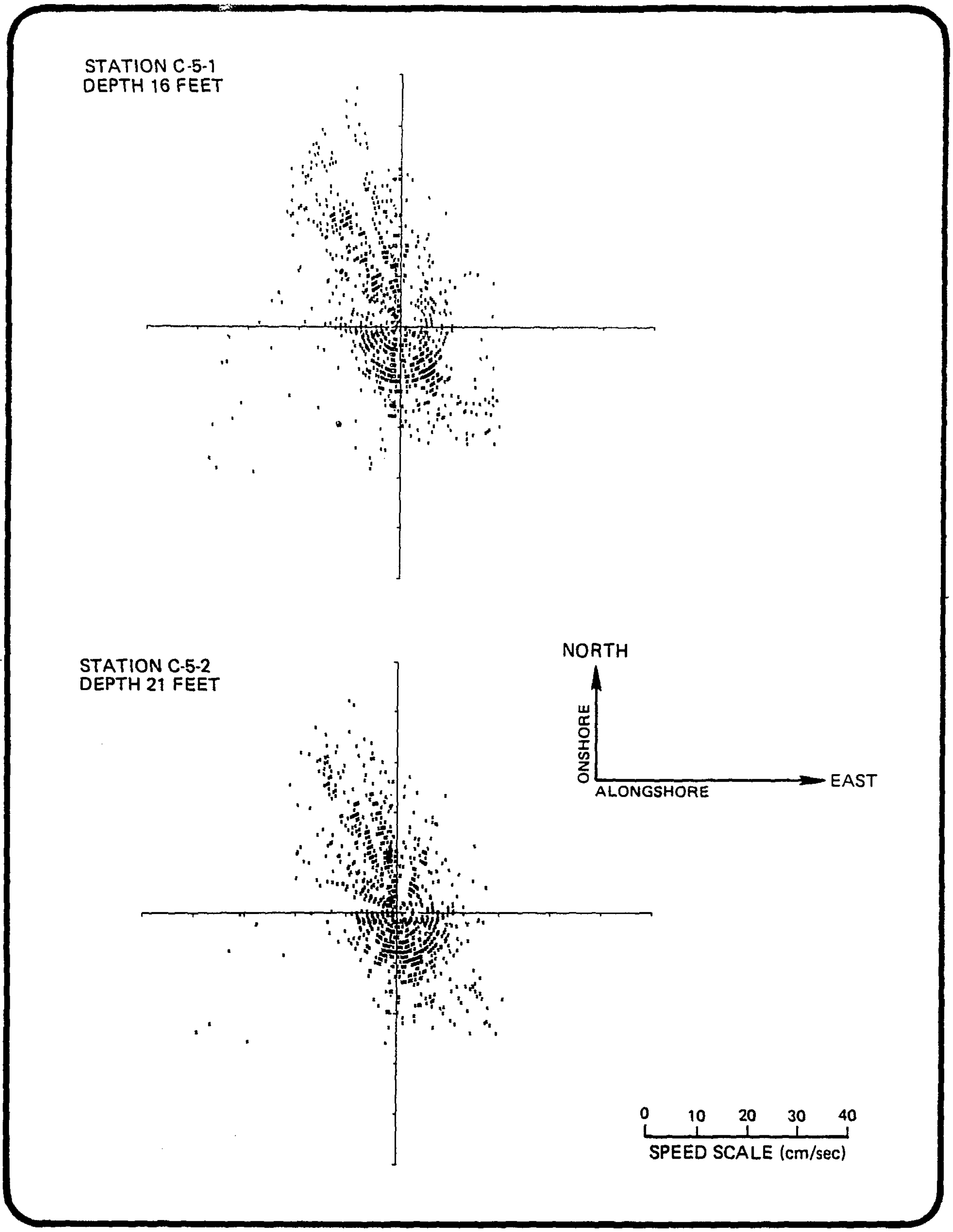


FIGURE G.2-11. Velocity scatter plot, proposed Chacahoula site, October 14 to November 3, 1977.

could indicate a directional malfunction. These differences will affect the orientation angle of the principal axis but may not be the only influencing factor.

Weeks Island

In a comparison of replicate current velocities for October (Figure G.2-9), measured at 11 feet (Stations W-5-1 and W-5-3) at Weeks Island, the broad ellipse plotted for the two meters shows that the measurements are similar. Meter W-5-3 exhibits a vague low-speed hole, but there are insufficient data to ascertain if this pattern is duplicated in meter W-5-1. Both diagrams show close agreement with regard to the orientation of the principal axis, which lies in an east-west direction.

Current velocities measured at 14.5 feet (Stations W-5-2 and W-5-4) during October exhibit a broad ellipse with a distinct low speed hole appearing at Station W-5-2. Overall there is less scatter for this depth than at 11 feet, possibly due to the decreased effect of changing wind direction and tides at these deeper levels. However, the most prominent difference in the behavior between these two stations is the mean direction of current flow as shown by the variation in the orientation of the principal axis (Figure G.2-9). The principal axis at Station W-5-2 lies in an east-west direction, whereas that of Station W-5-4 lies NE-SW. It is believed that this variation could be caused by a nonhomogeneous flow field at the site.

Comparison of velocities at each array show that for the first array (Stations W-5-1 and W-5-2) there is a wider scatter in the plot at the surface. However, the principal axes arrays are nearly identical and lie in an east-west direction.

In a comparison of stations the broader ellipse at the upper water level is much more evident. The difference in the orientation of the principal axes may be due to nonhomogemeity in the water column, possibl induced by vertical shear stresses causing a two-layered flow system.

The ellipse for the December-January data (Figure G.2-10) is more irregular and broadens in the westerly and northwesterly direction. The predominant principal axis appears to be in an east-west direction, although there also seems to be a spur axis which lies in a northwest-southeast direction. Here, a higher percentage of flow with a northward (onshore) component is apparent. There also appears to be a slight instrument malfunction in directional sensitivity. There are two holes at 18^{o} and 34.6^{o}.

When compared with the October data, the December-January currents show less coherence (i.e. greater scatter) particularly in the onshore direction. The orientation of the principal axis, however, is in an east-west direction.

Chacahoula

Comparison of current velocities measured at Chacahoula in 16 and 21 feet of water (October-November) indicates that the behavior of the currents at these two depths is similar (Figure G.2-11). The scatter density at 21 feet is more concentrated at the low-speed ranges, probably due to a more coherent flow. The orientation of the principal axes for the mean direction of current flow are identical and trend NNW-SSE.

G.2.2.5.2.2 Mean Currents

Current measurements were filtered using a 49-point running average and the data developed (Figures G.2-12, G.2-13 and G.2-14) present an average velocity vector for every 6 hours.

Weeks Island

Average current velocities measured at Weeks Island in October ranged from less than 5 cm/sec to approximately 33 cm/sec. These currents showed a variable flow direction, except for the period of October 21 to 24 (Julian days 294-297) when there was a pronounced northwestward drift (Figure G.2-12).

Minor directional differences occurred between the currents measured at the 14.5 foot depth, but a large difference occurred between the 11 and 14.5 foot depths at Array No. 2 (Stations W-5-3 and W-5-4, respectively), especially on Julian days 294 and 303. At that time current direction differed by as much as 180^{o}, suggesting that a two-layered flow system was operating at the Weeks Island diffuser site.

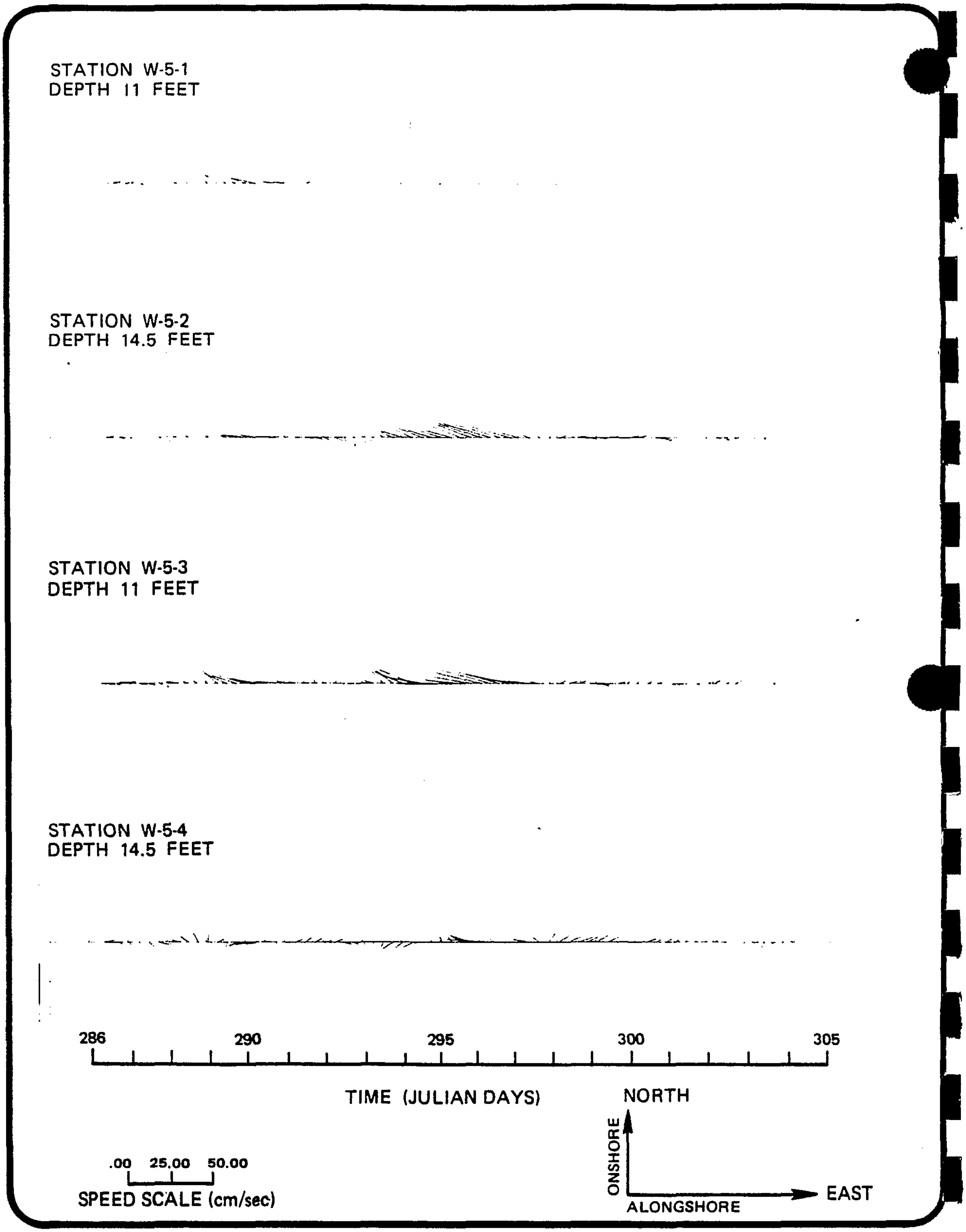


FIGURE G.2-12. Averaged velocity stick diagram, proposed Weeks Island site, October 13 to 31, 1977.

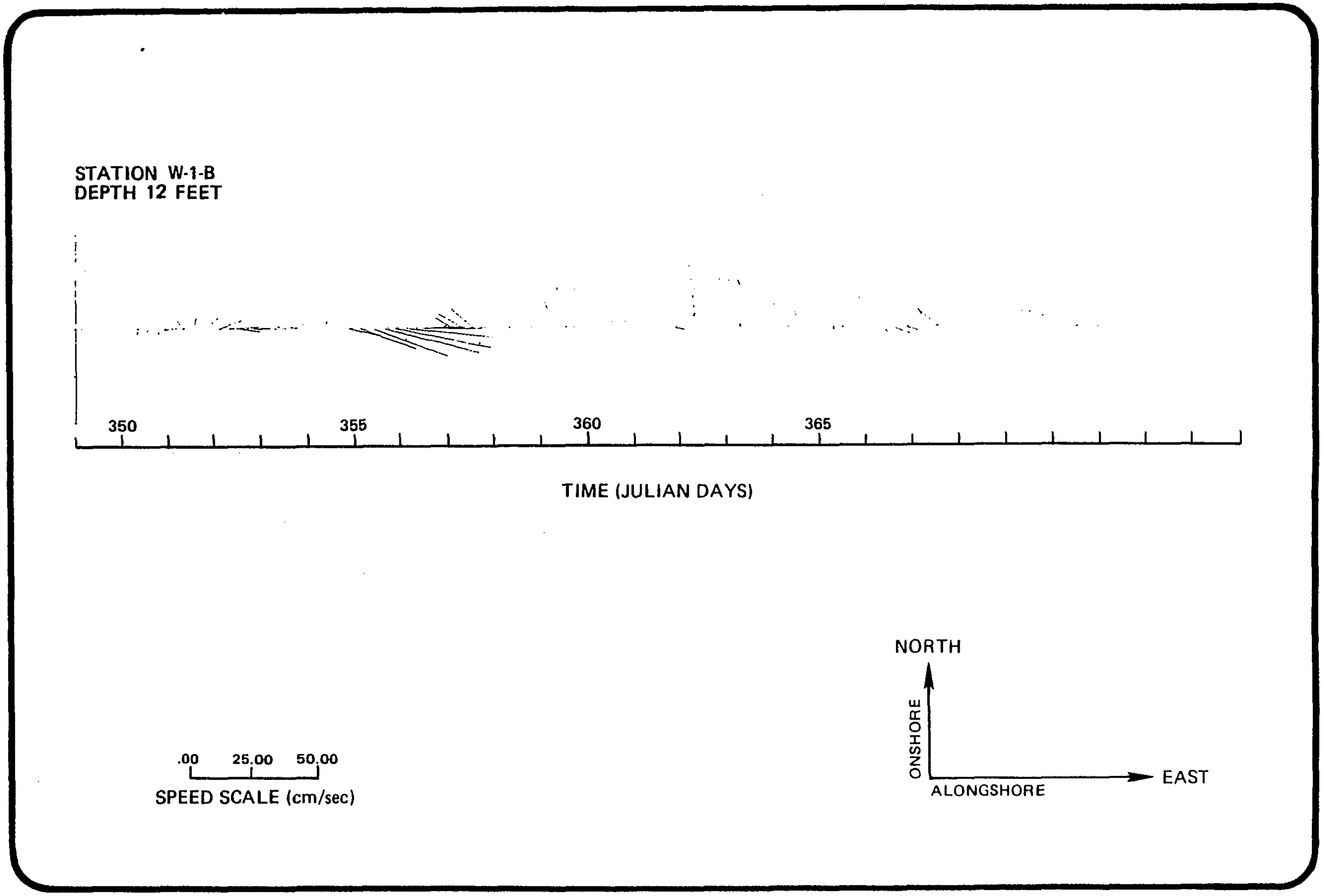
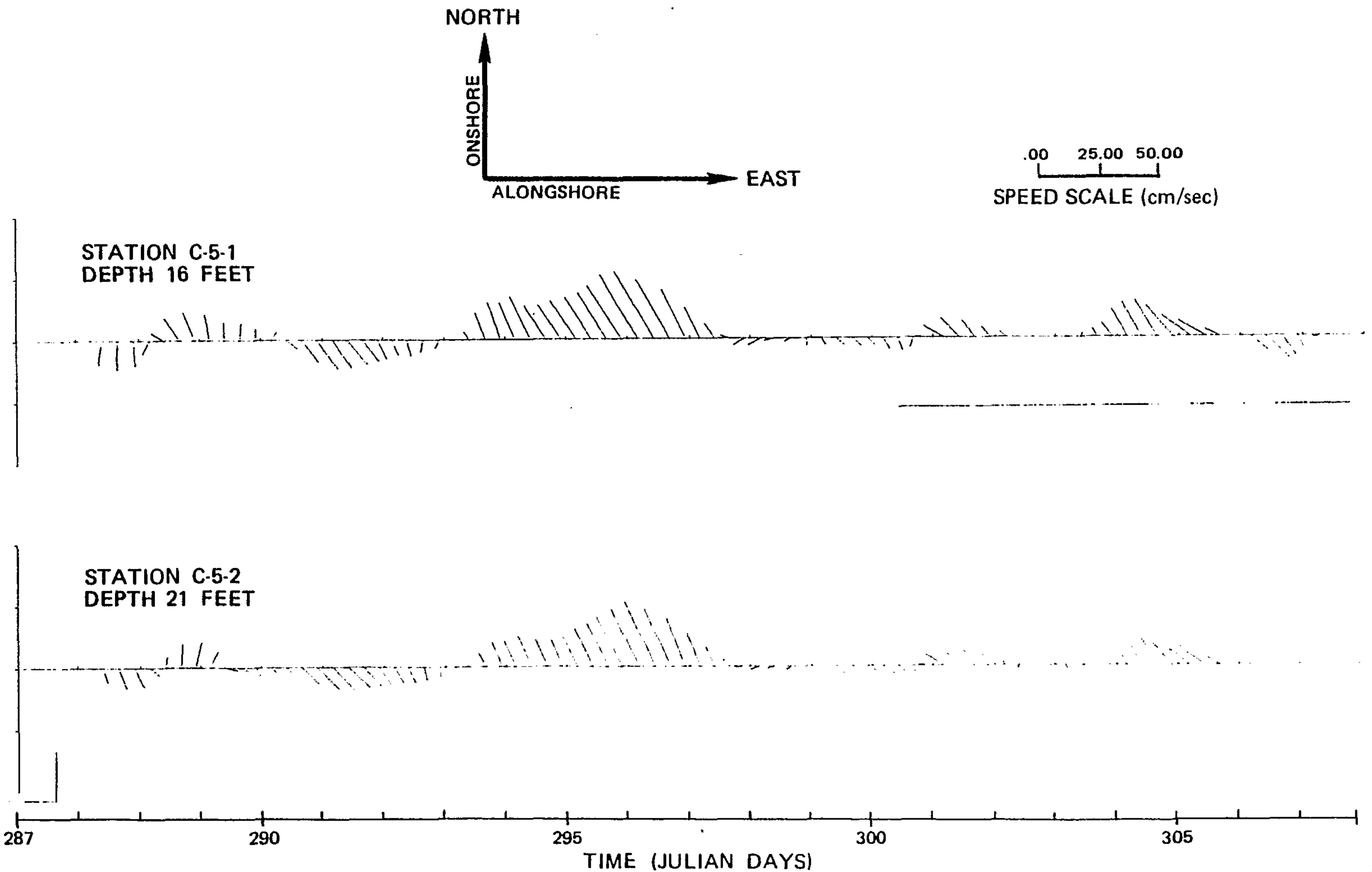


FIGURE G.2-13. Averaged velocity stick diagram, proposed Weeks Island site, December 15, 1977 to January 7, 1978.



[illegible]IGURE G.2-14. Averaged velocity stick diagram, [illegible]posed Chacahoula site, October 14 to November 3, [illegible]7.

Average current velocities at Weeks Island in December to January ranged from less than 5 cm/sec to approximately 53 cm/sec. The peak velocities are clearly reflected during the period for Julian days 354 to 356, when a strong easterly-southeasterly flow was present. The dominant direction of flow for this period, however, was to the north-northwest (Figure G.2-13).

Chacahoula

Average current velocities measured in October to November at the Chacahoula diffuser site ranged from less than 5 cm/sec to 32 cm/sec; onshore flow velocities tended to exceed offshore flow velocities (Figure G.2-14). Both meters showed close agreement in average current vector, which suggests that there is little two-layered flow at the Chacahoula site.

G.2.2.5.2.3 Progressive Vector Diagrams

Progressive vector diagrams (PVDs) were constructed by integrating in time each half-hourly current velocity vector. PVDs best represent the mean direction of current. When a drift current is absent, tidal forces become a predominant factor, and a diagram will show a flow pattern consisting of a series of overlapping loops, which indicate a condition of little or no net current displacement. As the strength of the drift current increases, the loops separate and will disappear entirely if the current drift velocity reaches a threshold value and prevents a tidal reversal.

A summary of the net current displacement and virtual direction for each station measured is presented in Table G.2-10. The virtual current direction is the heading of a line connecting the beginning point on the diagram to the end point. The net displacement is the length of this line.

Weeks Island

The large discrepancy in the net displacement of the two meters at 11 feet measured during October is due to the limited operational time of meter W-5-1. The drift during the first 6 days, however, is nearly

TABLE G.2-10 Progressive vector summary.

Meter	Depth (ft)	Virtual Direction	Net Displacement (km)	Period of Record (days)
W-5-1	11	311	19	18
W-5-2	14.5	305	19.5	18
W-5-3	11	315	70	18
W-5-4	14.5	322	14	18
C-5-1	16	319	70	20
C-5-2	21	339	43	20
WIB	12	353	118.5	23

identical. Both meters show a consistent net displacement to the northwest (Figure G.2-15). The two meters at 14.5 feet show a net displacement of 19.5 and 14 km, but with a variation in direction from 305° to 322°, respectively.

When the data from the meters in each array are examined, less directional variation in the currents is apparent. In one case the directional uniformity throughout the water column at each array suggests that the currents at the sites are driven by a common mechanism, whereas differences between each array could be induced by local topography or a nonhomogeneous flow field. The PVDs developed for the second current meter array illustrate that a tide-dominated circulation pattern occurred in the area between October 13 to October 23 (Julian days 286 to 296). Tidal affect on the bottom waters lagged a day to two behind its affect on the surface waters. During the next 2 to 4 days a pronounced northwest drift occurred, which was followed by an easterly drift during the last 6 days of this period (Julian days 302-307).

The PVD developed for December and January showed a shift in net drift from the northwest quadrant to north quadrant (onshore) (Figure G.2-16). At the beginning of the record, a period of tidal-dominated circulation (little net drift) was present; this flow was followed by 2½ days of strong eastward drift (Julian days 354-364). During the next 8 days (Julian days 357-364) a strong, nearly continuous northward drift occurred. A rotary tidal flow was superimposed on a net northwestward current drift in the last part of the study period.

Chacahoula

The two PVDs developed for the Chacahoula diffuser site for the October-November period clearly show a northwesterly current drift but with a greater net displacement for the 16 foot depth than for that measured at 21 feet (Figure G.2-17). The directional current patterns were consistent for both depths. After the first week of the study the reversing northerly-southerly drift was followed by a northwesterly drift (October 21-25; Julian days 294-298). A predominantly tidal-controlled circulation pattern occurred between October 25 and November

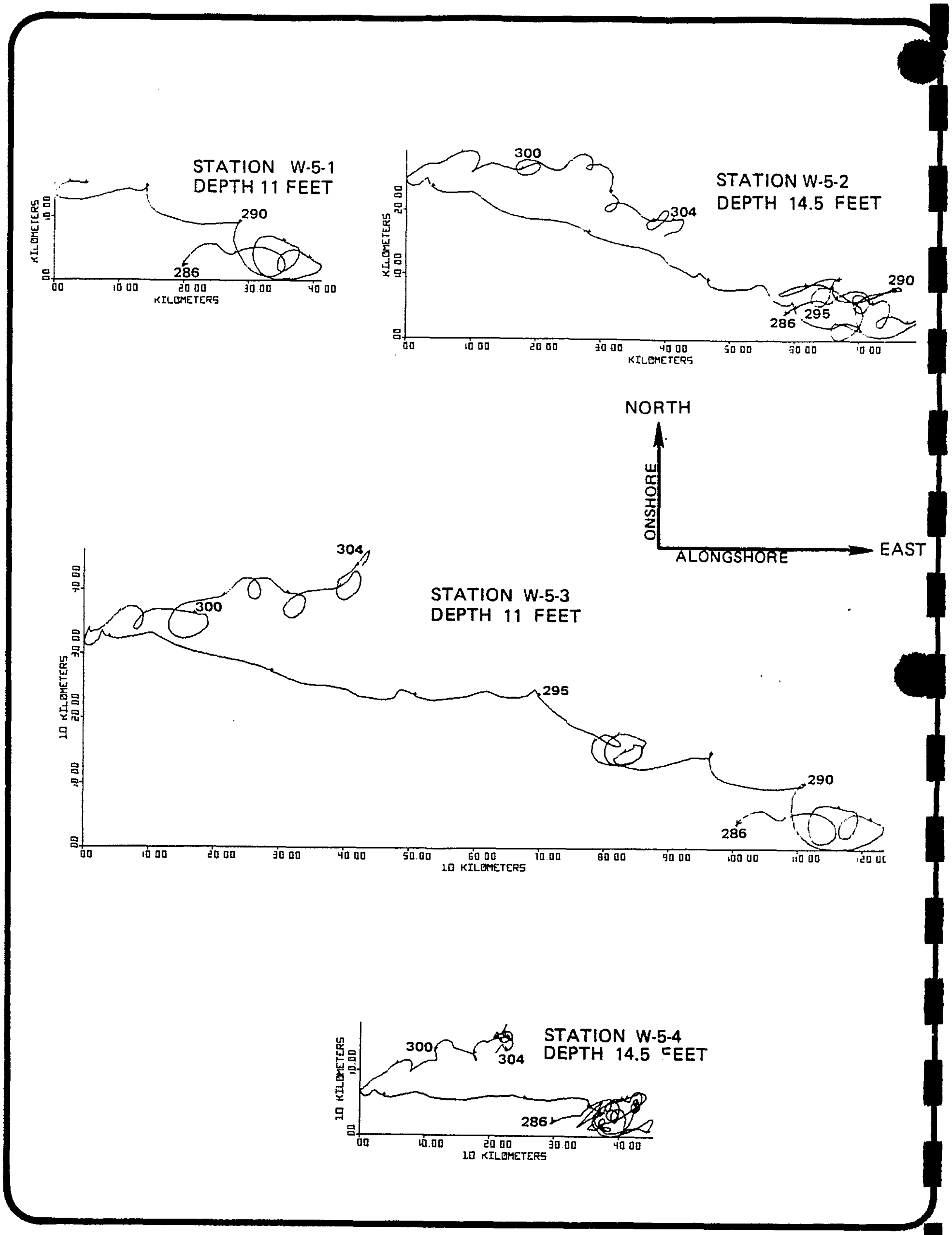


FIGURE G.2-15., Progressive vector diagrams, proposed Weeks Island site, October 13 to 31, 1977. Number designations are Julian da

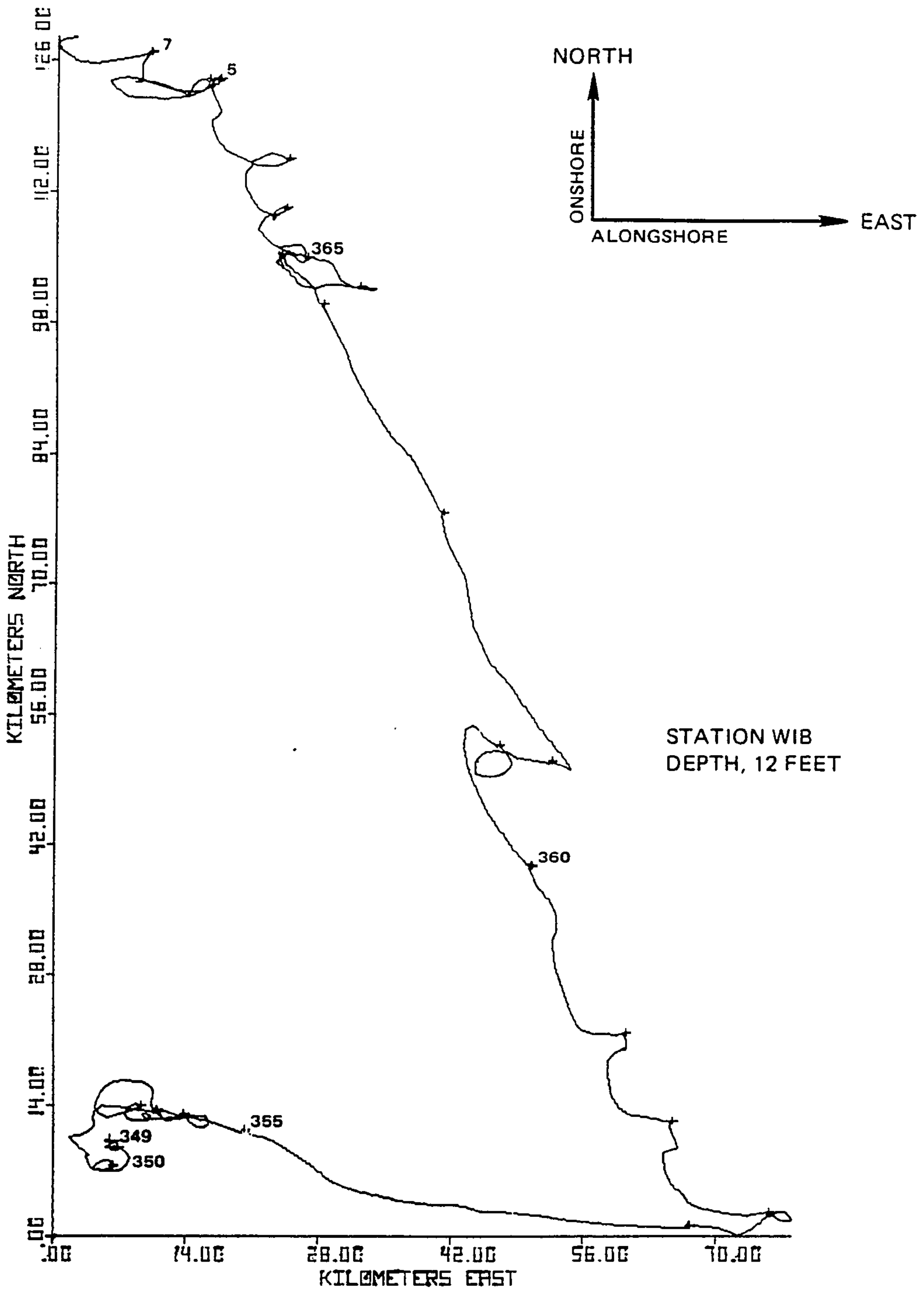


FIGURE G.2-16. Progressive vector diagrams, proposed Weeks Island site, December 15, 1977 to January 7, 1978. Number designations are Julian days.

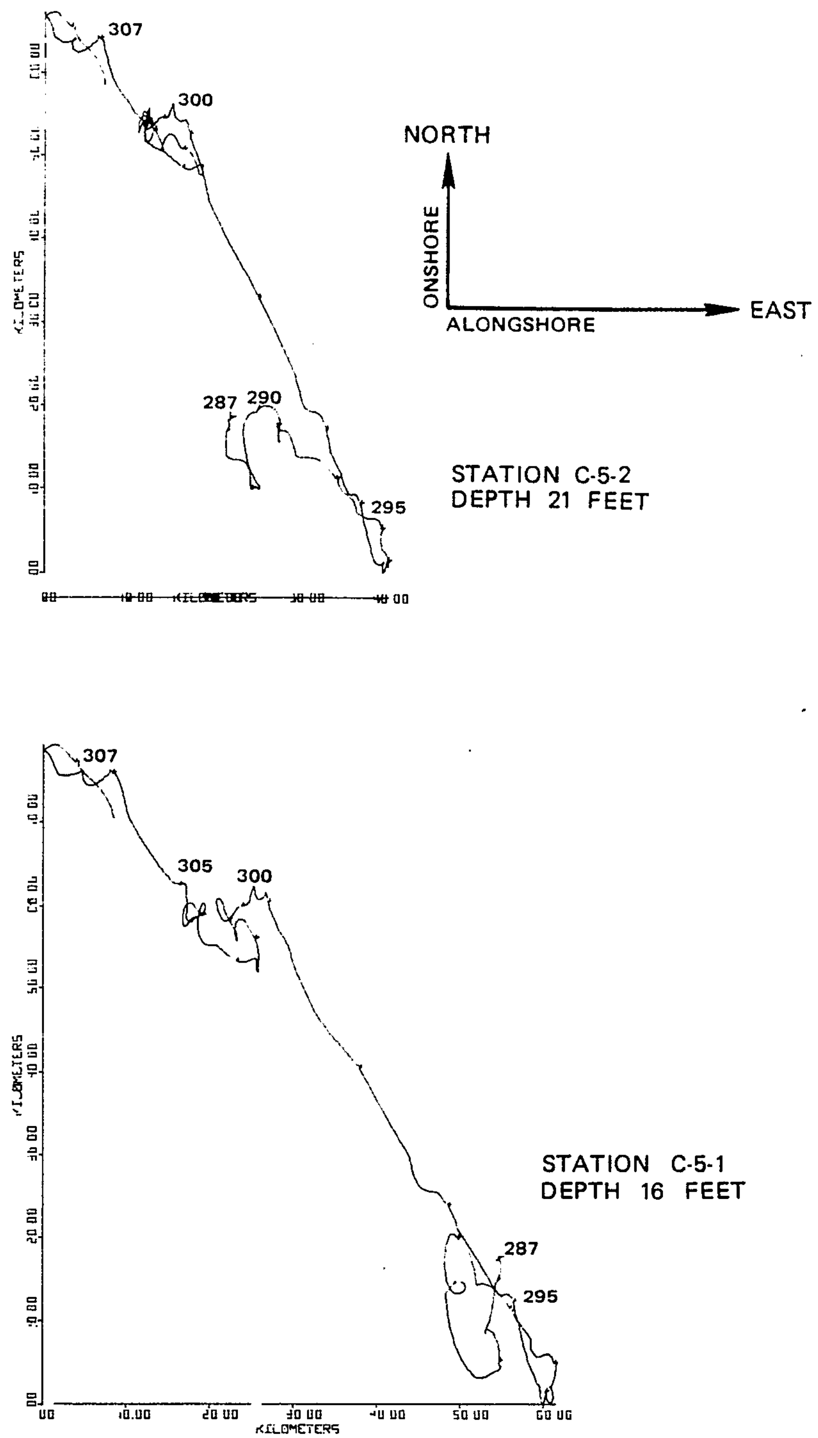


FIGURE G.2-17. Progressive vector diagrams, proposed Chacahoula site, October 14 to November 3, 1977. Number designations are Julian days.

1 (Julian days 298-305). This flow was followed by another short period of northwest drift, which quickly reversed to southeasterly on November 3 (Julian day 304).

Several important factors concerning current flow are reflected in the PVDs developed from the in situ measurements:

1) All of the stations show a net drift to the northwest during October.

2) Evidence of vertical shear in the water column is suggested by the greater net flow displacement measured in the upper portion of the water column.

3) A direct cause and effect relationship between the northwesterly drift of the currents was reflected in the current meter measurements for October 21 to 25 (Julian days 294-298) and meteorological data examined for this same interval.

G.2.2.5.2.4 Drogue Study

The results of a cursory drogue study undertaken on November 16 and December 2, 1977, showed the mean current drift on November 16 to be consistently WNW, but on December 2 the drift direction varied from SW to WNW. Neither of these studies was of long enough duration to distinguish acute tidal influences from long-term drift.

G.2.3 CHEMICAL OCEANOGRAPHY

Chemical factors such as oxygen, pH balance, nutrients, organic carbon, trace metals, hydrocarbons, and suspended matter in the nearshore Gulf of Mexico waters of Louisiana are highly dependent on the seasonal discharges of the Mississippi River in the southeast region and the Atchafalaya River in the southwest region. In general, the upper water layers are influenced by the less saline, less dense riverine waters, while the bottom water layers are affected by the more saline, denser Gulf water. Seasonal and meteorological conditions, however, affect the mixing of these two layers.

G.2.3.1 Dissolved Oxygen and pH Balance

Primary sources of oxygen in coastal waters result from transfer across the air-sea interface (surface mixing) and photosynthesis. Surface dissolved oxygen (DO) values in the northern Gulf average approximately 8.0 ppm. Low DO values are found in bottom waters, especially during the warm months. Near Marsh Island (Figure G.1-2) DO values averaged 8.1 ppm from April 1972 to March 1974; the lowest concentration was 7.0 ppm and the highest level was 8.7 ppm. There appeared to be no depth-related trend (Juneau, 1975). DO levels reported for the inshore areas and marshes of Caillou Bay (Figure G.1-2) were highest in March (11.2 ppm) and lowest in September (5.7 ppm); the sample average was 8.4 ppm (Barrett, 1971; Coastal Resources Unit, 1970).

DO measurements taken near the Louisiana Offshore Oil Port (LOOP) study area, east of the brine disposal sites, showed that surface DO was uniformly high, with station means averaging 7.2 to 8.0 ppm. At mid-depths, values averaged 4.8 ppm; at the bottom, values averaged 1.1 to 4.6 ppm. During December, 27 percent of the area was anoxic (less than 2 ppm); in July, 93 percent of the area was anoxic. During June and July 1973, the total anoxic area between the Southwest Pass and Ship Shoal was estimated at 1000 square miles (Flowers *et al*., 1975).

DO values, averaged over each sampling array, ranged from 5.1 to 10.8 mg/l and 6.1 to 11.4 mg/l at the Weeks Island and Chacahoula sites, respectively (Figure G.2-18). DO levels at stations at each site were

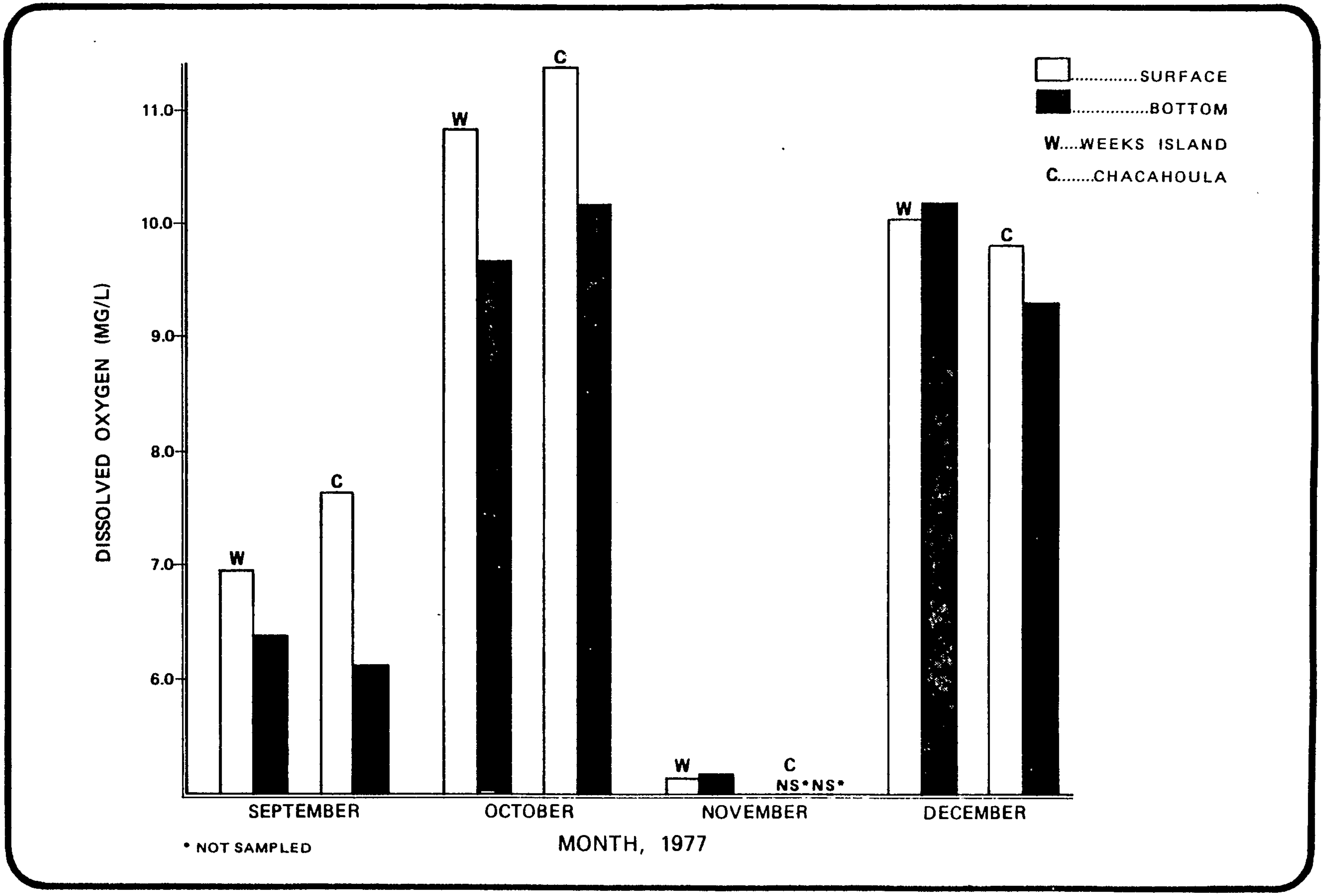


FIGURE G.2-18. Mean dissolved oxygen values at the Weeks Island and Chacahoula brine diffuser sites.

similar. During September and October, the surface water at both sites had a greater oxygen content than the bottom water. In November and December, possibly as a result of fall turnover, DO levels in the two layers were similar.

In eastern Louisiana Gulf waters, the biochemical oxygen demand (BOD) was generally low (2 mg/l). The average chemical oxygen demand (COD) was 170 mg/l. Because of its high organic load, the Mississippi River system has a major influence on the seasonal BOD and COD of the area. BOD decreased steadily from May through September; COD increases during summer (Flowers et al., 1975).

G.2.3.2 Inorganic Nutrients, Ions, and Organic Carbon

The Mississippi River has a tremendous influence on the input of nutrients into eastern Louisiana coastal waters. In a 1973 sampling effort conducted from the Mississippi River west to Caminada Bay (Ho and Barrett, 1975), inorganic nitrogen (nitrate and nitrite) values were one to two orders of magnitude greater during high river discharge periods than during normal flow periods. Furthermore, there was an inverse relationship between nitrate (NO_3) and nitrite (NO_2) and salinity levels; nitrate/nitrite decreased seaward with increasing salinity. Reactive silicate (SiO_2) and orthophosphate (PO_4) showed a similar but weaker relationship with salinity. Ammonia, organic phosphates, and organic nitrogen, remained fairly constant in coastal waters throughout various river flow periods (Ho and Barrett, 1975).

Assuming that the Atchafalaya River flow is 50 percent of the Mississippi River flow but that both carry proportionally the same nutrient load, the estimated amount of nutrients in billions of pounds discharged into the Louisiana coastal area between January and July 1973 (Ho and Barrett, 1975), during abnormally high water flow was:

	$NO_3 + NO_2$	PO_4	Dissolved SiO_2	Organic N	Organic C
Mississippi	1.96	0.08	2.90	1.82	21.70
Atchafalaya	0.98	0.04	1.45	0.91	10.85

In earlier studies (Barrett, 1971; Juneau, 1975) nitrate inshore of the proposed sites averaged 3.5 to 8.44 microgram-atoms per liter (μg-at/l); nitrite averaged 0.6 μg-at/l. Average inorganic phosphate ranged from 0.87 to 2.5 μg-at/l and total phosphate averaged approximately 4.0 μg-at/l. Seasonal trends were apparent but varied from station to station and year to year. Sulfate and calcium peaked during October, and averaged 122 mg/l and 73 mg/l, respectively for the year.

The results of the September sampling in the present study are consistent with previous studies. The greater influence of the Atchafalaya River on the Weeks Island site compared to Chacahoula is apparent in the means and ranges for nutrients, major ions, and organic carbon (Tables G.2-11 and G.2-12). Differences between sites in major ions were a function of differences in salinity. Similarly, nitrate and silicate in surface and bottom waters were higher at the Weeks Island site. PO_4 values at the two sites were similar. These values are within the range of those found in the coastal Louisiana region. No trends or relationships were found for nutrients in the pore water of the sediments. However, compared to the water column, PO_4 levels were lower and silicate was greater in the pore water. At the Weeks Island site, the influence of denser Gulf water in the bottom water can be seen.

The percent total organic content (% TOC) in the sediment at the diffuser sites was low due to the large influx of terrigenous clastic material, which effectively masked the organic carbon content. Because the Weeks Island site is nearer the source of organic material from the Atchafalaya River than the Chacahoula site, the % TOC was higher at Weeks Island. Dissolved organic carbon (DOC) and particulate organic carbon (POC) showed a similar trend. At each site, surface and bottom water DOC and POC values were similar and these values are close to those reported for other coastal areas.

TABLE G.2-11 Organic carbon and nutrients means and ranges in the water column for the proposed Weeks Island and Chacahoula brine diffuser sites, September 1977.

Station	% TOC (Sediments)	DOC (mg C/l)		POC (mg C/l)		PO_4 (μM)			SiO_4 (μM)			NO_3 (μM)		
		S	B	S	B	S	B	Pore	S	B	Pore	S	B	Pore
WEEKS ISLAND														
Mean	1.02	1.49	1.30	0.72	0.72	1.20	1.34	0.52	24.16	14.40	107.60	12.22	10.38	-
Range	.72-1.37	0.75-2.30	1.20-1.36	0.44-1.54	0.51-1.19	0.76-1.43	0.93-1.77	0.30-0.75	0.83-80.0	9.7-21.3	85.0-126.0	4.60-20.3	3.0-19.90	-
CHACAHOULA														
Mean	0.69	0.95	0.79	0.22	0.29	1.91	1.00	0.25	4.42	5.54	133.5	0.43	1.23	-
Range	.09-1.26	0.90-1.01	0.32-1.11	0.08-0.35	0.22-0.37	0.67-5.97	0.58-1.64	-	2.9-4.6	2.9-7.9	121.0-146.0	0.10- 1.0	0.40-2.9	-

S = Surface
B = Bottom
Pore = Sediment Pore Water

TABLE G.2-12 Major ion concentrations means and ranges (g/Kg) for the proposed Weeks Island and Chacahoula brine diffuser sites, September 1977.

		Cl	SO_4	Na	K	Mg	Ca
Weeks Island							
Surface	Mean	9.77	1.27	5.3	0.19	0.64	0.22
	Range	1.52 - 15.95	.12 - 2.19	0.7 - 8.9	.03 - .32	0.08 - 1.08	.06 - .34
Bottom	Mean	13.09	1.78	7.1	0.255	0.86	0.28
	Range	7.88 - 15.91	0.96 - 2.23	4.1 - 8.8	.15 - .32	.50 - 1.07	.19 - .34
Pore	Mean	13.06	2.39	7.36	0.306	0.928	.306
	Range	7.80 - 15.91	1.42 - 2.74	4.6 - 8.9	.20 - .35	.50 - 1.11	.18 - .37
Chacahoula							
Surface	Mean	17.21	2.42	9.74	.344	1.174	.364
	Range	16.94 - 17.67	2.40 - 2.47	9.3 - 10.1	.33 - .36	1.13 - 1.21	.35 - .38
Bottom	Mean	17.42	2.46	9.76	.348	1.178	.370
	Range	17.21 - 17.75	2.42 - 2.50	9.3 - 10.0	.33 - .36	1.13 - 1.22	.36 - .38
Pore	Mean	17.37	2.62	9.70	.35	1.215	.42
	Range	16.77 - 17.97	2.30 - 2.93	9.5 - 9.9	.35	1.18 - 1.25	.40 - .43

G.2.3.3 Trace Metals

Slowey and Hood (1971) found that in the Gulf of Mexico the average coastal values of manganese were an order of magnitude higher than open sea values, 3.9 μg/l compared with 0.31 μg/l. Both the coastal and open sea values for copper and zinc were 1.6 and 1.3 μg/l and 4.2 and 3.5 μg/l, respectively. Highest values in the open Gulf were usually found at surface and intermediate depths; deep waters had uniformly low values. High concentrations of metals at intermediate depths seemed to have originated outside the Gulf of Mexico and may have resulted from the release of trace metals during the decomposition of organisms. The riverine input of manganese into coastal waters was great, but it was negligible for copper and zinc.

With the exception of mercury, the values for dissolved metals collected in the LOOP study area (Flowers et al., 1975) from stations located 19.4 to 20 km offshore in 24.4 m of water and 27.4 to 36.6 km offshore in 33.5 to 42.6 m of water (Table G.2-13) are within the range of expected values for coastal marine environments. The values for mercury are higher, but may be due to variations in analytical techniques.

Heavy metal concentrations at the proposed Weeks Island and Chacahoula sites are greatly influenced by sediment input from the Atchafalaya River. In an area of high suspended matter, it is expected that the particulate phase, onto which metals adhere in the water column, would have a higher trace metal content than the dissolved phase. Generally, this trend is observed at the proposed brine diffuser sites (Table G.2-14). The Weeks Island site, which is closer to the river and which has a higher level of suspended matter, has higher particulate trace metal levels than the Chacahoula site but the levels found are low compared to those found in other coastal areas of the Gulf of Mexico. Due to sediment resuspension, trace metal levels in the bottom water particulate phase were higher than those measured in surface waters.

A portion of the particulate trace metal phase is weakly attached onto suspended matter and may be assimilated by organisms during digestion of particulate matter. The percent leachable fraction is a measure of

TABLE G.2-13 Dissolved metals (ppb) in surface and bottom waters of the LOOP study area.

	Cd		Cr		Cu		Fe		Pb		Mn		Hg		Ni		Zn	
STATION GRP III	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B
19.4-20 km,24.4m																		
June, 1973	1.8	0.9			1.0	0.8			1.1	ND					1.7	0.4	7.6	11.6
July													0.48	0.41				
Aug.			ND	10.6	0.6	ND	9.0	4.3	ND	8.9	2.4	3.1			0.9	ND	2.0	1.1
Oct.			21.1	10.5	0.7	4.3	4.3	9.9	ND	3.2	ND	2.1			ND	ND	2.6	3.4
Jan. 1974			3.5	ND	1.1	1.4	5.2	2.0	ND	3.3	1.1	4.1			1.7	ND	5.2	3.9
Range Surface	0.3 - 3.1		ND - 55.3		ND - 4.9		ND - 14.9		ND - 3.3		ND - 3.8		0.22 - 0.90		ND - 5.2		ND - 17.0	
Bottom	ND - 2.8		ND - 21.0		ND - 9.0		ND - 12.8		ND - 26.7		ND - 7.6		0.22 - 0.67		ND - 2.6		0.2 - 18.0	
Station GRP IV																		
27.4 - 36.6 km 33.5 - 42.6 m																		
June 1973	0.2	0.2			2.8	1.9			ND	ND					ND	ND	5.8	11.9
July													1.03	0.86				
Aug			7.9	4.0	2.1	2.2	1.4	3.6	17.5	0.8	ND	ND			1.3	ND	0.9	2.8
Oct			6.6	3.3	0.7	1.0	14.2	8.1	2.5	ND	1.2	ND			0.7	ND	5.6	3.4
Jan, 1974			9.2	4.6	2.0	0.8	3.9	2.0	8.3	0.8	2.8	3.7			ND	5.5	4.2	1.9
Range Surface	ND - 0.8		ND - 28.9		ND - 5.7		ND - 18.2		ND - 36.7		ND - 6.8		0.86 - 1.36		ND - 2.6		ND - 8.7	
Bottom	ND - 0.7		ND - 13.3		ND - 3.1		ND - 14.2		ND - 3.3		ND - 6.3		0.71 - 1.14		ND - 22.1		ND - 32.8	

Flowers, et al., 1975

TABLE G.2-14 Concentration of trace metals in the dissolved and particulate phase of the water column and in pore water (means and ranges from the proposed Weeks Island and Chacahoula brine diffuser locations (ppb).

		Dissolved				Particulate			
		Weeks Island		Chacahoula		Weeks Island		Chacahoula	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Cd	S	0.4	.03-.06	.03	.02-.05	.02	.006-.057	.0038	.0036-.004
	B	.05	.03-.07	.02	.02	0.59	.008-1.7	.013	.003-.039
	Pore	12.5	4.7-18	6.2	4.7-7.6				
Cu	S	1.4	0.9-1.8	0.8	0.66-0.92	0.68	.07-1.7	.053	.016-.129
	B	1.1	0.9-1.5	0.6	.57-.66	1.45	.06-3.1	.037	.001-.097
	Pore	.55	32-83	62	26-98				
Fe	S	<2	-	<2	-	1348	95-4200	52	5.6-97
	B	<2	-	<2	-	4043	130-7800	627	66-2200
	Pore	86	33-245	268	66-470				
Pb	S	0.06	.02-.09	0.12	.08-.15	0.8	.26-2.0	0.098	.003-.19
	B	0.08	.04-.21	0.05	.03-.08	1.97	.097-4.8	12.8	.038-51
	Pore	1.7	.8-2.2	1.1	.8-1.4				
Mn	S	0.8	.25-1.2	1.3	.62-3.8	21	2.2-62	1.46	1.16-3.7
	B	1.5	.54-2.1	1.4	.45-3.0	81	10-180	8.33	1.6-25
	Pore	1610	150-320	775	250-1300				
Hg	S	0.03	.01-.05	0.04	1.01-.05				
	B	0.04	.03-.04	0.03	.01-.05				
	Pore								
Ni	S	1.3	.9-1.9	1.5	1.2-1.7	1.6	<.126-4.3	0.073	.073
	B	1.2	1.0-1.7	1.2	.9-1.4	3.82	.17-8.0	2.9	2.9
	Pore	5.7	4.9-7.3	7.2	6.3-8.1				
Zn	S	<12	-	<12	-	5.6	3.2-12	3.57	.20-10.2
	B	<12	-	<12	-	31	.65-62	1.88	.24-3.5
	Pore	65	22-120	38	37-40				

S = Surface
B = Bottom
Pore = Sediment Pore Water

that portion of the particulate metal content which is soluble in weak acid and may be biologically assimilated. The percent leachable fraction ranged from the typically low iron level to several high values including manganese and cadmium.

Percent Leachable Fraction of Particulate Trace Metals

		Fe	Mn	Zn	Pb	Ni	Cu	Cd
Weeks Island	Surface	4.49	62.67	30.47	29.27	8.95	13.96	29.34
	Bottom	10.53	59.20	53.10	26.53	16.93	22.20	35.65
Chacahoula	Surface	8.64	74.26	38.07	36.08	--	34.86	74.67
	Bottom	18.26	74.22	57.85	31.08	--	28.03	67.02

The concentrations of dissolved heavy metals were much higher in the sediment pore water than in the overlying water column. This difference suggests that the metals may be diffusing from the sediments into the interstitial water (Table G.2-14). Generally, metals with a high percent leachable fraction (Mn, Cd) and metals associated with the minerals in the sediment (Fe, Zn) were found in high levels in the pore water.

Sediments at Weeks Island are finer than those at Chacahoula and as a result, Weeks Island samples had a significantly higher heavy metal concentration (Table G.2-15). Iron, which has similar properties to other trace metals, is not easily altered by anthropogenic effects, and thus is a good indicator of the source and residence of several of the trace metals. The following table presents the sediment metal/iron ratios for Weeks Island and Chacahoula:

	Mn/Fe ($x10^{-2}$)	Zn/Fe ($x10^{-4}$)	Pb/Fe ($x10^{-4}$)	Ni/Fe ($x10^{-4}$)	Cr/Fe ($x10^{-4}$)	Cu/Fe ($x10^{-4}$)	Cd/Fe ($x10^{-5}$)
Weeks Island	9.3	46.3	31.1	11.3	4.6	19.2	3.6
Chacahoula	6.6	49.4	26.5	10.7	4.4	7.3	1.1

TABLE G.2-15 Concentration of trace metals in sediments (means and ranges) from the proposed Weeks Island and Chacahoula brine diffuser locations (ppm).

	Weeks Island		Chacahoula	
	Mean	Range	Mean	Range
Al	1900	1500-2000	800	500-1100
Cd	0.22	0.19-0.27	0.04	0.02-0.06
Cr	2.7	2.2-3.3	1.5	1.0-2.0
Cu	11.0	7.8-13.0	2.9	1.0-6.7
Fe	6000	5700-6300	3500	2400-5000
Pb	18.7	16.8-20.9	9.2	6.4-13.9
Mn	555	507-627	234	154-384
Ni	6.8	5.8-7.7	3.7	2.9-4.6
Zn	27.8	24.6-30.9	16.6	13.1-21.2

Iron levels, which decrease from the Weeks Island to the Chacahoula site, are inversely correlated with sediment grain size. Zinc, nickel, and copper have a similar sediment size-dependence as iron since the metal/iron ratios of these three metals remain constant between the two sites. Copper and cadmium decrease more rapidly with increased grain size than does iron.

Zooplankton, consisting mostly of chaetognaths, had significantly higher levels of trace metals (except for copper) than did croaker and shrimp (Table G.2-16). This difference may be due in part, i.e., mostly surface sorption, to their high surface area to mass ratio relative to croaker and shrimp. The trace metal values found in the zooplankton were similar to others reported for zooplankton collected in the northwest Gulf of Mexico (Sims, 1975). Trace metal levels, with the exception of those for zinc, nickel, and cadmium, were generally low in white shrimp. Trace metal levels, with the exception of those for iron, copper, and aluminum, were also low in croakers.

G.2.3.4 Hydrocarbons

Of the estimated 6 to 12 million metric tons of hydrocarbons entering the oceans yearly, 50 percent are believed to result from organic decay, 17 percent from terrestrial runoff, 8 percent from atmospheric fallout, 4 percent from natural seepage, and the remaining 21 percent from oil producing and shipping operations (Ahearn, 1970). Hydrocarbon levels in the open ocean are generally less than 10 ppb at the surface and much lower in deeper waters.

Because the Gulf of Mexico has a high carbon load from river discharge and heavy oil production activity, it would be expected to have a high hydrocarbon content. However, various studies indicate that hydrocarbon levels in the Gulf of Mexico are the same order of magnitude as in the open ocean waters. Parker et al. (1972 as cited in LOOP, 1975) found n-alkane levels in East Bay, Louisiana, to be 0.2 ppb, 0.1 ppb 15 miles from Corpus Christi, Texas, and 0.63 ppb near a burning oil rig 15 miles southwest of Point Au Fer Island, in the region of the proposed

TABLE G.2-16 Heavy metal contents of selected organisms - proposed Weeks Island and Chacahoula brine diffuser sites.

Sample #	Sample Description[a] (Species)/Site-Station	Fe(ppm)	Mn(ppm)	Zn(ppm)	Pb(ppm)	Ni(ppm)	Cu(ppm)	Cd(ppm)	Al(ppm)
1	Croaker (*M. undulatus*) Weeks Is. - WT3	13.3	3.8	18.7	.05	.01	1.4	.003	2.52
2	White Shrimp (*P. setiferous*) Weeks Is. - WT3	6.4	2.2	56.3	.001	.24	27.3	.04	0.13
3	Zooplankton (chaetognaths) Weeks Is. - WT3	692.	21.9	162.	.55	6.0	15.6	1.56	1020.
4	White Shrimp (*P. setiferous*) Chacahoula - CT2	3.5	1.1	72.6	.005	.09	39.5	.02	0.13
	NW Gulf of Mexico Zooplankton[b]								
	#1	799.	12.6	115.	15.3	2.0	74.0	2.4	1252.
	#2	288.	9.8	58.	4.3	1.9	6.3	1.3	283.

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[a] Sample 1 - 4 fish pool; flesh only
Sample 2 - 5 shrimp pool; flesh only
Sample 3 - Whole sample; mostly chaetognaths
Sample 4 - 1 shrimp; flesh only

[b] Sims, 1975. #1 - Sample from near-shore off Corpus Christi, Texas.
#2 - Sample from directly offshore of the Atchafalaya, significantly further from land than the sites of this study.

Weeks Island brine diffuser site. The n-Paraffin levels were 0.63 ppb in water off Louisiana (IDOE, 1972, as cited in Bishop et al., 1975). The Gulf Universities Research Consortium (1974) detected hydrocarbon levels of 0.5 to 2.1 ppb in a control area, 0.8 to 6.0 near an operating rig, and 3.7 to 11.0 ppb in Timbalier Bay. The LOOP study (1975) reported hydrocarbon content ranging from 17 to 64 ppb in coastal Louisiana.

Hydrocarbons found in the Gulf of Mexico are predominately saturated hydrocarbons with low concentrations of aromatics; nonvolatile hydrocarbons were in the range of 1 to 12 ppb, and aromatics ranged from 1 to 3 ppb, with many samples undetectable. Paraffin compounds were high, the most abundant being single ring naphthenes. In general, surface waters had a higher content than deeper waters (Brown et al., 1973, as cited in Bishop et al., 1975). Flowers et al. (1975) found that hydrocarbons in coastal Louisiana comprised 80 to 90 percent of the surface water organic matter in coastal Louisiana with a range of 17 to 64 ppb. The predominant carbon tetrachloride extractable component was the fatty acid fraction of the lipids, 16 to 136 ppb. Other values found in the Gulf are 100 to 800 ppb for methyl ester fatty acids, and 200 to 1000 ppb for fatty alcohols, fatty acids, and fatty esters.

The Weeks Island site contained over twice the sediment hydrocarbon content (14,013.8 vs 6870.3 ppb) of the Chacahoula site (Table G.2-17). This difference seems to be largely as a result of the finer grain texture and the greater organic carbon content at the Weeks Island site. In the water column, the same trend is seen, with the Weeks Island site having a greater hydrocarbon concentration than the Chacahoula site (10.6 vs 1.8 ppb for surface samples and 9.2 vs 0.97 ppb for bottom samples).

Representative chromatographic traces of sediments indicate that substrate hydrocarbons at the Chacahoula site contain a greater relative contribution of polyolefin hydrocarbons characteristic of phytoplankton and zooplankton than at Weeks Island (Figure G.2-19). The chromatographic trace of sediments at Weeks Island (Figure G.2-20 and G.2-21) is dominated by waxes of higher plants and also shows greater petrogenic hydrocarbon contribution than the trace from Chacahoula.

TABLE G.2-17 Gas chromatograph carbon concentrations (means and ranges) in water samples and sediments from the proposed Weeks Island and Chacahoula brine diffuser sites.

	Hexane Fraction (ppb)		Benzene Fraction (ppb)		Total (ppb)
	Resolved	Unresolved	Resolved	Unresolved	
WEEKS ISLAND					
Surface Mean	0.204	7.906	0.200	2.254	10.564
Range	.0027-1.027	1.348-34.361	.0042-.906	.193-10.447	2.81-45.91
Bottom Mean	0.155	7.284	0.073	1.737	9.249
Range	.022-.489	1.591-8.974	.017-.347	.432-1.565	2.39-26.33
Sediment Mean	950.15	9624.7	587.7	2851.3	14013.8
Range	247-1,364	1,640-14,327	112-1,612	612-6,389	2,611-20,088
CHACAHOULA					
Surface Mean	0.050	1.367	0.106	0.270	1.793
Range	.019-.087	.672-2.347	0.033-.209	.079-.392	1.32-2.59
Bottom Mean	0.036	0.690	0.072	0.173	0.971
Range	.017-.048	.661-.736	0.003-.209	0-.392	0.88-1.42
Sediment Mean	393.7	4802.3	172.7	1501.6	6870.3
Range	111-835	714-13,540	122-356	331-4,180	1,430-18,910

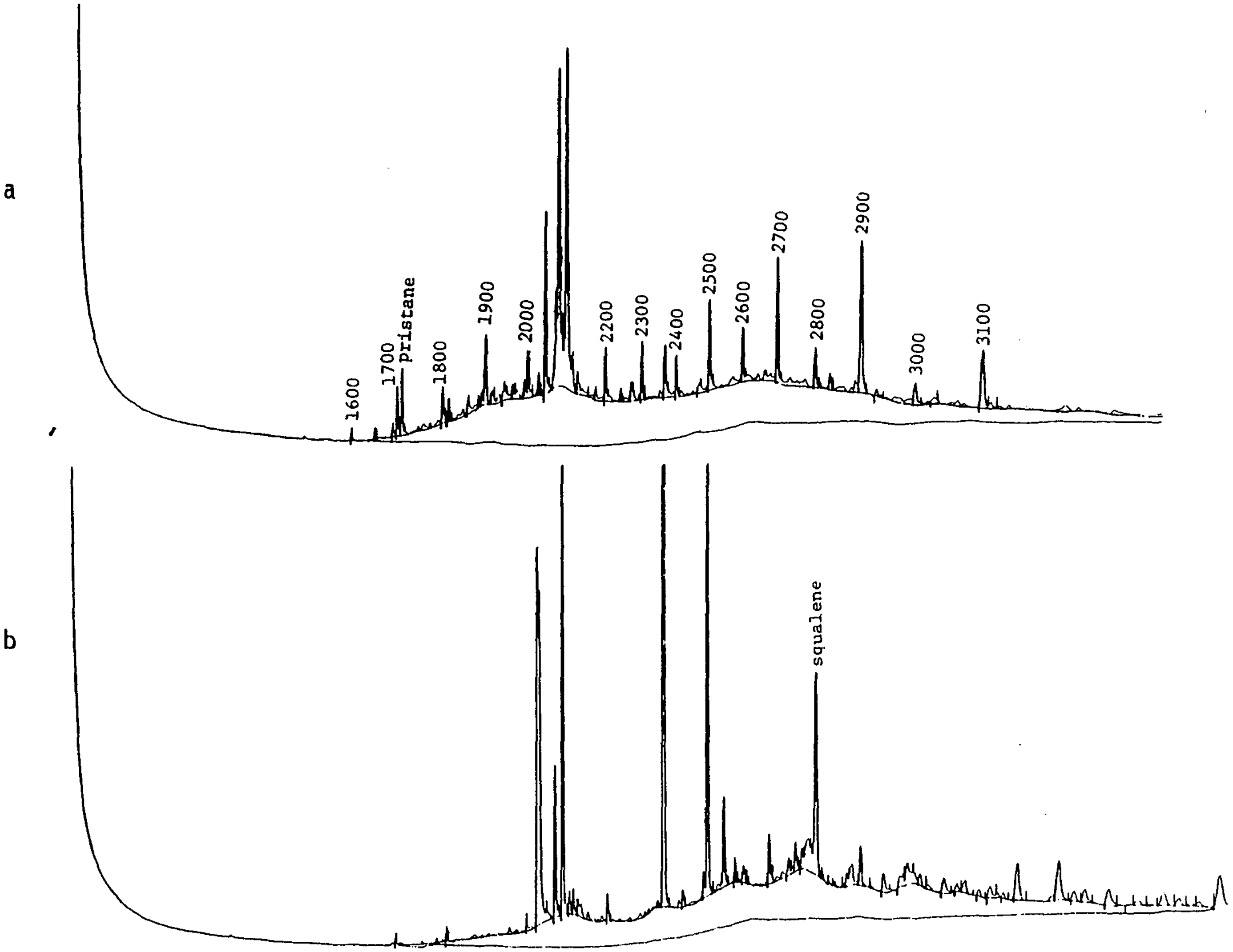

FIGURE G.2-19. Gas chromatographic trace of station CR-3 sediment: (a) hexane fraction, (b) benzene fraction, proposed Chacahoula site.

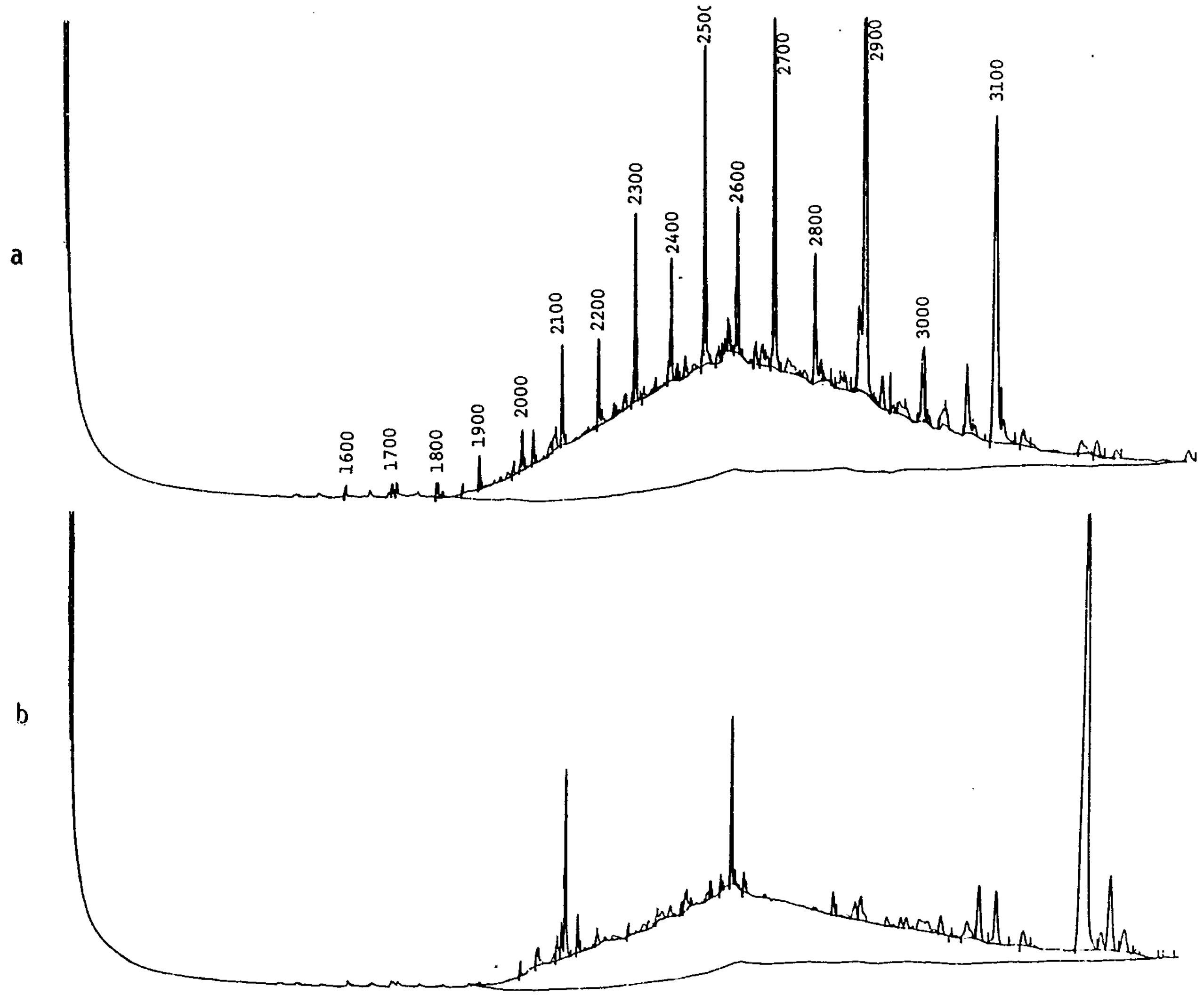

FIGURE G.2-20. Gas chromatographic trace of station WR-3 sediment: (a) hexane fraction, (b) benzene fraction, proposed Weeks Island sit[illegible]

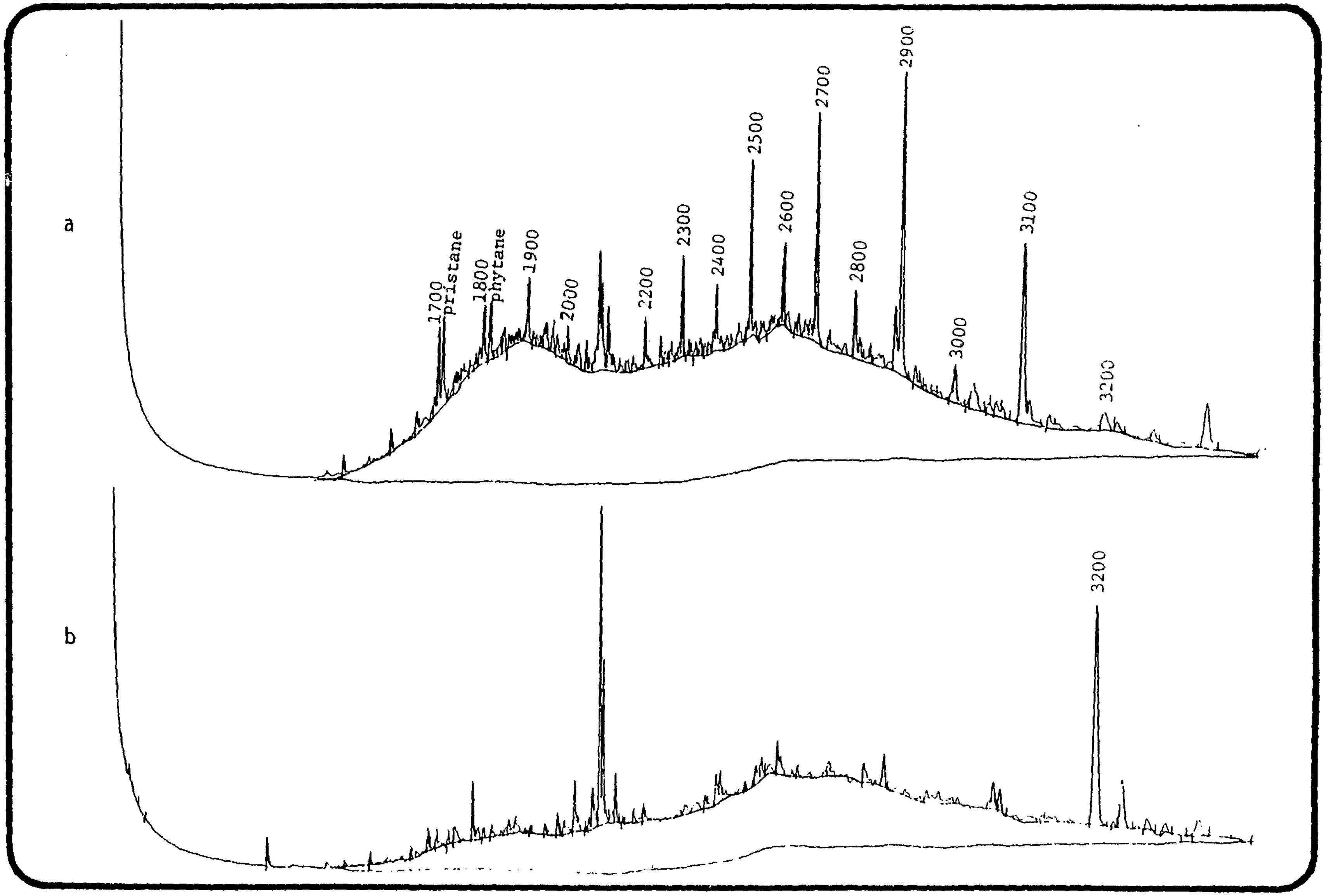

FIGURE G.2-21. Gas chromatographic trace of station W-5 sediment: (a) hexane fraction, (b) benzene fraction, proposed Weeks Island site.

The chromatographic traces of water column hydrocarbons in Figure G.2-22 are representative of the Weeks Island site. However, the aromat[illegible] fraction at Station W-2 (Figure G.2-23) shows extremely high concentrations of high molecular weight compounds. The trace of surface waters from Station W-5 (Figure G.2-24) shows a large petrogenic contribution, possibly a result of contamination from the ship's bilge.

The traces from the two water column chromatographic traces at Chacahoula (Figure G.2-25) show an abundance of n-alkanes aromatic contribution is slight.

A more quantitative analysis of the hydrocarbon components of the sediment and water column for certain stations in the Weeks Island and Chacahoula sampling grid has been performed using a combination gas chromatograph/mass spectrometer (Section G.5). Sediment samples contained abundant sulfur and in general, petrogenic hydrocarbon content increased with decreasing grain size (i.e., a greater petrogenic contribution at the Weeks Island site).

Hydrocarbon concentrations in biota from Weeks Island were greater than that from Chacahoula (Table G.2-18). Croaker samples contained twice the amount of hydrocarbons at Weeks Island than at Chacahoula, whereas white shrimp samples from Weeks Island contained almost an order of magnitude more of hydrocarbons than the samples for Chacahoula.

Chromatographic traces of croakers (Figure G.2-26) show that samples from Weeks Island had a large petrogenic hydrocarbon content while samples from Chacahoula had a large pristane peak, the predominant hydrocarbon in mixed phytoplankton and zooplankton samples. Chromatographic traces of white shrimp (Figures G.2-27, G.2-28, and G.2-29) show that the Weeks Island samples had a greater petrogenic contribution and more steranes, triterpenes, and polyolefins than the shrimp collected from Chacahoula. Mass spectrometric analyses of shrimp tissues from Weeks Island (Section G.5) show that the aromatic fraction contained a number of potentially toxic aromatic and chlorinated compounds.

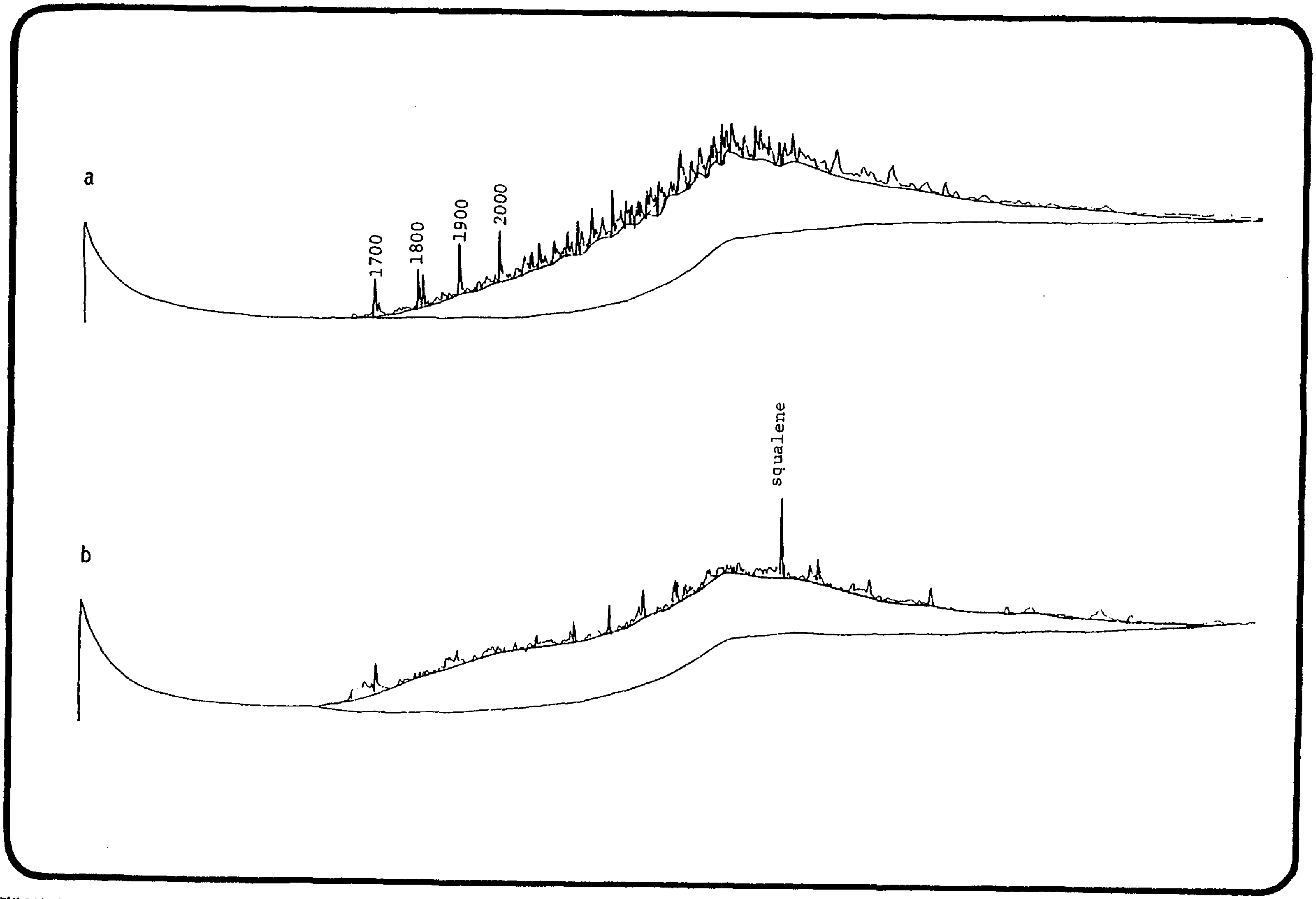

FIGURE G.2-22. Gas chromatographic trace of station WR-3 water collected at mid-depth: (a) hexane fraction, (b) benzene fraction, proposed Weeks Island site.

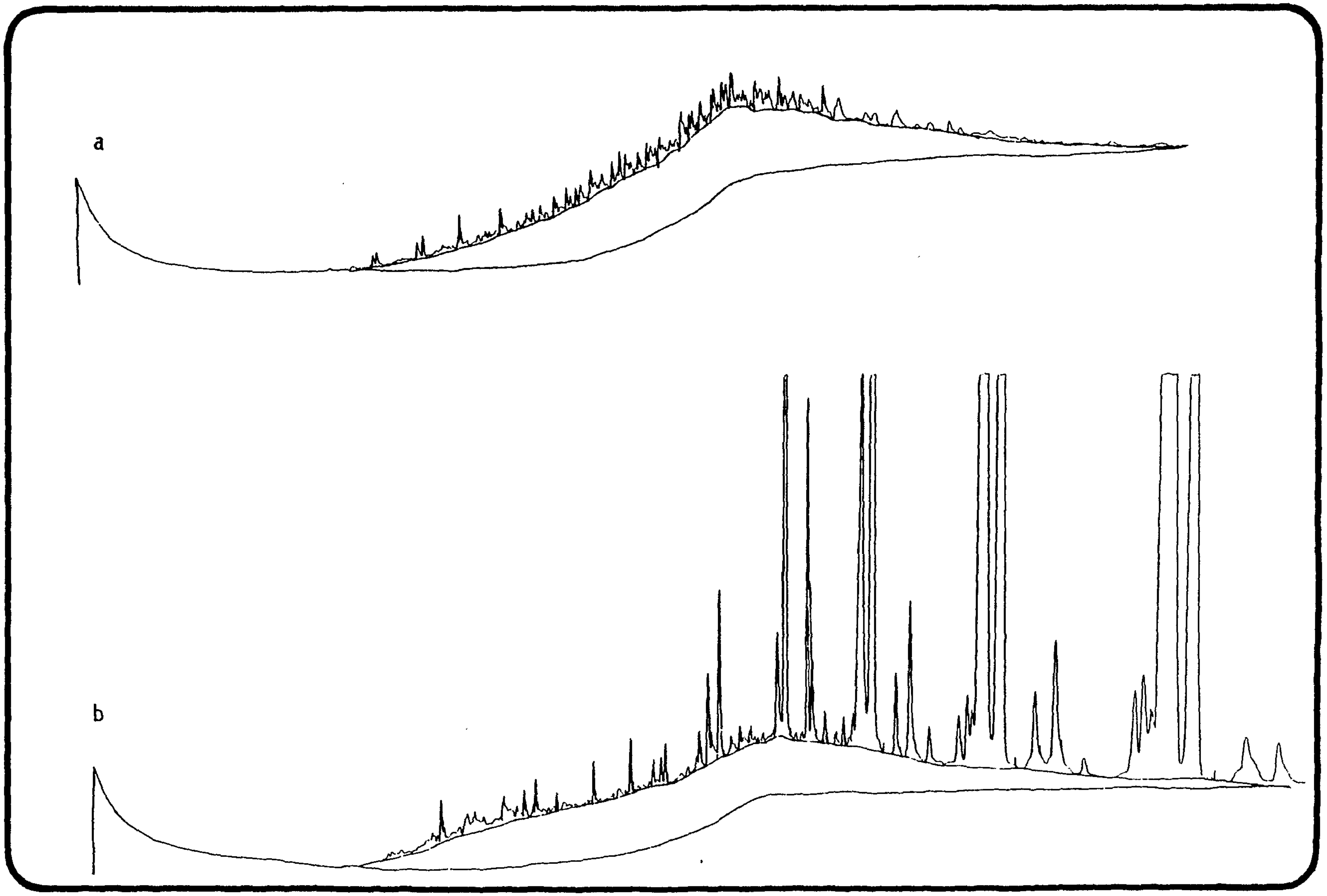

FIGURE G.2-23. Gas chromatographic trace of statio[illegible] W-2 surface water: (a) hexane fraction, (b) benzen[illegible] fraction, proposed Weeks Island si[illegible]

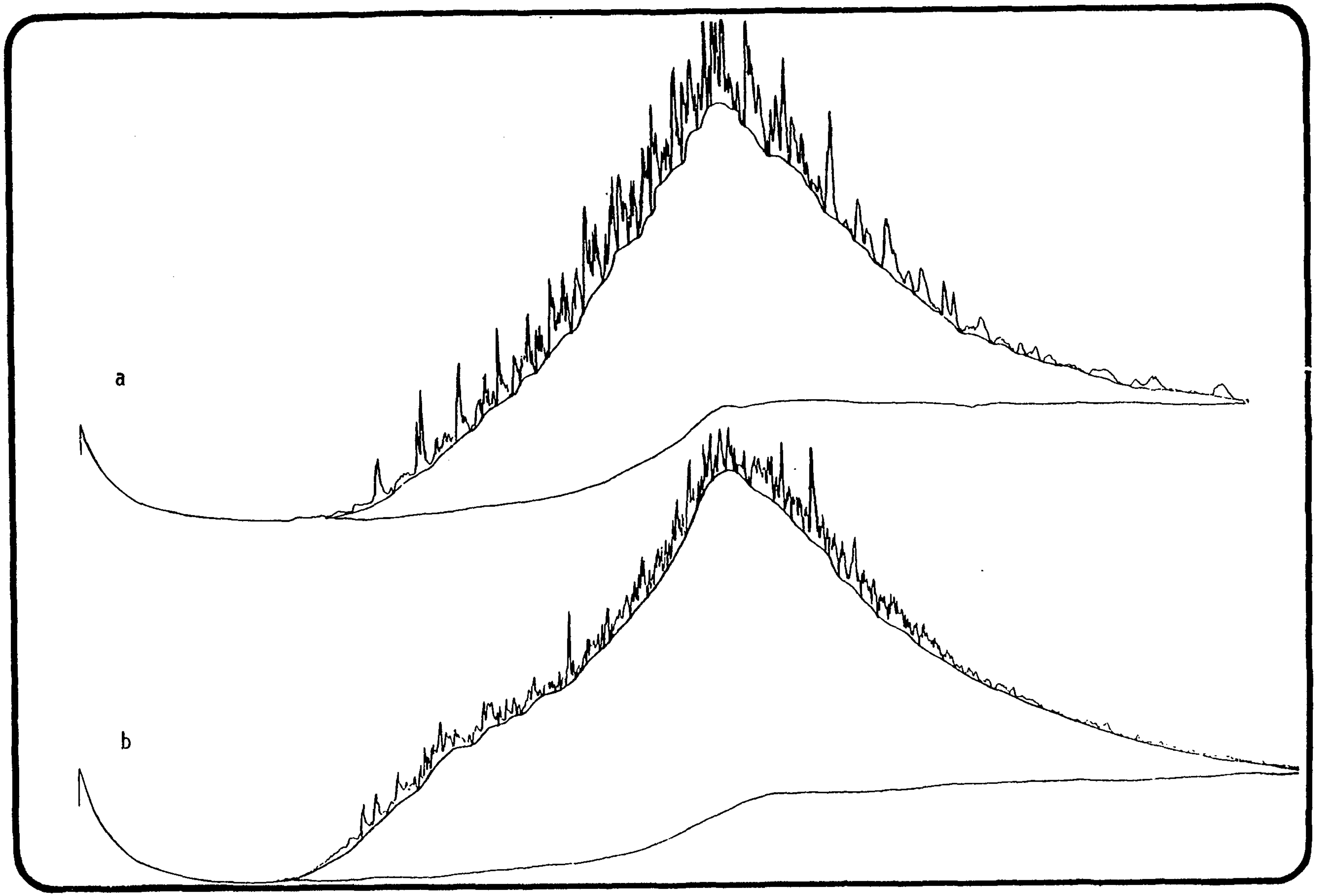

FIGURE G.2-24. Gas chromatographic trace of station W-5 surface water: (a) hexane fraction, (b) benzene fraction, proposed Weeks Island site.

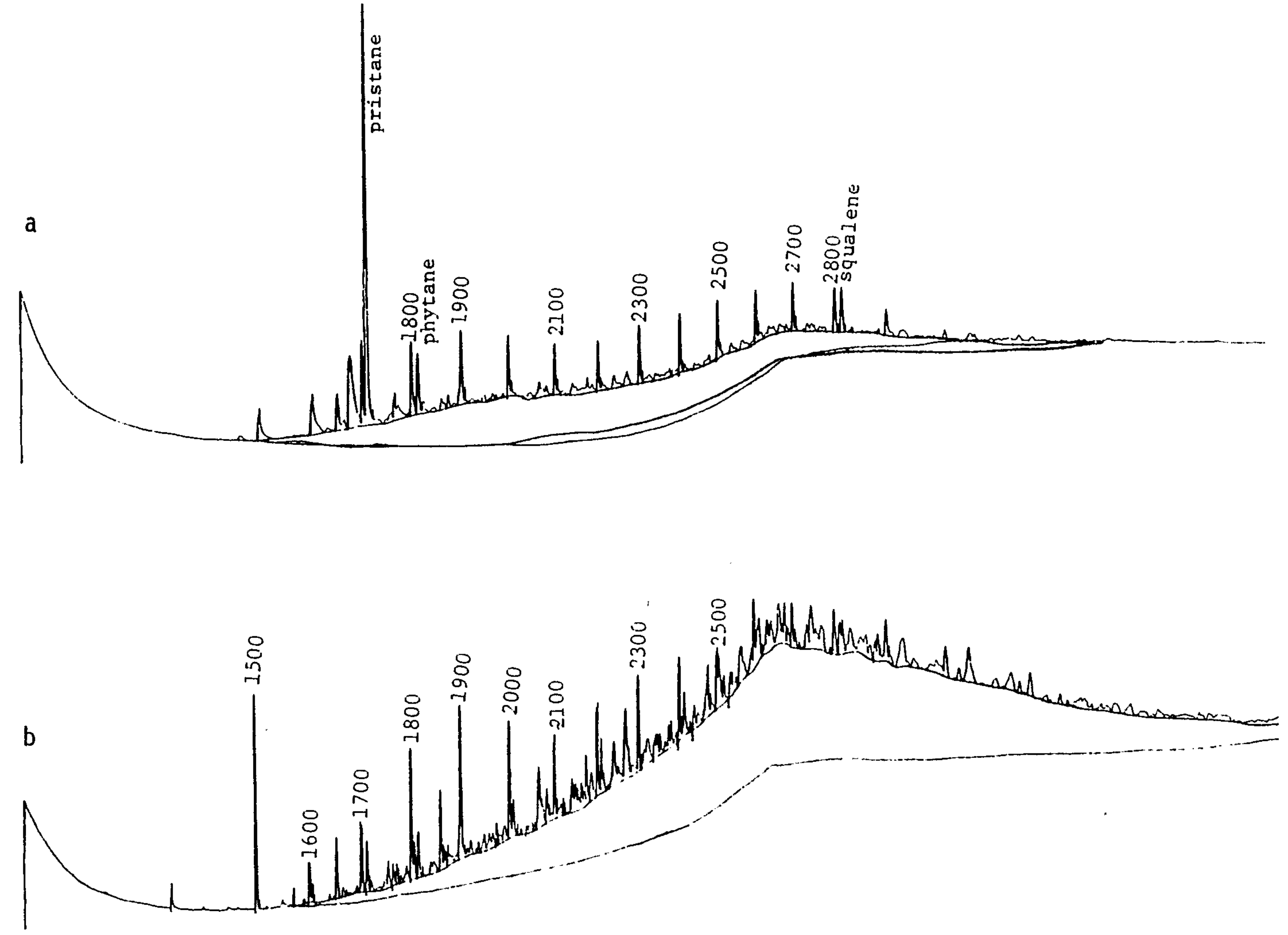

FIGURE G.2-25. Gas chromatographic trace of hexane extract of: (a) station CR-3 water (mid-depth), (b) station C-3 water (surface), proposed [illegible] site.

TABLE G.2-18 Hydrocarbon concentrations in organisms collected from the proposed Weeks Island and Chacahoula brine diffuser sites.

	Hexane Fraction (ppm)		Benzene Fraction (ppm)		Total (ppm)
	Resolved	Unresolved	Resolved	Unresolved	
WEEKS ISLAND (W1)					
Shrimp tails	0.023	0.649	0.105	0.407	1.184
Whole shrimp	0.276	12.628	0.245	2.832	15.981
Croaker w/o gut	0.509	8.16	Fatty Acid Methyl Ester Contamination		-
CHACAHOULA					
Croaker w/o gut	0.246	4.930	Fatty Acid Methyl Ester Contamination		-
Whole shrimp	0.046	1.528	0.094	1.037	2.705

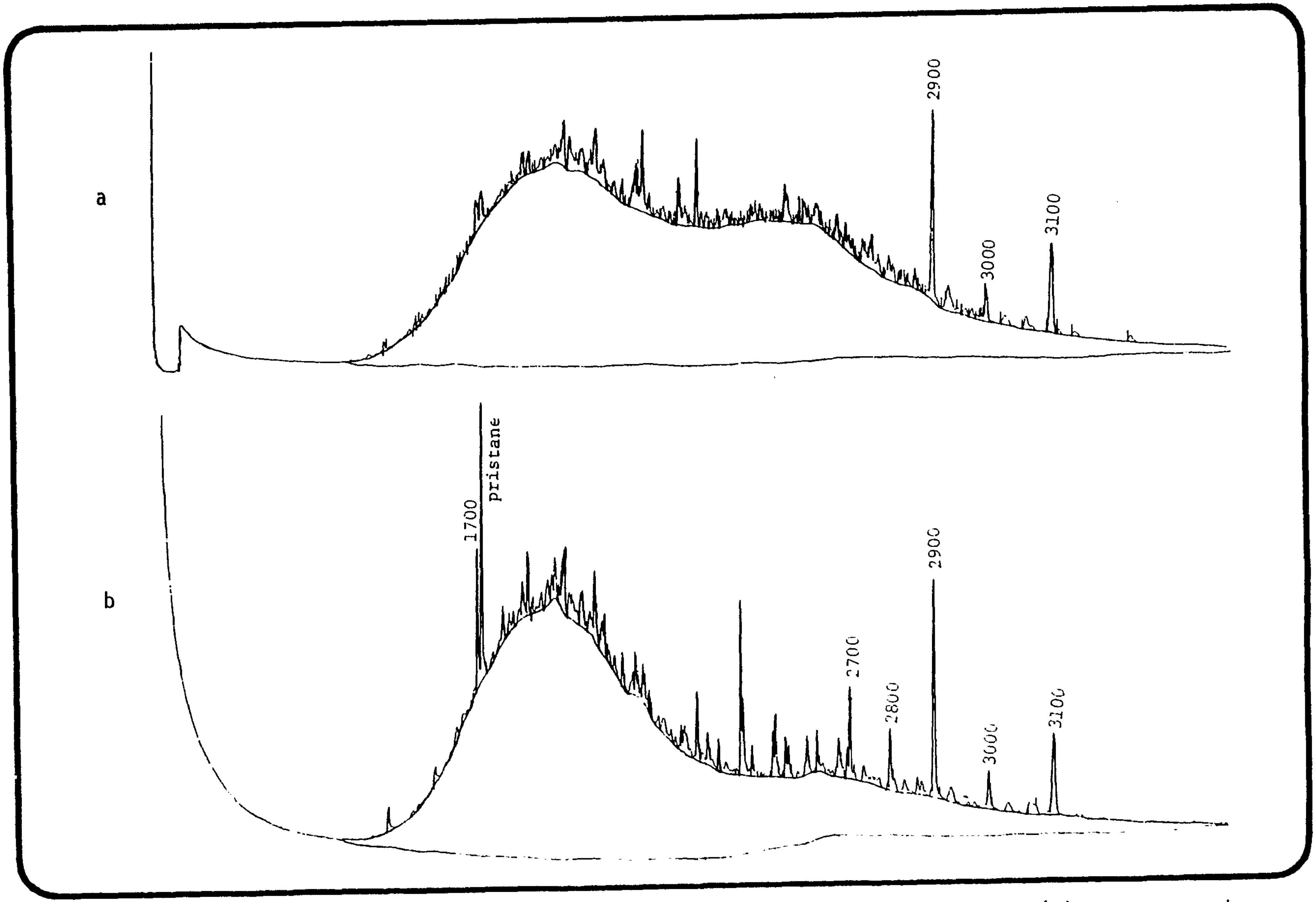

FIGURE G.2-26. Gas chromatographic trace of hexane fraction of croaker collected at (a) the proposed Weeks Island site and (b) the prop[illegible] Chacahoula site.

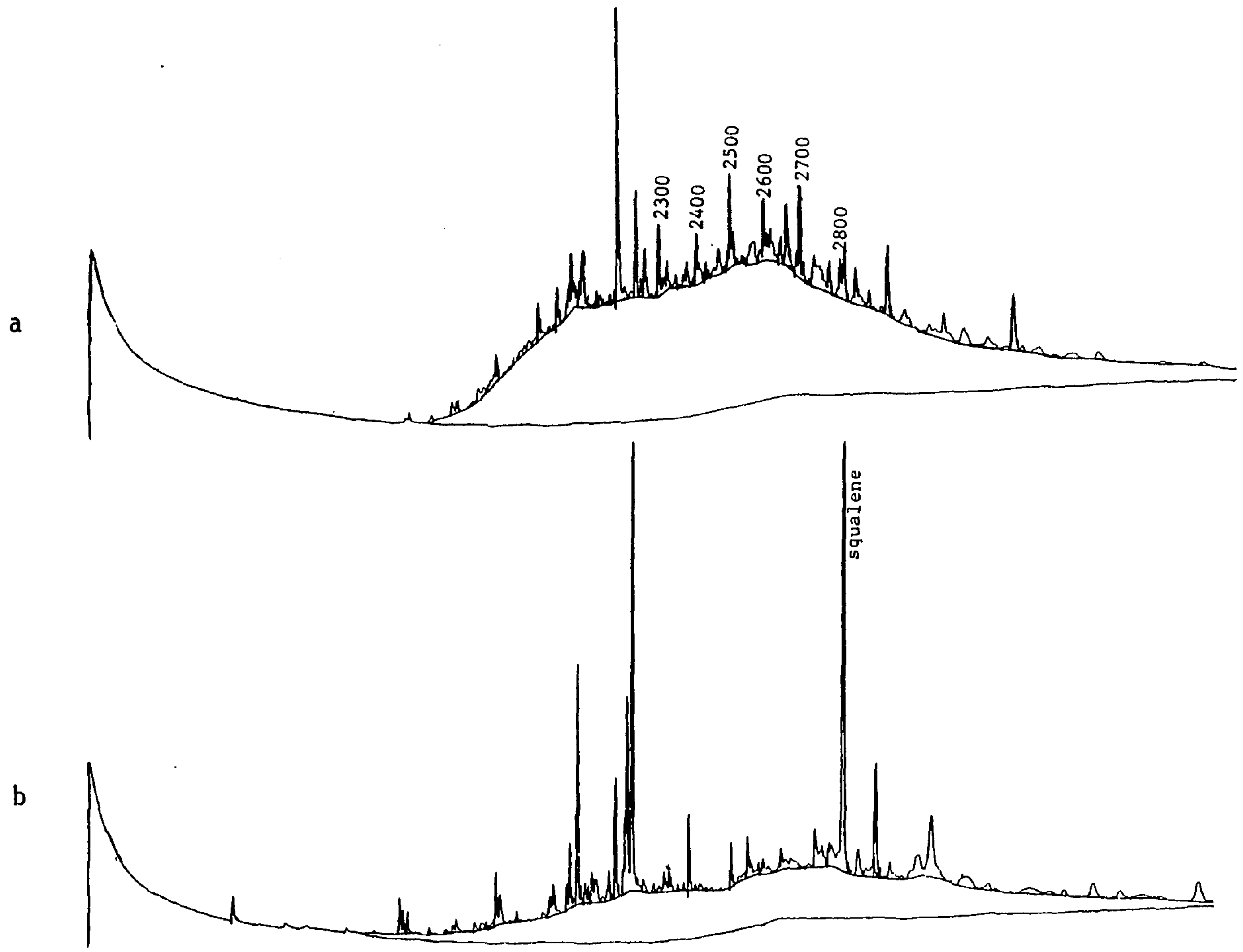

FIGURE G.2-27. Gas chromatographic trace of whole white shrimp collected at the proposed Weeks Island site: (a) hexane fraction, (b) benzene fraction.

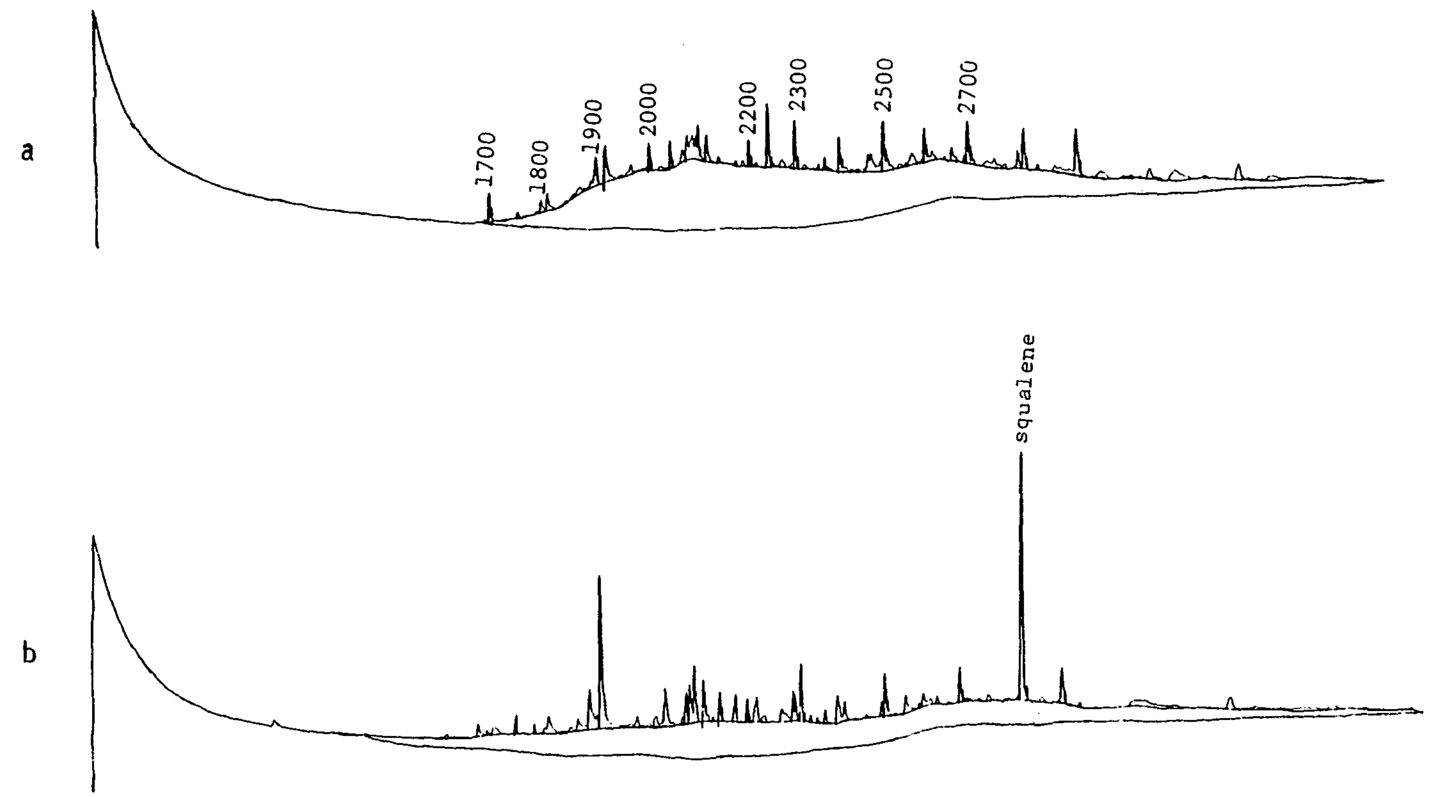

FIGURE G.2-28. Gas chromatographic trace of whole white shrimp collected at the proposed Chacahoula site: (a) hexane fraction, (b) benz[illegible] fraction.

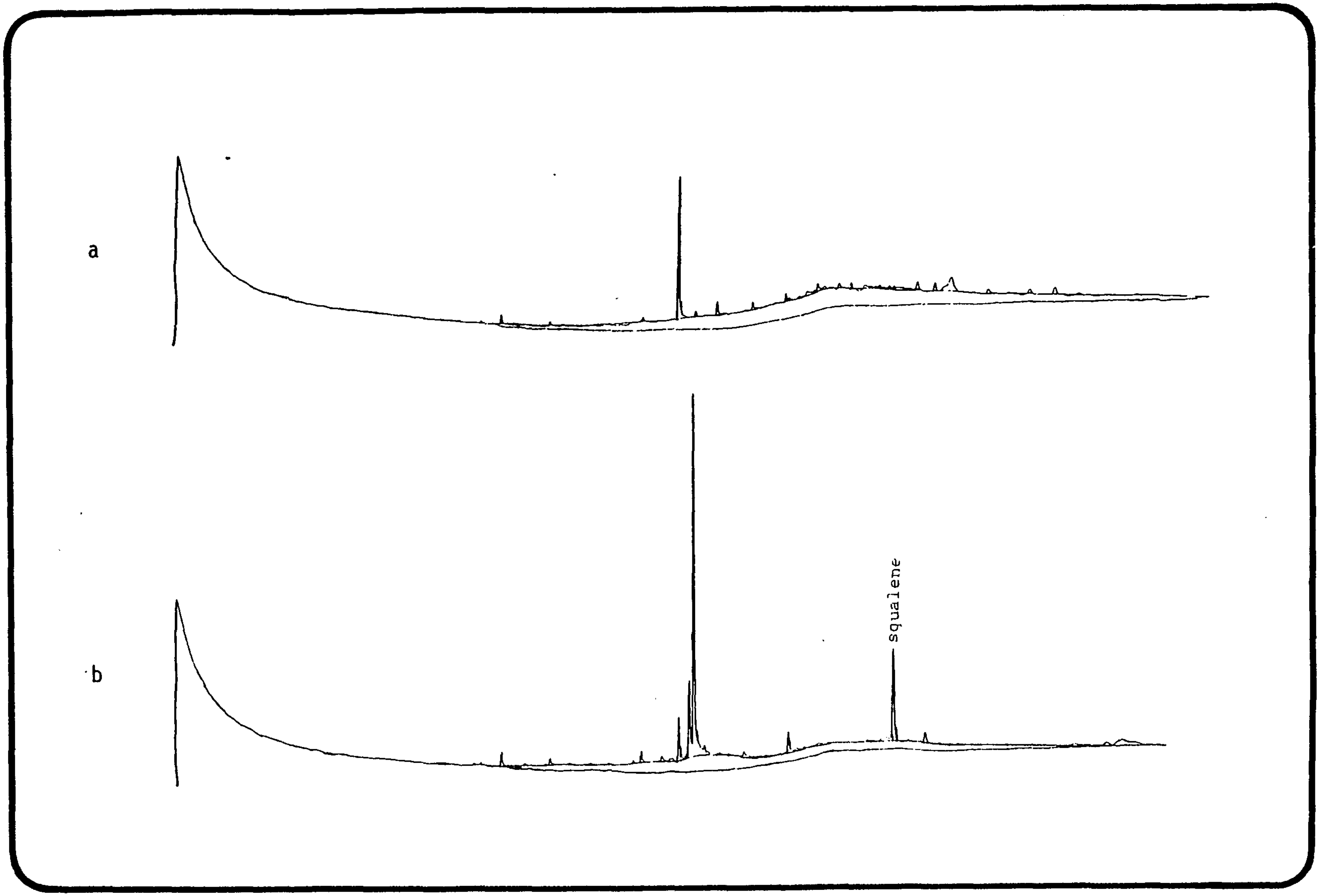

FIGURE G.2-29. Gas chromatographic trace of the tail portions of white shrimp from the proposed Weeks Island site: (a) hexane fraction, (b) benzene fraction.

G.2.3.5 Suspended Matter

The turbidity of a water body has a large influence on the amount of light which penetrates it, thus affecting photosynthesis and the resultant productivity of the area. The northern Gulf of Mexico is highly influenced by the Mississippi and Atchafalaya Rivers and generally the greatest turbidity occurs in shallow, inshore, low salinity waters. The effects of the Mississippi River on turbidity have been detected 15 to 18 miles offshore. (At stations in 25 to 30 feet of water, Secchi disc measurements ranged from 1.5 to 21 feet.) In a previous study, the lowest visibility occurred in February, May and June, while the greatest was in September and March (Flowers *et al.*, 1975).

Inshore of the Chacahoula brine diffuser site, the greatest turbidity, associated with the low salinity waters of the Atchafalaya River, occurred during June while the lowest occurred in August and November. The station averages ranged from 0.7 to 2.0 feet (Barrett, 1971). Inshore from the proposed Weeks Island site, turbidity was greatest in the winter and spring.

The influence of the Atchafalaya River on the suspended matter at the proposed brine diffuser sites is evidenced by the greater total suspended matter at the Weeks Island site:

		Total Suspended Matter (mg/l)	Particulate Organic Carbon (mg C/l)	POC/TSM (%)
Weeks Island				
Surface	Mean	24.0	0.72	3.0
	Range	3.0 - 51.7	0.44 - 1.54	
Bottom	Mean	63.5	0.72	1.13
	Range	18.5 - 165.4	0.51 - 1.19	
Chacahoula				
Surface	Mean	1.64	0.22	13.41
	Range	0.4 - 3.4	0.08 - 0.35	
Bottom	Mean	9.48	0.29	3.06
	Range	1.8 - 32.7	0.22 - 0.37	

Particulate organic carbon makes up a smaller proportion of the suspended matter at the Weeks Island site, perhaps resulting from masking by the large quantity of terrigenous material.

G.2.4 BIOLOGICAL OCEANOGRAPHY

G.2.4.1 Habitats

The coastline is, in general, irregular, being characterized by a series of estuaries, bays, and rivers. These support valuable sport and commercial fisheries including shrimp, crabs, oysters, and menhaden, which constitute almost 98 percent of Louisiana's fishery. In addition, these coastal waters serve as spawning and nursery areas for many of these species.

The salinity of these waters fluctuates seasonally due to freshwater runoff, precipitation, and evaporation. The most influential factors regulating salinity are the Gulf of Mexico and freshwater from the Mississippi and Atchafalaya Rivers (Louisiana Wildlife and Fisheries Commission, 1971). Salinity in this region varies from a few ppts in the estuaries to 36.5 ppt in the open Gulf waters. Water temperatures can vary seasonally from a low of about 43°F (6°C) in December to a high of around 96°F (35.6°C) in July. The net long-term drift ranges from 0.25 to 0.75 knots (15-49 cm/sec) to the west and parallel to the coast.

In general, turbidity is highest in the estuaries and coastal regions and decreases seaward. Dissolved oxygen may attain maximum values (11.2 ppm) during the winter months of December and January and lowest (below 5.0 ppm) during mid-summer (July and August). Water temperature usually is correlated with this chemical parameter. Nutrient (nitrogen, phosphorus) levels vary along the coast. Highest nutrient levels are normally found where salinity values are lowest, indicating that the major source of nutrients is from freshwater discharge into these coastal waters. Nutrient concentrations decrease with distance from the coast.

The offshore topography is gently sloping and roughly parallel to the coast. Within 20 nautical miles of the coast, the water depth varies from less than 3 feet to more than 60 feet, a slope of about 0.05 percent. The sediments in this area are predominantly composed of highly organic silts and clays with some fine to medium grained sands and shell fragments (LOOP, 1975).

G.2.4.2 Plankton

In Louisiana's coastal zone, freshwater runoff mixes with the waters of the Gulf of Mexico. As a result, the plankton community is both diverse and productive, and the indigenous populations are, in general, capable of tolerating wide fluctuations in temperature and salinity. Due to the mixing of freshwater with Gulf waters, marine, estuarine, and freshwater plankton species may be found in this neritic zone.

G.2.4.2.1 Phytoplankton

Phytoplankton are unicellular algae that rely on water currents for movement. These plankton, due to their ability to convert water and nutrients into organic compounds by photosynthesis, are considered "the grasses of the sea." It is through the process of photosynthesis that phytoplankton provide an abundant source of energy to the aquatic food web. The majority of the primary production in the area has been attributed to phytoplankton.

Diatoms and dinoflagellates seasonally dominate the phytoplankton community. During the LOOP (1975) study, 35 species and 26 genera of phytoplankton were identified (Table G.2-19). During the late spring-summer, the dominant genera included Ceratium, Exuviaella, Goniaulax, Gymnodinium, Asterionella, Biddulphia, Coscinodiscus, Cyclotella, Lithodismium, Navicula, Skeletonema, and Thalassiasira. From September through December, Biddulphia, Navicula, Nitzschia, and Rhizosolenia were predominant; dinoflagellates were absent. During winter, the diatoms Asterionella, Fragillaria, Guinardia, Porosiria, Rhizosolenia, Skeletonema, and Thalassiosira dominated.

Phytoplankton biomass and productivity undergo large spatial and temporal fluctuations in the Louisiana coastal waters. Total phytoplankton density has been reported (LOOP, 1975) to range from 0 to 305,000 cells/liter. In general, plankton biomass attained maximum values in surface waters. Biomass may attain a maximum from June through August and a minimum from October to March. Cell densities are highest in the coastal bays and neritic zone and decrease seaward. In the neritic zone, phyto-

TABLE G.2-19 Phytoplankton taxa observed during May, 1973 to March, 1974

Cyanophyta
- *Oscillatoria* sp.

Chlorophyta
- *Chlorella* sp.

Bacillariophyta
- *Asterionella japonica*
- *Bacillaria* sp.
- *Biddulphia alternans*
- *Chaetocerus compressum*
- *C. peruvianum*
- *C. pelagicum*
- *Coscinodiscus excentricus*
- *Coscinodiscus* sp.
- *Cyclotella* sp.
- *Fragillaria* sp.
- *Guinardia flaccida*
- *Hemidiscus* sp.
- *Lithodesmium undulatum*
- *Navicula distans*
- *Navicula* sp.
- *Nitzschia* sp.
- *Pleurosigma* sp.
- *Porosira stelliger*
- *Rhizosolenia acuminata*
- *R. alata*
- *R. fragilissima*
- *R. imbricata*
- *Skeletonema costatum*
- *Stauroneis membranacea*
- *Thalassiosira aestivalis*

Pyrrophyta
- *Ceratium furca*
- *C. hircus*
- *Ceratium* sp.
- *Exuviaella* sp.
- *Goniaulax* sp.
- *G. monilata*
- *Gymnodinium splendens*
- *Peridinium* sp.

Source: LOOP, 1975

plankton diversity may be greater than either open Gulf waters or inland waters due to the mixing of freshwater and marine genera. El Sayed (1972, as cited in U.S. Dept. of Interior, 1976) noted spatial values for primary production in inshore surface and integrated euphotic zone (0.55 mg C/m^3/hr and 7.04 mg C/m^2/hr, respectively) to be higher than those for offshore waters (0.21 mg C/m^3/hr and 5.45 mg C/m^{2}hr, respectively).

The phytoplankton community near the Weeks Island and Chacahoula brine diffuser sites conforms to the plankton community characteristic of the coastal waters of Louisiana. During the 4-month (September-December, 1977) investigation, 98 phytoplankton species were identified in these waters (Table G.2-20). The classes and number of species identified in each class are as follows: Bacillariophyceae (72), Dinophyceae (11), Chlorophyceae (8), Cyanophyceae (6), and Chrysophyceae (1). The majority of the Chlorophyceae and several of the Bacillariophyceae noted are freshwater species, having been introduced into these coastal waters by riverine discharge. These species, including Chlorella sp., Scenedesmus spp., Fragillaria sp. and Navicula spp., were, in general, more abundant in the surface waters at the Weeks Island site than at the Chacahoula site. About 35 of the diatom species observed in this area, among them Biddulphia spp., Chaetoceros spp., Rhizosolenia spp., Thalassiosira spp., and Skeletonema sp., are considered neritic forms (Cupp, 1943). Six diatom species observed more often at the Chacahoula site are predominantly oceanic forms, with nominal representation at Weeks Island. The dinoflagellates noted at the diffuser sites were predominantly neritic and marine species; two estuarine-neritic species (Dinophysis sp. and Peridinium sp.) occurred once in the surface waters at Weeks Island. The presence of freshwater, neritic, and oceanic phytoplankton species in these waters is consistent with this region where oceanic water is measurably diluted by freshwater runoff from the Mississippi and Atchafalaya Rivers. Figure G.2-30 presents the average phytoplankton density (standing crop) in surface and bottom waters for September through December 1977, for the two proposed brine diffuser sites. For

TABLE G.2-20 The quantitative and qualitative distribution (#/m^3) of phytoplankton species in the surface and bottom waters at the Weeks Island and Chacahoula brine diffuser sites from September to December, 1977.

SPECIES	SEPTEMBER		OCTOBER				NOVEMBER		DECEMBER			
	Weeks Island		Weeks Island		Chacahoula		Weeks Island		Weeks Island		Chacahoula	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Botto
CHLOROPHYCEAE												
Actinastrum hantzschii	0	0	0	0	0	0	0	0	4.73	0	0	0
Ankistrodesmus falcatus	0	0	7.33	0	0	0	0	0	1.18	0	0	0
Chlorella sp.	56.66	40.67	0	0	0	0	0	0	0	0	0	0
Chodatella quadriseta	8.33	0	0	0	0	0	0	0	0	0	0	0
Chlorococcum sp.	0	0	3.67	1.99	0	0	0	0	0	0	0	0
Scenedesmus armatus	0	0	0	4.63	0	0	0	0	0	0	0	0
S. bijugga	0	0	0	0	0	0	0	0	14.33	0	0	0
S. quadricauda	0	0	4.2	0	0	0	0	0	0	0	0	0
Total	64.99	40.67	15.2	6.62	0	0	0	0	20.24	0	0	0
CYANOPHYCEAE												
Agmenellum thermale	211	0	24.5	0	0	0	0	0	0	0	0	0
Anabaena sp.	0	0	0	0	0	100	0	0	0	0	0	0
Anacystis incerta	0	0	0	72.33	0	0	0	0	0	0	0	0
Oscillatoria spp.	0	18.63	0	0	1185	273.33	0	35.33	1014.33	0	121	0
Schizothrix calcicola	126	0	0	0	0	0	0	0	0	0	0	0
Spirulina subsalsa	0	0.67	0	0	0	0	0	0	0	0	0	0
Total	337	19.3	24.5	72.33	1185	373.33	0	35.33	1014.33	0	121	0
BACILLARIOPHYCEAE												
Centrales												
Actinoptychus undulatus	0	0	0	0	0	0	0	0	1.05	14.5	0	0
Bacteriastrum delicatulum	0.07	0.07	0	0	0	22.43	0	0	0	0	0	0
B. hyalinum	0.07	0	0	0	0	0	0	0	0	0	0	0
Biddulphia aurita	0	0	0	0	0	0	4.93	6.11	0	0	0	0
B. mobiliensis	0.26	1.39	0	5.3	0	7.8	4.43	0	0	0	0	0.20
B. sinensis	0.39	0.90	0	0	0	12.64	0	0	0	0	0	[illegible]
B. obtusa	0	0	0	3.72	0	0	0	0	0	0	0	[illegible]
Certatulina pelagica	0	0	0	0	0	0	0	0	3.6	0	0	[illegible]
Chaetoceros affinis	6.1	0.56	0	28.6	0	26.2	0	0	0	15.67	2.51	0
C. brevis	18.57	12.43	0	19.23	52.87	81.09	59.47	15.47	4.73	56.11	2.53	1.57
C. compressus	25.97	19.47	0	0	0	0	0	0	0	0	0	0
C. costatus	6.93	1.06	0	0	0	0	0	0	0	0	0	0
C. curvisetum	17.87	11.7	170.87	170.6	364.67	347.33	7.67	0	0	98.33	0	0
C. decipiens	2.93	0.26	0	0	26.8	4.07	0	8.83	13.03	95.67	0	4.5
C. didynum	0.13	0.10	0	0	18.37	0	0	0	0	15.4	0	0
C. lacinosum	0.9	0	0	0	345.67	447	0	0	0	0	0	0
Corethron criophylum	0.07	0.07	0	0.58	0	0	0	0	0	0	0	0
Coscinodiscus centralis	0	0	1.39	0	0	3.73	0	0	0	8.8	0	0
C. granii	0.07	0	0	0	0	0	0	0	0	13.2	0	0
C. lineatus	0	0	0	0	0	0	0	0	3.6	31.37	7.36	9.69
C. oculus-iridis	0	0.45	0	0	2.52	3.73	0	5.1	5.37	7.6	1.38	4.97
C. radiatus	0	0.55	0	3.84	0	1.26	12.23	0	0	14.05	0	0.61
Coscinodiscus sp.	0.39	0.16	0	0	0	0	12.06	11.21	9.13	3.05	0	0
Cyclotella cf. *C. caspia*	104.33	61	0	0	0	0	0	0	0	0	0	0
C. meneghiniana	8.33	20.33	8.57	1.33	0	0	0	0	0	0	0	0
Cyclotella sp.	0	0	0	0	24.5	0	0	0	0	0	0	0
Eucampa sp.	0	0	0	0	0	0	0	0	0	2.20	0	0
Guinardia flaccida	0	0	0	5.12	0	9.37	0	0	0	9.41	0	3.59
Hemidiscus hardmaniana	0	0	0	0	0	0	0	0	0	2.81	0	0
Hemiaulus hauckii	0	0.03	0	0	0	14.97	0	0	3.6	4.4	0	0
H. membranaceus	0	0	0	0	0	16.33	0	0	0	0	0	0
Leptocylindrus danicus	0	0.20	4.63	3.47	0	0	0	0	0	0	0	0
L. minimus	0	0	0	6.63	0	0	0	6.63	12.17	16.87	0	0
Lithodesmium undulatum	1.47	1.43	0	3.97	2.52	64.9	7.13	0	0	17.23	0.93	2.81
Melosira granulata	0	0	0	0	0	0	0	39	300.1	50.67	0	0
Rhizosolenia alata	0.13	0.10	0	2.89	3.77	0	0	0	0	0	0	0
R. calcar-avis	0	0	0	1.37	0	4.07	0	0	0	0	0	0
R. delicatula	0	0	0	0	0	0	0	0	0	0	2.03	1.30
R. fragilissima	0	0	0	0	0	7.47	0	0	0	0	0	0
R. imbricata	0	0.22	0	0	0	5.3	0	0	0	0	2.03	2.67
R. setigera	0.26	1.41	0	11.68	0	4.69	0	0	0	0	0	0

TABLE G.2-20 continued.

SPECIES	SEPTEMBER		OCTOBER				NOVEMBER		DECEMBER			
	Weeks Island		Weeks Island		Chacahoula		Weeks Island		Weeks Island		Chacahoula	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
R. stollerfothii	0.19	2.15	2.36	18.88	0	14.55	0	0	0	2.81	0	0
Skeletonema costatum	3953.1	3929.27	1688.67	1673.33	529.5	266.57	231.57	483	86	894.33	12.43	3.62
Stephanopyxis palmeriana	0	0.13	0	0	36.37	41.4	0	0	0	15.73	5.07	0
Streptotheca thamensis	0.9	0.86	2.45	19.4	0	16.73	0	24.0	0	0	0.93	0.74
Thallassiosiria aestivalus	0	0	0	0	0	0	0	0	0	8.8	0	0
T. eccentrica	0	20.33	13.7	779.93	8.49	353.8	11.9	36.97	0	0	6.02	1.34
T. rotula	0	0	0	0	0	0	0	0	0	36.67	0	0
Thalassiosiria sp.	59.39	101.33	0	0	345.47	4994.67	0	0	0	39.23	6.0	7.79
Total	4209.01	4191.37	1926.75	2782.03	1779.04	6858.04	353.95	654.28	467.48	1788.4	53.44	15.22
Pennales												
Amphiprora alata	0	0.22	0	0	0	0	0	0	0	0	0	0
Asterionella cf. A. formosa	0	0	0	0	0	0	0	0	142.87	0	0	0
A. japonica	15.17	34.67	5.3	54.5	417.33	214.57	0	45.67	0	0	0	0
Diploneis crabro	0	0.22	0	0	0	0	0	0	0	0	0	0
Fragillaria cf. F. leptostauron	52.66	0	0	0	0	0	0	0	0	0	0	0
Gyrosigma balticum	0.13	0.55	0	0	0	0	0	0	0	0	0.35	0.56
Navicula muralis	0	0	0	0.58	0	0	0	0	0	0	0	0
Navicula sp.	0	0	0	0	1.26	0	0	0	0	0	0	0
Nitzschia acicularis	0	0	0	9.27	0	22.43	0	0	0	0	0	0
N. capitata	0	0	0	1.73	0	4.07	0	0	0	0	0	0
N. closterium	0.07	0.32	0	0	1.26	3.73	2.38	0	0	4.4	0	0.20
N. longissima	0	0	0	0	3.06	2.04	0	0	0	0	0	0
N. paradoxa	0	0	0	0	0	51.13	0	0	0	0	0	0
N. pu gens	0.77	3.66	0	8.67	8.17	26.73	0	8.83	39.67	165.67	10.17	0
N. sigma	0	1.57	2.09	11.0	2.52	56.07	0	0	0	2.81	1.69	4.46
Nitzschia spp.	0	0	6.13	0	0	0	0	0	0	0	0	0
Plagiogramma staurophorim	0	0	0	0	0	0	0	0	0	0	0	0.61
Pleurosigma sp.	0	0	0	0	0	7.47	0	0	0	0	0	0
Synedra ulna	8.33	0	0	0	0	0	0	0	0	0	0	0
Thalassionema nitzschioides	1.6	1.75	0	45	130.2	917.67	0	8.83	14.83	171.33	26.73	9.43
Thalassiothrix splendens	0	0.13	0	0	0	0	0	0	0	0	0	0
Tropodoneis sp.	0	0.29	0	0	0	3.73	0	0	0	0	0	0
Total	78.73	43.38	13.52	130.75	563.8	1309.64	2.38	63.33	197.37	344.21	39.44	15.26
DINOPHYCEAE												
Ceratium furca	0	0	0	0	0	0	0	0	0	0	1.59	0
C. fusus	0	0	0	0	0	0	0	0	0	0	1.02	0
C. hircus	0	0.07	0	0	0	0	0	0	0	0	0	0
C. tripos	0	0	0	0	1.26	0	0	0	0	0	0	0
Cladopyxis sp.	0	0	0	0	0	0	0	0	0	0	0	1.51
Dinophysis caudata	0.13	0	0	0	0	0	0	0	0	0	0	0
Peridinium conicum	0.07	0	0	0	0	0	0	0	0	0	0	0
P. divergens	0.13	0.13	0	0	0	2.04	0	0	0	0	0	2.18
Peridinium sp.	0	0	0	0	0	0	0	4.76	0	0	0	0
Prorocentrum compressum	0	0.22	0	0	0	0	0	0	0	0	0	0
Pyrophacus sp.	0.07	0	0	0	0	0	0	0	0	0	0	0
Total	0.40	0.42	0	0	1.26	2.04	0	4.76	0	0	2.71	3.69
CHRYSOPHYTA												
Dictyocha fibula	0	0.03	0	0	0	0	0	0	0	0	0	0
Total	0	0.03	0	0	0	0	0	0	0	0	0	0
STATION TOTALS	4690.13	4295.17	1979.97	2991.73	3529.1	8543.05	356.33	757.70	1699.42	2132.61	216.59	64.17

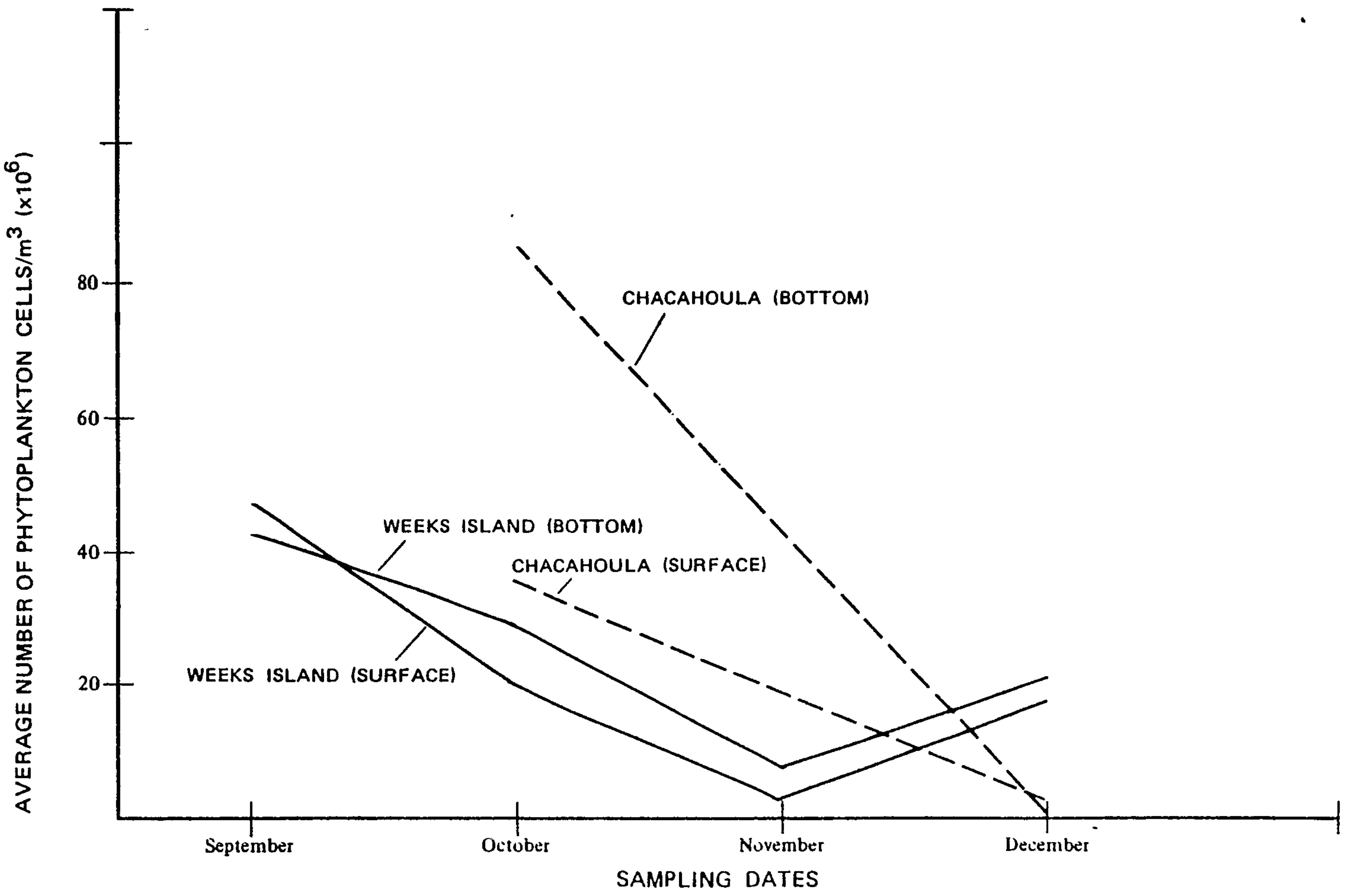

FIGURE G.2-30. Average phytoplankton cell densities at the proposed Weeks Island and Chacahoula this sampling period, the standing crop was highest in September and lowest in November or December. Chlorophyll a concentrations (Figure G.2-31, and Tables G.2-21 and G.2-22), which have been used to estimate phytoplankton standing crop, show a similar trend.

Surface and bottom water samples were obtained once (in September) from the Weeks Island and Chacahoula sites for chemical analyses. Silicate and phosphate concentrations at the bottom were generally greater than in the surface waters, while nitrate concentrations were greater in the surface waters. Even though surface phytoplankton density was greater in the surface waters in September at Weeks Island than in the bottom layers, the plankton density differential would be difficult to correlate to the observed nitrate-nitrogen difference between the two layers.

G.2.4.2.2 Zooplankton

Zooplankton are the free-floating animals of the aquatic ecosystem. This group has limited ability for horizontal movement yet undergoes vertical migration within the water column. Their major role is to transfer energy from the primary producers to higher levels of the food web. Eggs or larvae of fish, shrimp, crabs, oysters, and other organisms which spend a portion of their life cycles as plankton are termed meroplankton. Many other species are planktonic for their entire life cycle (holoplankton). Most zooplankton may be classified as herbivores, carnivores, or detritivores (detritus feeders). The most important and abundant herbivores are the copepods (e.g. Euchaeta sp., Eucalanus sp., and Acartia sp.). Euchaeta sp. and Corycaeus are typical carnivores.

Zooplankton species collected during the LOOP (1975) study are listed in Table G.2-23. Copepods were dominant during all sampling months, comprising 52 to 97 percent of the monthly total and averaging 79 percent over all months. Acartia sp. was the predominant copepod genus, constituting 53 percent of the total. In a similar study of the coastal waters of Louisiana, Gillespie (1971) reported that Acartia sp. made up an average of 60 percent of the total plankton density, with maximum in May and October. During the LOOP study, Paracalanus sp. was

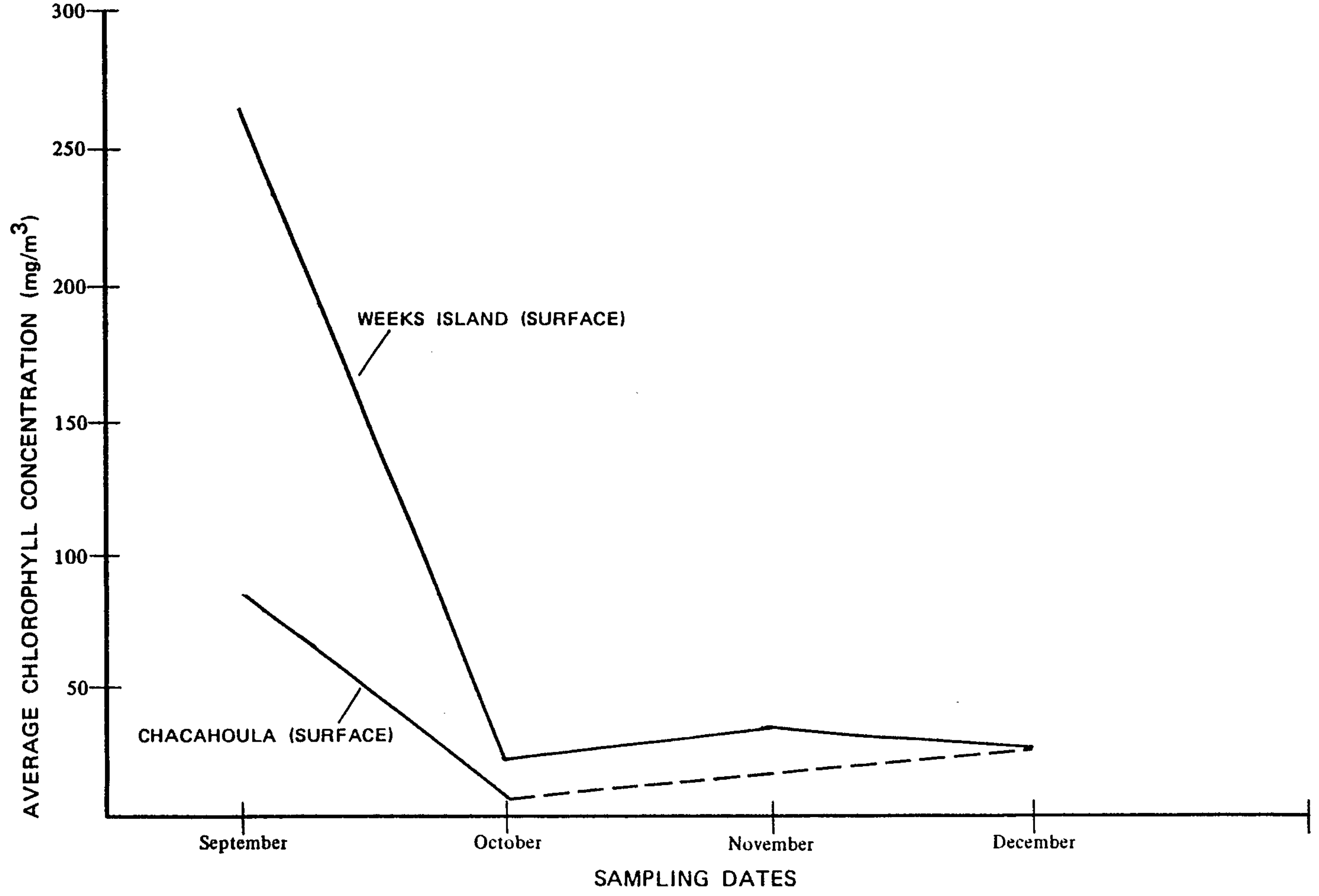

FIGURE G.2-1. Average surface chlorophyll concentration (mg/m³) at the proposed Weeks Island and Chacahoula brine diffuser sites, September - December 1977.

TABLE G.2-21 Chlorophyll concentrations (mg/m^3) at the Weeks Island site for four months - September to December, 1977.

Station	September	October	November	December[a]
W1				
W2	178.5		29.8	
W3		20.5	40.9	28.2
W5	376.0	21.9	28.2	40.9
W6				29.6
W7		21.4	53.9	
W8	263.2		43.7	33.7
W10	263.2		25.1	
W11		14.7	26.0	14.1
W14		22.3	25.1	23.5
W15	206.8		27.9	
WR1		23.3	36.3	
WR2		33.9		16.4
WR3	308.0	16.3	41.7	51.3
WR4		20.5	25.1	25.8
Average	265.8	21.6	33.60	29.2

---

[a] Values given are the average of surface and bottom values.

TABLE G.2-22 Chlorophyll concentrations (mg/m^3) at the Chacahoula site for four months - September to December, 1977.

Station	September	October	November	December
C2	20.7			
C3		12.5		
C5	101.1	12.3		29.1
C7		4.6		
C10		4.3		
C13		12.8		24.4
CR1		5.6		23.5
CR2		4.5		
CR3	130.9	8.6		
CR4		14.3		
CR5				
Average	85.9	8.9		25.3

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[a] Values given are the average of surface and bottom values.

TABLE G.2-23 A list of the zooplankton collected during the LOOP (1975) study.

Phylum PROTOZOA:
- Class Sarcodina

Phylum COELENTERATA
- Class Hydrozoa: medusae
- Class Scyphozoa: medusae

Phylum CTENOPHORA
- Class Tentaculata

Phylum ASCHELMINTHES
- Class Rotifera
- Class Nematoda

Phylum MOLLUSCA
- Class Pelecypoda: Lamellibranch larvae
- Class Pteropoda: larvae
- Class Cephalopoda: Squid larvae

Phylum ARTHROPODA
- Class Crustacea
  - Nauplei
  - Zoea
  - Megalops
  - Ostracoda
  - Cladocera
  - Copepoda
    - _Acartia_ sp.
    - _Centropages_ sp.
    - _Eucalanus_ sp.
    - _Labidocera_ sp.
    - _Paracalanus_ sp.
    - _Pontella_ sp.
    - _Oithona_ sp.
    - Herpacticoids
    - Misc. Copepods

TABLE G.2-23 continued.

- Amphipods
- Isopods
- Mysidacea
- Cumacea
- Stomatopoda larvae
- Decapoda:
  - *Lucifer faxoni*
  - *Acetes americanus*
  - Penaeid post larvae
  - Caridean post larvae
  - Unidentified decapod post larvae

Phylum CHAETOGNATHA
- *Sagitta* sp.

Phylum CHORDATA
- Subphylum Tunicata
  - Class Larvacea
    - *Oikopleura* sp.
  - Class Thaliacea
    - Doliolids
- Subphylum Verterata
  - Fish eggs
  - Fish larvae

SOURCE: Ragan, 1975.

the second most abundant genus, comprising 28 percent of the copepods. Gillespie reported this species occurring only in coastal waters east of Timbalier Bay, Louisiana, in the early spring and absent during the summer months. Other copepods periodically present in quantity were centropages sp., Oithona sp., Eucalanus sp., Labidocera sp., and Temora sp.

A general successional pattern of zooplankton species occurred throughout the year (Gillespie, 1971). Pteropods were abundant from July to November, with a maximum in October. In July, August, and February, pelecypod larvae were abundant. Cirripedia nauplii were present throughout the year, having maxima in April and October. Decopod larvae were found from April to November, with a maximum in August. From April through November, fish larvae were present having a density peak in June. Zooplankton peaks ($1441/m^3$) occurred in May with lows ($740/m^3$) in March and again from June through September. During the LOOP study, mean zooplankton densities ranged from 2,000 to 120,000 organisms per cubic meter. Densities from mid-depths were generally higher than at the surface. In general, zooplankton maxima have been recorded in May through June and in September and November. Minima have been noted December through March, and June through September (LOOP, 1975; Gillespie, 1971). These periods of minima and maxima have been correlated to such environmental parameters as phytoplankton density, water temperature and salinity, local currents, winds, and predation, especially by ctenophores.

During the 4-month sampling program, zooplankton from eight phyla were identified (Table G.2-24). The copepods dominated this community during all sampling months and were most abundant at the Chacahoula site. During this period, this group comprised 89 to 96 percent of the zooplankton community. Acartia tonsa was the dominant species at Weeks Island from September through November and contributed more than 45 percent of the zooplankton biomass (Table G.2-25). Temora tubinata, a euryhaline and eurythermal species, was dominant at Chacahoula in October and again in December, while Paracalanus crassirostris dominated (35 percent) this

TABLE G.2-24 Average number of zooplanton (#/m^3) identified at the Weeks Island and Chacahoula brine diffuser sites during September - December 1977.

		SEPTEMBER		OCTOBER		NOVEMBER	DECEMBER	
		Weeks Island	Chacahoula	Weeks Island	Chacahoula	Weeks Island	Weeks Island	Chacahoula
HYDROZOA								
Hydromedusae		0.0026	0	0	0	0	0.0038	0
	TOTAL	0.0026	0	0	0	0	0.0038	0
CTENOPHORA								
Beroe sp.		0.0026	0	0.0206	0	0	0	0
	TOTAL	0.0026	0	0.0206	0	0	0	0
CHAETOGNATHA								
Sagitta inflata		2.4768	3.0069	0.0568	0.7869	1.6898	0.8823	34.0041
	TOTAL	2.4768	3.0069	0.0568	0.7869	1.6898	0.8823	34.0041
BRYOZOA								
Larvae		17.1440	25.1548	0	0	0	0	0
	TOTAL	17.1440	25.1548	0	0	0	0	0
GASTROPODA								
Veliger		0	0	0	0.0129	0	0	0
	TOTAL	0	0	0	0.0129	0	0	0
ANNELIDA								
Polychaeta		0.5183	0	0	1.1274	0	0	1.1610
	TOTAL	0.5183	0	0	1.1274	0	0	1.1610
CIRRIPEDIA								
Cypris		0.2837	0.0542	0	0.2348	0	0.7739	0
Nauplii		0	0	5.160	0.0851	20.6398	0	0
	TOTAL	0.2837	0.0542	5.160	0.3199	20.6398	0.7739	0

TABLE G.2- 24 continued.

		SEPTEMBER		OCTOBER		NOVEMBER	DECEMBER	
		Weeks Island	Chacahoula	Weeks Island	Chacahoula	Weeks Island	Weeks Island	Chacahoula
COPEPODA								
Nauplii		143.2916	29.4117	16.2023	21.0529	181.7079	2.3219	6.7079
Acartia tonsa		241.2793	696.0139	37.1001	10.5263	347.7812	32.5077	23.2198
Caligus sp.		0.0619	0	0.0026	0	0	0	0
Centropages sp.		0	0	0	0.3767	0	0	0.2580
Eucalanus attenuatus		0	0.5031	0	4.6233	0	0	2.2188
Labidocera sp.		1.9594	1.935	0	0.049	0	3.2120	9.3911
Paracatanus crassirostris		56.2951	7.7399	16.1739	5.5212	85.7327	42.1826	139.3188
PseudodiaTomus coronatus		0.921	0	0	0	0	0	0
Temora tubinata		0.0516	0.2012	0.0026	28.6626	0	0.1548	154.7865
Corycaeus subulatus		0	0	0	0.0593	0	0	0
Oithona colcarva		57.3271	22.6347	0	0	0	0	0
O. brevicornis		0	0	5.7921	7.0175	44.3756	22.4458	144.9948
O. subulatus		0	0	0	0.4205	0	0	0
Oncaea sp.		0	0	0	0	0	0	0.6450
Sapharella sp.		0	0	0	2.5542	0	0	0
Euterpina acutifrons		0	0	0	15.5057	0	0	0
Longipedia sp.		0.1032	0	0	0	0	0	0
Microsettela sp.		0	0	0	0.0568	0	0	0
	TOTAL	501.2902	758.4395	75.2736	96.426	659.5974	102.8248	481.5407
MYSIDACEA								
Mysidopsis sp.		0.0129	0	0	0	0	0	0.0516
	TOTAL	0.0129	0	0	0	0	0	0.0516
ISOPODA								
Aegatha oculata		0.0026	0	0.0026	0	0	0	0.0026
	TOTAL	0.0026	0	0.0026	0	0	0	0.0026

TABLE G.2-24 continued

	SEPTEMBER		OCTOBER		NOVEMBER	DECEMBER	
	Weeks Island	Chacahoula	Weeks Island	Chacahoula	Weeks Island	Weeks Island	Chacahoula
DECAPODA							
Calinectes sapidus	0.0129	0	0	0	0	0	0.0026
Clibanarius vittatus	0.0232	0	0	0	0	0	0
Hexapanopeus angustifrons	0	0.0503	0	0	0	0	0
Lucifer faxoni	0.0296	0	0	0	0	0	0.5366
Ocypodidae	0.0077	0.0193	0	0	0	0	0
Palaemonetes sp.	0.0722	0	0	0.3379	0	0	0.0026
Panaeopsis sp.	0.0026	0	0	0	0	0.0038	0
Penaeus setiferus	0.0026	0	0	0	0	0	0
Petrolisthes armatus	0.0077	0	0	0	0	0	1.6899
Pinnixa sp. zoea	0.5289	0.1354	0.0103	0.5470	0.5160	0	7.5154
Rithropanopeus harrissi	1.3184	0	0	0	0	0	0
Xanthid megalops	0.5212	0.0580	0	0.1522	0	0	0
Unidentified	0	0.2941	0	0	0	0	0
TOTAL	2.527	0.5571	0.0103	1.0371	0.5160	0.0038	9.7445
CHORDATA							
Anchoa mitchici	0	0	0	0	0.0155	0.0077	0
Gobidae Larvae	0	0	0.0026	0	0	0	0
Larvacea	0	0	0.8334	0	0.0774	0	12.0382
TOTAL	0	0	0.8360	0	0.0929	0.0077	12.0382
STATION TOTAL	524.2607	787.2125	81.3599	99.7102	682.5359	104.4963	538.4885
NUMBER OF SPECIES	28	16	13	21	9	11	20

TABLE G.2-25 The percentage composition of the zooplankton comprising the four dominant species at the Weeks Island and Chacahoula brine diffuser sites during September - December 1977.

	September		October		November		December	
	Weeks Island	Chacahoula	Weeks Island	Chacahoula	Weeks Island	Chacahoula	Weeks Island	Chacahoula
Acartia tonsa	46.19	88.43	45.69	10.55	50.95		25.72	
Bryozoa Latvae		3.19						
Copepod Nauplii	27.40	3.73	19.95	21.11	26.62			
Euterpina acutifrons				15.506				
Labidocera sp.							2.54	
Oithona brevicornis			7.13		6.50		35.52	26.92
Oithona colcarva	10.70	2.87						
Paracalanus crassirostris	10.76		19.92		12.56		33.38	25.87
Sagitta inflata				15.55				6.31
Temora tubinata				28.74				28.74

community at Weeks Island in December. Other numerically important copepod genera were Oithona spp. and Euterpina sp. In the September collections, bryzoan larvae were the codominant zooplankton at both sites. Similarly, the cirripedia nauplii were second in abundance to the copepods in October and November at Weeks Island. The chaetognath, Sagitta inflata was present during each month at both sites, however it was most abundant at the Chacahoula site in December. The decapods contributed approximately 13 to 28 percent of the species recorded at both sites.

During the 4-month sampling program, average densities ranged from 81 to 788/m^3 (Table G.2-24). Figure G.2-32 denotes the zooplankton concentration (#/m^3) at each site. With the exception of the November sampling at Chacahoula (samples were not taken), the zooplankton biomass at the Chacahoula site was greater than that at Weeks Island. At both sites, minimum zooplankton biomass occurred in October. Maximum values were attained in November at Weeks Island (682/m^3) and in September at Chacahoula (787/m^3). The plankton pulse varies from year to year, but generally is evident during September through November.

Trace metal analyses performed on selected samples from the diffuser sites are presented in Section G.5, Table G.5-11. There were higher concentrations of all metals, except copper, in zooplankton than in fish and shrimp samples. This is due, in part, to the concentrating ability of these secondary producers (mostly chaetognaths) and also to the extremely high surface area/mass ratio relative to macrofauna. Compared with two zooplankton samples taken from other studies in the northwest Gulf of Mexico (Table G.5-11), manganese (Mn), zinc (Zn), and nickel (Ni) contents were greater while lead (Pb) content was considerably less. Concentrations for the remaining heavy metals, iron (Fe), copper (Cu), cadmium (Cd), and aluminum (Al), were, within the range for the northwest Gulf samples.

G.2.4.3 Benthic Invertebrates

Benthic invertebrates are important contributors to the trophic structure of the coastal region. Many phyla and trophic levels are

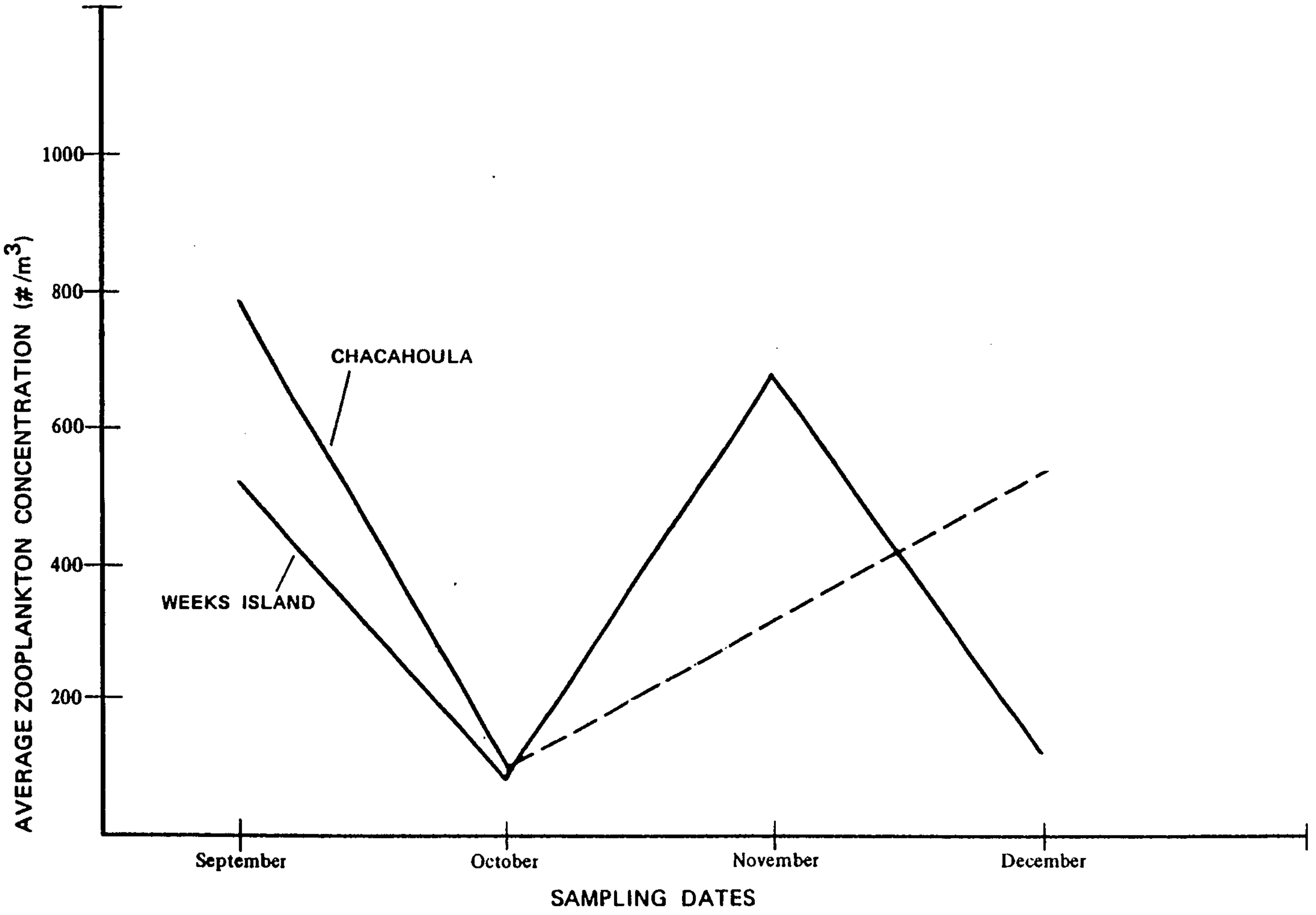

FIGURE G.2-32. Average zooplankton concentrations (#/m^3) at the proposed Weeks Island and Chacahoula brine diffuser sites during September - December 1977.

represented. Some benthic organisms feed on detritus and phytoplankton, converting their energy into a form not otherwise useable by higher organisms. Many others are carnivores as well as prey for higher carnivores. Many of the higher carnivores are commercially important species such as shrimp, blue crab, croaker, and red drum. Shrimp, crabs, and fish that spend at least part of the time on the bottom are considered as nekton since they are highly motile and are most often caught with bottom trawls. The American oyster (Crassostrea virginica), the only benthic organism of significant commercial importance in the region, does not inhabit the project area.

Benthic invertebrate distribution and abundance is affected by such factors as substrate, depth, DO, salinity, and temperature. The substrate of coastal Louisiana consists mainly of silt with fine sand and clay. The DO in bottom water is often low. A highly significant positive correlation was found in the Louisiana coastal waters west of the Mississippi River between DO and total number of invertebrates and total number of polychaetes. Statistically significant negative correlations were found between salinity and total polychaetes, total invertebrates, and phoronids. It was also reported that between the 25 and 140 foot depths there was a general decrease in density of benthic macroinvertebrates; however, densities were usually higher at stations in 49 to 62 feet of water than at those in 25 to 30 (Ragan, 1975).

Ragan (1975) reported the presence of 24 taxa of benthic macroinvertebrates (collected by ponar grab) during a 1973-1974 survey (Table G.2-26). Polychaetes were the most abundant organism, averaging 69 percent of the total number of organisms and ranging between 29 and 92 percent. Phoronids and pelecypods were the second and third most abundant organisms, respectively. These three groups made up 94 percent of the samples. The mean density for total invertebrates was $860/m^2$ with the range at individual stations from $180/m^2$ to $2700/m^2$. Seasonal variation in density varied with depth; however, at shallow stations (25-62 feet) peaks occurred in January and March, while at the deeper stations (70-140 feet) the highest densities were in September and December. Further-

TABLE G.2-26 Benthic Infauna collected by Ponar Grab Sampler in Louisiana Coastal waters during the LOOP Study

Scyphozoa: Medusae (Jellyfish)
Anthozoa: Sea anemones

Nemertinea: Ribbon worms
Nematoda: Roundworms
Polychaeta: Sandworms
Gastropoda: Snails
    Cancellaria reticulata
    Oliva sayana
    Polinices duplicata
    Other gastropods
Pelecypoda:
    Mulina sp.
    Other Pelecypods
Isopoda: Isopods
Amphipoda: Amphipods
    Clibanarius vittatus: hermit crab
    Other hermit crabs
    Spider crabs
    Unidentified crabs
    Crangon sp.: Snapping shrimp
    Xiphopenaeus sp.: Sea bobs
    Unidentified shrimp
Phoronida
Chaetognatha: Arrow worms
    Sagitta sp.: Arrow worm

Echinodermata: Ophiuroidea - Brittle star
Cephlachordata: Lancelets
    Salpa sp.

SOURCE: Ragan, 1975.

more, these trends may depend on seasonal fluctuations in bottom salinity and DO rather than on light and temperature. Ragan (1975) concluded that the region's benthic invertebrates were not "exceptionally productive," though they were significantly more productive in the onshore areas than in offshore areas.

In contrast to the LOOP study, ninety-five taxa of benthic invertebrates were collected at the Weeks Island site and 98 taxa were collected at Chacahoula (Table G.2-27) during the September-December 1977 survey. Species diversity as measured by the Shannon-Weaver index, was calculated for each site during the sampling program.

This is a tool for measuring the quality of the environment and the effect of stress on the structure of a macrobenthic community. The use of this tool is based on the generally observed phenomenon that relatively undisturbed environments support communities having large numbers of species with no individual species present in overwhelming abundance. When species in this community are ranked on the basis of their numerical abundance, there will be relatively few species with large numbers of individuals and large numbers of species represented by few individuals. Stress trends to reduce diversity of making the environment unsuitable to some species or by giving to other species a competitive advantage.

The calculated species diversity show that the index was always lower at Weeks Island (Table G.2-28) compared to Chacahoula (Table G.2-29) suggesting that the benthic invertebrates at Weeks are subjected to a condition of changing or higher environmental stress.

The density of organisms for a particular station ranged from 165 to 1410/m^2 at Weeks Island, and 48 to 1585/m^2 at Chacahoula (Tables G.5-22 through G.5-28) and on a monthly basis was always lower at Weeks Island (Tables G.2-28 and G.2-29). Densities remained relatively constant at Weeks Island; at Chacahoula there was a significant decline in December. The mean densities and maximum density reported by Ragan (1975) and the highest density (1585 organisms/m^2) reported at Chacahoula were lower than the lowest mean density reported at similar depths off the Texas coast over the same time period where densities ranged from 1673 to 5008 organisms/m^2 (U.S. Dept. of Energy, 1978).

TABLE G.2-27 Summary comparison of benthic macroinvertebrate (infauna) collected at the Weeks Island and Chacahoula brine diffuser sites, September - December, 1977.[a]

	Weeks Island	Chacahoula
Total number of taxa	95	98
Mean monthly density range (individuals/m^2)	530-604	560-700
Mean monthly diversity ($\overline{d}$) range	3.3-3.8	4.0-4.3
Number of polychaete taxa	28	26
Number of crustacean taxa	24	38
Number of mollusk taxa	33	23
Number of miscellaneous taxa	10	11
Percentage of polychaetes (monthly range)	64-73	57-66
Percentage of crustaceans (monthly range)	0.5-16	6-9
Percentage of mollusks (monthly range)	7-9	7-13
Percentage of miscellaneous groups (monthly range)	12-22	12-26
Number of taxa unique to site	29	34

[a] Data based on material in Tables G.5-22 through G.5-28.

TABLE G.2-28 Summary of benthic macroinvertebrate collections at the Weeks Island survey site (September-December, 1977)[a,]

	COLLECTION DATE			
	September	October	November	December
ANTHOZOA (SEA ANEMONES)	R	R		UC
RHYNCHOCELA (NEMERTEANS)	A	A	A	A
CHAETOGNATHA (ARROW WORMS)				
Sagitta sp.	C	UC	C	A
GASTROPODA (SNAILS)				
Anachis obesa		UC	R	UC
Anachis sp.	R			
Nassarius acutus	UC	C	C	C
Tectonatica pussilla	R	UC		R
Polinices duplicatus	R	R		
Epitonium rubicola			R	
Epitonium sp.	R	R		
Prunum apicinum	R			
Prunum sp.		R		
Terebra protexa			R	
Terebra sp.				R
Neritina sp.	R			
Olivella dealbata		R		
Turbonilla sp.		UC		UC
Cantharus cancelarius			R	
SCAPHOPODA (TUSK SHELLS)				
Dentalium texasianum	R			
PELECYPODA (CLAMS)				
Mulinia lateralis	C	C	C	C
Nuculana concentrica	C	C	C	C
Anadara ovalis		R	R	
Chione sp.	R		R	

TABLE G.2-28 (continued)

	COLLECTION DATE			
	September	October	November	December
Noetidae	R			
Semele proficua	R	R	R	R
Semele bellastritta	R			
Pandora trilineata				R
Lucina multilineata	R			
Lucina amiantus				R
Tellina sp.		UC	R	R
Abra aequalis		UC	R	UC
Gemma sp.		R		
Mactra sp.		R		R
Solen viridis			R	
Macoma constricta			C	
Macoma sp.		UC		UC
POLYCHAETA (BRISTLE WORMS)				
Spiophanes bombyx	A	A	A	A
Streblospio benedicti	A	A	A	A
Cossura longocirrata	A	A	A	A
Sigambra sp.	C	C	C	C
Lumbrineris sp.	R	UC	UC	UC
Lepidasthenia varia	UC	R	R	
Pseudeurythoe ambigua	C		R	R
Malmgrenia cf. *lunulata*	R			R
Glycera sp.	R	R		
Lepidonotus sp.	R			
Gyptis brevipalpa	UC	UC	R	R
Clymenella torquata	C	R	R	R
Chaetopterus variopedatus	R			
Onuphis opalina	R			
Onuphis sp.			R	UC
Diopatra cuprea	UC	UC	UC	UC
Megelona rosea		R	UC	R

TABLE G.2-28 (continued)

	COLLECTION DATE			
	September	October	November	December
Cirratulus sp.				R
Amphictes gunneri		UC		
Chone infundibuliformis			R	
Glycinde solitaria	C	R	UC	UC
Paraonis fulgens	R			
Neanthes succinea	UC	C	C	C
Aglaophamus verrilli	UC	UC	UC	UC
Syllidae	R	UC	R	R
Stenolepis sp.		R		
Scolupus cf. *elongatus*	R	R		
Ancistrosyllis spp.	R	R	R	UC
OLIGOCHAETA (AQUATIC EARTHWORMS)	C	C	A	A
CRUSTACEA (CRABS, ISOPODS, ETC.)				
Monoculodes intermedius		R		
Corophium sp.			R	
Ogyrides limicola	R	R		
Campylaspis rubicunda	R	R		
Oxyurostylis smithi	UC	R		
Edotea montosa	R	R		
Paracaprella pusilla	R		R	
Calidus sp.			R	
Mysidopsis bigelowi		UC		
Lucifer faxoni	R			R
Acetes americanus cardinea	R	UC	R	
Hargeria rapax			R	
Xiphipeneus kroyeri	R			
Penaeus setiferus		A		
Upobegia affinis	R		R	
Callianassa latispina	R	R	R	
Polyonyx gibbesi	R			
Euceramus praelongus	R		R	

TABLE G.2-28 (continued)

	COLLECTION DATE			
	September	October	November	December
Pagurus bullisi	R	UC	UC	R
Hepatus pudibundus	R			
Panopeus turgidus	R			
Panopeus herbstii		R	R	
Portunus sayi	R			
Pinnixa chaetopterana	UC	C	R	UC
ECHINODERMATA (SEA STARS)				UC
Amphipholis sp.	UC	C	C	
HEMICHORDATA (ACORN WORMS)			UC	UC
Ptychodera bahamensis	C	C		
CEPHALOCHORDATA (LANCELETS)				UC
Branchistoma sp.	UC	R	UC	
Total Taxa	61	55	49	42
Density (m^2)	540	604	533	530
Diversity ($\overline{d}$)[c]	3.8	3.5	3.3	3.3

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[a] Data from Tables G.5-22 through G.5-25: based on 32 samples in September and October and 38 in November and December

[b] A-Abundant (100 or more collected); C-Common (20-99 collected); UC-Uncommon (19-5 collected); R-Rare (less than 5 collected)

[c] Diversity calculated using Shannon-Weaver index, $\overline{d} = \frac{C}{N} (N \log_{10} N - \Sigma n_i \log_{10} n_i)$

TABLE G.2 -29 Summary of benthic macroinvertebrate collections at the Chacahoula survey site (September - December 1977)[a,b].

	COLLECTION DATE		
	September	October	December
ANTHOZOA (SEA ANEMONES)		R	
TURBELLARIA (FLATWORMS)		R	
RHYNCHOCELA (NEMERTEANS)	C	C	C
CHAETOGNATHA (ARROW WORMS)			
Sagitta sp.	C	C	UC
GASTROPODA (SNAILS)			
Anachis obesa		UC	
Anachis sp.	R		
Nassarius acutus	R	C	R
Tectonatica pussilla	UC	C	R
Epitonium rubicola		R	
Oliva sayana		R	
Cyclotremiscus sp.		R	
Sinum maculatus			R
Sinum perspectivum	R		
Turbonilla sp.			R
Cantharus cancelarius	R	R	
PELECYPODA (CLAMS)			
Mulinia lateralis	C	C	
Nuculana concentrica	C	C	R
Nuculana maculatus	R		
Chione sp.	R		
Semele proficua	R		
Semele bellastritta	R		
Lucina multilineata		R	
Tellina sp.	C	C	UC
Abra aequalis	C	UC	UC
Eucrassatella speciosa	C		
Solen viridis		R	
Macoma sp.		R	

TABLE G.2-29 continued.

	COLLECTION DATE		
	September	October	December
POLYCHAETA (BRISTLE WORMS)			
Spiophanes bombyx	A	A	C
Streblospio benedicti	A	A	C
Cossura longocirrata	UC	UC	R
Sigambra sp.	C	UC	R
Lumbrineris sp.	C	A	C
Lepidasthenia varia	R	R	
Pseudeurythoe ambigua	R		
Malmgrenia cf. *lunulata*	R		
Glycera sp.	R	R	R
Gyptis brevipalpa	R		R
Clymenella torquata	C	C	C
Onuphis opalina	UC		
Onuphis sp.		R	
Diopatra cuprea	R	UC	R
Megelona rosea	R	UC	R
Cirratulus grandis	UC	UC	
Amphictes gunneri			R
Chone infundibuliformis	C	C	
Glycinde solitaria	C	UC	R
Neanthes succinea	C	C	UC
Aglaophamus verrilli	A	A	C
Syllidae		UC	R
Armandia maculata	R		R
Stenolepis sp.	C	C	UC
Scolupus cf. *elongatus*	C	C	
Ancistrosyllis spp.	UC	UC	
OLIGOCHAETA (AQUATIC EARTHWORMS)	A	C	C

TABLE G.2-29 continued.

	COLLECTION DATE		
	September	October	December
CRUSTACEA (CRABS, ISOPODS, ETC.)			
Monoculodes intermedius	R		
Monoculodes sp.		R	
Ampelisca abdita	R	R	R
Polyonyx gibbesi		R	
Corophium louisianaum	R		
Priscillina sp.	R		
Ogyrides limicola	C	UC	R
Campylaspis rubicunda	R		
Listriella barnardi	R		
Speocarcinus lobatus	R	UC	
Leptochela serratorbita		R	R
Oxyurostylis smithi	C	UC	R
Mysidopsis bigelowi	R	C	
Lucifer faxoni	UC	UC	
Acetes americanus cardinea	R	UC	
Alpheus heterochaelis	R		
Automate kingsleyi	UC	R	
Hippolyte pleracantha	R		
Xiphipeneus kroyeri			R
Penaeus setiferus	UC		
Upobegia affinis	R	R	
Callianassa latispina	UC	UC	UC
Callianassa jamicense		UC	
Argissa bamatipes	R		
Euceramus praelongus	R	R	R
Pagurus bullisi	R	UC	R
Haustoriidae		R	
Callinectes similis		R	
Albunea paretti		R	
Chasmocarcinus mississippiensis		R	

TABLE G.2-29 continued.

	COLLECTION DATE		
	September	October	December
CRUSTACEA (CONT'D)			
Squilla empusa		R	
Osachila sp.		UC	
Persephona aquilonaris	R	R	
Panopeus herbstii		R	
Portunus sp.		R	
Pinnixa chaetopterana	UC	C	UC
Pinnixa retinens	R		
Pinnotheres ostreum	R		
ECHINODERMATA (SEA STARS)			UC
Holothuroidea		R	
Amphipholis sp.	C	UC	
HEMICHORDATA (ACORN WORMS)			R
Ptychodera bahamensis	R	UC	
CEPHALOCHORDATA (LANCELETS)			
Branchistoma sp.	UC		R
Total Taxa	68	68	39
Density (m^2)	698	700	560
Diversity $(\overline{d})^c$	4.2	4.3	4.0

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[a] Data from Tables G.5-26 through G.5-28; based upon 30, 34 and 9 samples, respectively.

[b] A - abundant (100 or more collected); C - common (20-99 collected); UC - uncommon (19-5 collected); R - rare (less than 5 collected).

[c] Diversity calculated using Shannon-Weaver index,

$$\overline{d} = \frac{c}{N} (N \log_{10} N - \Sigma n_i \log_{10} n_i).$$

The benthic macroinvertebrate assemblages at both sites were dominated by polychaetes, which comprised 57 to 73 percent of the organisms collected each month (Table G.2-27). Mollusks and crustaceans were usually the second and third most abundant groups. These relationships are similar to those reported by Ragan (1975) in that the dominant taxa were the polychaetes; however, in his collections polychaetes were generally more abundant. Also, phoronids were not collected during this survey; in Ragan's survey (1975), they were the second most abundant group (about 22 percent).

There do not appear to be any significant differences in the benthic assemblages among the various stations at either site; however, there were differences between the two sites. There were 29 taxa unique to Weeks Island and 34 taxa unique to Chacahoula (Table G.2-27). The most apparent contrast between the two sites was the abundance of Cossura longocirrata and Sigambra sp. (polychaetes), and Penaeus setiferus (white shrimp) at Weeks Island and of Lumbrineris sp. and Aglaophamus verrilli (polychaetes) at Chacahoula (Tables G.2-28 and G.2-29).

G.2.4.4 Nekton

G.2.4.4.1 Regional and Site Specific Characterization

The high primary and secondary productivity of coastal Louisiana resulting from the interaction of the Mississippi River delta system and the Gulf of Mexico, provides an extremely suitable habitat for one of the major fisheries areas in the United States. Some of the major fisheries include shrimp, menhaden, oysters, and blue crabs. Average annual harvests (value and weight) of the major commercial fisheries for Louisiana during 1963 to 1967 are presented in Table G.2-30. Many of these species depend on the bays and estuaries for spawning, feeding, growth, and as a nursery (Table G.2-31).

Commercial landings in coastal and inland Louisiana during 1976 were 1.2 billion pounds, valued at $138.0 million. Menhaden was the leading species in weight (1.1 billion pounds) and second in value ($37 million). Shrimp was second in weight (82 million pounds) but first in value ($80 million). The blue crab ranked third in weight (15.2 million

TABLE G.2-30 Average annual harvest of major commercial fish and shellfish for Louisiana (1963-1967).

Species	Weight[a]	Value[b]
Menhaden	713.06	10.12
Shrimp	73.51	26.68
Croaker	23.71	0.42
Oyster	9.97	4.39
Blue Crab	8.27	0.73
Spot	4.62	0.08
Catfish and bullheads	4.59	0.78
Seatrout	4.11	0.19
Red drum	0.53	0.09
TOTAL	842.37	43.48

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[a] Millions of pounds

[b] Millions of dollars

Source: U.S. Army Corps of Engineers, 1973.

TABLE G.2-31 Migratory behavior of coastal organisms.[a]

Month	Movement into Estuaries (or nearshore zone)	Movement from Estuaries
Jan	Southern Hake, Red Drum (peak)	Menhaden, Spadefish
Feb	Stingray, Brown Shrimp Postlarvae, Menhaden, Spadefish	
Mar	Gulf Killifish, Spot, Cutlassfish, Hogchoker, Butterfish, Rough Silverside, Flounder, Tonguefish	Blue Catfish, Sheepshead Minnow, Longnose Killifish
Apr	Gafftopsail Catfish, Sea Catfish, Bluefish, Bumper, Sand Seatrout, Southern Kingfish, Shipjack Herring (in and out same month), Adult Croaker, Back Drum (peak), Pinfish, Atlantic Threadfin, Toadfish, Midshipman	Bighead Searobin
May	Striped Anchovy, Lizardfish, Sardine, Spanish Mackerel, White Shrimp Postlarvae	Menhaden, Southern Hake
June	Needlefish, Pompano, Crevalle Jack, Leatherjacket, Atlantic Moonfish	Butterfish
July	Ladyfish, Lookdown	
Aug		Ladyfish, Atlantic Threadfin
Sept		Adult Croaker, Rough Silverside
Oct	Menhaden, Sheepshead Minnow, Bighead Searobin	Sardine, Bluefish, Leatherjacket, Atlantic Moonfish, Sand Seatrout, Cutlassfish, Spanish Mackerel

TABLE G.2-31 continued.

Month	Movement into Estuaries (or nearshore zone)	Movement from Estuaries
Nov	Blue Catfish, Juvenile Croaker	Striped Anchovy, Gafftopsail, Sea Catfish, Needlefish, Pompano, Crevalle Jack, Bumper, Lookdown, Pinfish, Tonguefish, Toadfish, Midshipman, White Shrimp Juveniles
Dec	Longnose Killifish	Stingray, Lizardfish, Gulf Killifish, Spot, Southern Kingfish, Flounder, Hogchoker

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[a] Derived from data contained in cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana, Phase IV, Biology. Perret, et al., 1971.

Source: U.S. Department of Commerce, 1977a.

pounds) and fourth in value ($3.1 million). Oysters were third in value ($9 million). Louisiana led all States in volume and was third in value (U.S. Dept. of Commerce, 1977b).

Sportfishing in the Louisiana coastal area is extremely popular and provides for a large industry. The bays and nearshore regions yield Atlantic croaker, spot, red drum, seatrout, black drum, southern flounder, sheepshead, and spadefish. Oil rigs provide a reeflike environment with assemblages of cobia, crevalle jack, greater amberjack, sheepshead, great barracuda, king mackerel, blue runner, and Atlantic spadefish.

Recent studies of central coastal Louisiana (Perret, 1971; Ragan and Harris, 1975) characterize the region as having more than 42 species of invertebrates (Table G.5-36). Some of the more abundant invertebrates found in these studies are seabob, brief squid, white shrimp, brown shrimp, and blue crab.

Based on trawl data (September to December 1977) from Weeks Island the most numerically abundant invertebrates collected were the white shrimp, seabob, blue crabs (including juveniles), and brief squid (Table G.2-32). The white shrimp, brief squid, and moon jellyfish were the most numerically abundant invertebrates collected from trawls (September - December 1977) at the Chacahoula site (Table G.2-33). At least 21 taxa of invertebrates were collected at the Weeks Island site compared to 17 at Chacahoula. The total number of invertebrates collected and the number of collections in which they were present was also much higher at Weeks Island than at Chacahoula (Tables G.5-33 through G.5-35). The brown shrimp were not very abundant in trawl collections at either site, which may be expected since data at locations which are further offshore indicate peak abundance between June and late October.

Five and four species of commercially important invertebrates were collected, respectively, at the Weeks Island and Chacahoula survey sites. Invertebrates, particularly commercially important ones, were more abundant in the trawls at Weeks Island that at Chacahoula. Commercial trawling activities were in progress at both sites during this survey; however, they were much more concentrated in the vicinity of

TABLE G.2-32 Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site (September-December, 1977).

COMMON NAME	SCIENTIFIC NAME	COLLECTION DATE			
	Invertebrates	September	October	November	December
Hydroid colony	Hydrozoa		P	P	
Sea nettle	Chrysaora quinquecirrha	UC			
Cabbagehead	Stomolophus meleagris	C			
Sea anemone	Calliactis tricolor	R			
Sea anemone (unidentified)	Anthozoa			UC	
Moon snail	Polinices duplicatus	UC		R	
Arc shell (clam)	Arcidae	R	R		
Brief squid	Lolliguncula brevis	C	A	C	C
Mantis shrimp	Squilla empusa	C	UC	C	R
White shrimp	Penaeus setiferus	A	A	A	A
Brown shrimp	Penaeus aztecus	C	R	UC	
Penaeid shrimp	Penaeidae (juvenile)	C		A	
Seabob	Xiphopeneus kroyeri	A		A	A
Rock shrimp	Sicyonia dorsalis	UC			
Striped hermit crab	Calibanarius vittatus		R		
Hermit crab	Pagurus pollicaris	R			
Purse crab	Persephona aquilonaris	R	R		
Spider crab	Libinia sp.			R	
Blue crab	Callinectes sapidus	C	R	A	UC
Swiming crabs	Portunidae (juvenile)	A	UC	R	UC
Bryozoan	Bryozoa		P	P	
	Fish				
Shrimp eel	Ophichthus gomesi			R	
Gulf menhaden	Brevoortia patronus	R		R	
Bay anchovy	Anchoa mitchilli	A	A	A	A
Striped anchovy	Anchoa hepsetus	R	UC		
Sea catfish	Aris felis	A	C	A	R
Gafftopsail catfish	Barge marinus	C			
Atlantic midshipman	Porichthys porosissimus	C	R		

TABLE G.2-32 continued.

COMMON NAME	SCIENTIFIC NAME	COLLECTION DATE			
	Fish	September	October	November	December
Skilletfish	Gobiesox strumosus				R
Crested cusk-eel	Ophidion welshi	UC		R	
Chain pipefish	Syngnathus louisianae	R		R	R
Atlantic moonfish	Vomer setapinnis		R		
Lookdown	Selene vomer		R		
Atlantic bumper	Chloroscombrus chrysurus	UC	C		
Bluntnose jack	Hemicaranx amblyrhynchus	UC			
Crevalle jack	Caranx hippos		R		
Southern kingfish	Menticirrhus americanus			R	
Atlantic croaker	Micropogon undulatus	A	C	UC	R
Sand seatrout	Cynoscion arenarius	A	A	A	A
Spot	Leiostomus xanthurus	R			UC
Star drum	Stellifer lanceolatus	A	A	A	A
Banded drum	Larimus fasciatus			R	
Silver perch	Bairdiella chrysura				R
Spadefish	Chaetodipterus faber	R	UC	R,	R
Atlantic threadfin	Polydactylus octonemus	UC			
Southern stargazer	Astroscopus y-graecum		R	R	
Fat sleeper	Dormitator maculatus	R			
Atlantic cutlassfish	Trichiurus lepturus	R	A		R
Gulf butterfish	Peprilus burti	UC	R		UC
Bighead sea robin	Prionotus tribulus			R	R
Blackfin sea robin	Prionotus rubio	R			
Fringed flounder	Etropus crossotus	R	R	R	
Bay whiff	Citharichthys spiloperus	UC	R	R	
Lined sole	Achirus lineatus		R	R	R
Hogchoker	Trinectes maculatus	R		UC	UC
Blackcheek toungfish	Sumphurus plagiusa	UC	UC	UC	UC
Least puffer	Sphoeroides parvus	A	UC	R	R

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[a] Data from Tables G.5-29 through G.5-32.

[b] A - Abundant (more than 50 collected); C - Common (21-50 collected); UC - Uncommon (5-20 collected); R - Rare (less than 5 collected); P - Present

TABLE G.2- 33 Summary of trawl catches of invertebrates and fish collected at the Chacahoula survey site (September-December, 1977).

COMMON NAME	SCIENTIFIC NAME	COLLECTION DATE		
	Invertebrates	September	October	December
Hydroid colony	Hydrozoa		P	
Moon jellyfish	*Aurelia aurita*		A	R
Sea anemone	*Calliactis tricolor*		UC	UC
Sea anemone (unidentified)	Anthozoa	UC		
Southern oyster drill	*Thais haemastoma*			R
Channeled whelk	*Busycon contrarium*		R	
Brief squid	*Lolliguncula brevis*	UC	A	C
Mantis shrimp	*Squilla empusa*		R	R
White shrimp	*Penaeus setiferus*	R	R	A
Brown shrimp	*Penaeus aztecus*		R	UC
Penaeid shrimp	Penaeidae (juvenile)			A
Hermit crab	*Pagurus pollicaris*	R	UC	R
Spider crab	*Libinia* sp.			R
Blue crab	*Callinectes sapidus*			R
Swimming crab	*Portunus* sp.			R
Swimming crabs	Portunidae (juvenile)	R	R	
Starfish	*Luidia clathrata*		R	R
	Fish			
Scaled sardine	*Harengula pensacolae*		R	
Gulf menhaden	*Brevoortia patronus*		R	
Bay anchovy	*Anchoa mitchilli*	A	A	UC
Striped anchovy	*Anchoa hepsetus*	UC	A	
Offshore lizardfish	*Synodus poeyi*		R	
Sea catfish	*Aris felis*	UC	C	R
Atlantic midshipman	*Porichthys porosissimus*		R	R
Crested cusk-eel	*Ophidion welshi*			R
Atlantic moonfish	*Vomer setapinnis*		R	
Atlantic bumper	*Chloroscombrus chrysurus*	UC	A	
Bluntnose jack	*Hemicaranx amblyrhynchus*		R	
Lane snapper	*Lutjanus synagris*	R		
Longspine porgy	*Stenotomus caprinus*		R	

TABLE G.2-33 continued.

COMMON NAME	SCIENTIFIC NAME	COLLECTION DATE		
		September	October	December
Fish				
Pinfish	*Lagodon rhomboides*		R	
Southern kingfish	*Menticirrhus americanus*		UC	UC
Atlantic croaker	*Micropogon undulatus*	C	A	A
Sand seatrout	*Cynoscion arenarius*	C	UC	R
Silver seatrout	*Cynoscion nothus*			A
Spot	*Leiostomus xanthurus*	R	C	
Star drum	*Stellifer lanceolatus*	R		UC
Banded drum	*Lrimus fasciatus*			A
Spadefish	*Chaetodipterus faber*	R		R
Atlantic cutlassfish	*Trichiurus lepturus*	UC	UC	R
Gulf butterfish	*Peprilus burti*	R	R	R
Bighead sea robin	*Prionotus tribulus*			R
Blackfin sea robin	*Prionotus rubio*	R	R	R
Fringed flounder	*Etropus crossotus*	R	R	R
Blackcheek toungfish	*Symphurus plagiusa*		R	R
Least puffer	*Sphoeroides parvus*	R	R	UC
Striped burrfish	*Chilomycterus schoepfi*	R		

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[a] Data from Tables G.5-33 through G.5-35.

[b] A - Abundant (more than 50 collected); C - Common (21-50 collected); UC - Uncommon (5-20 collected); R - Rare (less than 5 collected); P - Present

Weeks Island. At one time during the October survey at least 23 trawlers were observed within a 5-mile radius of the Weeks Island site. There were no threatened or endangered invertebrates collected during this survey, as was expected based on regional data.

Fish tend to dominate the nekton, outnumbering invertebrates in both number of species and total individuals and weight. The regional ichthyofauna have been characterized with at least 105 fish species (Table G.5-37) (Perret, 1971; Ragan and Harris, 1975; Dunham, 1972; Juneau, 1975). Many other fish which are scarce or elusive are also likely to inhabit the area, since more than 600 species of fish are known to occur in coastal Gulf water off Texas (U.S. Dept. of Energy, 1978).

Some of the more abundant fish of the region include the bay anchovy, Atlantic croaker, sea catfish, rock seabass, Gulf menhaden, Atlantic cutlassfish, fringed flounder, spot, sand seatrout, Gulf butterfish, Atlantic bumper, blue spotted searobin, and Atlantic threadfin. Depth, distance offshore, and DO have been shown to have a highly positive correlation with nekton abundance in this region. Seasonal differences may also affect species abundance (Ragan and Harris, 1975).

The bay anchovy, sand seatrout, and star drum were numerically the most abundant fish collected from trawls at the Weeks Island site, although the Atlantic croaker and sea catfish were also common (Table G.2-32). At the Chacahoula site the bay anchovy and Atlantic croaker were numerically most abundant; striped anchovy, Atlantic bumper, banded drum, and silver seatrout were also abundant at times (Table G.2-33). Thirty-six species of fish were collected at the Weeks Island site compared to 30 at Chacahoula. The total number of fish collected and the number of collections in which they were present were also much higher at the Weeks Island site than at Chacahoula (Tables G.5-25 through G.5-31). Other differences in fish distribution include the relatively high number of striped anchovy (September), Atlantic croaker, banded drum, and silver seatrout (December) collected at Chacahoula and very low number (no silver seatrout) collected at the Weeks Island site (Tables G.5-29 through G.5-35).

The low number of Gulf menhaden and absence of stingrays, which are usually abundant in this part of the Gulf, are probably due to their movement to shallow water and/or estuaries during the seasons sampled. Ladyfish, bluefish, Spanish mackerel, pompano, and crevalle jack, which are likely to be present in the vicinity of both sites were not collected (except for one crevalle jack at the Weeks Island site) during the trawl surveys, but their relatively high swimming speeds may have allowed them to escape. The Atlantic cutlassfish was the largest fish collected (with respect to length), the largest being about 22 inches. The second largest fish collected was a sand seatrout of about 14 inches; however, few fish exceeded 10 inches in length (Tables G.5-29 through G.5-35).

There was no evidence of commercial finfish operations in the vicinity of either site during the trawl surveys. This may have been because the shrimp were not running and the menhaden were moving out of the estuaries. Likewise no sportfishing was observed in the vicinity of either site, but these areas may provide a more productive sportfishery at other times of the year.

Eight species of major commercial fish (based on 1976 Louisiana Landings List) were collected at the Weeks Island site and seven were collected at Chacahoula. Sportfishing species included the Crevalle Jack and sand seatrout at Weeks Island and the sand and silver seatrout at Chacahoula.

Regional data which takes into consideration seasonal variations in migration and behavior should be used to compare the fisheries of the two sites. There were no threatened or endangered fish collected during this survey, as was expected based on regional data.

G.2.4.4.2 Life Histories of Major Nektonic Species

G.2.4.4.2.1 Shrimp

The life histories of brown and white shrimp are fairly similar. Mating and spawning take place offshore. During mating, the male transfers a sperm capsule or spermatophore to the female. Upon spawning, the female releases 500,000 to 1,000,000 eggs, simultaneously fertilizing them with the stored sperm. The timing of this event with white shrimp seems to depend on water temperature and occurs in 8 to 31 meter (m) depths from March to October with peaks in June or July. Brown shrimp spawn throughout the year in waters of 46 m or greater and from spring to early winter in shallower water. Spawning activity of the brown shrimp does not occur in waters of less than 14 m depths. The eggs of both species are demersel and hatch within 24 hours (Gaidry and White, 1973; Christmas and Etzold, 1977; Lindner and Cook, 1970; Cook and Lindner, 1970).

Larval shrimp go through 5 nauplii, 3 protozoeal, and 3 mysid stages. During this time (2 to 3 weeks), they are planktonic, drifting with the currents towards the bays and estuaries. Brown shrimp postlarvae enter the estuaries in winter and early spring; white shrimp postlarvae enter from June to September (Christmas and Etzold, 1977). These shrimp concentrate in the shallow, vegetated, fresh waters of the estuary. In warm waters, they grow rapidly, settling to the bottom and feeding omnivorously. As the shrimp grow to the juvenile stage in the estuary, they move to more saline water. White shrimp have a greater tolerance for lower salinities than do brown shrimp; during periods of rapid growth, the optimum salinity for the former is 0.5 to 10 ppt, and for the latter is 19 ppt. However, both species can withstand a wide range of salinities (Barrett and Gillespie, 1973; 1975).

After being in the estuaries for a few months, depending on environmental conditions, the young shrimp move offshore; white shrimp remain in the estuary longer and migrate at a larger size than do brown shrimp.

Shrimp are capable of reaching maturity and spawning within a year, making the shrimp an annual crop. Brown shrimp are found from Cape Cod to Yucatan but are absent on the west coast of Florida. White shrimp are distributed from Long Island to Yucatan but are absent in western and southeastern Florida. Highest densities are in depths of 27 to 55 m and up to 35 m respectively (Christmas and Etzold, 1977).

The seabob is of minor importance in the commercial shrimp fishery and is exploited primarily in the fall and winter months when the brown and white shrimp have moved offshore. Approximately 90% of the Gulf seabob catch occurs in Louisiana. They are primarily caught in shallow water, 2 to 4 m, and tend to concentrate along the beach after a cold front passes. They are found from Cape Hatteras through the Gulf of Mexico and Caribbean Sea to Brazil. It appears that this shrimp completes its life cycle in a narrow zone of the coastline, out to 13 m depth contour, and rarely, if ever, enters bays or estuaries either in the juvenile or adult stage. The females is gravid during the spring, summer, and fall. Laboratory studies indicate that the seabob larvae go through 5 naupliar and 1 protozoeal stage. However, data on the presense of larval, postlarval, and juvenile stages in nature is rare (Christmas and Etzold, 1977; Juneau, 1977).

G.2.4.4.2.2 Blue Crab

The blue crab (Callinectes sapidus) ranges from Nova Scotia to Uruguay and is found mainly in estuaries and shallow oceanic waters. Females tend to be in more saline waters than the males, but both can tolerate waters of from 0.7 to 88 ppt. Mating occurs from late winter to early fall while the female is in the soft-shell stage of molt; the male passes the spermatozoa into the female for storage of up to 1 year. The female then moves to more saline waters where spawning occurs. As the 700,000 to 2,000,000 eggs are released, they become fertilized by the stored sperm. The embryos become attached to the females abdomen until hatching, a process of 9 to 15 days. Only one or two of these eggs will survive to adulthood (Jaworski, 1972).

Larval zoeal stage lasts from 30 to 39 days, with the organism undergoing from 4 to 8 molts. Optimum salinities for survival and growth of the larvae are 15 to 45 ppt. The zoea then metamorphose into megalops, a stage lasting 6 to 20 days. The megalops is crablike in appearance and is able to swim or walk on the bottom. Optimum salinities for this stage are greater than 15 ppt. The final metamorphosis leads to the juvenile crab, an active predator that migrates from one part of the estuary to another with the seasons in search of food. As it grows, the exoskelton is repeatedly shed in molting. Growth to maturity requires 12 to 18 months; the lifespan is 2 to 4 years, though many are caught upon reaching commercial size, 12 to 18 months after hatching (Jaworski, 1972).

The blue crab is omnivorous and as such plays an important role in the coastal ecosystem. Rangia clams, mussels, xanthid crabs, snails, fish, plants and insect larvae have been reported in the diet of the blue crab, as well as scavenged material. In turn, the species, especially smaller members, are fed upon by spotted seatrout, red drum, Atlantic croaker, black drum, and sheepshead. Blue crab larvae and eggs are also found in the diet of many fish (Adkins, 1972).

G.2.4.4.2.3 Gulf Menhaden

The Gulf menhaden, found mainly in the Gulf of Mexico, comprises a majority of the U.S. menhaden fishery. Adult menhaden overwinter from 65 to 100 km offshore in waters of 90 m depth. There they spawn from late fall through the winter. The larvae move into the estuarine nurseries in September through April. They remain in the low salinity waters, metamorphose into juveniles, and return to the open Gulf during October through February. Menhaden have a relatively short lifespan, returning to the spawning areas after one year. Most of the fisheries catch consists of one and two year old fish. In general, menhaden are found in a wide range of salinities, 0 to 60 ppt (U.S. Dept. of Commerce, 1977a).

G.2.4.4.2.4 Anchovy

Two species, bay and striped, are abundant off the Louisiana coast, The striped anchovy prefer more saline, clearer water and are thus found further offshore than the bay anchovy, which are generally restricted to bays and nearshore areas. Both species are found in schools and have similar life histories. Diet consists mainly of mysids and copepods (Hildebrand and Schroeder, 1972). Spawning occurs in the spring, summer, and fall and the pelagic eggs hatch within a day. An influx of bay anchovy eggs and larvae into the estuaries has been reported during January through June, and in September and November. The larvae and young juveniles tend to reside in low salinity areas and move to higher salinity waters as they grow (Dunham, 1972).

G.2.4.4.2.5 Sciaenid Fishes

Atlantic croaker. This fish is one of the most abundant in the Louisiana coastal area. Spawning occurs from October to May in the shallow open sea. As with the other estuarine-dependent species, the larvae move into the estuary where they feed and grow. They remain in the estuary until the onset of cold weather, then move offshore. They are bottom feeders, consuming mainly annelids, mollusks, and ascidians. Atlantic croaker are distributed from Massachusetts to Texas and are found in salinities ranging from 0 to 75 ppt (Hildebrand and Schroeder, 1972; U.S. Dept of Commerce, 1977a).

Seatrout. Various types, including the spotted seatrout and weakfish, are found in the Gulf of Mexico. The sand seatrout is the most abundant coastal species. It is confined to the Gulf of Mexico and is found in waters of from 1.3 to 32.5 ppt. Spawning occurs in the spring and summer, near passes and inlets. The adults and larvae move into the bays during the summer then offshore with the onset of cold weather (U.S. Dept. of Commerce, 1977a).

Red Drum or redfish are found from Massachusetts to northern Mexico commonly in the 5 to 30 ppt range though they have been taken in waters of between 0 to 50 ppt. The adults under 3 years generally remain in the bays and spawn in the shallower waters of the Gulf near passes during the fall. Older adults make spawning runs along the coast in the late summer and winter (U.S. Dept of Commerce, 1977a). Juveniles tend to remain in the bays until fall when some migrate to the Gulf. Red drum are known to live at least 8 years.

G.2.4.5 Threatened or Endangered Species

Several threatened or endangered (U.S. Dept of Interior, 1977a) species of marine reptile have been reported in the northern Gulf of Mexico (Table G.2-34). The Atlantic Ridley turtle population has undergone severe reductions since the 1940's when their number was almost 40,000. In 1976, the number of nesting females was in the range of 400 to 500. The Atlantic Ridley nests in abundance only in Tamaulipas, Mexico. Its

TABLE G.2-34 Threatened or endangered reptiles and mammals reported in the northern Gulf of Mexico.

Common Name	Scientific Name	Distribution	Status	Food Source
Reptiles				
Atlantic Ridley Turtle	Lepidochelys kempii	Tropical and Temparate seas	Endangered	Portunid Crabs
Hawkshill Turtle	Eretmochelys imbricata	Tropical Seas	Endangered	--
Leatherback Turtle	Dermochelys coriacea	Tropical and Temperate seas	Endangered	Jellyfish
Mammals				
Sperm Whale	Physeter catodon	Offshore Louisiana; Mississippi and Alabama	Endangered	Squid, shark and bonyfishes
Black Right Whale	Eubalaena glacidis	Entire Gulf of Mexico	Endangered	Zooplankton-copepods
Humpback Whale	Megaptera novaeangliae	Rare in Gulf of Mexico; one siting off Florida	Endangered	--
Sei Whale	Balaenoptera borealis	Offshore Louisiana	Endangered	Krill, schooling fish, copepods
Fin Whale	Balaenoptera physalis	Offshore Texas and Louisiana	Endangered	Krill, squid and small fish
Blue Whale	Balaenoptera musclus	Offshore Texas	Endangered	Euphausids

Source: U.S. Department of the Interior, 1977a; 1977b.

primary foraging area is in the northern Gulf of Mexico coastal area, especially off Louisiana where it feeds heavily on portunid crabs (Callinectes sp.). There are records of Leatherback turtles having been caught by shrimp trawlers off the coast of Louisiana. This species nests in tropical waters but ranges throughout the Gulf and Western North Atlantic to Nova Scotia. The Leatherback turtle has been associated with large concentrations of jellyfish on which they feed (U.S. Dept. of Interior, 1977b). The Hawksbill turtle has been reported to range the warmer coastal waters of the Atlantic Ocean between New England and Brazil (Conant, 1958).

Six species of endangered (U.S. Dept. of Interior, 1977a) marine whales (Table G.2-34), have been sighted in the northern Gulf of Mexico. Most were fortuitous sightings (U.S. Dept. of Interior, 1976) and do not indicate indigenous populations.

G.2.4.6 Unique or Important Habitats

Several shipwrecks (Figure G.2-33) which serve as artificial reefs are within a few miles of the proposed Weeks Island and Chacahoula brine diffuser sites. Two wrecks are located about 7 miles to the west of the Chacahoula site, and one wreck is approximately 7 miles to the west of the Weeks Island site. In a neritic zone where sand and silt substrates prevail, these shipwrecks provide a hard, stable substrate for the attachment of aquatic organisms (e.g. barnacles, macroalage, bryozoans) as well as protective cover for a variety of juvenile organisms. The abundant aquatic life on these structures also provides a readily available food source for the sheepshead, spadefish, jackfish, seatrout, and drum.

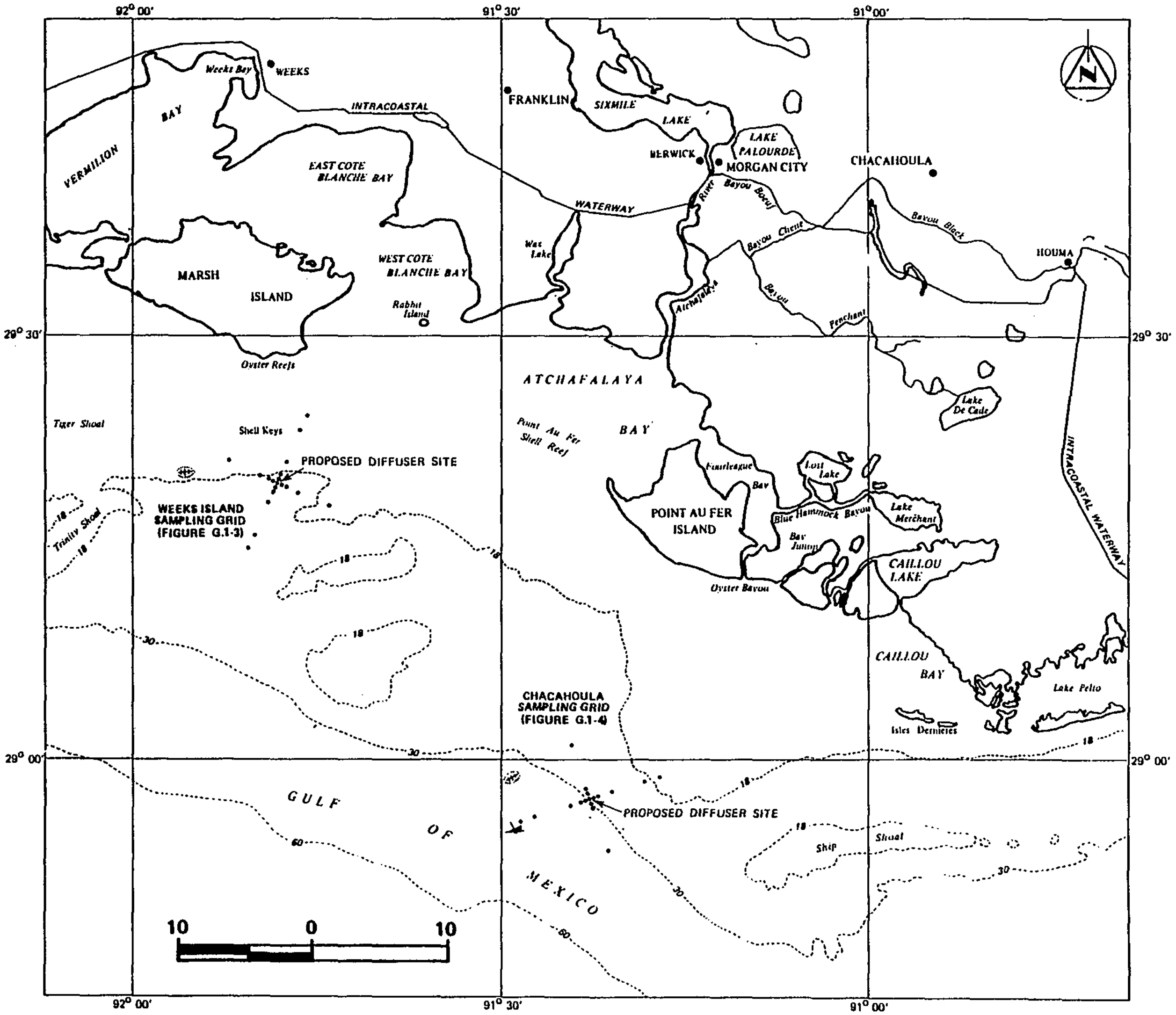


FIGURE G.2-33. Shipwrecks in the region of the proposed diffuser sites.

G.3 IMPACTS OF BRINE DISPOSAL ON THE MARINE ENVIRONMENT

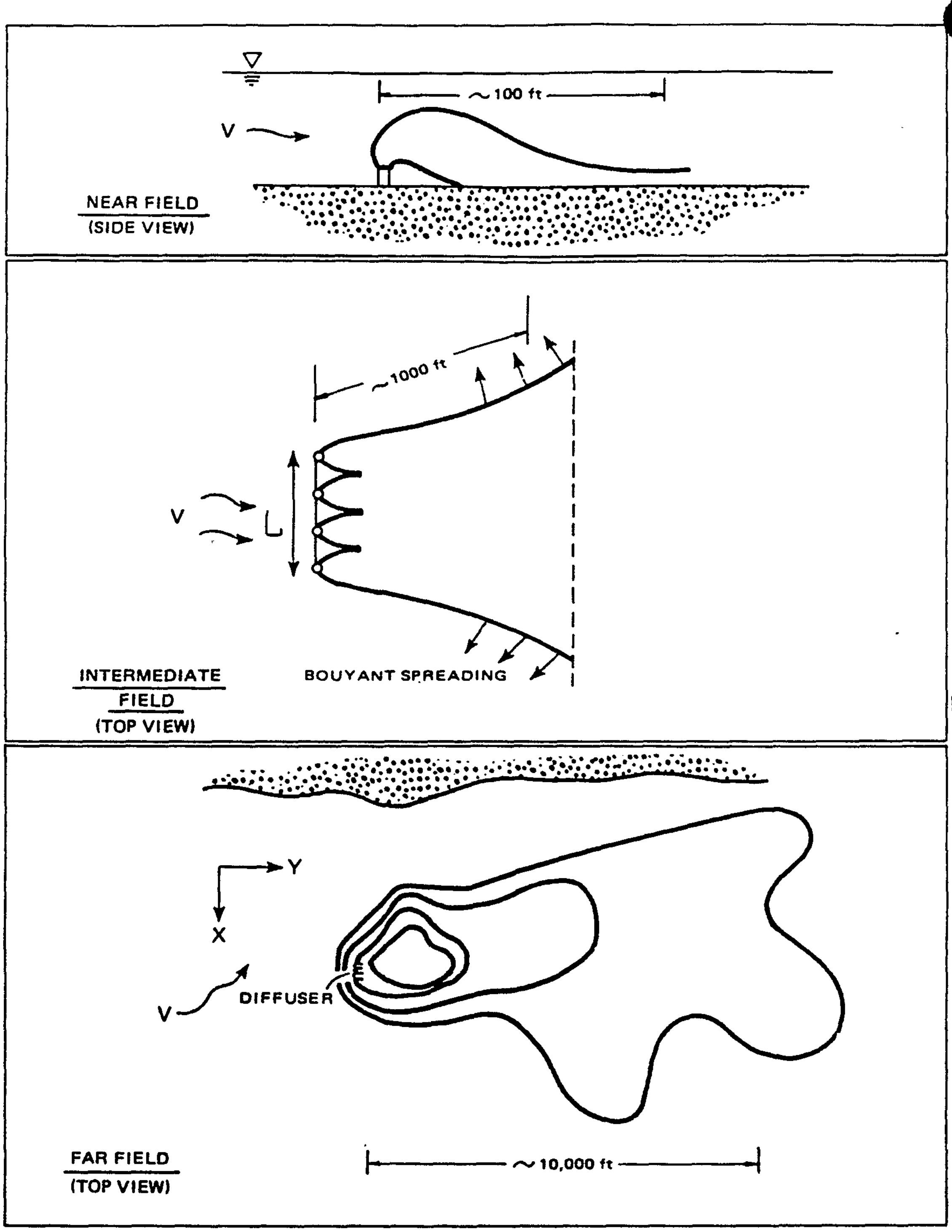
G.3.1 Impacts on the Physical Environment

G.3.1.1 Introduction

Disposal of brine from the Capline Group in the Gulf of Mexico would be a large scale operation over the short term, but over the life of the project this disposal would be undertaken only infrequently. Initially, expansion of Capline Group crude oil storage capacity by leaching new caverns would involve discharge of brine over a period of 50 to 60 months. Subsequent filling of new caverns would require disposal of additional brine over 24 months. For study purposes, the larger disposal rate during leaching was selected to maximize the magnitude of projected impacts. If either the Weeks Island or Chacahoula storage sites are selected for development in the Capline Group, offshore brine disposal would be utilized.

To determine the most efficient diffuser design and location for the diffuser system, a mathematical simulation model was used. The model was developed by the Ralph Parsons Laboratory at the Massachusetts Institute of Technology (MIT) and the model runs were used by the National Oceanographic and Atmospheric Administration (NOAA) in a study undertaken at the request of DOE to determine the effects of brine disposal connected with the SPR program (U.S. Dept. of Commerce, 1977a). The MIT model is a time-dependent model which simulates the transient plume conditions at the diffuser site when wind-driven current speeds and direction are input to a computer for analysis. The analysis utilizes results from diffuser performance studies conducted by the U.S. Corps of Engineers Waterways Experiment Station to determine the mathematical dilution factors in the near and intermediate fields (0 to 1000 feet from the diffuser). Salinity concentrations in the far-field region were calculated using the MIT Transient Plume Model, which has been calibrated through thermal discharge studies (see Section G.1.3).

The regions of analysis for the MIT Model are shown in Figure G.3-1. In the near-field region, dilution is affected by turbulent jet mixing and is a function of diffuser design, ambient current velocity,



SOURCE: U.S. Department of Commerce, 1977a.

FIGURE G.3-1. Regions of analysis for the MIT Model.

and (in shallow water which would limit plume rise), water depth. The trajectory of each plume, and the lateral spreading of each plume after it falls to the bottom, are strongly affected by the (negative) buoyancy flux of the discharge. The near field region is assumed to extend downstream until the plumes from adjacent nozzles merge to form a continuous plume, a distance on the order of 100 feet.

The intermediate field is characterized primarily by buoyant lateral spreading and vertical collapse of the plume. Ambient diffusion acts to further dilute the plume, but its importance, initially, is secondary to buoyant spreading. The intermediate field is assumed to end (and the far field to begin) at about 1000 feet, corresponding to the point at which vertical collapse of the plume due to buoyancy is comparable with vertical growth due to diffusion.

The far field is the largest of the three regions and is characterized by the ambient processes of advection and diffusion. These processes are essentially independent of diffuser design and are the ones which ultimately control any accumulation of effluents.

G.3.1.2 Brine Plume Salinity Analysis

G.3.1.2.1 Estimated Baseline Conditions

A plume analysis was initially conducted (U.S. Dept. of Commerce, 1977a) using historical current data to determine the excess salinity values at the bottom, mid-depth, and surface for various scenarios of current speed, direction, and duration including stagnant conditions.

Computations were made for the 10 combinations (5 for each site) of water depths, estimated current sequences, and diffusion coefficients as shown in Table G.3-1. The base case analysis for the Weeks Island site (Run No. 5) assumes a 2000-foot bottom diffuser length, a water depth of 20 feet, a flow rate of 650,000 BPD (42 cfs), and a four-day wind-driven current cycle. The base case analysis for the Chacahoula site (Run No. 18) assumes a 3420-foot bottom diffuser length, a water depth of 30 feet, a flow rate of 1,100,000 BPD (71 cfs) and a four-day wind-driven current cycle. Additional analyses consider the effect of stagnant flow

TABLE G.3-1 Summary of parameters used in brine discharge calculations (for a bottom diffuser).

Variables		Discharge Parameters		Diffuser Parameters			Current Parameters			Diffusion Parameters		Calculation Times
Run	Condition Tested	Qo (cfy)	Ac_o (ppt)	II (ft)	L (ft)	N	T (hr)	A (fps)	B (fps)	Kz (ft^2/o)	K_h (ft^2/s)	T_n (hr)
5	Base case	42	230	20	2,000	34	96	0.5	-1.0	.001	$.003\sigma_h^{1.15}$	309,333 357,381
14	Stagnant flow	42	230	20	2,000	34	384	0.25	-0.75	.001	$.003\sigma_h^{1.15}$	477,573 669,765
15	Reduced Vert. Diff.*	42	230	20	2,000	34	96	0.5	-1.0	.0003 (10' ceiling)	$.003\sigma_h^{1.15}$	309,333 357,381
16	Reduced Hor. Diff. *	42	230	20	2,000	34	96	0.5	-1.0	.001	$.001\sigma_h^{1.15}$	309,333 357,381
17	Reduced Vert. & Hor. Diff.*	42	230	20	2,000	34	96	0.5	-1.0	.0003 (10' ceiling)	$.001\sigma_h^{1.15}$	309,333 357,381
18	Base case	71	230	30	3,420	58	96	0.5	-0.1	.001	$.003\sigma_h^{1.15}$	309,333 357,381
19	Stagnant flow	71	230	30	3,420	58	384	0.25	-0.75	.001	$.003\sigma_h^{1.15}$	477,573 669,765
20	Reduced Vert. Diff. *	71	230	30	3,420	58	96	0.5	-1.0	.0003 (10' ceiling)	$.003\sigma_h^{1.15}$	309,333 357,381
21	Reduced Hor. Diff.*	71	230	30	3,420	58	96	0.5	-1.0	.001	$.001\sigma_h^{1.15}$	309,333 357,381
22	Reduced Vert. &Hor. Diff. *	71	230	30	3,420	58	96	0.5	-1.0	.0003 (10' ceiling)	$.001\sigma_h^{1.15}$	309,333 357,381

* Diff. = Diffusivity

SOURCE: U.S. Dept. of Commerce, 1977a.

conditions (Run Nos. 14 and 19) and reduced values of horizontal and vertical diffusion coefficients (Run Nos. 15, 16, 17, 20, 21, and 22).

Current sequences assumed in the model were a combination of tidal and, for the alongshore component only, wind-driven components assumed as:

$u = u_T$ (inshore component)

$v = v_T + v_W$ (alongshore component)

Rotary tidal components were specified in the form:

$$u_T = 0.3 \cos \left(\frac{2\pi}{24} t\right)$$

$$v_T = 0.6 \cos \left(\frac{2\pi}{24} (t + 6)\right)$$

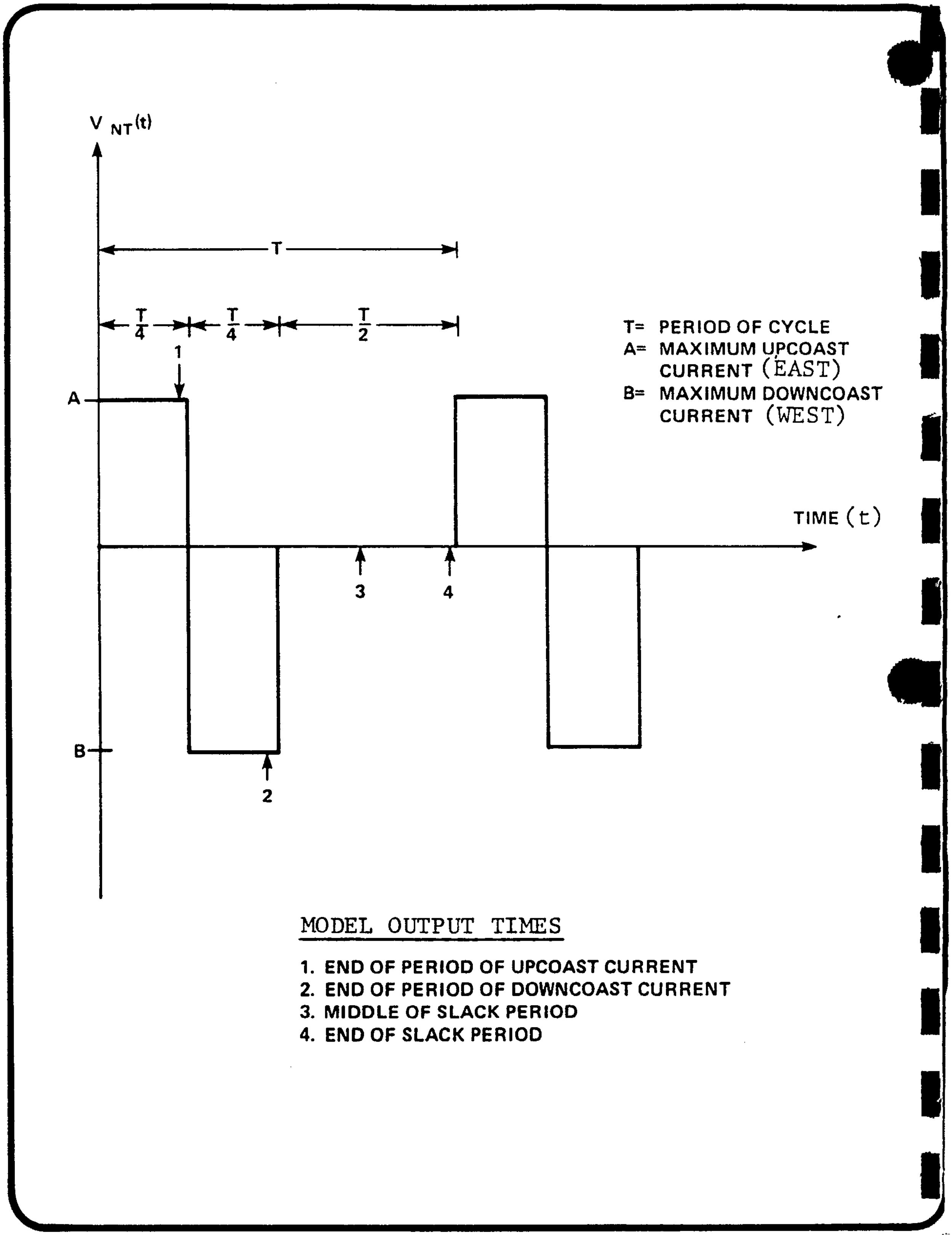
where t is in hours and u_T and v_T are in ft/sec. The wind-driven current was assumed to fit the schematic cycle described in Figure G.3-2. Although idealized, this sequence reproduces the observed phenomena of wind reversals following the passage of a front, coupled with periods of stagnation. A 4-day wind-driven cycle was selected to simulate conditions of moderate wind and current. A 16-day wind-driven cycle was selected to simulate the buildup of salinity concentrations with time during an 8-day period of stagnation.

G.3.1.2.2 Results and Conclusions (Estimated Currents)

For each run, excess concentrations were calculated four times within the current sequence and at three depths (bottom, mid-depth, and surface). Isoconcentration plots for those depths and times (shown in Table G.3-1) at which predicted excess concentrations exceeded 0.1 ppt are presented in "Analysis of Brine Disposal in the Gulf of Mexico, Capline Sector" (U.S. Dept. of Commerce, 1977a).

Conclusions drawn from the model outputs may be summarized as follows:

1. The current sequence has only a moderate effect on the maximum predicted concentration in the far field (∿2-5 ppt), but it substantially influences the shape of the predicted plume. Periods of strong ambient currents produce long



T= PERIOD OF CYCLE
A= MAXIMUM UPCOAST CURRENT (EAST)
B= MAXIMUM DOWNCOAST CURRENT (WEST)

MODEL OUTPUT TIMES

1. END OF PERIOD OF UPCOAST CURRENT
2. END OF PERIOD OF DOWNCOAST CURRENT
3. MIDDLE OF SLACK PERIOD
4. END OF SLACK PERIOD

FIGURE G.3-2. Idealized non-tidal current cycle.

narrow plumes with salinity concentrations near the diffuser remaining relatively low. During periods of weak ambient currents, the plumes tend to remain close to the diffuser.

2. Salinity concentrations in the vicinity of the diffuser are generally higher for cases of strong ambient currents within a current cycle. The time T_1 for each cycle represents a time when the current is instantaneously high, but the effects of prior stagnation and/or a reverse current duration can be seen.

3. Extended stagnation periods significantly increase background salinity concentrations. An eight-day stagnation period resulted in an increase of 1 ppt compared to a one or two-day stagnation period.

4. Reduction of the horizontal and vertical turbulent diffusion coefficients has no significant effect on the maximum predicted salinity concentration in the far field. If the vertical diffusion coefficient is reduced (by, for example, a factor of 3.3), bottom concentrations over the entire plume are increased slightly (0.5 ppt). The effect is greatest closest to the diffuser. At increased distances away from the diffuser, more mixing takes place, and the predicted concentrations approach those of the base case analysis. If the horizontal diffusion coefficient is reduced by a factor of three, for example, the lateral spreading of the plume is reduced, which increases the predicted bottom concentrations along the centerline of the plume.

5. A plot of affected bottom areas vs. excess salinity for various runs is shown in Figures G.3-3 through G.3-8. The base case calculations for Weeks Island and Chacahoula indicate that an increase of less than 5 ppt above ambient may be expected within a boundary of 10^6 square feet (23 acres). Figures G.3-6 and G.3-8 illustrate four time periods for the runs (14 and 19) with extended stagnation. An overall

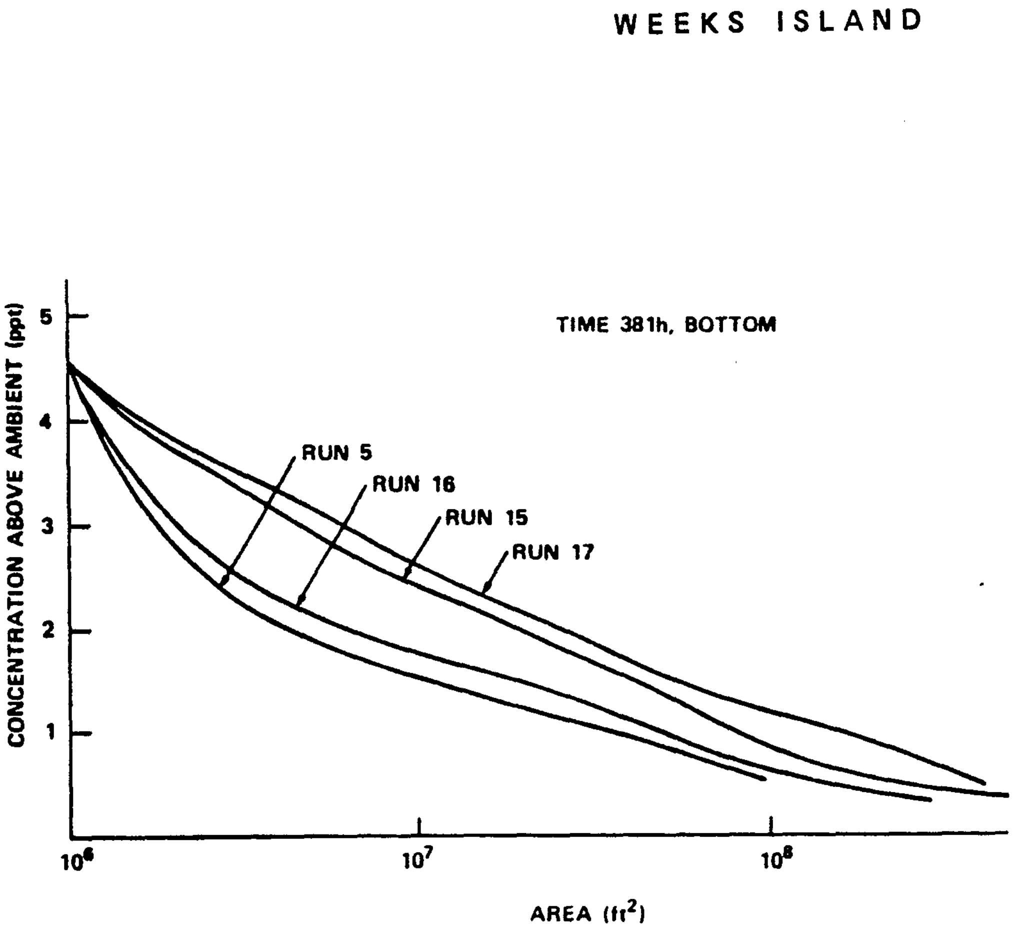


FIGURE G.3-3. Bottom concentrations versus area for various runs at Weeks Island for output time 4 (see Fig. G.3-2).

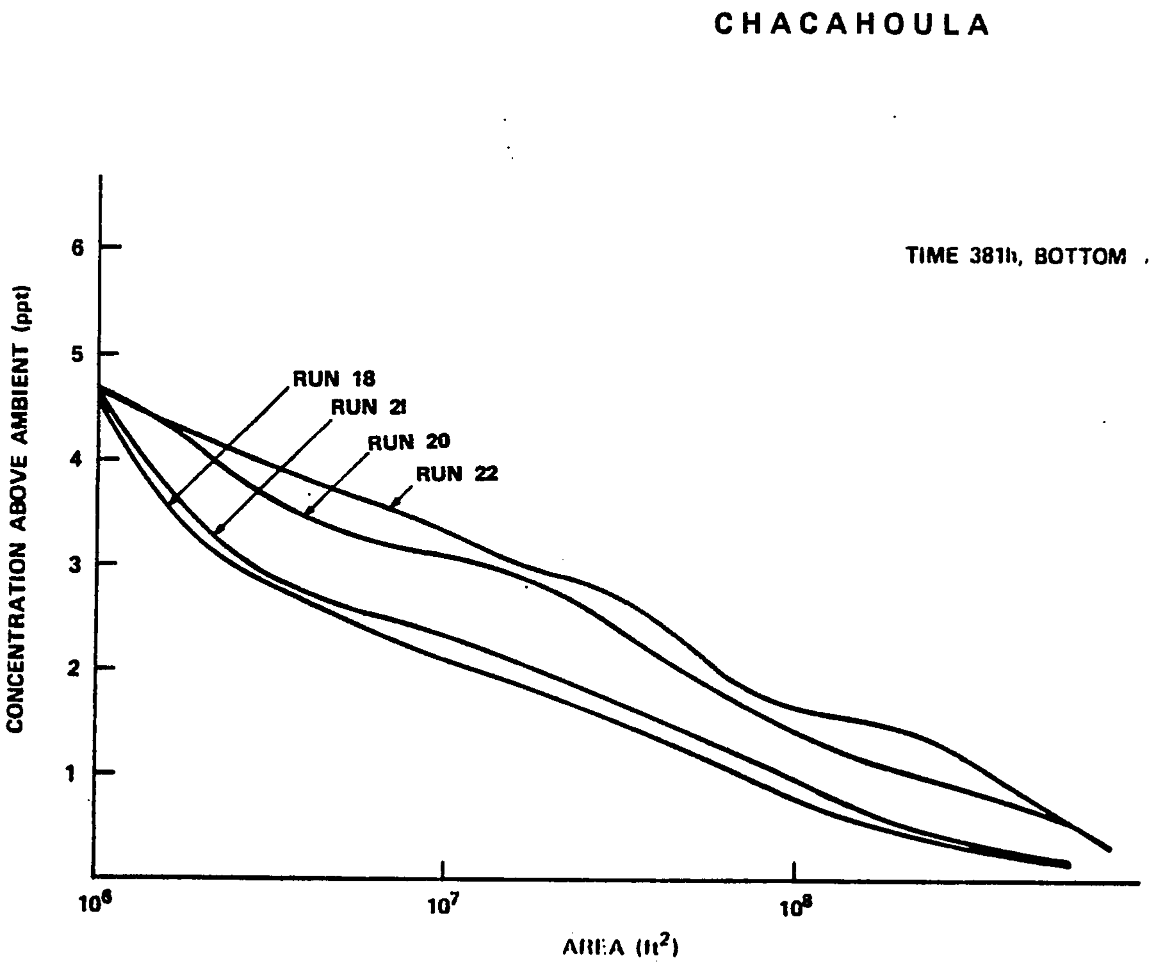


FIGURE G.3-4. Bottom concentrations versus area for various runs at Chacahoula for output time 4 (see Fig. G.3-2).

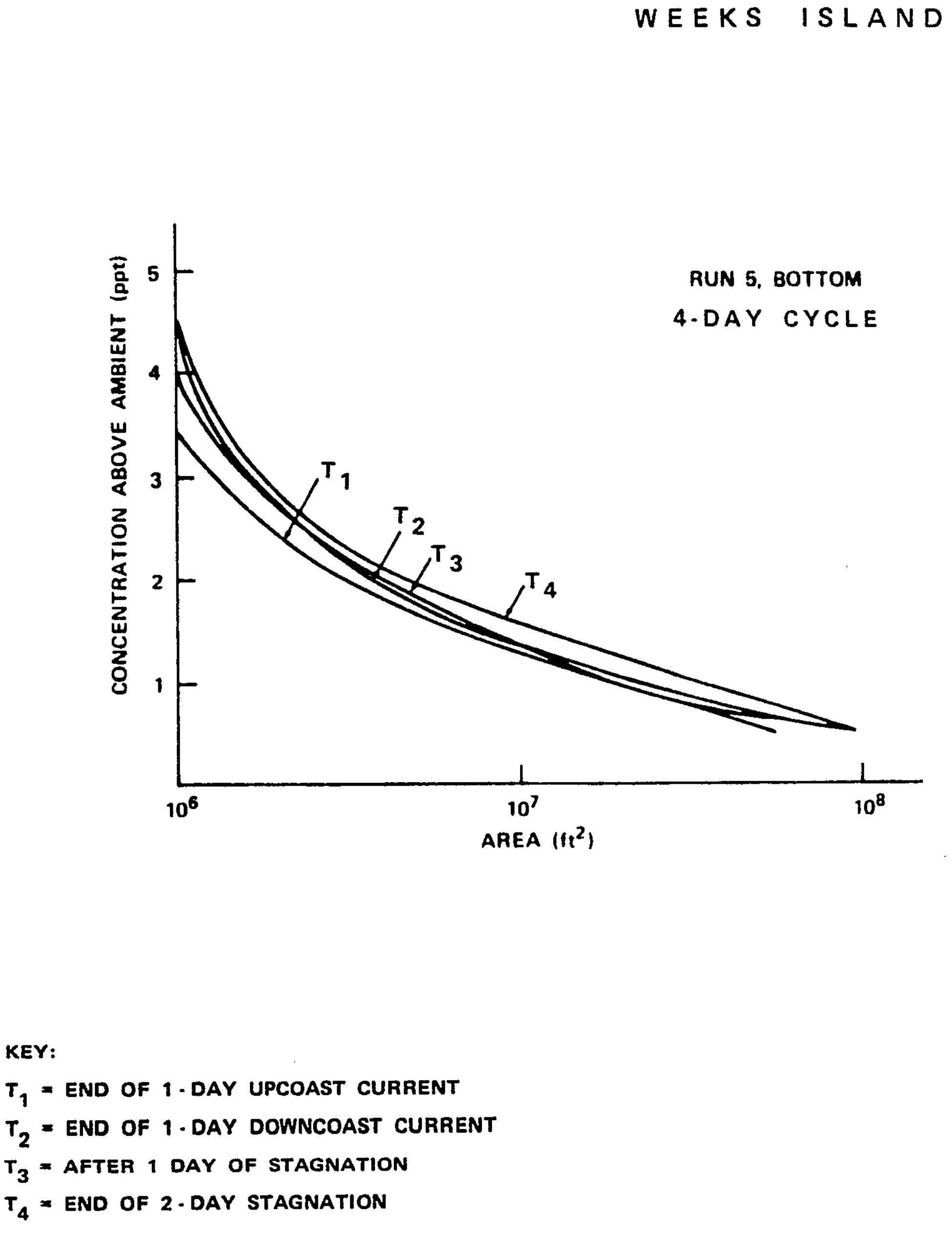


FIGURE G.3-5. Bottom concentrations versus area for base case calculations at Weeks Island (run 5) for output times 1,2,3,4 (see Fig. G.3-2)

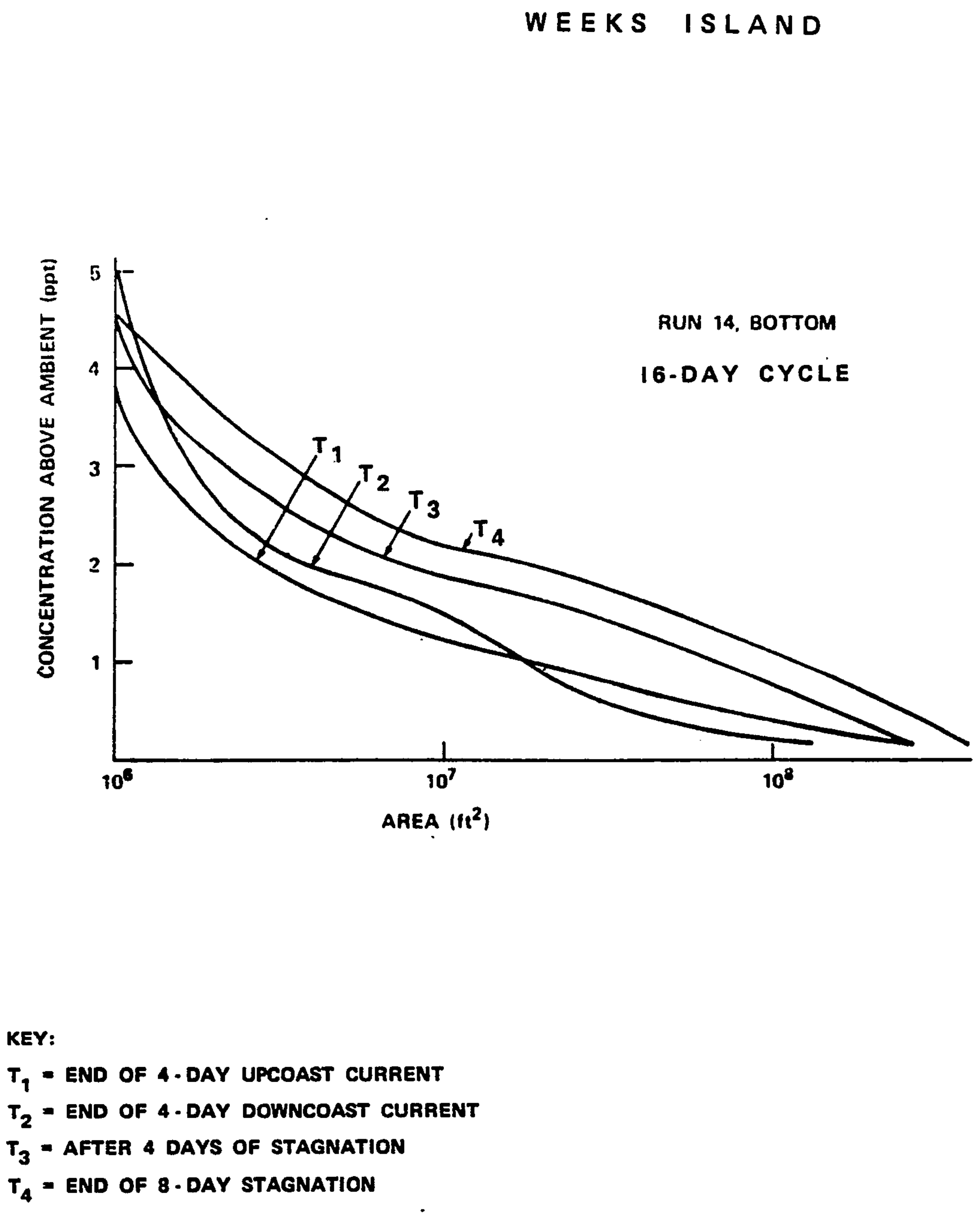


FIGURE G.3-6. Bottom concentrations versus area for calculations with a 16-day cycle - Weeks Island (run 14) for output times 1,2,3,4,(see Figure G.3-2).

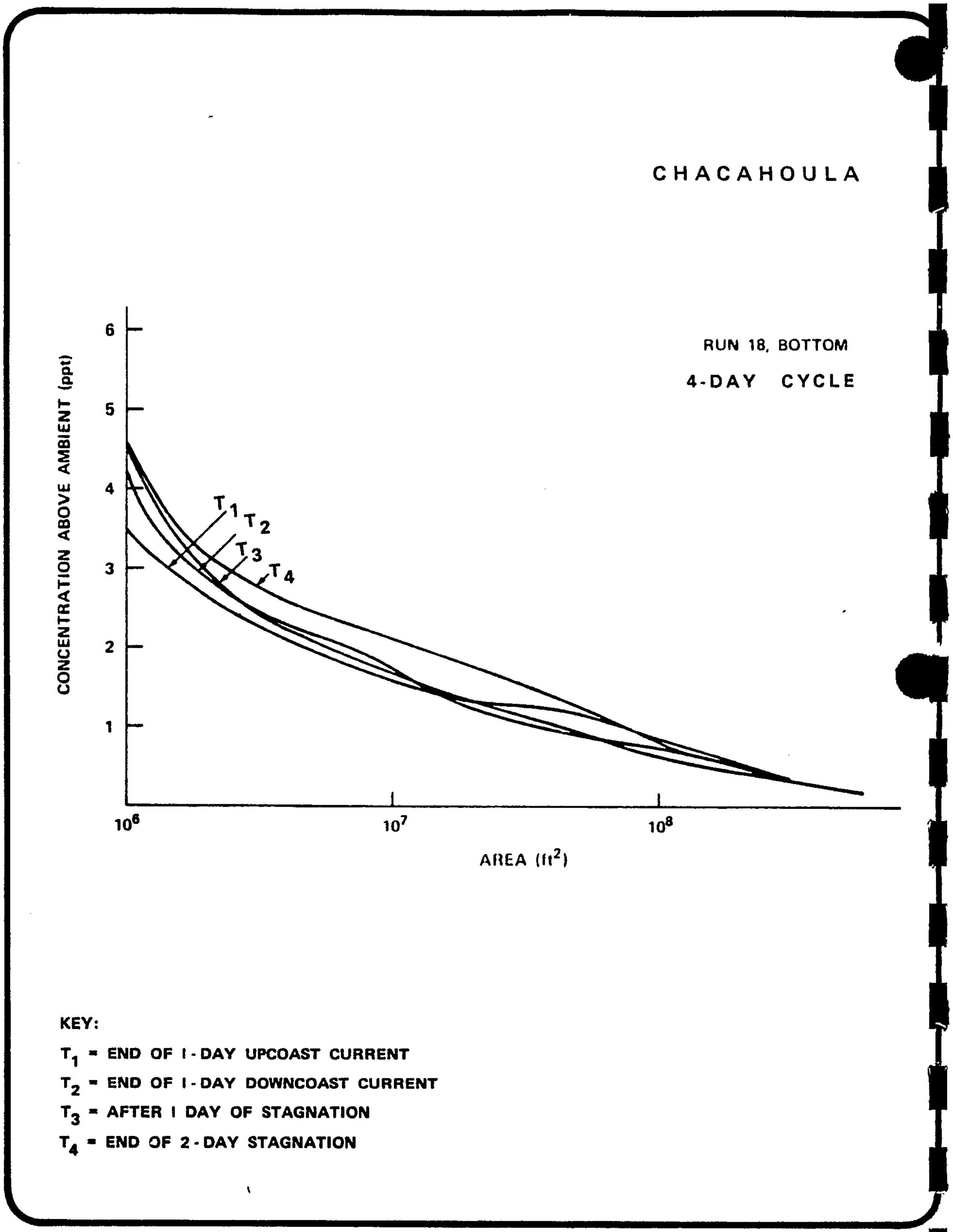


FIGURE G.3-7. Bottom concentrations versus area for base case calculations at Chacahoula (run 18) for output times 1,2,3,4 (see Fig. G.3-2)

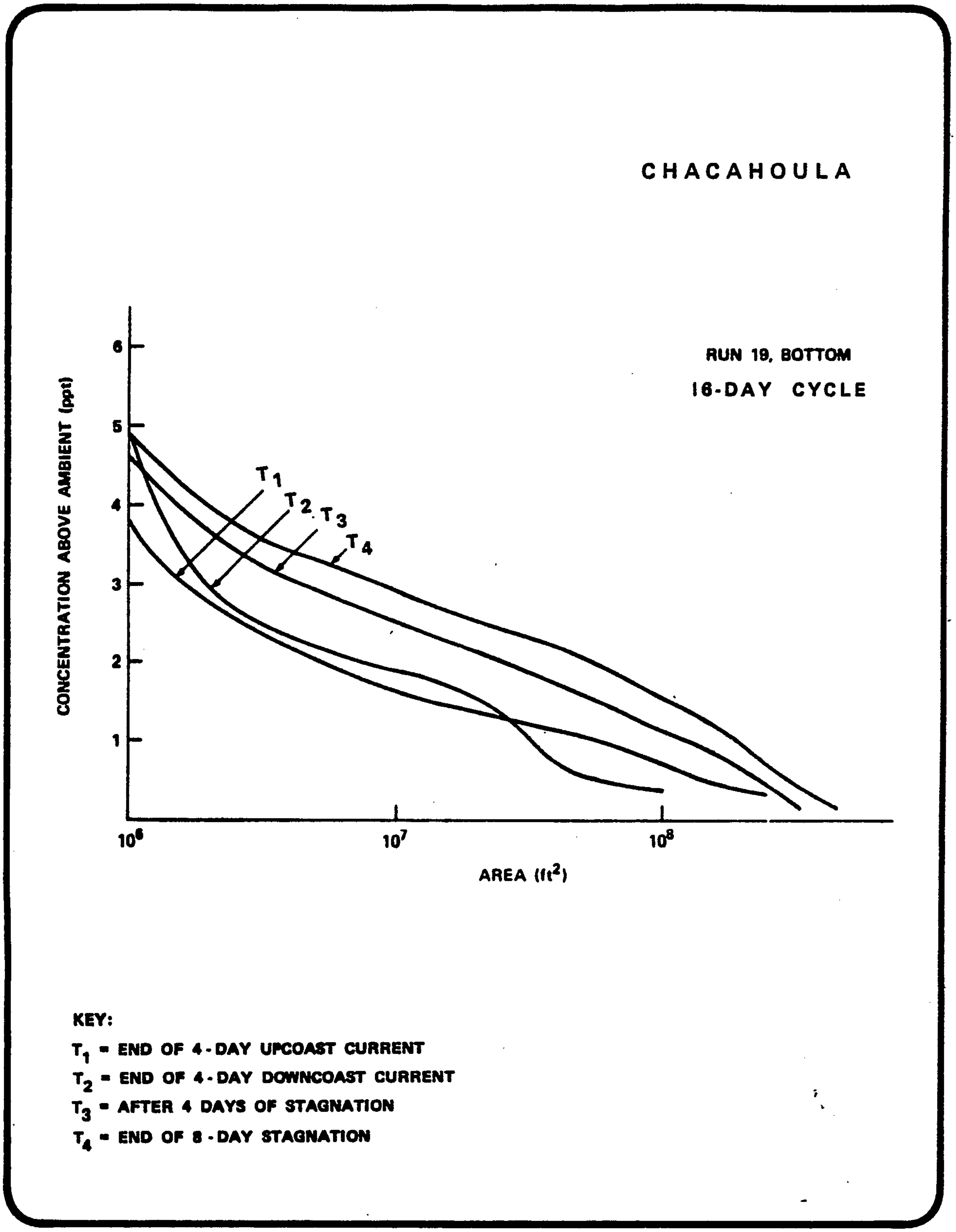


FIGURE G.3-8. Bottom concentrations versus area for calculations with a 16-day current cycle at Chacahoula (run 19) for output times 1,2,3,4 (see Fig. G.3-2).

increase in background salinities of approximately 1 ppt occurs between the T_1 curve (after 4 days of upcoast curre and the T_4 curve (after 8 days of stagnation). A plot at the end of a slack water period (T_4) with reduced horizontal and vertical diffusion (Run Nos. 17 and 22) shows:

a) Salinity concentrations in the near field remain similar;

b) The area within isoconcentration lines is increased by a factor of 4 or 5 over the base case condition.

The effect on bottom areas by reducing only the vertical diffusion (Run Nos. 15 and 20) is greater than reducing only the horizontal diffusion (Run Nos. 16 and 21). This behavior occurs because the former process moves excess salinity concentrations away from the bottom, while the latter process merely redistributes the saline mass along the bottom.

G.3.1.2.3 Observed Baseline Conditions, Results and Conclusions

A second plume analysis was conducted (U.S. Dept. of Commerce, 1978b) using *in situ* current data collected at the Weeks Island and Chacahoula diffuser sites during October and November, 1977 (see Figu G.2-2 through G.2-13). These data, while not statistically charactertic for the whole year, represent actual currents at the diffuser site. Figures G.3-9 through G.3-16 depict contours of the far-field salinity patterns emanating from the proposed diffuser at 3-hour intervals durin a tidal cycle. A total of about 13 days of data on observed currents was input to the model prior to outputting the salinity contours shown. The figures represent an instant time analysis of the plume as it would dynamically change in response to changes in the tidal and wind-driven currents found in the proposed diffuser area. Figure G.3-17 and G.3-18 illustrate the current velocity vectors at two depths, corresponding to the times the plume model outputs were taken.

The October-November in-situ current data indicates that the currents at the two sites are weaker than previously estimated using the historical current data (U.S. Dept. of Commerce, 1977a). The expected dilution effect of the currents would therefore be less, causing an increase in the observed excess salinity and temperature values at the sites.

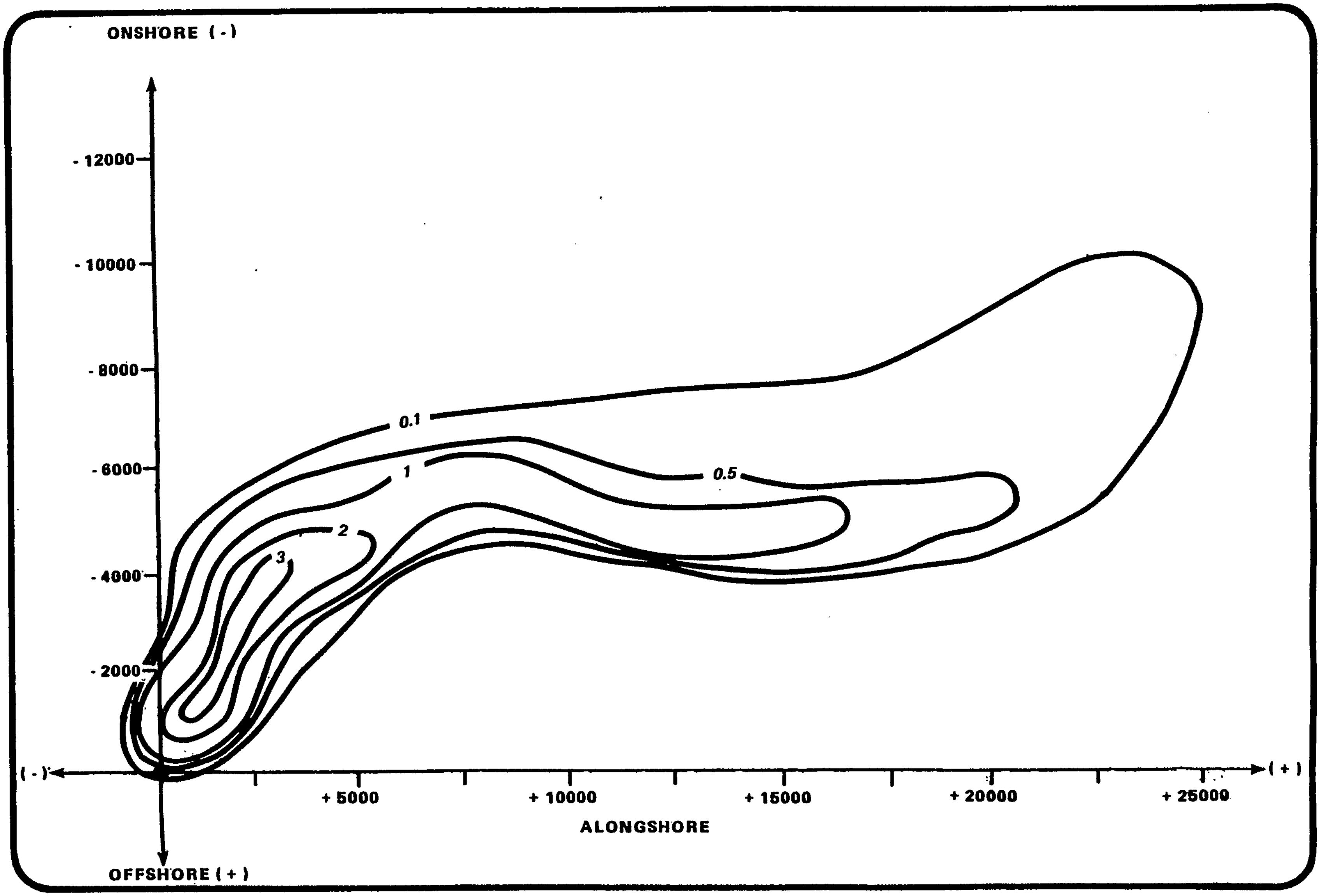


FIGURE G.3-9. Contours of excess salinity concentration (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed Weeks Island site using observed currents at T = 0 hrs.

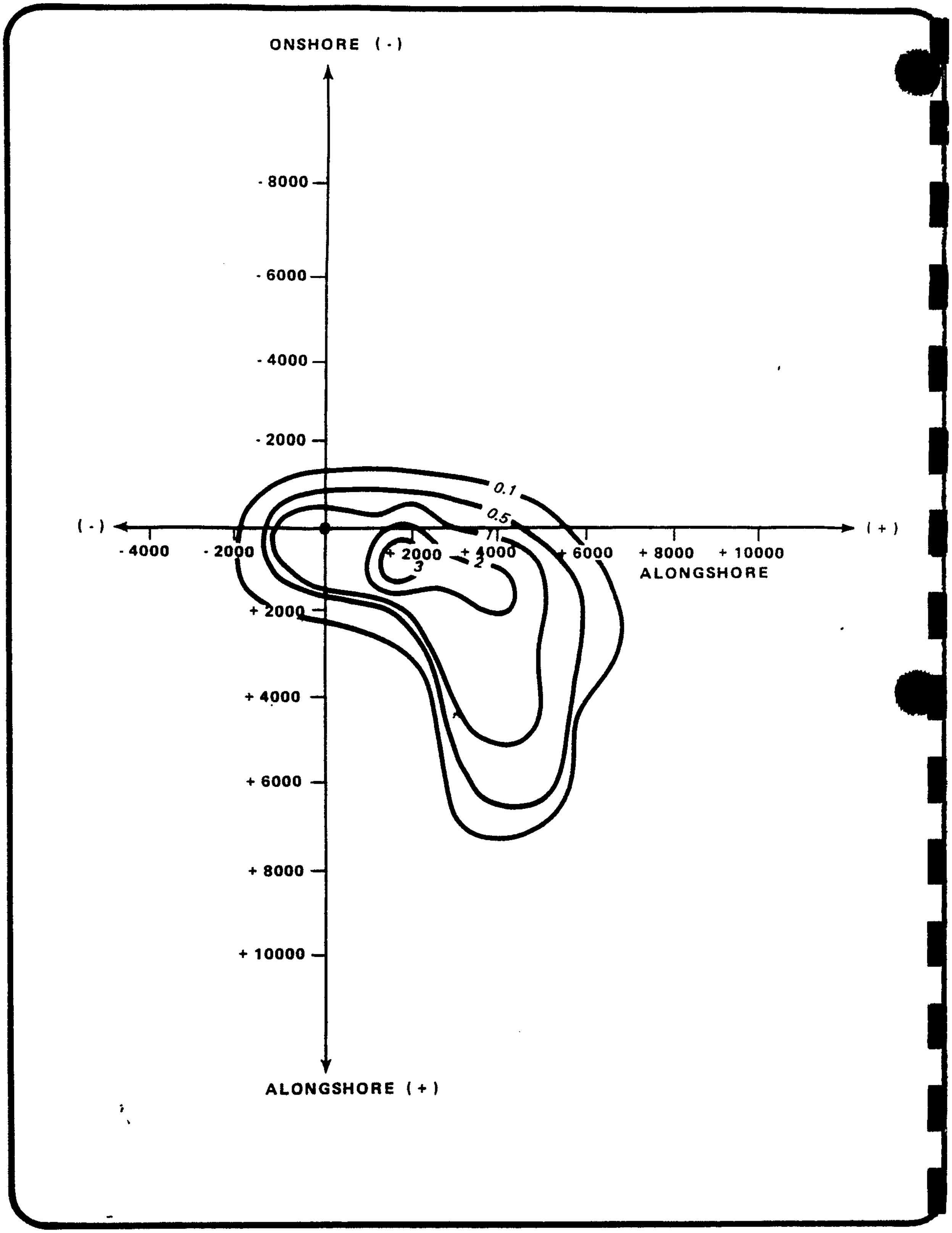


FIGURE G.3-10. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed Weeks Island site using observed currents at T=3 hrs

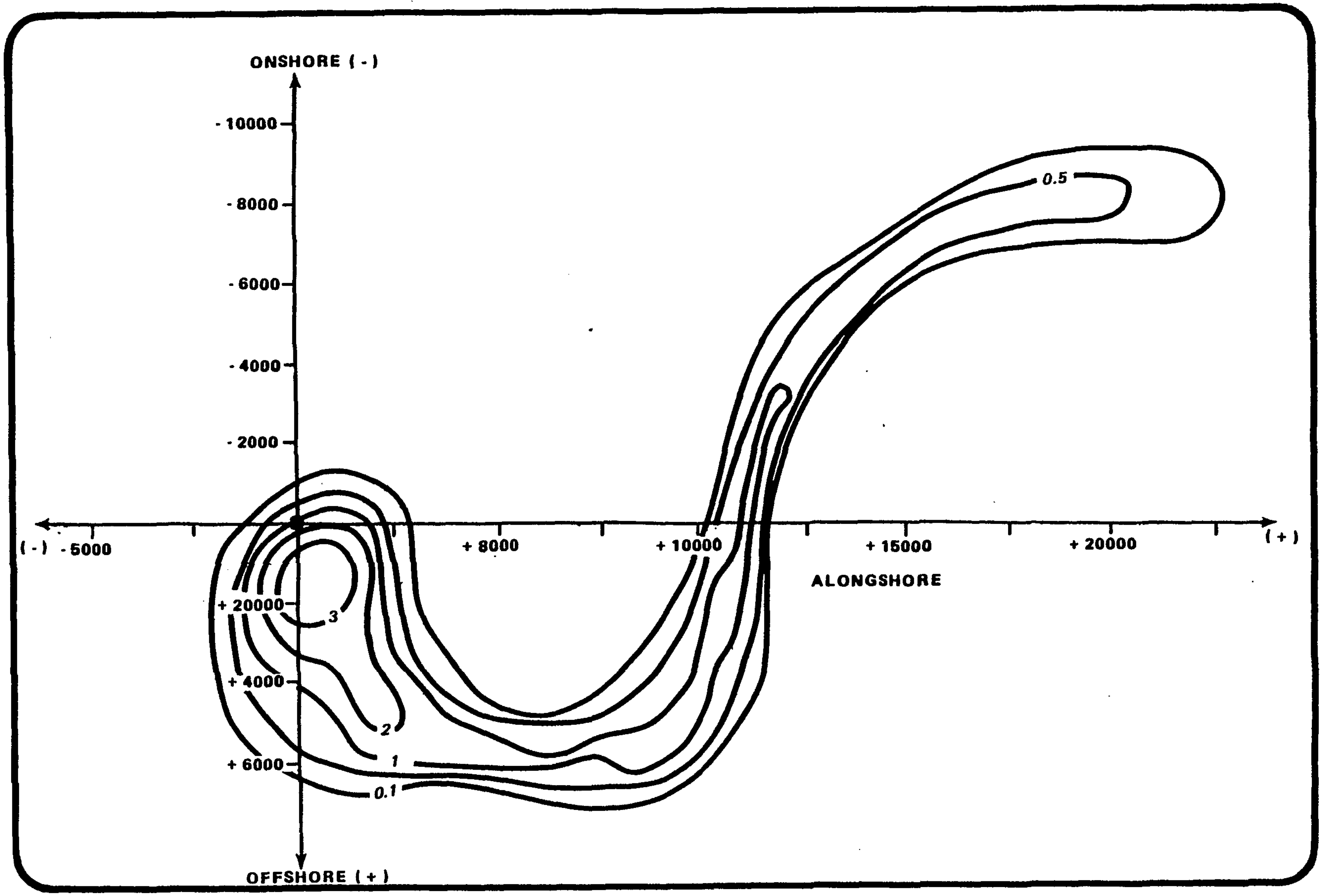
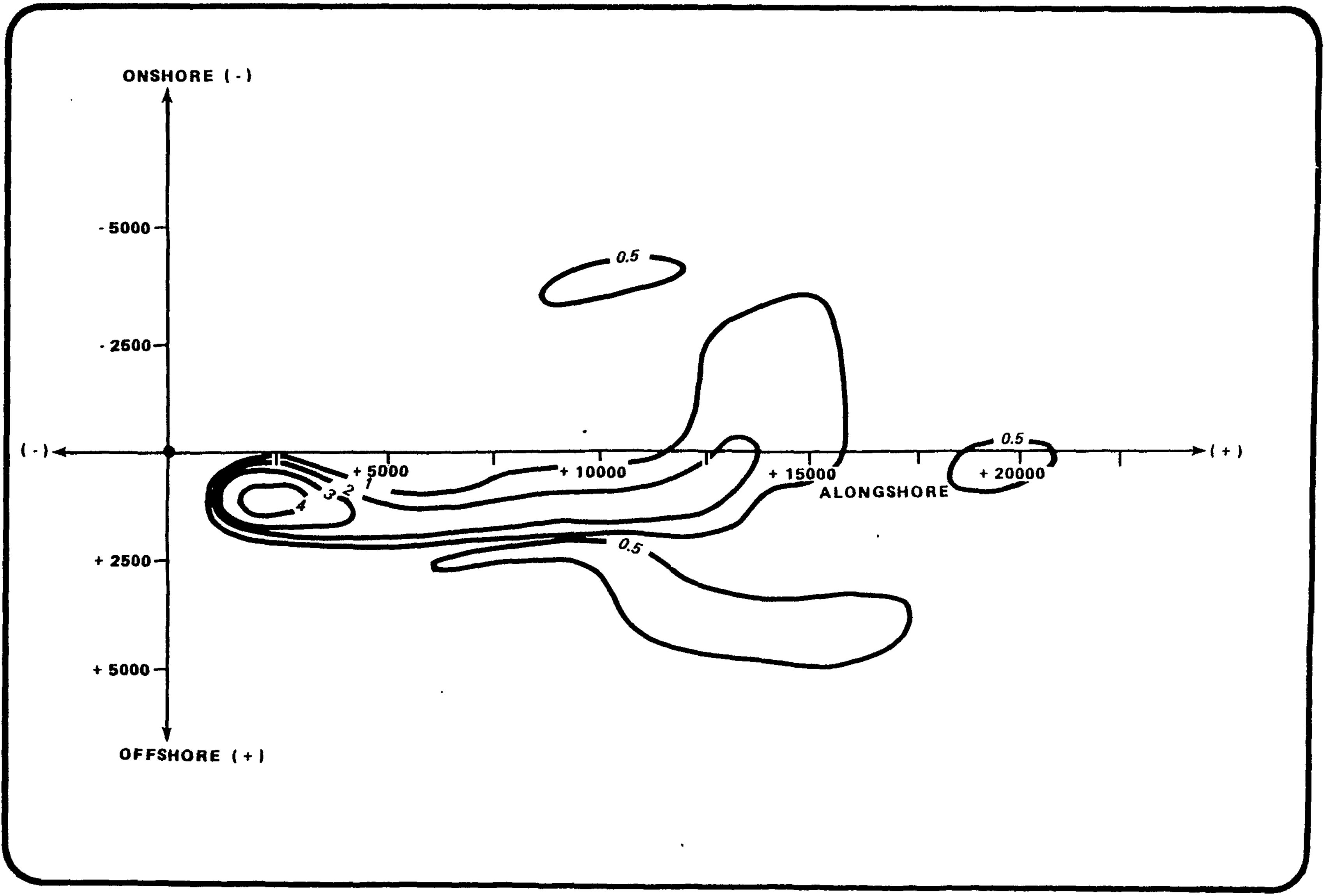


FIGURE G.3-11. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed Weeks Island site using observed currents at T = 9 hrs.



[redacted] URE G.3-12. Contours of excess salinty concentra[illegible]s (ppt) at various distances (feet) from th[redacted] of the diffuser (dot) for [redacted] proposed [redacted]s I[redacted]d s[redacted] us[redacted] obs[redacted]d [redacted]

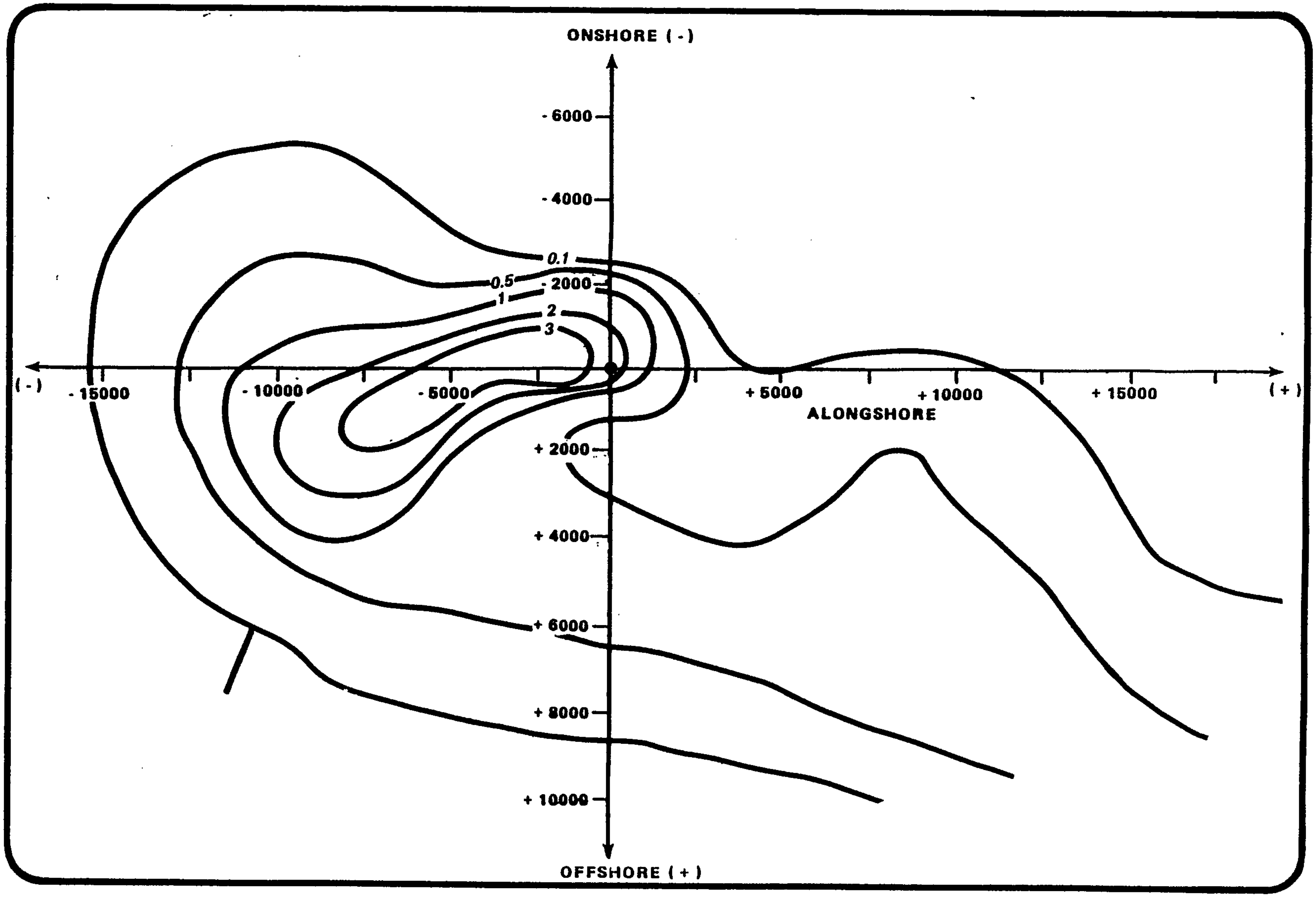


FIGURE G.3-13. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed Chacahoula site using observed currents at T = 0 hrs.

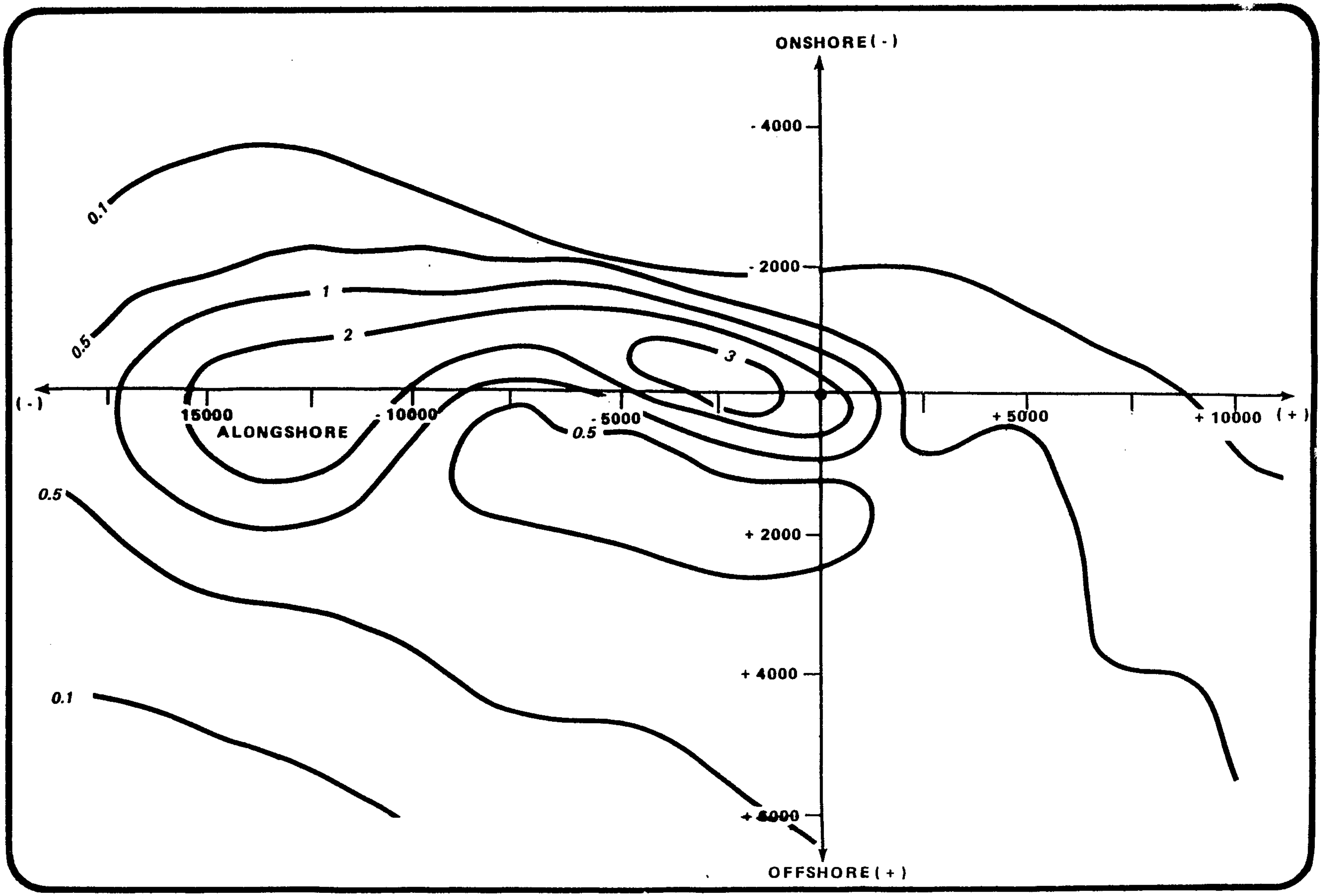


FIGURE G.3-14. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed Chacahoula site using observed currents at T = 3 hrs.

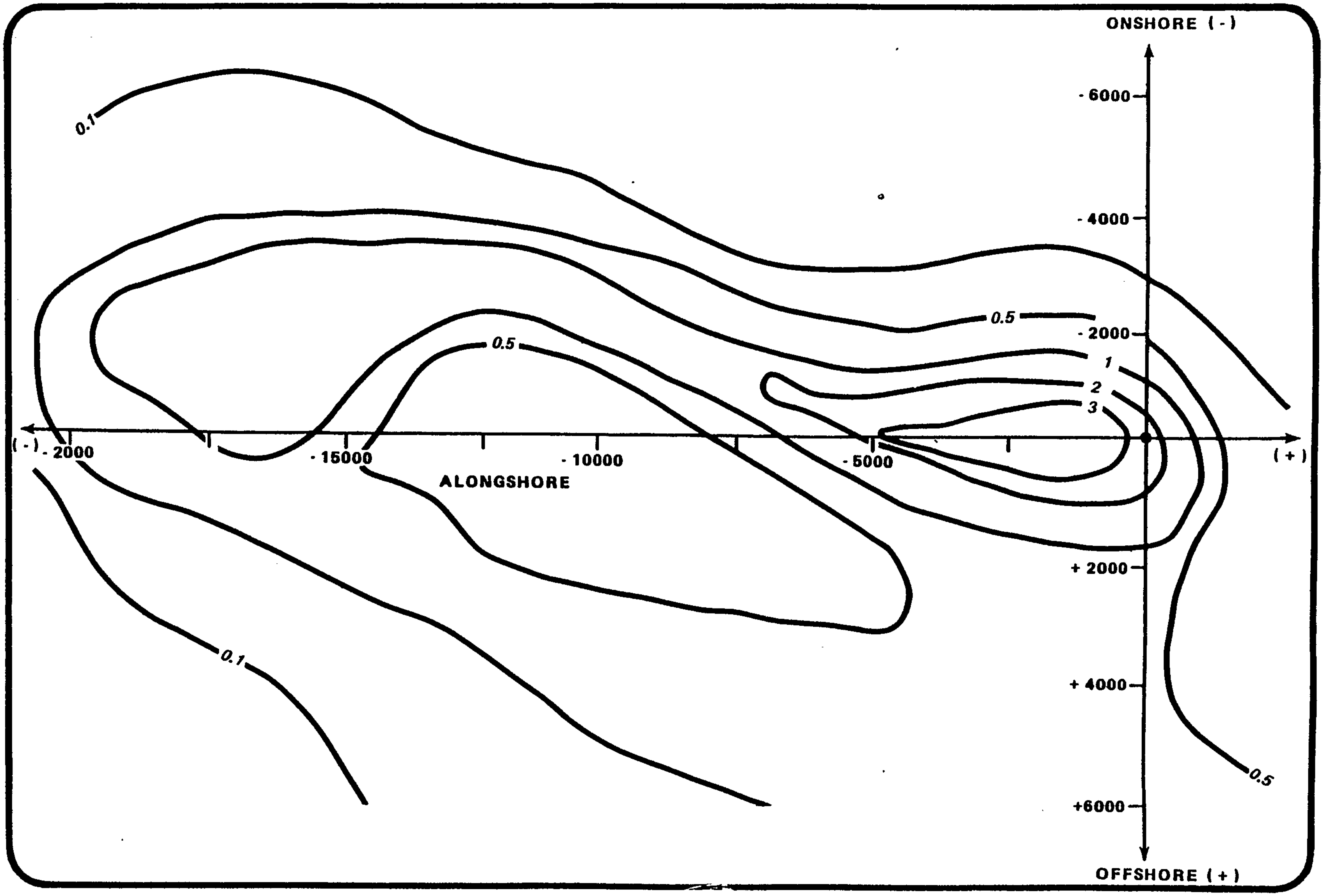
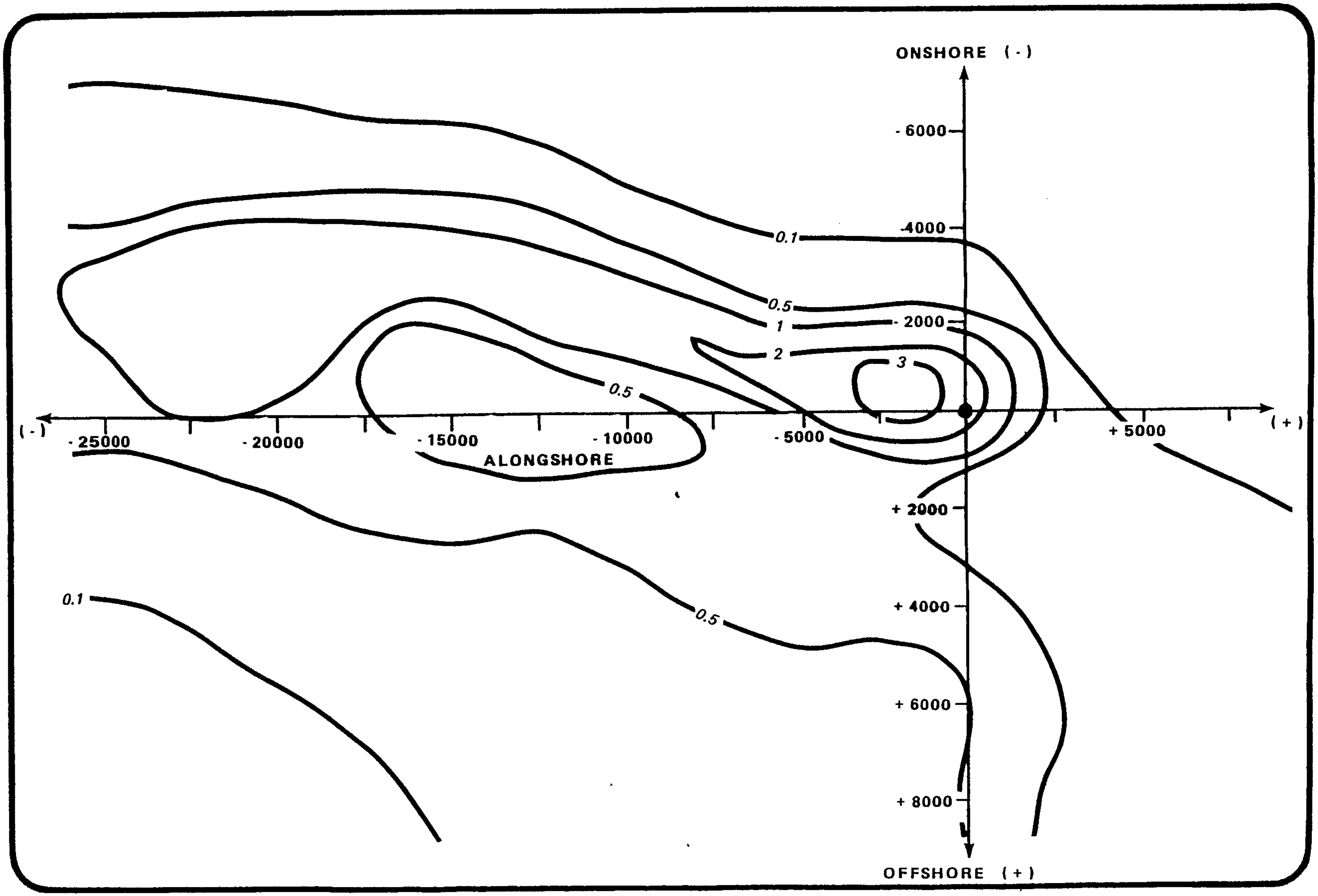


FIGURE G.3-15. Contours of excess salinity concentrations (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed Chacahoula site using observed currents at T = 6 hrs.



GURE G.3-16. Contours of excess salinity concent[illegible]ons (ppt) at various distances (feet) from the center of the diffuser (dot) for the proposed [illegible]aca[illegible]a site using obse[illegible]

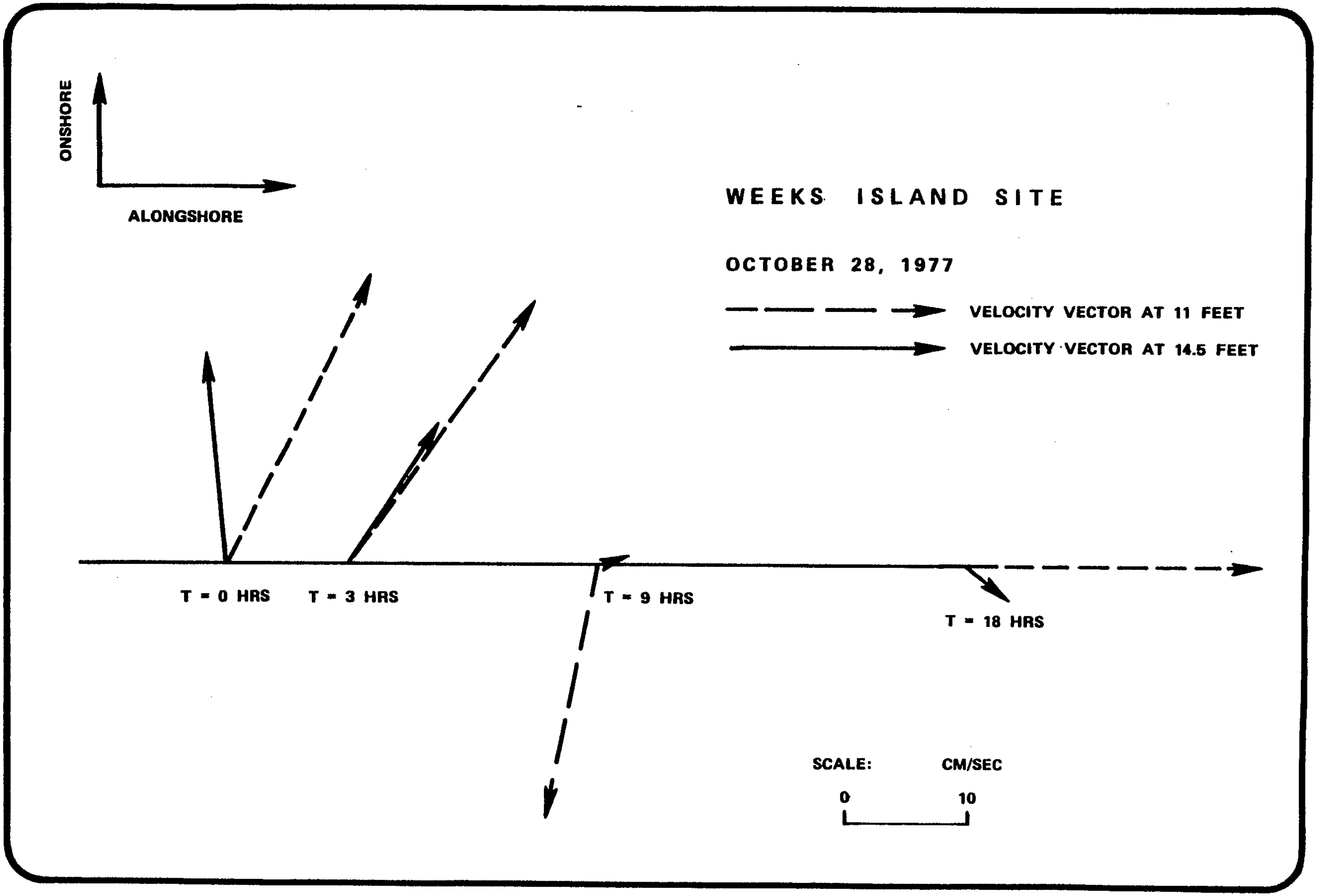


FIGURE G.3-17. Weeks Island current velocity vectors at depths of 11 and 14.5 feet corresponding to the snapshot times for the plume model output (see Figures G.3-9 through G.3-12).

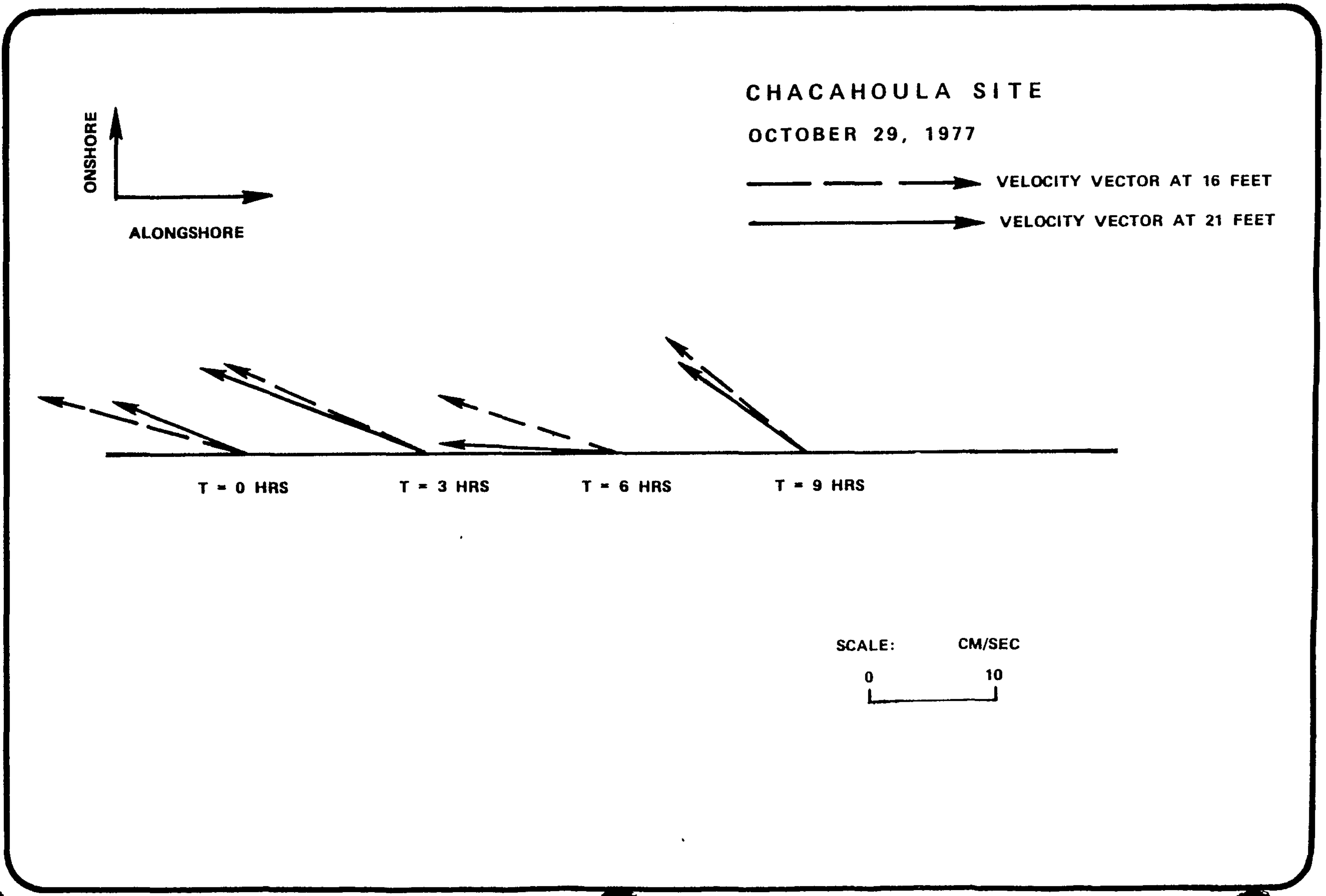


FIGURE G.3-18. Chacahoula current velocity vect[illegible] at depths of 16 and 21 feet corresponding to the snapsho[illegible]mes [illegible] th[illegible]ume[illegible]el [illegible]ut [illegible] Fi[illegible]es ([illegible]3 [illegible]ugh [illegible]-16[illegible]

The expected plume patterns, using the observed current data, closely parallel the patterns predicted by inputting estimated current data. The isopleths of salinity in the figures are plotted where the predicted excess salinity contours exceed 0.1 ppt. With the exception of the 0.1 ppt isohaline, the four predicted plumes are similar, reflecting the effects of ambient currents in the area on the shape of the plume pattern. Excess far field salinity concentrations do not exceed 2 ppt for any of the plumes described; this is also consistent with predictions using estimated currents. Salinity concentrations near the diffuser head are relatively high due to the positive dependence of the nearfield dilutions on current speed.

G.3.1.3 Brine Plume Thermal Analysis

The brine which would be discharged from Capline Group diffusers at Weeks Island or Chacahoula (Figure G.3-19) would originate either from the initial leaching of caverns or from water displacement of stored oil during a cavern fill period. Because of the earth's thermal influence in these deep caverns, the effluent brine would be elevated in temperature. The temperature of the brine before disposal in the Gulf of Mexico would thus be influenced by this geothermal heating and is related to the depth of the leached caverns in the earth, the residence time in the caverns, the temperature of the displaced oil, the retention time of the brine in the holding pits and any heat loss or gain in the pipeline to offshore. Although it has been conservatively estimated that the temperature of the brine will be 130°F, observations made for various flow rates at several operational salt domes show that the temperature of the brine before injection into a brine holding pit will be more realistically at a temperature of 120°F or less.

Observed Temperature and Flow Rates for Brine at Several Gulf Coast Salt Domes

Salt Dome	Brine Temperature (° F)	Oil Temperature (° F)	Flow Rate (BPH)	Well Number
Bryan Mound	120	80	1500 1000	2 4
Bayou Choctaw	80-90	80	1250[a]	15
West Hackberry	80-90	80	1500 1000	6 11

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[a] Fill at Bayou Choctaw is intermittent; the average is 1250 BPH but actual injection rate is 2200 BPH.

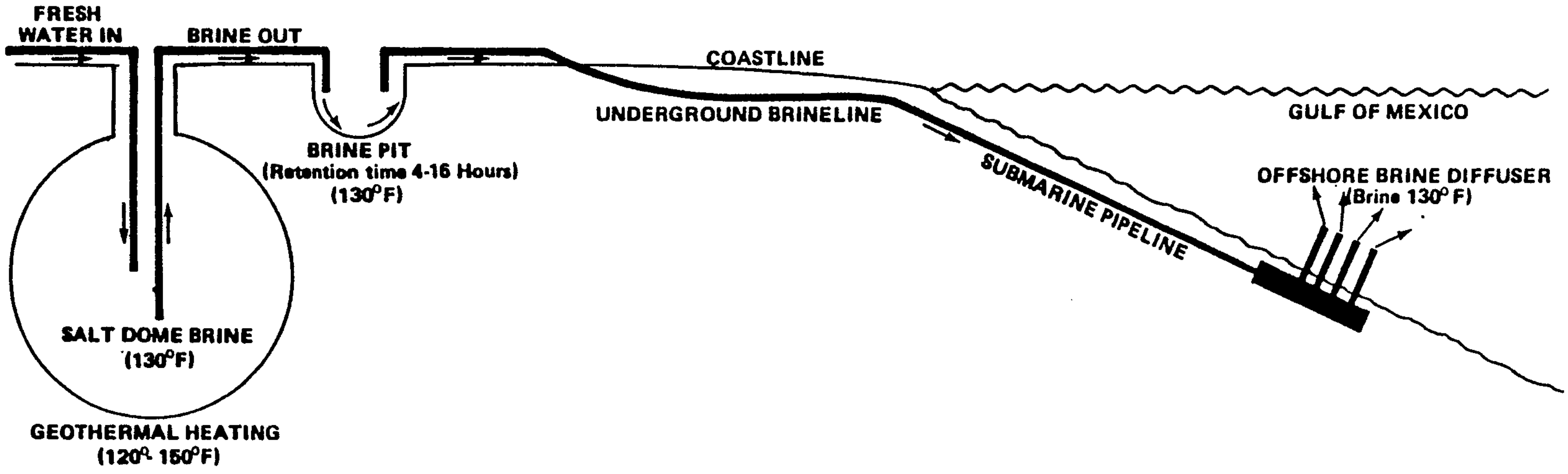


FIGURE G.3.19. Schematic model for brine temperature analysis

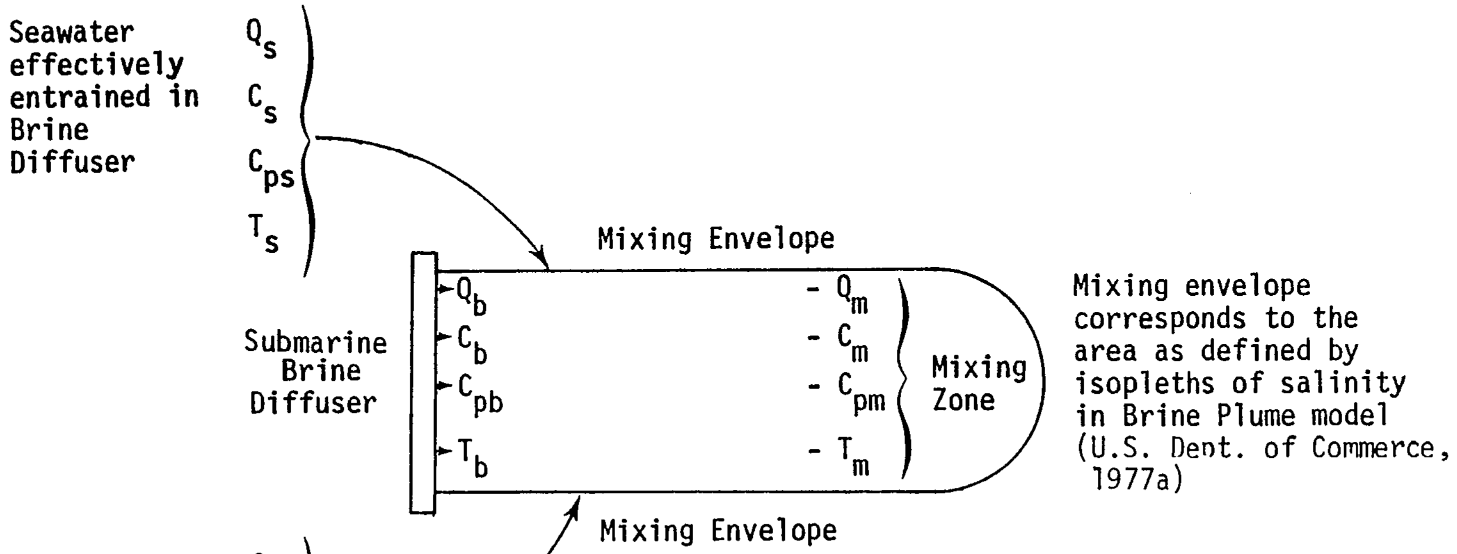
An analysis of heat transfer properties in the proposed brine disposal pipeline was conducted to determine the expected heat loss in the disposal when the brine is pumped from the brine pit to the diffuser head (Figure G.3-19). This analysis was carried out for conditions where the temperature of the brine at the inlet ranged from 70°F to 140°F and ambient ground temperatures ranged from 50°F to 70°F. The results of this analysis in the table below indicate that the maximum temperature differential (ΔT) between the inlet and the outlet (i.e., the diffuser ports) would occur for the case when the inlet temperature was 140°F and the ground temperature was 50°F, but this difference would only amount to 3.2°F due to the insulating effect of the pipe coatings of tar wrap and concrete. Therefore the temperature of the brine at the diffuser head considered below should conservatively remain within the temperature range of about 115° to 120°F.

Brine Temperature (°F) at the Proposed Diffuser Ports
as a Function of Ground Temperature and Brine
Temperature at the Pipeline Inlet

Brine Inlet Temperature (°F)	Ground Temperature (°F)		
	50	60	70
140	136.8	137.2	137.6
130	127.2	127.6	128.1
110	108.1	108.5	108.9
90	88.9	89.3	89.6
70	69.6	69.9	70.0

G.3.1.3.1 General Approach

To estimate the potential impacts from excess temperatures which might result from discharge of brine to the Gulf of Mexico through a Capline Group diffuser at either Weeks Island or Chacahoula, a simplistic heat flow model (Figure G.3-20) was evaluated and analyzed. A correlation was made between excess temperature and excess salinity profiles, assuming 90°F seawater (probable maximum) and brine temperatures varying from 90°F to 150°F. The brine dispersion model as discussed in Section G.3.1.1 provided a basis for applying this correlation to expected mixing conditions in the Gulf of Mexico at the diffuser



Where: Q = Flow rate (cfs)

C = Salinity Concentration (ppt)

C_p = Specific heat (BTU/16m-^{o}F)

T = Temperature (^{o}F)

[illegible]URE G.3-20. Schematic model of mixing zone relati[illegible]hips for brine plume temperature analysis.

sites. The simplified analysis presented here does not account for buoyancy effects in the water column due to elevated brine temperatures. The analysis should be reasonably accurate within the mixing zone which is located close to the brine diffuser.

Since the temperature of the brine within the salt dome is not accurately known and temperature will vary with residence time and the other factors described above, a parametric analysis was used to relate the difference in the temperature in the brine plume compared to the ambient water temperature (ΔT_1) with the temperature of the brine (T_b) (see Figure G.3-20).

G.3.1.3.2 Salinity Dilution Calculation

The basic analysis for the salinity dilution effects corresponds to the area at the diffuser site defined by the MIT model (Section G.3.1.1) above; in this analysis salt is conserved throughout mixing zones such that:

$\rho m\ Q_m\ C_m = \rho b\ Q_b\ C_b + \rho s\ Q_s\ C_s$; where $\rho m\ Q_m = \rho b\ Q_b + \rho s\ Q_s$, and ρ is the specific gravity of the corresponding fluid.

$$C_m = \frac{\rho b\ Q_b\ C_b + \rho s\ Q_s\ C_s}{\rho b\ Q_b + \rho s\ Q_s}$$

Define: $${}_{\Delta}C_1 = C_m - C_s = \frac{\rho b\ Q_b\ C_b + \rho s\ Q_s\ C_s}{\rho b\ Q_b + \rho s\ Q_s} - C_s$$

Or $${}_{\Delta}C_1 = \frac{\rho b\ Q_b\ (C_b - C_s)}{\rho b\ Q_b + \rho s\ Q_s}$$

Solve for Q_s: $$Q_s = \frac{\rho b\ Q_b\ (C_b - C_s) - \rho b\ Q_b\ ({}_{\Delta}C_1)}{\rho s\ {}_{\Delta}C_1}$$

Define: $C_b - C_s = {}_{\Delta}C_2 = \text{constant}$

Then $$Q_s = Q_b \left(\frac{{}_{\Delta}C_2}{{}_{\Delta}C_1} - 1 \right) \frac{\rho b}{\rho s} \qquad (1)$$

G.3.1.3.3 Heat Dilution Calculation

Assume conservation of energy in mixing zone:

$$\rho_m Q_m C_{pm} T_m = \rho_b Q_b C_{pb} T_b + \rho_s Q_s C_{ps} T_s; \text{ where}$$

$$\rho_m Q_m = \rho_b Q_b + \rho_s Q_s \text{ and within most of mixing zone,}$$

$$C_{pm} \approx C_{ps} \quad \text{(i.e., substantial dilution)}$$

Also, heat capacity per unit volume is nearly independent of salinity, or $\rho_s C_{ps} = \rho_b C_{pb} = \rho_m C_{pm}$

then:

$$T_m = \frac{\rho_b Q_b C_{pb} T_b + \rho_s Q_s C_{ps} T_s}{(\rho_b Q_b + \rho_s Q_s) C_{pm}} = \frac{\rho_s C_{ps} (Q_s T_s + Q_b T_b)}{C_{pm} (\rho_b Q_b + \rho_s Q_s)}$$

Define:

$$\Delta T = T_m - T_s = \frac{\rho_s Q_b T_b - \rho_b Q_b T_s}{\rho_s Q_s + \rho_b Q_b}$$

Using equation (1): $$\Delta T = \frac{\Delta C_1}{\Delta C_2} \left(\frac{\rho_s}{\rho_b} T_b - T_s \right) \qquad (2)$$

Using equations (1) and (2) and site specific data for Q_b, C_b, C_s, ρ_s, ρ_b, and T_s, we can solve for Q_s and ΔT, as a function of T_b and ΔC_1.

G.3.1.3.4 Application to Capline Group Diffusers

The following data have been applied to the diffuser at Bryan Mound:

Q_b = 42 cfs at Weeks Island, 71 cfs at Chacahoula

ΔC_w = 240 ppt; C_b 270 ppt; C_s = 30 ppt

T_s = 32^oC = 90^oF

ρ_s = 1.02

ρ_b = 1.2

Then, from Equation (1):

$$Q_s = Q_b \; \frac{240}{\Delta C_1} - 1 \quad \frac{1.2}{1.02} = f\,(\Delta C_1)$$

and from Equation (2):

$$\Delta T = \frac{\Delta C_1}{240}\,(0.85\,T_b - 90) = f\,(\Delta C_1, T_b)$$

Therefore, using the salinity change profiles (ΔC_1) as calculated in Section G.3.1.3.2 above, we can calculate Q_s, and for various assumed brine temperatures, T_b, we can correlate ΔT with ΔC_1.

Figure G.3-21 plots correlations calculated between ΔC_1, and ΔT, for a range of T_b from 150°F to 90°F and for an assumed $T_s = 90°F$.

To apply these results, the profiles of excess salinity which appear in Section G.3.1 above can be replotted for excess temperature profiles. Within the range of ΔC_1 as plotted, ΔT, will be less than 1°F, which indicates a very small area will be affected by elevated brine temperatures. Concentration profiles of salinity excess would be needed in the near field to show the area of possible thermal impact. Therefore under worst case conditions it is expected that at the boundary of the 25-acre mixing zone an increase in temperature of less than 1°F would occur during summer temperature maxima.

The presence of a strong thermocline or halocline at the proposed diffuser site might possibly inhibit the vertical movement of the plume discharge water and thus increase the area affected by elevated temperatures. The condition would most likely occur in the spring when freshwater inflow, due to high river flow, is a maximum, and the surface waters are beginning to warm due to solar heating.

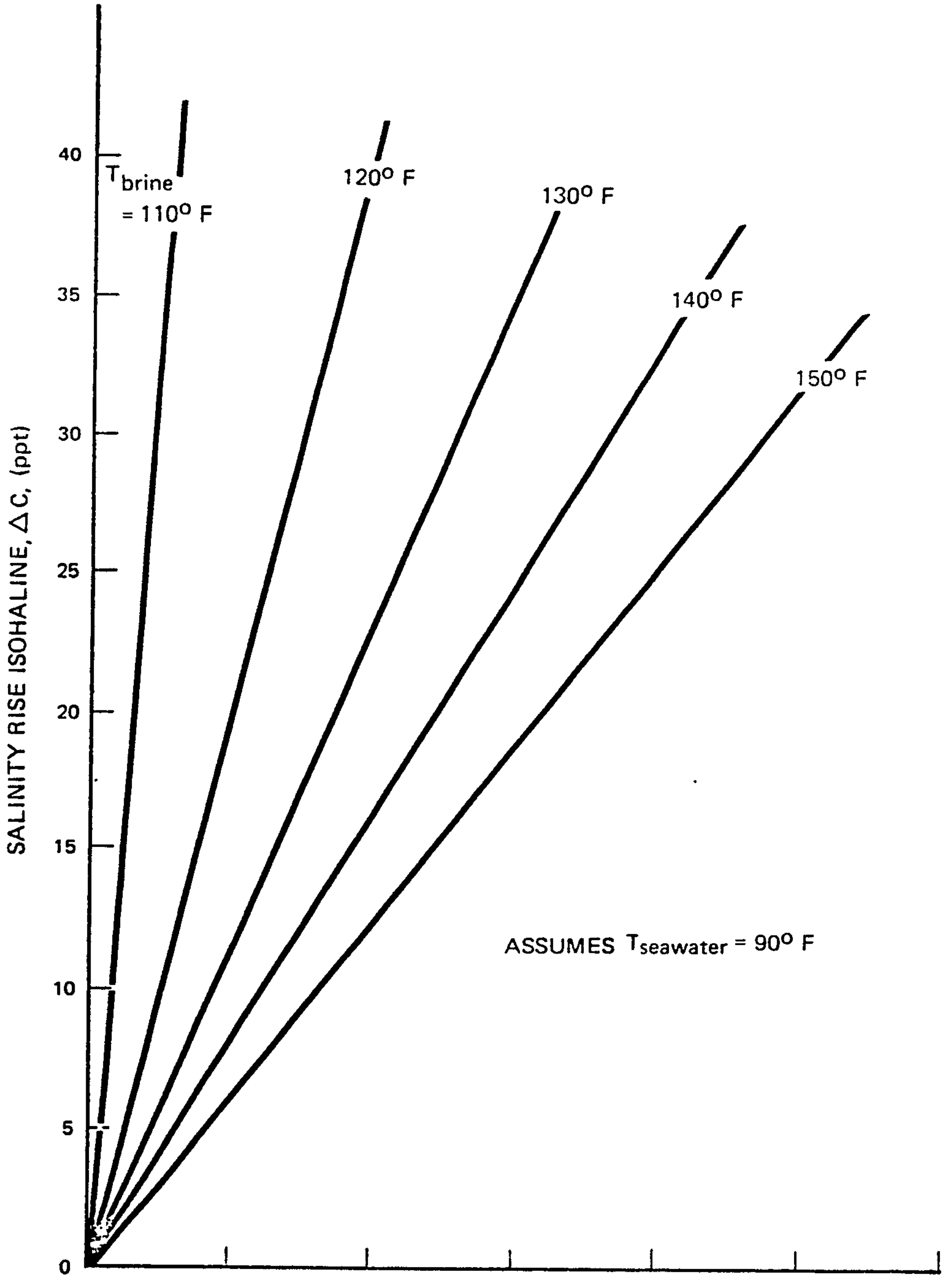


FIGURE G.3-21. Temperature rise (ΔT) versus salinity rise (ΔC) correlation.

G.3.2 IMPACTS ON WATER QUALITY

Impacts on the water quality of the Gulf of Mexico during brine discharge could include increased salinity, hydrocarbon, and trace metal levels, disruption of seawater ion proportions, and alterations in chemical constituent solubilities. Construction and operation impacts would differ in that during operation, water used for oil displacement would be in contact with oil and would be in the cavern for a longer period. As a result, displacement water would be warmer and more saline and would also contain petroleum hydrocarbons.

The areal extent of the brine plume has been predicted using a mathematical model and current patterns observed in the Weeks Island-Chacahoula area (Section G.3.1). Excess salinity contours of the predicted plumes are assumed to be tracers reflecting the distribution of other components that may be discharged during brine diffusion.

Louisiana has established specific water quality criteria which may be applicable at the proposed brine diffuser locations. Segment 12, Table G.3-2, is the area directly affected by the proposed Weeks Island-Chacahoula brine diffusers; other segments may be indirectly affected. The U.S. Environmental Protection Agency (EPA) has also proposed water quality criteria (Table G.3-3).

G.3.2.1 Brine Chemistry

Approximately 500 salt domes are found in the Gulf of Mexico coastal basin. They originated from the Louann salt layer of the Triassic-Jurassic Age, which underlies virtually the entire Gulf Coast basin. Because of common origin of this brine, the chemical composition of the salt domes except as noted for Bayou Choctaw are similar (Table G.3-4).

Approximately 99% of salt dome brine consists of sodium chloride; most of the remaining 1% is calcium sulfate. Brine in existing caverns is saturated (317 g/l or 263 ppt) with respect to sodium chloride; for new caverns this saturation level is expected to occur only during the operation phase. During the initial solution mining process for new caverns, residence time for the brine would be relatively short and therefore total dissolved solids levels would be less than the levels

TABLE G.3-2 Specific water quality criteria - State of Louisiana.

		WATER USES				CRITERIA						
AGENCY I.D. NUMBER	SEGMENT DESCRIPTION	PRIMARY CONTACT RECREATION	SECONDARY CONTACT RECREATION	PROPAGATION OF FISH AND WILDLIFE	DOMESTIC RAW WATER SUPPLY	CHLORIDE (mg/l) Not to exceed	SULPHATE (mg/l) Not to exceed	DISSOLVED OXYGEN (mg/l) Not less than	pH RANGE	COLIFORM	TEMPERATURE °C	TOTAL DISSOLVED SOLIDS (mg/l) Not to exceed
	1. ATCHAFALAYA BASIN											
010010	Atchafalaya River - Headwaters (Barbre Landing) to Mile 118 (1.2 miles below mouth of Bayou Boeuf) (Includes Grand Lake and Six Mile Lake)	X	X	X	X	65	70	5.0	6.5 to 8.5	200	33	440
010020	West Atchafalaya Borrow Pit Canal (St. Landry and St. Martin Parishes)	X	X	X		100	75	5.0	6.0 to 8.5	200	32	500
010030	Atchafalaya River - Mile 118 to Atchafalaya Bay (Tidal)	X	X	X		--	--	4.0	6.5 to 9.0	200	35	--
010040	Intracoastal Waterway (North-South) - Bayou Sorrel to Morgan City		X	X		150	75	5.0	6.0 to 8.5	1000	32	500
010050	Intracoastal Waterway (East-West) - Bayou Boeuf Locks to Wax Lake Outlet		X	X		150	75	5.0	6.0 to 8.5	1000	32	500
010060	Wax Lake Outlet (Tidal)		X	X		--	--	4.0	6.5 to 9.0	1000	15	--
010070	Atchafalaya Bay (Tidal)		X	X		--	--	5.0	6.5 to 9.0	70	35	--
	2. BARATARIA BASIN											
020010	Bayou Verret (Includes Bayou Chevereuil, Bayou Citamon and Grand Bayou, etc.)	X	X	X		1000	500	5.0	6.0 to 8.5	200	32	2000
	4. MERMENTAU - VERMILION-TECHE BASIN											
040120	Vermilion River - Origin to Intracoastal Waterway	X	X	X		230	36	5.0	6.0 to 8.5	200	32	350
040130	Vermilion River - Intracoastal Waterway to Vermilion Bay (Tidal)		X	X		--	--	4.0	6.5 to 9.0	1000	35	--
040140	Bayou Tigre - Origin to Vermilion Bay (Tidal)		X	X		--	--	4.0	6.5 to 9.0	1000	35	--
040150	Lake Peigneur (Tidal)		X	X		--	--	4.0	6.0 to 8.5	--	35	--
040190	Bayou Teche - Headwaters to Keystone Locks and Dam	X	X	X	X	43	32	5.0	6.0 to 8.5	200	32	220
040200	Spanish Lake	X	X	X		250	75	5.0	6.0 to 8.5	200	32	500
040210	Bayou Teche - Keystone Locks and Dam to Charenton Canal	X	X	X	X	80	50	5.0	6.0 to 8.5	200	32	350
040213	Tete Bayou	X	X	X	X	80	50	5.0	6.0 to 8.5	200	32	350
040214	Loreauville Canal	X	X	X	X	80	50	5.0	6.0 to 8.5	200	32	350
040215	Lake Fausse Point (Including Dauterive Lake)	X	X	X	X	80	50	5.0	6.0 to 8.5	200	32	350
040216	Charenton Canal - Lake Fausse Point to Bayou Teche	X	X	X	X	80	50	5.0	6.0 to 8.5	200	32	350
040220	Bayou Teche - Charenton Canal to Wax Lake	X	X	X	X	125	68	5.0	6.0 to 8.5	200	32	500
040225	Charenton Canal - Bayou Teche to Intracoastal Waterway	X	X	X		250	75	5.0	6.0 to 8.5	200	32	500

TABLE G.3-2 continued.

		WATER USES				CRITERIA						
AGENCY I.D. NUMBER	SEGMENT DESCRIPTION	PRIMARY CONTACT RECREATION	SECONDARY CONTACT RECREATION	PROPAGATION OF FISH AND WILDLIFE	DOMESTIC RAW WATER SUPPLY	CHLORIDE (mg/l) Not to exceed	SULPHATE (mg/l) Not to exceed	DISSOLVED OXYGEN (mg/l) Not less than	pH RANGE	COLIFORM	TEMPERATURE °C	TOTAL DISSOLVED SOLIDS (mg/l) Not to exceed
040226	Charenton Canal - Intracoastal Waterway to West Cote Blanche Bay (Tidal)	X	X	X		--	--	4.0	6.5 to 9.0	200	35	--
040230	Vermilion Bay (Tidal)		X	X		--	--	4.0	6.5 to 9.0	70	35	--
040240	West Cote Blanche Bay (Tidal)		X	X		--	--	4.0	6.5 to 9.0	70	35	--
040250	East Cote Blanche Bay Waterway (Tidal)		X	X		--	--	4.0	6.5 to 9.0	70	35	--
040270	Intracoastal Waterway (East-West) - Vermilion Lock		X	X		--	--	4.0	6.5 to 9.0	1000	35	--
	5. <u>MISSISSIPPI BASIN</u>											
050020	Mississippi River: From Old River Control Structure to Huey P. Long Bridge above New Orleans		X	X	X	75	120	5.0	6.5 to 9.0	2000	32	400
	11. <u>TERREBONNE BASIN</u>											
110010	Lake Verret	X	X	X		100	75	5.0	6.0 to 8.5	200	32	350
110020	Lake Palourde	X	X	X	X	100	75	5.0	6.0 to 8.5	200	32	300
110030	Bayou Boeuf - Lake Palourde to Morgan City	X	X	X	X	100	75	5.0	6.0 to 8.5	200	32	300
110040	Intracoastal Waterway (East-West) - Morgan City to Larose	X	X	X	X	250	75	5.0	6.0 to 8.5	200	32	500
110050	Bayou Black - Intracoastal Waterway to Houma	X	X	X	X	250	75	5.0	6.0 to 8.5	200	32	500
110060	Bayou Terrebonne - Thibodaux to Bourg	X	X	X		230	55	5.0	6.0 to 8.5	200	32	875
110100	Bayou Choctaw - Headwaters to Intracoastal Waterway		X	X		250	75	5.0	6.0 to 8.5	1000	32	500
110110	Bayou Grosse Tete - Headwaters to Intracoastal Waterway		X	X		25	25	5.0	6.0 to 8.5	1000	32	200
110120	Bayou Plaquemine - Headwaters to Intracoastal Waterway		X	X		250	75	5.0	6.0 to 8.5	1000	32	500
110130	Upper Grand River and Lower Flat River - Headwaters to Intracoastal Waterway		X	X		250	75	5.0	6.0 to 8.5	1000	32	500
110140	Intracoastal Waterway (North-South) - Port Allen to Bayou Sorrel		X	X		250	75	5.0	6.0 to 8.5	1000	32	500
110150	Lower Grand River and Bell River - Bayou Sorrel to Lake Palourde (Includes Bayou Goula and Grand Bayou)		X	X		250	75	5.0	6.0 to 8.5	1000	32	500
110190	Bayou du Large - Houma to Bay Junop (Tidal)	X	X	X		--	--	4.0	6.5 to 9.0	70	35	--
110200	Lake Hache, Lake DeCade, Lost Lake and Four-League Bay (Tidal)		X	X		--	--	4.0	6.5 to 9.0	70	35	--
110210	Bayou Penchant and Lake Penchant - Morgan City to Lake DeCade (Scenic River) (Tidal)	X	X	X		--	--	4.0	6.5 to 9.0	70	35	--
110220	Caillou Bay		X	X		--	--	5.0	6.5 to 9.0	70	35	--
110280	Bayou Lafourche - Donaldsonville to Larose	X	X	X		70	55	5.0	6.0 to 8.5	200	32	50
110290	Bayou Lafourche - Larose to Gulf of Mexico (Tidal)	X	X	X		--	--	4.0	6.5 to 9.0	200	35	--
	12. <u>GULF OF MEXICO</u>											
	Gulf of Mexico and other open coastal waters not specifically identified in the tables	X	X	X		--	--	5.0	6.5 to 9.0	70	32	--

TABLE G.3-3 Proposed EPA numerical criteria for water quality.

Parameter	Public Water Supply Intake (μg/l)	Marine Water Constitutents (Aquatic Life) (μg/l)	Freshwater Aquatic Life (μg/l)
Arsenic	50	50	---
Cadmium	10	10	30 (hardness >100 μg/l) 4 (hardness <100 μg/l)
Chromium	50	100	50
Copper	1000	50	1/10 LC 50
Lead	50	50	30
Mercury	2.0	1.0	0.2
Nickel	---	100	1/50 LC 50
Zinc	5000	100	5/1000 LC 50
Cyanides	200	10	1/20 LC 50 (.005 μg/l)
Aldrin	1	5.5	0.01
DDT	50	0.6	0.002
Dieldrin	1	5.5	0.005
Chlorodane	3	---	0.04
Endrin	0.2	0.6	0.002
Heptachlor	0.1	8	0.01
Heptachlor epoxide	0.1	---	---
Lindane	4	5	0.02
Phenols	1.0	---	1/20 LC 50 (0.1 μg/l)
Oil and Grease	---	1. Not detectable as a visible film, sheen discoloration of the surface, or by odor. 2. Does not cause tainting of fish or invertebrates or damage to biota. 3. Does not form an oil deposit on the shores or bottom of the receiving body of water.	1. None visible on surface. 2. 1000 μg/kg hexane extractable substances in sediments. 3. 1/20 LC 50.
pH	---	6.5 - 8.5	6 - 9
Ammonia	---	400	1/20 LC 50 (20 μg/l)
Hydrogen Sulfide	---	10	---
Sulfides	---	---	2
Dissolved Oxygen	---	6.0 μg/l	4.0 μg/l (>31°C)
Phosphorus	---	0.1	---
Diazinon	---	---	0.009
Malathion	---	---	0.008
Parathion	---	---	0.001
Suspended and settleable solids	---	---	80 μg/l
Turbidity and light penetration	---	---	10% change in compensation pT
Color	---	---	10% change in compensation pT
Toxaphene	5	0.10	0.01

SOURCE: U.S. Environmental Protection Agency, 1973.

TABLE G.3-4 Preliminary analysis of brine in various salt domes of the Gulf Coast.

Element	Brine Sample[a]							Sea	Weeks	Chaca-
or Ion	BC-6	BC-17	BC-19	BM-5	SK-10	SU-2	WH-11	Water[a]	Island[e]	houla[e]
Na[b]	102,800	121,200	120,400	117,600	120,800	121,600	120,800	10,561	6,200	9,750
K[b]	7,420	194	19	296	3	3	5	380	222	346
Ca[b]	5,300	420	330	720	370	910	420	400	250	367
Mg[b]	4,880	10	9	9	2	4	5	1,272	750	1,176
Cl[b]	200,000	200,000	196,000	194,000	198,000	196,000	200,000	18,980	11,430	17,310
SO_4[b]	1,480	1,340	800	1,960	800	2,200	1,440	2,649	1,520	2,440
Ag[c,d]	<10 (<4)	<10 (<4)	<10 (<4)	<10 (<4)	<10 (<4)	<10 (<4)	<10 (<4)	0.3	---	---
As[c,d]	<2 (<200)	10 (<200)	6 (<200)	2 (<200)	<2 (<200)	<2 (<200)	4 (<200)	15	---	---
Ba[c]	<400	<400	<400	<400	<400	<400	<400	50	---	---
Cd[c,d]	100 (96)	2 (<20)	2 (<20)	<2 (<20)	2 (<20)	8 (<20)	<2 (<20)	---	---	---
Cr[c,d]	8 (<20)	<2 (<20)	<2 (<20)	<2 (<20)	<2 (<20)	<2 (<20)	<2 (<20)	---	---	---
Cu[c,d]	14 (25)	20 (17)	16 (54)	2 (<10)	<2 (<10)	<2 (<10)	<2 (<10)	5	---	---
Hg[c]	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	0.03	---	---
Mn[c]	40,000	420	320	100	140	280	160	5	---	---
Ni[c,d]	<2 (6)	2 (4)	2 (6)	2 (<4)	<2 (<4)	<2 (24)	<2 (<4)	0.1	---	---
Pb[c,d]	34 (40)	26 (20)	26 (24)	2 (<20)	12 (<20)	<2 (<20)	2 (<20)	4	---	---
Sb[c,d]	<2 (<20)	<2 (<20)	<<2 (<20)	<2 (<20)	<2 (<20)	<2 (<20)	<2 (<20)	---	---	---
Se[c]	<2	<2	<2	<2	<2	<2	<2	4	---	---
Zn[c]	16,000	80	400	80	4	32	<2	5	---	---

[a] Sample Code (Cavern number follows the Name code)

BC - Bayuu Choctaw
BM - Bryan Mound
SK - Starks
SU - Sulfur Mines
WH - West Hackberry
Sea water analyses - Sverdrup, Johnson & Fleming, 1942.

[b] Units - Brine samples: mg/l; sea water sample: mg/kg.

[c] Trace elements units: brine samples ug/l; sea water sample: ug/kg

[d] For brine samples, values in parentheses were by Emission Spectography while those not in parentheses were by Atomic Absorption.

[e] Average of mean, surface and bottom sample concentrations during September, 1977.

discharged during oil storage operations (270 g/l or 230 ppt). Compared to normal seawater, sodium and chloride in the brine solution are an order of magnitude higher, but magnesium is two orders of magnitude lower; calcium and sulfate concentrations are similar to those in seawater, while potassium is slightly lower.

Of the trace metals analyzed in brine, manganese, and zinc amounts are greater than in seawater (Table G.3-4). However, in most cases, the heavy metal concentrations in the brine are within the acceptable EPA standards (Table G.3-3).

The water chemistry of Bayou Lafourche and the Intracoastal Waterway (ICW) must also be considered since these waters are the proposed sources for raw water at the Chacahoula and Weeks Island storage sites, respectively, and their chemical constituents would eventually be discharged at the diffusers. Additionally, the Gulf of Mexico and/or the Mississippi River are alternatives to Bayou Lafourche; the Gulf is also an alternative to the ICW. Water quality levels from sampling stations in the Capline region (Table G.3-5) are, however, well within EPA recommended guidelines and would not restrict the use of either the proposed or alternative water sources.

G.3.2.2 Impacts

The major impact of brine discharged to the Gulf of Mexico would be increased salinity levels within the plume (Section G.3.1.2). Associated with this increase would be an alteration in the constant composition of seawater. In particular, calcium/magnesium ratios, which are normally 0.3 for seawater, are at least two orders of magnitude larger in brine.

A model used to predict the concentration of various chemical components at various excess salinity contours for brine disposal in the Texoma Group (FEA, 1977b) (Table G.3-6) forecasts that many of the free chemical components would assume near normal levels within the 10 ppt excess salinity contour. At Weeks Island and Chacahoula, an area of about 30 and 50 acres, respectively, would be encompassed in the larger 4 ppt excess salinity contour during an 8-day slack period, as predicted by the MIT model (Section G.3.1.1). Furthermore, changes in the calcium to magnesium free concentration ratios are predicted to be small.

TABLE G.3-5 Water quality data from sampling stations in the Capline region.

	ATCHAFALAYA RIVER (MAIN CHANNEL) AT MYETTE POINT		LOWER ATCHAFALAYA RIVER AT MORGAN CITY		WAX LAKE OUTLET AT CALUMET		ATCHAFALAYA BAY AT EUGENE ISLAND		VERMILION RIVER AT STATE HWY 3073 NEAR LAFAYETTE		BAYOU TECHE AT KEYSTONE LOCK NEAR ST. MARTINSVILLE		VERMILION BAY AT CYPREMORT POINT		INTRACOASTAL WATERWAY AT VERMILION LOCK (EAST)		MISSISSIPPI RIVER AT PLAQUEMINE		MISSISSIPPI RIVER AT UNION		BAYOU PENCHANT AT BAYOU CHENE		BAYOU LAFOURCHE AT INTRACOASTAL WATER AT LAROSE	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Arsenic (As) (ug/l)	3	1	4	1	5	2	11	1	-	-	3	-	3	1	12	1	4	2	8	2	6	1	6	1
Dis. Arsenic (As) (ug/l)	2	0	2	0	2	0	2	0	5	4	2	-	2	0	2	0	2	1	2	1	3	0	2	1
Tot. Cadmium (Cd) (ug/l)	2	0	2	0	3	0	3	0	-	-	0	-	6	0	3	0	1	0	2	0	3	0	12	0
Dis. Cadmium (Cd) (ug/l)	2	0	2	0	2	0	0	0	3	0	0	-	1	0	0	0	1	0	0	0	1	0	0	0
Tot. Chromium (Cr) (ug/l)	20	6	20	0	30	<10	60	<10	-	-	<10	-	30	<10	40	<10	30	0	30	0	30	<10	30	<10
Hex. Chromium (Cr_6) (ug/l)	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
Tot. Copper (Cu) (ug/l)	6	4	11	3	12	4	13	3	-	-	8	-	9	2	14	1	65	4	27	4	9	3	18	4
Dis. Copper (Cu) (ug/l)	6	1	7	2	6	1	10	0	12	5	8	-	5	1	7	1	5	2	6	0	6	1	10	1
Tot. Lead (Pb) (ug/l)	8	0	12	0	14	0	14	0	-	-	3	-	12	0	18	3	12	0	16	0	20	0	18	3
Dis. Lead (Pb) (ug/l)	8	0	2	0	2	0	2	0	3	0	0	-	0	0	7	0	0	0	3	0	3	0	4	0
Tot. Mercury (Hg) (ug/l)	.6	0	.3	0	1.5	0	.9	0	.9	.3	0	-	.3	0	.6	0	.6	0	.4	0	.9	0	1.1	0
Sus. Mercury (Hg) (ug/l)	.2	0	.3	0	1.2	0	.6	0	-	-	-	-	.1	0	.3	0	.5	0	.8	0	.8	0	.9	0
Dis. Mercury (Hg) (ug/l)	.2	0	.1	0	.3	0	.3	0	-	-	0	-	.2	0	.5	0	.3	0	.3	0	.2	0	.5	0
Tot. Nickel (Ni) (ug/l)	13	2	16	[illegible]	22	3	20	3	-	-	-	-	21	0	16	2	24	3	13	4	15	0	10	5
Dis. Nickel (Ni) (ug/l)	3	0	5	6	5	0	4	0	-	-	-	-	4	0	4	0	2	0	2	0	7	0	6	0
Tot. Zinc (Zn) (ug/l)	140	0	80	10	80	20	90	10	-	-	30	-	100	10	90	10	130	20	90	10	80	10	110	10
Dis. Zinc (Zn) (ug/l)	20	0	20	0	20	0	20	0	30	7	10	-	20	0	20	0	40	0	20	0	20	0	50	0

TABLE G.3-6 Free component concentrations at the various excess salinity contours as predicted by modelling.

	Excess Salinity in Parts Per Thousand				
Component	0.0	10.0	30.0	60.0	159.4
Barium	1.4 μg/l	1.6 μg/l	2.2 μg/l	3.1 μg/l	6.6 μg/l
Cadmium	.009 μg/l	.005 μg/l	.002 μg/l	.0007 μg/l	.0001 μg/l
Calcium	359.5 mg/l	376.8 mg/l	404.8 mg/l	448.9 mg/l	400.8 mg/l
Chloride	19.36 g/l	26.63 g/l	41.48 g/l	64.52 g/l	118.06 g/l
Chromium	N*	N	N	N	N
Copper (II)	0.8 μg/l	0.8 μg/l	0.8 μg/l	0.8 μg/l	0.8 μg/l
Iron (III)	N	N	N	N	N
Lead	0.2 μg/l	0.3 μg/l	0.2 μg/l	0.1 μg/l	.004 μg/l
Magnesium	505.5 mg/l	508.0 mg/l	503.1 mg/l	488.5 mg/l	432.6 mg/l
Manganese (II)	3.1 μg/l	112.1 μg/l	201.6 μg/l	212.6 μg/l	148.9 μg/l
Mercury	N	N	N	N	N
Nickel	1.2 μg/l	1.7 μg/l	2.6 μg/l	3.5 μg/l	4.6 μg/l
Potassium	371.8 mg/l	402.7 mg/l	465.3 mg/l	567.0 mg/l	797.6 mg/l
Silver	N	N	N	N	N
Sodium	10.51 g/l	15.24 g/l	25.06 g/l	40.23 g/l	75.41 g/l
Sulfate	1095.1 mg/l	920.2 mg/l	697.4 mg/l	480.3 mg/l	226.7 mg/l
Tin (II)	N	N	N	N	N
Zinc	1.4 μg/l	4.8 μg/l	4.8 μg/l	4.8 μg/l	3.2 μg/l

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*N specifies zero or essentially zero free concentration.

Levels of trace metals in the discharge would be related more to the leachwater source than the salt of the dome. As shown in Table G.3-6 the quality of the water source is well within recommended criteria. During flood or low-flow periods, heavy metal concentrations could increase in the intake water, possibly exceeding EPA recommended discharge levels. Resulting brine heavy metal levels may tend to exceed the ambient levels found at the diffuser site (Tables G.2-14 and G.2-15). A portion of the particulate heavy metals would settle out in the salt cavern, thereby decreasing the metal levels in the brine. Once discharged, the Texoma model predicts that due to formation of greater amounts of heavy metal-chloro complexes and other soluble species, free concentrations of heavy metals would generally be less at elevated salinities. At lower excess salinities, concentrations of free heavy metals would be higher; however, because of expected overall low levels little impact may be anticipated from trace metals discharged in the brine.

The predicted number of precipitate types would remain constant throughout the brine plume with the concentrations of most precipitates increasing with increases in salinity. The high levels of dissolved and precipitated solids would tend to have an affinity for the surface of existing particulates. Formation and possible settling of these particulates could have an influence on the sessile marine life in the disposal area (FEA, 1977b).

The elevated salinity and temperature of the brine water would result in its deoxygenation. Anoxic waters are known to occur in this area already. However, jet dilution at the diffuser site would cause a rapid increase in oxygen levels to near ambient levels. There is no BOD or COD associated with the brine. Predictions from other brine disposal studies have estimated reductions of oxygen levels from ambient by 0.6 mg/l within the 20 ppt excess salinity contour, 0.1 to 0.2 mg/l within the 4 ppt excess salinity contour and 0.06 mg/l within the 2 ppt excess salinity contour (FEA, 1977a; U.S. Dept. of Energy, 1978). Wind mixing in these shallow waters would aid in reoxygenation. Impacts from low DO values would occur only in the immediate vicinity of the diffusers. The pH of the water column should not be altered, since none of the constituents in the brine should affect pH levels.

At Weeks Island, brine discharge rates during leaching would be approximately 600 MBCD over 4 years; discharge rates during oil fill would be 190 MBCD over 1.5 years. At Chacahoula, these rates would be 1250 MBCD over 5 years for leaching and 350 MBCD over 2 years during oil fill. Although salinities in the leachwater would be about 15% lower, impacts during this phase, especially at Chacahoula, would be greater than during operation as a result of higher rates of brine discharge over longer periods.

During the operational phase, petroleum hydrocarbons dissolved in the brine would be discharged. The equilibrium concentration of crude oils in brine is 31 ppm. However, there would be insufficient time, turbulence, and circulation to allow the oil to reach the equilibrium concentration. Modeling studies (FEA, 1977a) indicate that the hydrocarbon concentration in brine discharged to the surface control facility would average 16 ppm for the later stages of the initial oil fill; a concentration gradient of 0 to 31.4 ppm would exist in the cavern, with the top 50 feet of brine becoming saturated with oil. During subsequent oil refills, a dense refractory layer would have time to form, reducing diffusion and dissolution of oil into the brine. The brine transferred to the surface control facility during subsequent refills would contain an average hydrocarbon content of 6 ppm. Depending on cavern geometry, the oil concentration would vary from 4 to 15 ppm. However, reduction of oil content during brine discharge due to vaporization of light hydrocarbons would result in an estimated oil concentration in the discharged brine of approximately 6 ppm. Historical data on the content of hydrocarbons discharged from similar brine cavern oil storage operations were collected. In Manosque, France, discharged oil-in-brine levels were 4.6 ppm (Range: 0.0-13.8 ppm) in operational caverns and 3.3 ppm (Range: 0-10 ppm) in the solution mining of new caverns. In Etzel, Germany, the hydrocarbon concentration of the brine discharge was less than 1 ppm (FEA, 1977a).

The predicted level is an order of magnitude greater than ambient hydrocarbon concentrations at the Weeks Island and Chacahoula brine diffuser sites. If hydrocarbons are diluted as rapidly as ionic components, however, elevated oil levels would occur only in the immediate vicinity of the diffuser sites. It is expected that local mixing and dispersal mechanisms would have a moderating effect.

Many of the chemical characteristics of the brine discharge have been predicted to be diluted to near-ambient levels within a small area surrounding the diffuser. Outside of this area, no one chemical component may be in high enough concentrations to be toxic but a number of compounds may act synergistically. Seasonal factors such as temperature and river input may also act synergistically with the brine plume. These impacts would mostly affect the biology and ecology of the site area (Section G.3.3).

G.3.3 IMPACTS TO THE BIOLOGICAL ENVIRONMENT

G.3.3.1 Impact of Changes in Salinity and Temperature on Aquatic Organisms

The salinity and temperature regimes of the marine environment exert a major influence on the distribution of marine organisms. Water temperature is generally more important to the distribution of individual organisms and faunal assemblages than is salinity. Water temperature controls the lives of most aquatic animals; since they are poikilotherms, their body temperatures are at or near the temperature of the water environment and their temperature varies with changes in the water column. In the Gulf of Mexico, the average maximum surface water temperature rarely exceeds 85°F and at a depth of about 1000 feet the temperature remains at about 41°F. These two physico-biological parameters and their potential for change are important to the development of a diffuser site. Their impact on biological assemblages at the diffuser sites are discussed in the following sections.

Aquatic organisms are best suited, physiologically, to an optimum salinity range. Fauna and flora having limited salinity tolerance ranges are termed stenohaline; those having a wide salinity tolerance, euryhaline. Even though these organisms exhibit optimum salinity ranges, they often live in waters outside these ranges. Within the estuarine and neritic ecosystems, aquatic organisms may encounter a wide range of salinity regimes. Estuaries and other coastal water bodies, where seawater is measurably diluted with freshwater, seasonally undergo wide salinity variations.

An organism's response to salinity stress will vary during particular stages of its life cycle. The adult stages may show a tolerance to wide salinity regimes, whereas narrow ranges are required for spawning and rearing of larvae. Hence, a species may change from stenohaline to euryhaline during its life cycle, and even within a certain life stage may tolerate different and often non-optimum growth salinity ranges. This is exemplified by the life cycle of many Gulf of Mexico marine species which alternate between environments of low and high salinity.

Much of the spawning activity occurs in the Gulf, while the nearshore and estuarine habitats having lower salinities are utilized as nursery areas.

Environmental temperature changes have pronounced effects on an organism's response to variations in salinity. Aquatic organisms exhibit maximum tolerance to salinity variations when the temperature of their environment is within their optimum physiological temperature range. Within the Gulf coast estuaries and coastal waters, seasonal variations in water temperatures may be extreme, particularly in the summer and winter months when temperatures may approach or exceed some organisms' temperature limits. During these months, slight variations in salinity may cause excessive stress on these organisms.

G.3.3.2 Impacts to Plankton

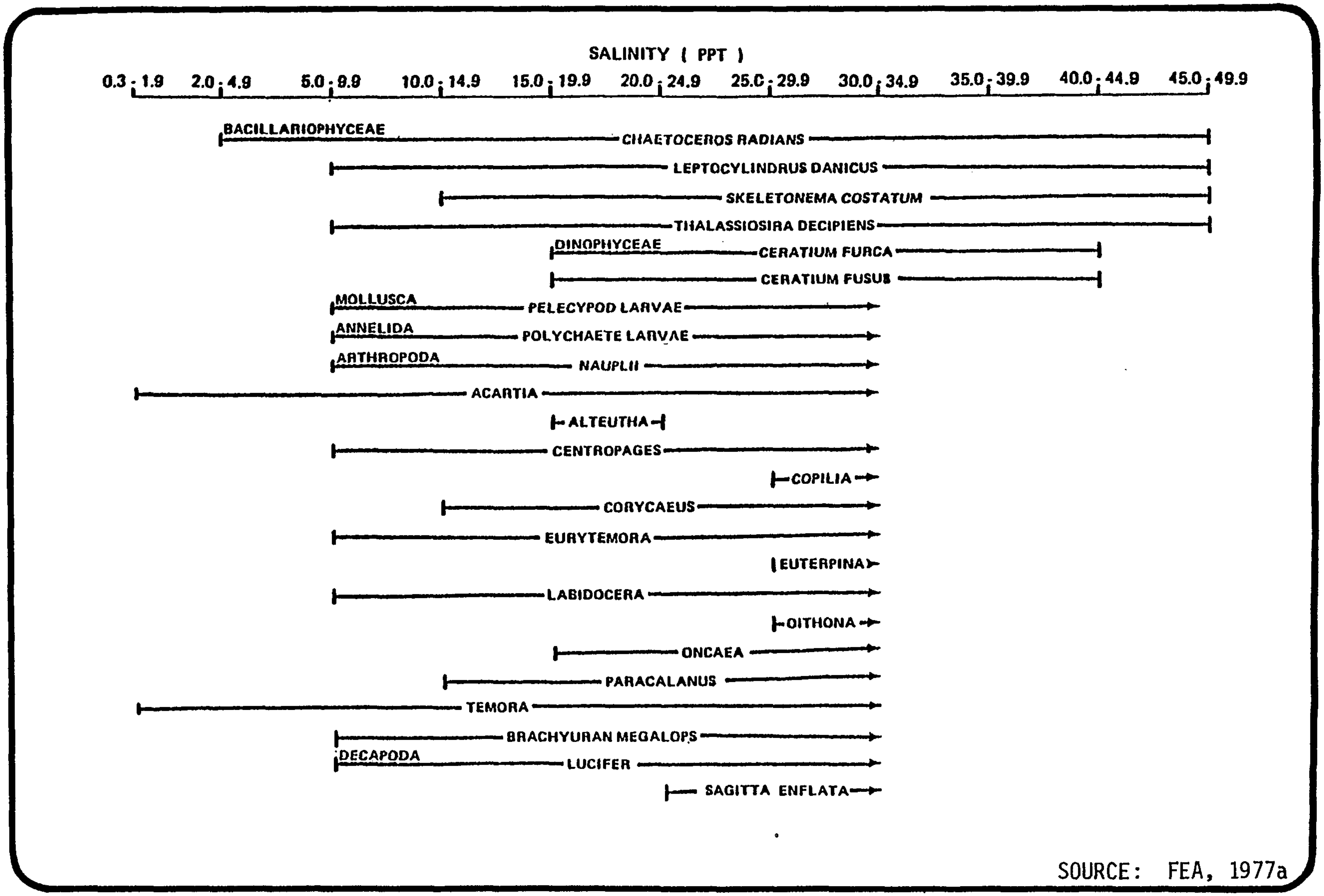
Plankton, due to their limited power of mobility, may become entrained in the brine discharge plume. The plankton in the upper half of the water column, in the vicinity of the bottom-flowing brine discharge, will probably not encounter the section of the plume inducing adverse impacts. Plankton in the lower half of the water column encountering the plume at the diffuser would be entrained. The duration of exposure or "residence time" of plankton in the plume during non-slack periods is not likely to exceed several hours. Only a very small portion of this time would be spent in the sector of the plume near the diffuser where extreme salinity levels (from 5 to 230 ppt above ambient) and temperatures (from 1 to 120^{o}F above ambient) would occur. Plankton entrained in the plume produced during a worst case, eight-day slack in the longshore nontidal current, due to very low ($\sim$ 1 cm/sec) current velocities would probably remain in the plume for a longer time. It is assumed that recovery from salinity and/or temperature shock would commence when the plankton are carried out of the immediate area of the plume. It is possible that during the cooler seasons temperatures within sectors of the plume could temporarily stimulate plankton life processes (e.g., photosynthesis, feeding, metabolism). It has been estimated that the extent of the brine plume having salinity and temperature values which could induce severe physiological stress on the entrained plankton would be relatively small. The following table shows approximate acreages for the area within excess isohalines during both a conservative 8-day slack period using estimated currents as well as during non-slack periods (using observed currents) at the Capline brine diffuser sites:

	Weeks Island		Chacahoula	
PPT	Non-slack Period	8-day Slack Period	Non-slack Period	8-day Slack Period
1	500	2900	1400	4600
2	250	400	450	1300
3	40	100	125	200
4	---	30	---	50

The data presented indicate that the acreages within each isohaline are up to about three times greater at Chacahoula compared to Weeks Island. The high salinity-temperature region of the plume resulting from an 8-day slack in the longshore nontidal currents would be considerably larger than under ambient current conditions but present for shorter periods. It has been estimated that the temperature at the 4 ppt isohaline, assuming a discharge temperature of 120^{o}F, would be less than 1^{o}F above ambient. The plankton biomass entrained in this sector of the plume produced during a stagnation period, due to low current velocities (∿ 1 cm/sec) and limited duration, would be comparatively small.

The salinity tolerances of several plankton species that might be found in the vicinity of the diffuser site are given in Figure G.3-22. Within given tolerance ranges, these species have physiologically optimum salinity ranges. Above and below these ranges, life processes may be adversely modified.

Bioassay analyses were undertaken by NOAA (U.S. Department of Commerce, 1978a) to assess the impact of various brine concentration at 72^{o}F and 86^{o}F on selected plankton and nekton species over a 9-day period. Of



SOURCE: FEA, 1977a

FIGURE G.3-22. Distribution of several organisms which may be encountered in the waters at the proposed Weeks Island and Chacahoula diffuser sites.

the three phytoplankton species studied, only Skeletonema costatum was collected during the current study. The conclusions drawn from these bioassay studies were:

(1) Each algal species exhibited characteristic responses to various concentrations of brine:

T. chuii - most tolerant
H. carterae - tolerant
S. costatum - most sensitive

(2) No growth occurred in 40 percent (143 ppt) brine solution in any species, but a concentration of 20 percent (94 ppt) and 10 percent (64 ppt) was inhibiting in varying degrees as follows:

% Brine	Salinity (ppt)	H. carterae	S. costatum	T. chuii
0.0	30.0	++	++	++
0.1	31.0	++	+++	++
0.2	31.5	++	++	++
0.5	32.0	++	++	++
1.0	34.0	++	++	++
2.0	39.0	++	+	+
5.0	46.0	++	+	+
10.0	64.0	--	--	+
20.0	94.0	--	--	--
40.0	143.0	--	--	--

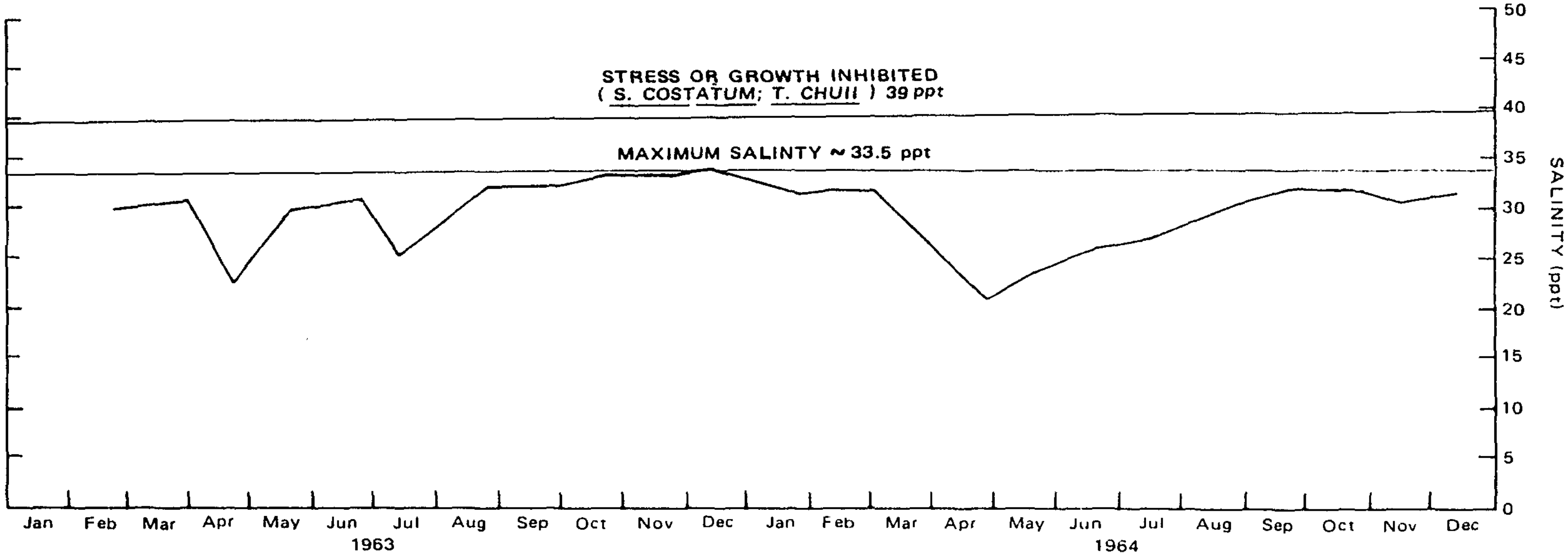
(+++ = better than control; ++ = similar to control; + = less than control; -- = no growth).

(3) A concentration of 5 percent brine is the highest amount of brine at which a stand of phytoplankton may reasonably be expected to be sustained.

(4) Increase in temperature (from 72° to 86°F) had no significant effect on the growth of any of the algae tested in concentrations up to a 5 percent brine concentration.

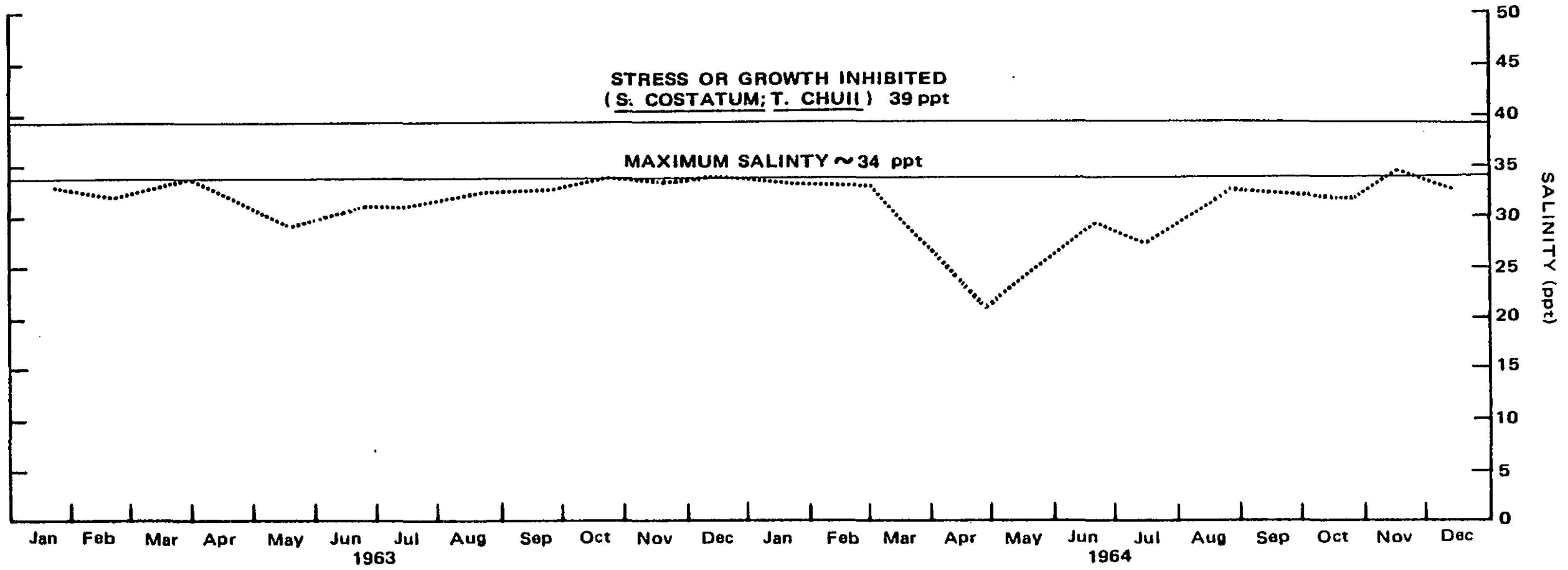
Impact assessment of the brine disposal on the marine phytoplankton in the study area should consider two points: 1) because of the relatively small size of the (bottom-flowing) plumes under consideration, a proportionately small percentage of the total phytoplankton biomass in the coastal shelf waters would be entrained and therefore impacted by the plumes under consideration; and 2) the residence time of phytoplankton entrained in the plume produced during periods of normal current and tidal flow would be brief and would amount to no more than a few hours duration.

Figures G.3-23 and G.3-24 present a 2-year salinity record (1963-1964) of Louisiana coastal waters (Gagliano, 1973) in the vicinity of the Capline brine diffuser sites. The maximum recorded salinity values recorded during this period were approximately 33.5 ppt at Weeks Island in December of 1963 and 34 ppt at Chacahoula in April and December of 1963 and November of 1964. In general, maximum values were noted in the winter and early spring months. Based on salinity tolerances obtained from bioassays conducted on selected phytoplankton species (U.S. Department of Commerce, 1978a) the salinity level at which growth was retarded for <u>Skeletonema costatum</u> and <u>Tetraselmis chuii</u> was approximately 39 ppt. Based on this, the area within the brine discharge that could potentially kill or retard the growth of these phytoplankton would be within the 5.5 ppt excess isohaline (<<40 acres) at Weeks Island and within the 5.0 ppt excess isohaline (<<125 acres) at Chacahoula, during months when salinities approached maximum values. When ambient salinities are lower, this high stress zone would be substantially smaller. If an 8-day slack in the nontidal longshore currents should occur, these areas would become considerably larger but the probability of a slack period this long is low (Section G.2.1). Assuming the plankton entrained in the plume at the diffuser would be killed due to the transitory effects of high salinity (∿ 264 ppt) and high water temperatures (120-130°F) and utilizing the average phytoplankton cell densities in the bottom samples taken September through December 1977, about 4300 x 10^4 cells at Chacahoula and 2370 x 10^4 cells at Weeks Island would be destroyed for each cubic meter of water entrained in the plume at the diffuser. Considering the



SOURCE: (1) Gagliano, 1973. (2) Cox, 1978.

FIGURE G.3-23. Salinity record in the vicinity of the proposed Weeks Island brine diffuser site, 1963 and 1964,(1) showing the brine co[illegible]tration at which phytoplankton are [illegible]sse[illegible] gr[illegible] is [illegible]ib[illegible].(2)



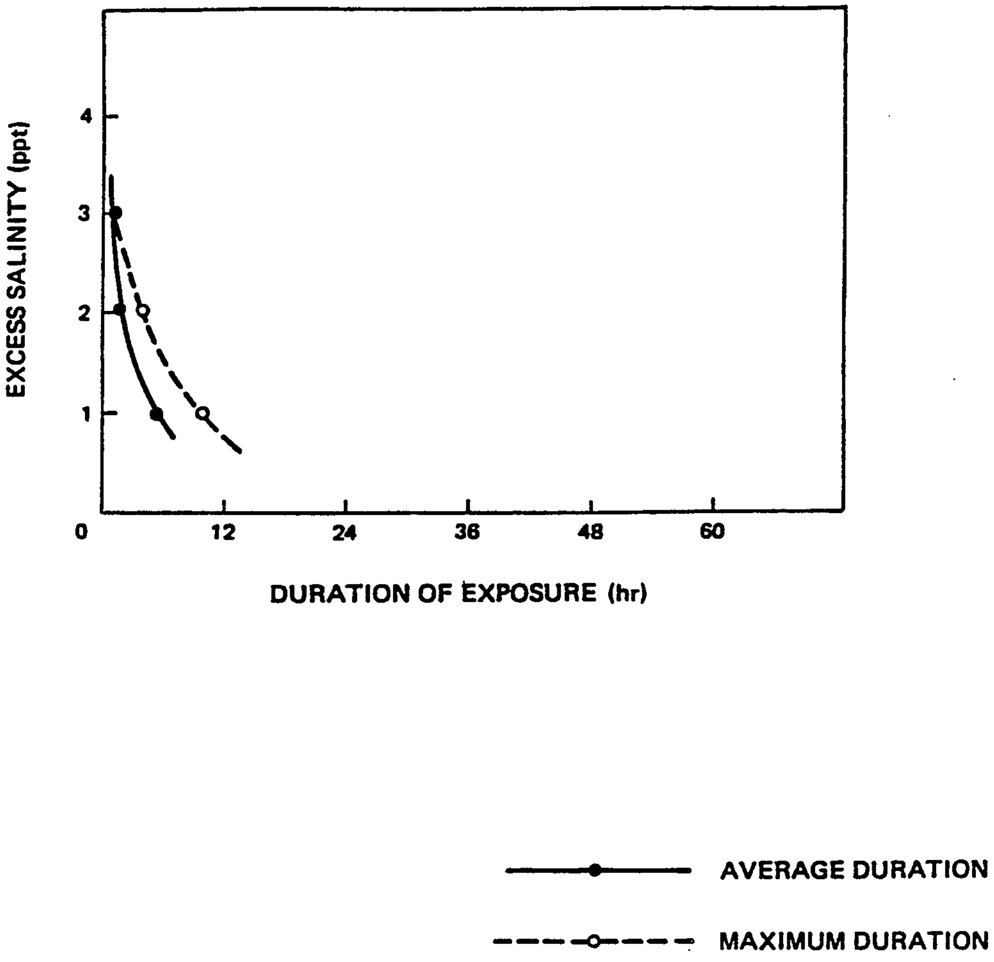
SOURCE: (1) Gagliano, 1973. (2) Cox, 1978.

FIGURE G.3-24. Salinity record in the vicinity of the proposed Chacahoula brine diffuser site 1963 and 1964,[1] showing the brine concentration at which phytoplankton are stressed or growth is inhibited.[2]

same assumptions, about 350 and 475 zooplankton would be destroyed at Weeks Island and Chacahoula, respectively, for each cubic meter of water entrained in the plume at the diffuser. These values would vary throughout the year and would probably be considerably greater during the winter or early spring months when plankton biomass generally attains maximum values (Green, 1978). In the far-field sector of the plume where salinity and temperature values are near ambient, plankton productivity may be temporarily reduced.

Figure G.3-25 illustrates a Langrangian model output based on currents considered characteristic of the proposed Seaway brine diffuser site off Freeport, Texas (U.S. Dept. of Commerce, 1978a). This data is used as an approximation of the duration of exposure of the plankton entrained in the intermediate field of the plume (i.e., within a region of 300 to 400 feet of the diffuser). In the Langrangian presentation, fish larvae, eggs, phytoplankton, and other zooplankton are assumed to be carried with the ambient waters and entrained in the diffusing brine effluent plume. These organisms would be exposed to excess salinity as a function of the location of their entrainment in the plume and the prevailing diffusion rate of excess brine at the location of the drifting organisms. The excess salinity (>30 ppt) calculations are shown with average and maximum exposure durations. As illustrated, the maximum exposure to 1 ppt excess is about 10 hours. The bioassay results and plume modelling suggest that only elevated salinity levels within the nearfield region of the plume are expected to significantly retard growth of phytoplankton (U.S. Department of Commerce, 1978a).

Chemical impacts would be expected as a result of brine discharge into into the Gulf of Mexico (Section G.3.2.2). Ion ratios in the discharge plume would be expected to be altered, especially the calcium/magnesium ratio. These changes could be expected to induce physiological stress on the plankton community entrained in the plume. The concentrations of several heavy metals (Pb, Hg, Zn, and Mn) in the plume may exceed EPA recommended discharge levels. Plankton entrained in the plume may adsorb or absorb these metals, thus providing an accessible source of heavy metals to other components of the food web. As a result of brine discharge, if turbidity were to increase, light penetration would be locally reduced,



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-25. Excess salinity versus duration of exposure for drifting planktonic species entrained in the brine plume.

thus temporarily reducing primary productivity. In addition, DO concentrations may decrease in the vicinity of the diffuser, leading to a further temporary reduction in primary productivity. It has been estimate (Section G.3.2.2) that approximately 6 ppm of oil would be contained in the brine discharge. Plankton are threatened primarily by a floating slick or dissolved hydrocarbons within the plume. Bioassays undertaken to assess the sublethal effects of petroleum products on marine organisms (Hyland and Schneider, 1976) have indicated that phytoplankton, when exposed to various hydrocarbons in concentrations of 10^{-4} ppm to 38 ppm, illustrate a depression in growth rate or a reduction in photosynthesis. Mixed phytoplankton populations of Monochrysis lutheri, Phaeodactylum tricornutum, Skeletonema costatum and Chlorella sp., among others, when exposed to a range of crude and fuel oils in concentrations of 1 ppm to 200 ppm, also illustrated reductions in growth rate and photosynthesis. Venezuelan crude oil in concentrations of 10 μg/l to 30 μg/l induced a stimulation in photosynthesis. The copepod Calanus helgolandicus, when exposed to suspended oil droplets in lab vessels in concentrations of 10 ppm, showed a decrease in feeding and metabolic activities. Plankton entrained in the brine discharge containing oil concentrations of 6 ppm could experience short-term impacts to their metabolic activity (e.g., metabolism, photosynthesis). Major changes in the plankton community due to oil contamination have not been reported (Hyland and Schneider, 1976).

Outside the high salinity-temperature sector of the plume in the proximity of the brine diffuser, no single chemical constituent introduced by the plume would be expected to be present in concentrations toxic to marine life. However, these chemicals may act synergistically to induce adverse impacts on the biological community.

During the brine discharge period, temporary stagnation periods in the longshore nontidal currents are anticipated. Even though these periods are not expected to occur for more than from several hours to 2 days, an 8-day slack in the longshore currents is considered. If such a slack period were to occur, the area within the 4 ppt excess isohaline would increase to about 30 acres and 50 acres, respectively, for the Weeks Island and Chacahoula plumes. The bottom area covered by the 1°F excess isohaline would increase as well. As a consequence, the sector of the plume near the diffuser having a high salinity-temperature regime and causing severe physiological stress on the plankton would increase during this period.

G.3.3.3 Impacts to Benthos

Brine disposal in the Gulf of Mexico would have a significant effect on certain components of the benthic invertebrate community, since the dense brine will sink towards the bottom. The area of greatest stress to the benthic organisms would be within the 4 ppt isohaline. Many of the sessile (nonmotile) organisms living within the range of this contour would be killed (U.S. Department of Commerce, 1977a), particularly in areas near the diffuser where salinities may approach values of up to 264 ppt and excess temperatures would vary from less than 1°F at the 4 ppt isohaline to as high as 120°F at the diffuser port. Assuming total mortality in this area, about 2.1×10^6 and 3.6×10^6 benthic invertebrates per acre would be killed, respectively, at Weeks Island and Chacahoula (based on mean density values from the five stations at the center of each site; Tables G.5-22 through G.5-28). This value would vary with seasons but is likely to be greater in the summer during periods of highest productivity. Based on conservative estimates, about 30 and 50 acres, respectively, would be covered by the 4 ppt isohaline during an 8-day slack period in longshore non-tidal currents at Weeks Island and Chacahoula.

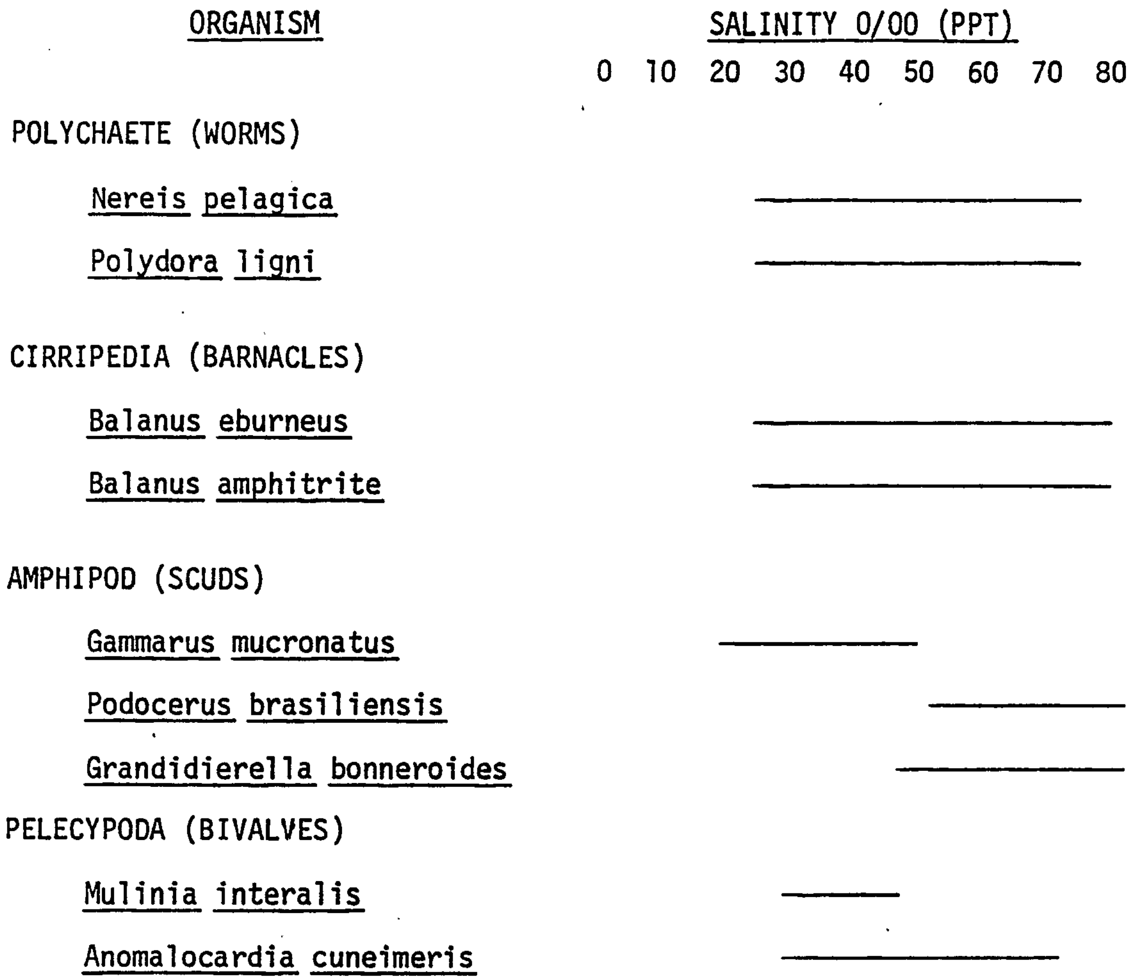
Several heavy metal precipitates (copper hydroxide, iron hydroxide, strontium sulphate and aluminum hydroxide) are expected to be present within the brine plume in concentrations exceeding ambient concentrations. Bioaccumulation of these metal precipitates may occur in the food web as a result of ingestion by detritivores and filter-feeding benthic organisms. Ingestion of these metals by benthic organisms could include disturbances of the metabolic processes of selected populations.

Outside of the nearfield area, little or no significant adverse effects to benthic organisms would occur. Although an excess salinity gradient of about 1.0 ppt may extend for several miles from the diffuser site under various combinations of environmental conditions, the salinity increase (less than 4 ppt) in the far field is unlikely to have a significant adverse impact on the benthic community near the site.

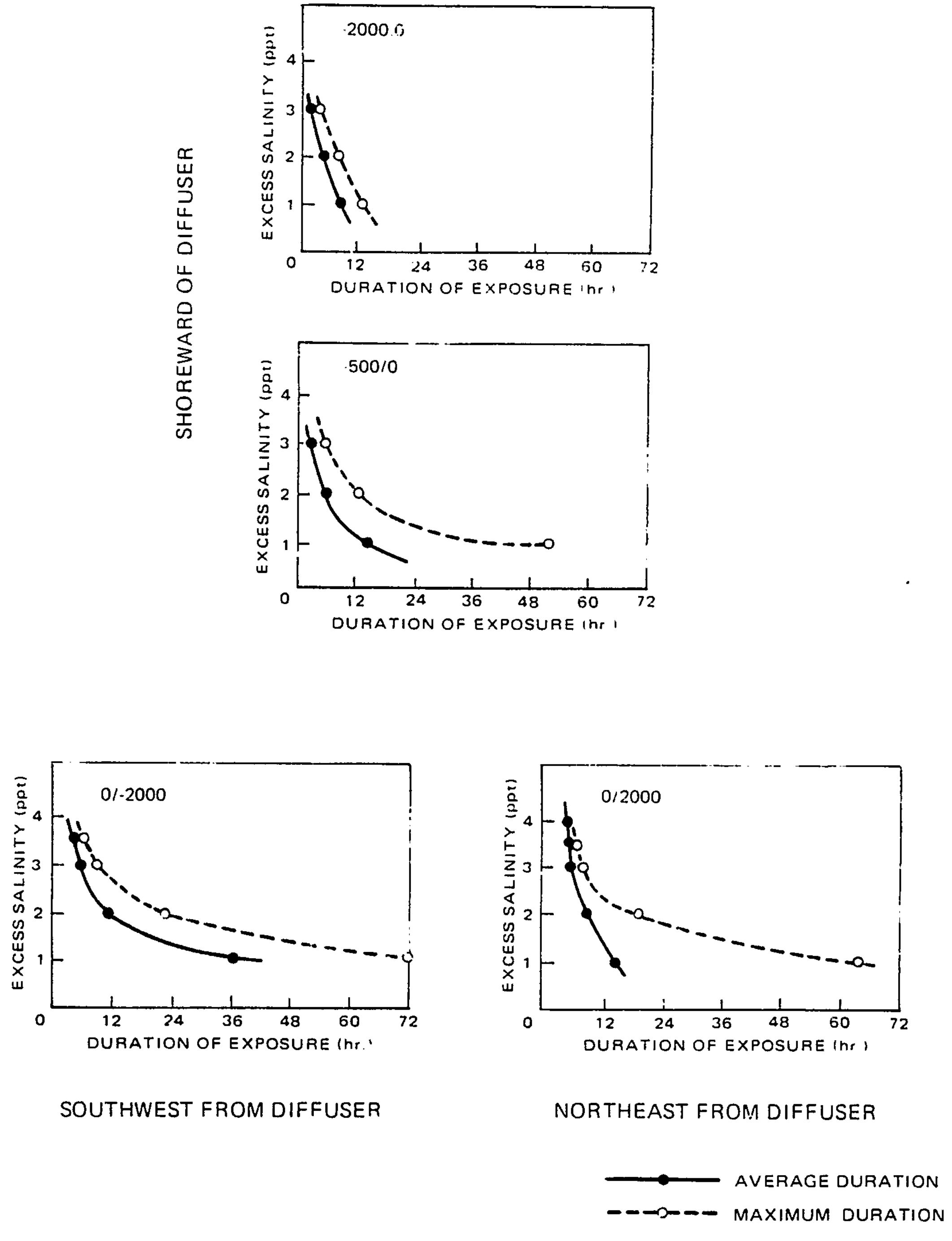
Data are limited on the salinity tolerance of marine benthic invertebrates or infauna. Salinity ranges of 24 to 82 ppt (Table G.3-7) have been reported by Hedgpeth (1967) for several species of benthic invertebrates, and these data indicated that invertebrates, and in particular polychaetes, are capable of quick recovery even after large communities are killed by adverse salinity changes (Gunter, Ballard, and Venkatarmiah, 1974). Bioassay studies (Neff, 1978) of the polychaete <u>Neanthes</u> <u>arenaceodentata</u> revealed this benthic species was able to withstand salinities of 40 to 53.3 ppt. To evaluate the potential impacts of increased salinities on the polychaetes, an Eulerian approach (hypersaline exposure at fixed locations affected by the plume) was employed using the MIT Transient Plume Model (U.S. Department of Commerce, 1978a). An idealized brine plume (Figure G.3-26) was determined from currents typical of the area (0-1.5 knots) and exposure conditions versus duration of exposure were plotted for various locations within this plume (Figure G.3-27). Since salinities would not be high enough to cause significant mortalities to polychaetes in the far-field, mortality curves were not plotted. These studies also showed that <u>Neanthes</u> was better able to tolerate high brine concentrations at a temperature of 68°F than at either 59°F or 86°F. Although adult <u>Neanthes</u> seem well adapted to withstand stress from high salinity levels, the developmental stages of this species are not. Similar trends in salinity tolerance levels and temperature interaction may be expected for many other polychaete species and related benthic invertebrate infauna taxa. <u>Neanthes</u> was able to acclimate to relatively high concentrations of petroleum hydrocarbons and although there was a reduction in fecundity, it was partially compensated by increases in oocyte maturation rate and decrease in brood mortality.

Although many of the benthic invertebrates are of little or no direct economic value, the infauna occupy important trophic positions in the food web. The benthic invertebrate data analyzed for the diffuser sites (Section G.2.4.3) do not reveal the presence of either threatened

TABLE G.3-7 Salinity ranges for benthic invertebrates in the northwestern Gulf of Mexico having a recorded occurrence in salinities above 45 ppt.

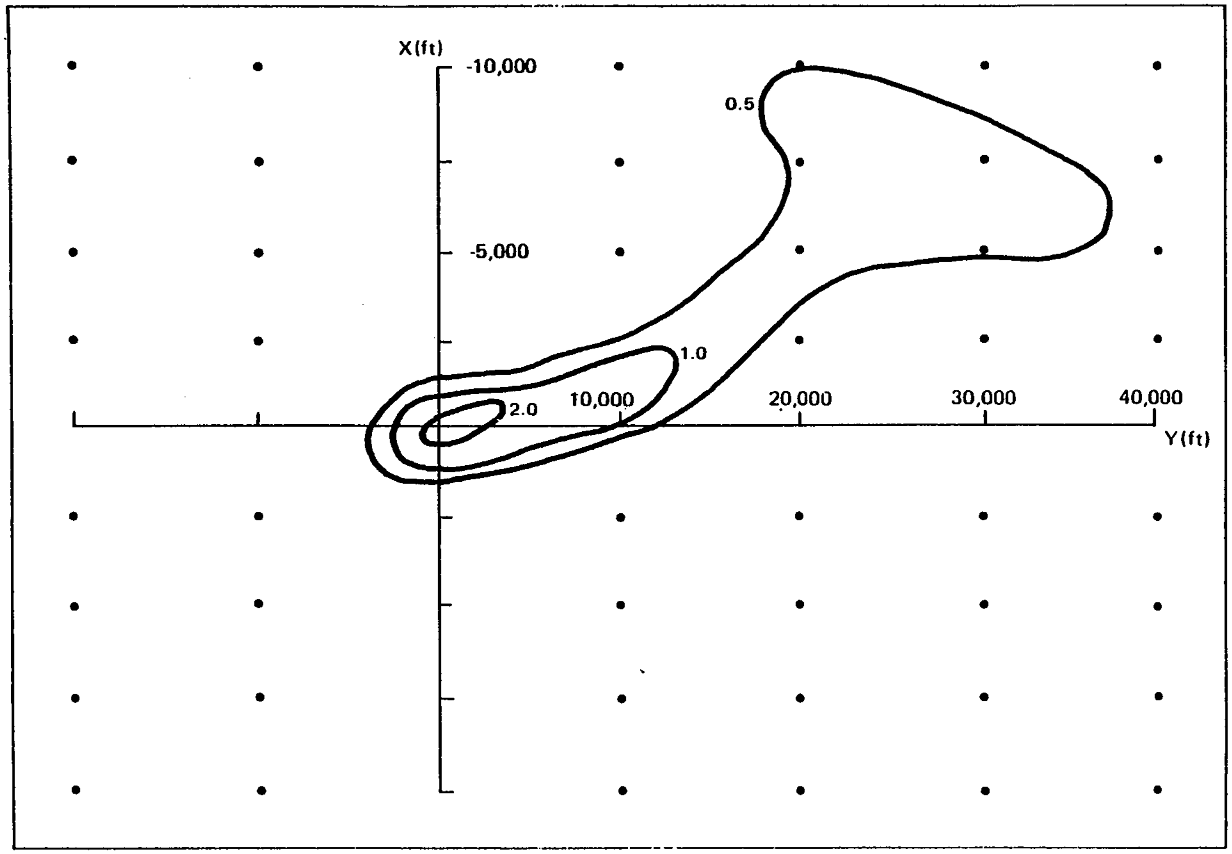


Source: Hedgpeth, 1967



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-26. Excess salinity versus duration of exposure at indicated gri points.



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-27. Idealized brine plume and analysis region shoreward (X direction) and alongshore (Y direction) from the diffuser. Excess salinity contours in ppt.

or endangered species or unique communities within the excess 4 ppt isohaline. On a regional basis, the environmental loss of the benthic community within this brine plume is not expected to be significant.

G.3.3.4 Impacts to Nekton

The impacts of the brine diffusers on nekton would depend upon various factors including the season, the life stage of the organism and its life history. Generally, the impacts of brine disposal on the adult stages of the nekton would be expected to be minimal since these organisms are active swimmers and could avoid the plume impact area. However, the adults of certain species, such as shrimp and crab, depend on the bottom for burrowing, food, cover, and breeding and would be be impacted to a greater extent than fully nektonic species. In the Louisiana coastal region, these economically important nektonic organisms include the brown and white shrimp, blue crab, menhaden, and the Atlantic croaker. Eggs and larvae of nektonic organisms tend to be more sensitive to environmental perturbations than the adults and have no escape mechanism, and thus would be affected to a greater extent over a larger area. The impacts on these early life stages would be greatest during the spring and summer when reproductive activity is at a maximum.

The greatest impact of brine discharge on nekton would be increased salinity and temperature, although increased turbulence, particulates, and hydrocarbon levels, decreased DO, and altered calcium/magnesium ratio may also cause environmental stress. The area of greatest stress to the nekton would be within the 4 ppt isohaline where salinity and temperature values would occur. Most of the nekton would be excluded from this area since salinities may approach values of 264 ppt and temperatures may be as high as 120°F. Based on conservative estimates about 30 and 45 acres, respectively, would be covered by the 4 ppt isohaline during an 8-day slack period in longshore non-tidal currents at Weeks Island and Chacahoula. Normal non-slack conditions would have much smaller areas enclosed by the same isohaline. Outside of the nearfield area, temperature will approach ambient; however, an excess salinity gradient of about 1.0 ppt may extend several miles from the diffuser. No significant impact to the nekton would be anticipated in this area.

Of the chemicals which may be released with the brine at Weeks Island and Chacahoula, trace metals are expected to be within the EPA acceptable range for marine life. However, hydrocarbons, which would be released only during the oil refill phase of the project, would occur in levels much higher than those of ambient, averaging 6 ppm. Bioassay data on a wide variety of marine organisms reveal a lethal level range of 1 to 100 ppm soluble petroleum fractions for adult stages and 0.1 to 1.0 ppm for larval and juvenile life stages. Adverse sublethal physiological impacts have been found to occur from 1 to 10 ppb (Hyland and Schneider, 1976).

Jet dilution would be expected to decrease hydrocarbon levels rapidly; however, physiological dysfunction may occur to nekton which have not avoided or rapidly traversed the region. These include disruption of normal feeding and reproductive patterns possibly due to disruption of chemotactic sensing. Low-level hydrocarbon pollution has been found to result in decreased growth, delayed hatching, and abnormal behavior and development in fish and macroinvertebrate eggs and larvae (Hyland and Schneider, 1976). Incorporation of petroleum hydrocarbons in marine organisms may result in tainting of edible species, especially important in this high-yield commercial fisheries area.

In general, nektonic populations affected by hydrocarbons would probably recover quickly since larval and adult immigrants would replace individuals that were eliminated during the 1.5 to 2 years of oil refill. Nektonic organisms dependent on the benthos would be affected to a greater extent, because hydrocarbons accumulate in sediments to higher levels and for longer periods.

An increase in the amounts of dissolved and precipitated solids could have an indirect effect on the nekton. Increased turbidity would result in decreased productivity, thus decreasing available food sources. Possible settling of the particulates could have an influence on benthic life, another food source for the nekton. Lower DO levels would also affect sessile organisms decreasing food sources for nekton. Furthermore, nektonic organisms would tend to avoid these low oxygen areas. However, oxygen levels are expected to assume near normal levels relatively rapidly. The calcium/magnesium ratio, which is normally 1:3 in seawater, is at least two orders of magnitude greater in brine. When discharged, the alteration of ion balance in the water column may affect muscular activity and nerve transmission in nektonic organisms.

The exit velocity of water from the diffuser ports has been set at 25 ft/sec to facilitate mixing. The resulting turbulence would probably cause mortalities among fish and macroinvertebrate eggs and larvae. Furthermore, salinities would be high where the discharge velocity is great, compounding the impact of turbulence.

G.3.3.4.1 Shrimp

In brine bioassays performed on three life stages of white shrimp: eggs, nauplii, and early protozoeal stages, the concentration of brine at 82°F that was lethal to the embryonic shrimp was between 2.45 and 3.2% brine by volume (36.5 to 38.0 ppt) (Wilson et al., 1978).

These studies also indicated that at 82°F the 24-hour LD_{50} (lethal dose to 50% of the test organisms) of postlarvae was between 6.3 and 6.5% brine (49 ppt). At 87.8, 89.6, and 91.4°F, the 24-hour LD_{50}'s were 5.9, 4.75, and 4.4% brine, respectively (approximately 48, 43, and 42 ppt). It appeared that salt dome brine is less toxic to nauplii than t embryos or early postlarvae. Although the nauplii survive, they may not metamorphose to the first protozoeal stage after exposure to concentratio under 3.0 percent brine (39 ppt). Furthermore, if exposed from the time of egg cleavage to protozoeal stage, development may be inhibited at brine concentrations under 3.0 percent (Wilson et. al., 1978).

In other studies (FEA, 1977a), the salinity preference of postlarval of brown and white shrimp (Table G.3-8), have been examined in gradient tanks with salinity ranges from 0 to 70 ppt and 0 to 50 ppt, respectively The results indicate that the shrimp preferred lower salinity levels than those that would be normally expected in the open Gulf. It was hypothesized that the shrimp key in on salinity gradients to navigate during their migration to the less saline inshore nursery grounds. It was concluded from statistical analysis of the data that a seasonal variation in salinity preference by the postlarvae was being expressed, especially by the brown shrimp, which preferred highest salinities in the spring. White shrimp postlarva showed a seasonal preference only when exposed to low salinities.

TABLE G.3-8 Salinity preference of postlarvae of brown and white shrimp[a].

SEASON	P5[b]	P25	P50	P75	P95	P75-P25	P95-P5
SUMMER							
Brown	41.4	28.9	20.6	13.9	7.2	15.0	34.2
White	43.5	34.5	28.0	21.1	11.1	13.4	32.3
FALL							
Brown	47.3	36.0	27.4	19.2	10.0	16.8	37.3
White	41.0	28.5	21.1	13.6	5.8	14.9	35.2
SPRING							
Brown	49.1	38.1	29.9	21.9	11.4	16.2	37.7

[a] Salinity values (ppt).

[b] P5 represents the salinity value at or above which the top 5% of the most salinity tolerant members are found. P50 would be the median value where 50% of the members are above and 50% are below the indicated salinity values.

Source: Keiser and Aldrich (1976).

At temperatures of 73° to 78°F, postlarvae of brown shrimp grew equally well at salinities of 2 to 40 ppt. Postlarvae of white shrimp produced twice as much tissue at intermediate salinities (10 to 15 ppt) compared to conditions at 20 and 35 ppt and temperatures above 77°F. Postlarvae of brown shrimp produced the most tissue at salinities of 30 ppt and 90°F (FEA, 1977a). These data indicate that postlarval penaeid shrimp are tolerant of both salinity and temperature variations.

Several studies have indicated that adult white shrimp generally are less tolerant of high salinity than adult brown shrimp, but other studies have shown no differences in salinity preference of the two postlarval penaeid shrimp species. Adult white shrimp have been collected under conditions where the salinities ranged from 0.2 ppt to more than 47 ppt; and brown shrimp have been taken in areas where salinities range from 0.1 ppt to 69 ppt. This wide range of salinity values indicates that these two penaeid shrimp are euryhaline species (FEA, 1977a). The preferred temperatures (based on catch data) for adult white and brown shrimp are 68° to 86°F and 68° to 95°F, respectively (Copeland and Bechtel, 1974).

Experiments on the susceptibility of the white shrimp to oilfield brine showed that for one case all shrimp died within 2 hours after exposure to an oilfield brine concentration of 42 ppt; white shrimp survived indefinitely when similarly exposed to evaporated bay water with salinities of 45 ppt. The conclusion was that the ionic composition of the brine may exert a greater influence on organisms than the high concentrations (FEA, 1977a).

Little information is available about the way ionic composition affects shrimp. It is suspected that locomotory activity of penaeid shrimp may be inversely correlated to their respective blood serum magnesium levels (FEA, 1977a).

Within the impacted area of the diffuser site, the number of shrimp affected, based on National Marine Fisheries Service shrimp statistics (U.S. Dept. of Commerce, 1975; 1976a), would be approximately 4.55 shrimp per acre. These statistics are based on the annual average catch collected from trawls taken over a large area and as such, the calculated number will vary widely depending on the season and duration of impact.

and distribution of shrimp schools. Outside of this area the brine effluent would probably not have a significant adverse effect on adult shrimp, but hatching and larvae development could be affected (Figures G.3-28 and G.3-29).

G.3.3.4.2 Blue Crabs and Oysters

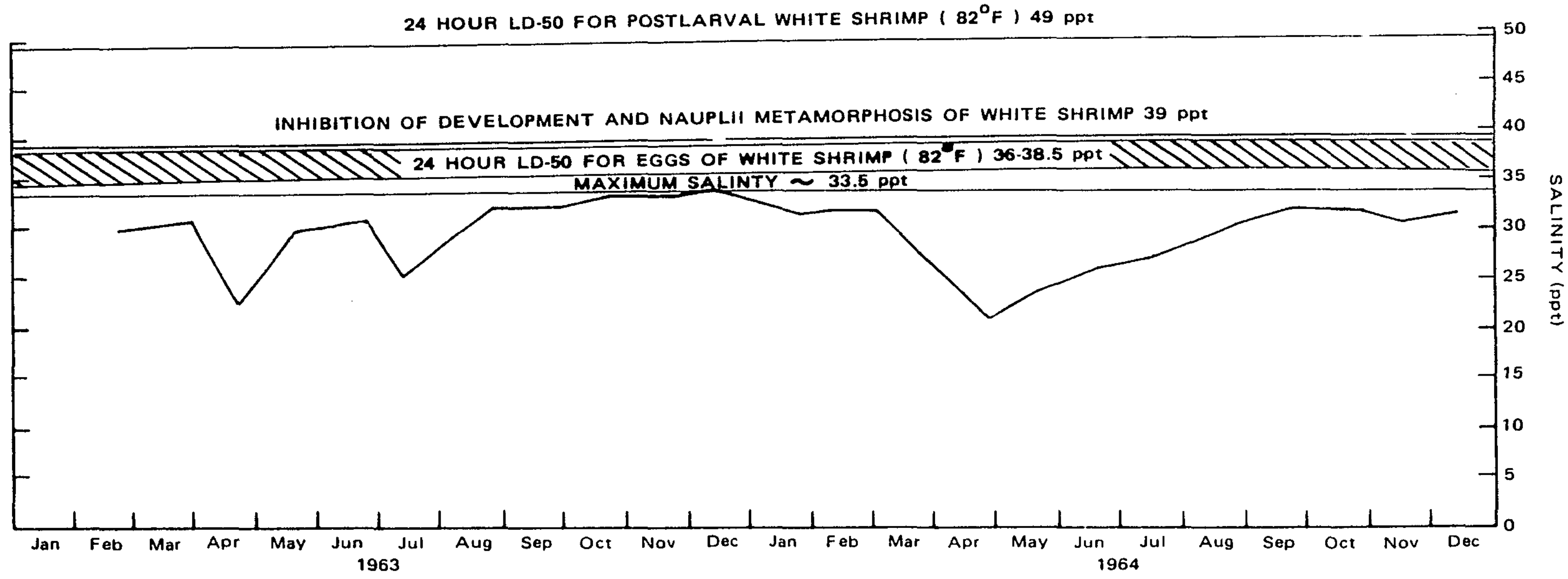
Adult blue crabs have a wide range of salinity tolerance (0.7 to 88 ppt) and spawn in waters with relatively high salinity (Jaworski, 1972). Five percent brine (44 ppt) at 82°F was lethal to blue crab yolk (Johnson and Williams, 1978). Adult blue crabs spend much of their existence on the bottom. They have been found in abundance at the shallower Weeks Island site but are rare if at all present at the Chacahoula site.

Oysters, another commercially important species in coastal Louisiana, develop and grow in low salinity waters, under 15 ppt, however, they are not found in the region of the proposed diffuser sites.

G.3.3.4.3 Fish

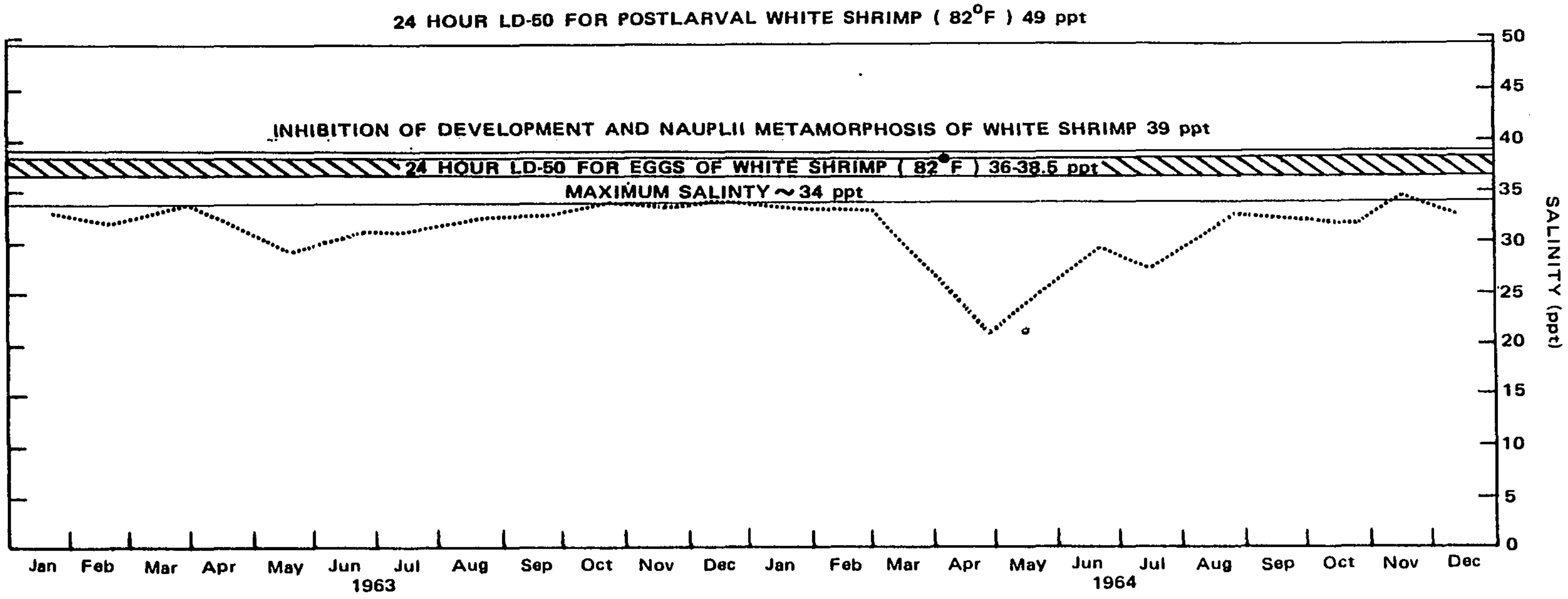
The environmental impact of brine disposal at the proposed site would be expected to be minimal to adult fish which generally avoid areas with adverse salinity concentrations. Although salinity tolerances for marine fish vary between fspecies, it is usually the younger developmental stages of the fish that would be expected to be less tolerant to salinity changes. However, some marine teleost eggs can tolerate wide ranges of salinity. For example, Atlantic herring eggs have hatched under laboratory conditions in salinities up to 90 ppt, and the eggs of the sheepshead minnow have hatched in salinities of 110 ppt *in situ*. Yolk sac larvae of the Atlantic herring survive and remain active for at least 24 hours at salinities of 60 to 65 ppt. The larvae of Gulf menhaden have metamorphosed in the laboratory at salinities of 25 to 40 ppt (FEA, 1977a).

Bioassays conducted on spotted seatrout eggs and larvae when exposed to salt dome brine for 48 hours at 80.6°F resulted in significantly increased mortalities at a concentration equivalent to approximately 40 ppt. These mortalities did not differ from those of comparable salinities using artificial seawater, indicating that the ionic composition of brine may not have an impact (Johnson and Williams, 1978). The planktonic life stages entrained into the plume would only be exposed to excess



SOURCE: (1) Gagliano, 1973. (2) Wilson et al., 1978

FIGURE G.3-28. Salinity record in the vicinity of the proposed Weeks Island brine diffuser site, 1963 and 1964,(1) showing the brine concentrations at which white shrimp eggs, [illegible]vae [illegible] po[illegible]rve[illegible]e s[illegible]sed [illegible] ki[illegible].[2]



SOURCE: (1) Gagliano, 1973. (2) Wilson et al., 1978.

FIGURE G.3-29 Salinity record in the vicinity of the proposed Chacahoula brine diffuser site, 1963 and 1964,[1] showing the brine concentrations at which white shrimp eggs, larvae and postlarvae are stressed or killed.[2]

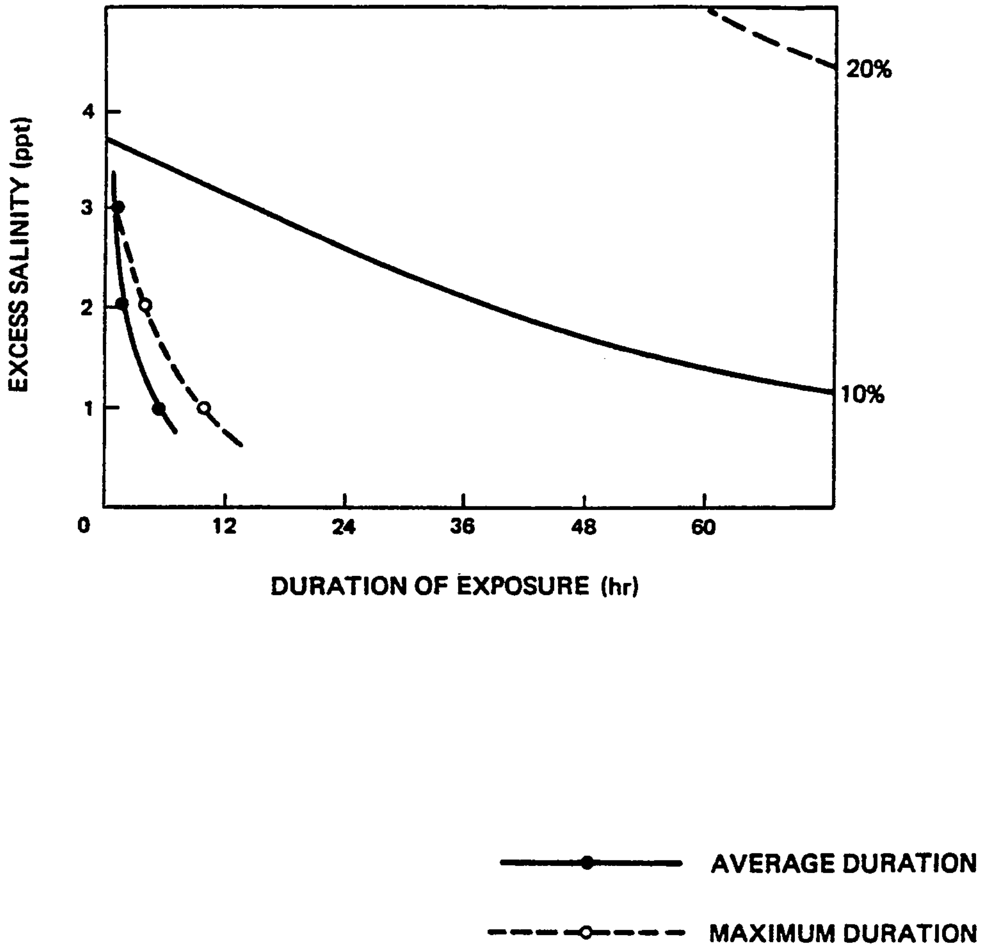
salinities for a relatively short time (in terms of hours). Using observed currents at the proposed Seaway Group brine diffuser site off Freeport, Texas, and assuming that these organisms would be entrained within a region 300 to 400 feet from the diffuser, the two curves in Figure G.3-30 represent estimates of average and maximum plume exposure (U.S. Department of Commerce, 1978a).

Brine bioassays of larval spotted seatrout were performed for exposure periods of 1 and 2 hours (Table G.3-9). The 48 hour-LD_{50} of a 1 hour exposure to the brine was about 48 ppt (6.2% by volume) and for a 2 hour exposure it was about 41 ppt (3.5% by volume). When entrained under the conditions depicted in Figure G.3-30), the brine discharge exposures are expected to be lethal to less than 10 percent of spotted seatrout larvae.

Supranormal salinities may cause changes in growth rates and energy expenditure, lead to gill tissue damage and asphyxiation, and affect metabolic rate, activity, and neuromuscular functions. Since the DO level decreases as salinity increases, the physiological effects may be indirect. This is revealed by growth rate experiments involving desert pupfish. As salinity increased, a progressive retardation of development was observed. These results were attributed to lower oxygen levels in the water (FEA, 1977a). Several investigators have reported that the size distribution of fish is directly related to salinity.

The expenditure of energy in marine organisms may result from both direct and indirect effects of salinity. It has been shown that within a certain optimum salinity range a minimum amount of energy needs to be expended in order to maintain osmotic gradients; thus, large amounts of energy can then be directed to growth. Above the optimum salinity range an increase in metabolic process occurs and is generally accompanied by an increase in uptake of oxygen. Above 35 ppt, the oxygen uptake rate in the starry flounder increased 15 percent. In order to sustain osmotic and ionic regulation at above-optimal salinity regimes, additional energy is expended (FEA, 1977a).

The majority of fish encountered in the proposed diffuser areas are euryhaline and have a high tolerance to wide salinity ranges (Table



SOURCE: U.S. Department of Commerce, 1978a.

FIGURE G.3-30. Excess salinity versus duration of exposure for drifting planktonic species entrained in the brine plume. Area above the 10% line denotes environmental conditions lethal to at least 10 percent of laboratory tested specimens. (Data for larval spotted seatrout).

TABLE G.3-9 Average mortality of 1 hour posthatch larval spotted seatrou[illegible]t short term exposure to salt dome brine (based on 4 replicate[illegible].

Percentage (Volume/Volume)[a]		Exposure Time (Hours)	Total Test Time (Hours)	Mortality (%)[b]	Exposure Time (Hours)	Total Test Time (Hours)	Mo[illegible] (%
10.0	[55]	1	24	3.00 (2.57)	1	48	[illegible] (16.
5.0	[44]	1	24	2.07 (2.11)	1	48	[illegible] ([illegible]
2.0	[36]	1	24	2.56 (0.76)	1	48	16. [illegible]
1.0	[34]	1	24	2.47 (2.48)	1	48	12 (3
0.5	[33]	1	24	2.85 (2.33)	1	48	[illegible] (1
0.0	[30]	1	24	0.68 (0.78)	1	48	[illegible]
10.0	[60]	2	24	80.55 (8.33)	2	48	98 [illegible]
5.0	[48]	2	24	10.13 (1.44)	2	48	[illegible] (7
2.0	[42]	2	24	3.78 (1.03)	2	48	[illegible] ([illegible]
1.0	[39]	2	24	4.18 (2.19)	2	48	17 ([illegible]
0.5	[38]	2	24	4.00 (2.14)	2	48	6 (2
0.0	[36]	2	24	2.35 (1.65)	2	48	[illegible] (1

LC_{50} = 1 hr - 24 hr = >10% V/V, 1 hr - 48 hr = 8.4 ± 2.2% V/V
2 hr - 24 hr = 7.5 ± 2.5% V/V, 2 hr - 48 hr = 3.5% V/V

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[a] [ ] = measured salinity in ppt.

[b] ( ) = 1 standard deviation

SOURCE: Johnson and Williams, 1978.

G.3-10). Generally the upper limit of this tolerance is about 75 to 80 ppt; the lower limit is that of freshwater, less than 5 ppt. However, the sheepshead minnow has been reported in waters with salinities ranging up to 142.4 ppt (FEA, 1977a).

Commercial fishery activities, particularly for white shrimp, would not be disturbed by the diffuser ports as non-snag features would be incorporated into the design.

Sport fishing in the region should be unaffected by the brine disposal except in the immediate area around the diffuser where most sport fish would be excluded.

G.3.3.5 Impacts to Threatened or Endangered Species

It is not expected that the endangered species which have been listed for the northern Gulf of Mexico (Section G.2.4.5) would be significantly affected by the brine discharge. Although data concerning the salinity and temperature tolerances of these species are sparse, these highly mobile organisms would probably avoid regions of the plume they found undesirable. If these organisms moved through the plume, they would probably experience only temporary salinity-temperature stress and would move to more favorable areas in the water column either above or to the side of the plume. Because of the short duration of this stress, recovery should commence soon after they encounter their preferred, ambient temperature-salinity regimes.

G.3.3.6 Impacts to Unique or Important Habitats

The shipwrecks located within several miles of the Capline brine diffuser sites (Section G.2.4.6) are considered to be unique and important habitats. Little information is available concerning the reef communities inhabiting these wrecks, however, because they are present in these coastal waters, they are probably eurythermal and euryhaline.

Based on the characteristics of the discharge plume (Section G.3.1) and the distance of the wrecks from the diffusers (∿7 miles), these reef communities should not be impacted by the farfield sector of the plume. If the far-field segment of the plume where salinity values would probably not exceed 0.5 ppt above ambient and temperatures near ambient

TABLE G.3-10 Salinity tolerances of some coastal Louisiana fishes.

	SALINITY (PPT)			REFERENCE[a]	COMMENTS
	RANGE	GREATEST ABUNDANCE	HIGHEST RECORDED SALINITY TOLERANCE		
Ladyfish			75	Gunter 1967	Die at 100 ppt
Gulf menhaden	0-30	5-24.9		LWL&FC 1971	
	<1->60			Reintjes and Pacheco 1966	Die at 80 ppt
Striped anchovy	>29.9	>15		LWL&FC 1971	
			75	Gunter 1967	Die at 100 ppt
Gizzard shad			60	Copeland and Moseley 1967	Brine dominated system
Sea catfish	0->30	>10		LWS&FC 1971	
	2-36.7	>30		Gunter 1945	
Sheepshead minnow			75	Gunter 1967	Die at 100 ppt
			60	Copeland and Moseley 1967	Brine dominated system
			142.4	Simpson and Gunter 1956	
Gulf killifish			55.1-58.6	Renfro 1969	
Longnose killifish			75	Gunter 1967	Die at 100 ppt
Tidewater silverside			75	Gunter 1967	Die at 100 ppt
			55.1-58.6	Renfro 1960	
Rock seabass	>5->30			LWL&FC 1971	
Pinfish			75	Gunter 1967	Die at 100 ppt
	15-26[b]			U.S. Corps of Engineers 1976	
Sand seatrout	0.2->30			LWL&FC 1971	
Spotted seatrout			75	Gunter 1967	Die at 100 ppt
		15-35	77	Tabb 1966	
	15-45[b]			U.S. Corps of Engineers 1976	
Banded drum	5->30	>15		LWL&FC 1971	
Spot	0.2->30	>10		LWL&FC 1971	
	0-33.9			Nelson 1969	
Southern kingfish	2->30	10		LWL&FC 1971	
Atlantic croaker	0->30			LWL&FC 1971	
			75	Simmons 1957	
			75	Gunter 1967	Die at 100 ppt
	15-35[b]			U.S. Corps of Engineers 1976	
Black drum	0.2-24.9			LWL&FC 1971	
			75	Gunter 1967	Die at 100 ppt
			80	Simmons and Breuer 1962	Eyes are glazed
	15-45[b]			U.S. Corps of Engineers 1976	
Red drum	5-29.9			LWL&FC 1971	
	0.8-37.6			Kilby 1955	
			50	Simmons and Breuer	
	15-40[b]			U.S. Corps of Engineers 1976	
Striped mullet	0->30	5-19.9		LWL&FC 1971	
			60	Copeland and Moseley 1967	Brine dominated system
			75	Gunter 1967	Die at 100 ppt
			55.1-58.6	Renfro 1969	
	25-85[b]			U.S. Corps of Engineers 1976	
Atlantic threadfin	1.6-29.9	20		LWL&FC 1971	
Atlantic cutlassfish	0.2->30	>15		LWL&FC 1971	
Blackfin searobin	10-24.9			LWL&FC 1971	
Fringed flounder	5-29.9	20		LWL&FC 1971	
Southern flounder	0->30			LWL&FC 1971	
	0-50			U.S. Corps of Engineers 1976	
	12-35[b]			Ibid.	
Blackcheck toungfish	0.3-29.9	>10		LWL&FC 1971	
		>30		Gunter 1945	

[a] LWL&FC - Louisiana Wildlife and Fisheries Commission.

[b] Ideal salinity range.

Source: FEA, 1977a.

should encompass the reefs, little, if any physiological stress would be anticipated. Polyhaline organisms in this mesohaline region may be stimulated by increased salinities.

G.4 ALTERNATIVE DIFFUSER SITES

Utilizing basic siting criteria, alternative brine diffuser sites were selected to determine if any of the anticipated impacts at Weeks Island and Chacahoula could be mitigated by relocating to areas further offshore. The alternative Weeks Island site is about 20 nautical miles south of the entrance to Atchafalaya Bay in about 20 feet of water; the alternative Chacahoula site is about 18 nautical miles off of Isles Dernieres in about 20 feet of water. Sediments at these sites consist of gray sandy shale or gray shales.

The criteria were divided into three general categories: engineering, environmental, and economic. The primary engineering requirement was that the diffuser site be in a minimum of 20 feet of water, to ensure maximum dilution of the brine jet in the water column. Economic criteria required that the length of pipeline be minimized, to reduce construction and operational costs. Usually considered an environmental requirement, yet certainly an economic one as well, was that the diffuser site not be located in a prime shrimp habitat or sportfishing area.

Baseline environmental sampling was undertaken monthly at the Weeks Island and Chacahoula sites from September to December 1977, to determine the impacts of brine discharge in these waters. In January 1978, a second series of field monitoring programs were initiated at the alternative sites to characterize the physical, chemical, and biological environment of the area.

G.5 SUPPLEMENTARY DATA

The following section presents original and reduced data obtained during the four sampling cruises in September through December, 1977. A discussion of the cruises and of the sampling and data preparation methodology has been presented in Section G.1.

TABLE G.5-1. Water temperature (^{o}C) data for the proposed Weeks Island brine diffuser site, September through December, 1977.

	September		October[a]		November[a]		December[a]	
	S	B	S	B	S	B	S	B
W1	27.5	27.5	21.0	21.5	18.0	18.0	13.0	15.0
W2	27.5	27.5	20.5	22.0	18.0	18.0	13.0	15.0
W3	27.0	27.0	20.0	22.0	17.5	17.0	12.5	14.5
W4	28.0	27.0	20.5	22.0	17.5	17.5	12.5	14.5
W5	26.5	27.2	21.0	22.0	17.5	17.5	13.0	14.5
W6	27.5	27.0	20.5	22.0	17.5	17.5	13.5	14.5
W7	28.0	27.0	20.5	22.0	17.0	17.0	12.0	14.5
W8	27.0	27.0	20.0	21.5	17.0	16.5	12.0	13.0
W9	27.0	27.0	20.0	21.0	16.5	16.5	12.0	13.0
W10	27.0	27.0	19.5	22.0	17.5	17.0	12.5	14.0
W11	27.0	27.0	20.0	22.0	17.5	17.5	13.0	14.0
W12	27.0	27.0	19.0	22.0	17.5	17.5	12.5	13.5
W13	27.5	27.0	21.0	22.0	17.5	17.5	14.0	14.5
W14	27.5	27.0	21.0	21.0	17.5	17.5	12.5	14.5
W15	27.5	27.5	21.0	21.5	17.5	17.5	13.0	14.5
WR1	27.5	27.5	21.0	21.5	18.0	18.0	12.5	15.5
WR2	27.0	27.0	18.0	20.5	17.0	17.0	13.0	13.5
WR3	27.0	27.0	19.5	20.0	16.5	16.5	12.0	13.0
WR4	27.5	27.5	21.5	21.0	17.5	17.5	13.0	14.0
MEAN	27.29	27.14	20.29	21.55	17.39	17.31	12.71	14.18
S.D.	0.38	0.22	0.85	0.60	0.43	0.48	0.53	0.71

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[a] Temperature reported for nearest half unit.

S = Surface

B = Bottom

S.D. = Standard Deviation

TABLE G.5-2. Water temperature (^{o}C) data for the proposed Chacahoula brine diffuser site, September through December, 1977[a].

	September		October[b]		December[b]	
	S	B	S	B	S	B
C1	28.0	28.0	23.0	23.0		
C2	28.0	27.5	22.0	21.5		
C3	28.0	27.5	21.5	20.5		
C4	28.0	27.5	22.0	21.5		
C5	29.0	27.5	22.0	20.5	17.5	17.0
C6	28.0	27.5	21.0	20.5		
C7	28.0	27.5	21.0	20.5		
C8	28.5	28.0	21.5	20.5		
C9	28.5	28.0	20.0	20.5		
C10	28.0	28.0	21.5	20.5		
C11	28.5	27.5	21.0	21.0		
C12	28.0	27.5	22.0	20.5	17.5	17.0
C13	-	-	22.0	21.0	17.5	17.0
CR1	28.0	28.0	23.0	24.0	17.5	18.0
CR2	28.5	28.0	21.0	21.5		
CR3	28.5	28.5	20.0	20.0		
CR4	28.0	28.0	22.0	21.5	17.5	18.0
MEAN	28.22	27.78	21.56	21.18	17.5	17.4
S.D.	0.31	0.31	0.84	1.02	0.0	0.55

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[a] Data not obtained for November.

[b] Temperature reported for nearest half unit.

S = Surface
B = Bottom
S.D. = Standard Deviation

TABLE G.5-3 Salinity (ppt) data for the proposed Weeks Island Brine diffuser site, September through December, 1977[a].

	October[b]		November[b]	
	S	B	S	B
W1	19.5	23.5	28.5	29.5
W2	18.0	23.5	28.0	28.5
W3	18.0	22.5	28.0	28.5
W4	17.5	23.5	28.0	28.0
W5	16.5	21.0	28.0	28.0
W6	19.0	23.5	28.0	28.0
W7	18.5	22.5	27.0	27.0
W8	15.5	21.5	26.0	27.0
W9	16.0	18.0	21.0	22.0
W10	10.5	24.5	25.5	27.5
W11	14.5	21.5	25.5	27.5
W12	12.5	21.5	24.5	27.5
W13	16.5	21.5	28.0	28.0
W14	18.0	23.0	28.0	28.0
W15	19.0	21.5	28.0	28.0
WR1	20.5	23.0	28.0	29.5
WR2	9.5	23.5	24.5	25.0
WR3	11.5	18.0	16.0	19.5
WR4	17.0	18.5	28.0	28.0
Mean	16.21	21.89	26.24	27.10
S.D.	3.15	1.92	3.13	2.47

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[a] Data not obtained for September and December.

[b] Salinity reported for nearest half unit.

S = Surface

B = Bottom

S.D. = Standard Deviation

TABLE G.5-4 Salinity (ppt) data for the proposed Chacahoula Brine Diffuser Site, September through December, 1977[a].

	October[b]	
	S	B
C1	25.5	26.0
C2	26.0	28.0
C3	28.0	28.5
C4	28.0	28.0
C5	28.0	28.5
C6	29.0	29.0
C7	30.0	30.0
C8	28.0	28.0
C9	29.0	29.0
C10	26.5	28.5
C11	29.0	29.0
C12	28.0	28.5
C13	28.0	28.5
CR1	25.0	25.5
CR2	27.0	28.0
CR3	29.0	29.0
CR4	29.0	29.0
Mean	27.82	28.26
S.D.	1.39	1.09

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[a] Data not collected for September, November and December.

[b] Salinity reported for nearest half unit.

S = Surface

B = Bottom

S.D. = Standard Deviation

TABLE G.5-5 Dissolved oxygen (mg/l) data for the proposed Weeks Island brine diffuser site, September through December, 1977.

	September		October		November		December	
	S	B	S	B	S	B	S	B
W1	7.1	7.1	11.2	9.6	5.4	5.4	10.0	10.2
W2	7.0	6.6	11.2	9.7	5.2	5.2	10.3	10.5
W3	6.1	6.0	11.4	9.8	5.0	5.2	10.0	10.3
W4	6.8	6.1	10.9	9.5	5.0	5.2	10.5	10.5
W5	7.0	5.0	10.6	8.9	5.2	5.2	10.8	10.4
W6	6.9	6.4	11.0	9.4	4.9	5.1	10.2	10.2
W7	6.4	6.1	10.4	9.4	4.9	5.1	9.8	10.4
W8	6.7	6.1	10.8	9.3	5.0	5.1	9.6	10.0
W9	6.9	6.4	10.7	9.8	5.0	5.1	9.4	9.9
W10	6.4	6.1	10.2	9.0	4.9	5.0	9.6	9.6
W11	7.9	6.2	11.0	9.9	5.0	5.1	10.2	10.2
W12	8.1	6.5	10.0	9.1	5.3	5.2	9.2	10.1
W13	6.8	6.5	10.6	9.3	5.0	5.1	10.6	10.4
W14	7.1	6.6	10.6	9.2	5.0	4.9	10.6	10.7
W15	6.7	6.7	10.6	9.2	5.4	5.4	10.8	10.5
WR1	7.2	7.0	10.8	9.8	5.4	5.4	--	10.4
WR2	6.4	6.1	10.0	8.7	4.9	5.0	9.0	9.2
WR3	7.4	6.0	11.0	10.5	5.2	5.2	10.2	10.0
WR4	6.8	6.7	12.8	13.4	5.4	5.4	10.3	10.4
MEAN	6.93	6.33	10.83	9.66	5.11	5.17	10.06	10.21
S.D.	0.49	0.46	0.61	1.00	0.19	0.14	0.53	0.36

Key: S = Surface
B = Bottom
S.D. = Standard Deviation

TABLE G.5-6 Dissolved oxygen (mg/l) data for the proposed Chacahoula brine diffuser site, September through December, 1977.

	September		October		November[a]		December	
	S	B	S	B	S	B	S	B
C1	7.4	4.7	11.2	9.3				
C2	7.5	2.5	11.4	10.4				
C3	7.5	6.3	11.8	10.4				
C4	7.7	7.1	11.6	10.6				
C5	7.4	6.3	11.8	9.6			9.4	9.30
C6	7.7	6.2	11.2	10.8				
C7	7.8	6.4	11.2	10.2				
C8	7.8	7.3	10.8	10.0				
C9	8.0	7.0	11.8	11.6				
C10	7.8	6.6	11.4	10.6				
C11	7.6	6.7	11.5	10.5				
C12	7.6	6.5	11.4	10.0			10.0	9.0
C13	--	--	11.9	9.7			10.0	9.0
CR1	7.2	4.4	11.2	8.5			9.9	9.8
CR2	7.7	7.4	11.4	10.4				
CR3	7.7	7.7	10.6	10.8				
CR4	7.7	4.7	11.4	9.6			9.8	9.7
MEAN	7.63	6.11	11.39	10.18			9.82	9.30
S.D.	0.20	1.37	0.35	0.70			0.25	0.41

Key: S = Surface
B = Bottom
S.D. = Standard Deviation

[a] Data not obtained for November.

TABLE G.5-7 Data for dissolved heavy metals, nutrients, and major ionic species from water column and underlying pore waters - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.

Site	Station	Depth (m)	Fe (µg/kg)	Mn (µg/kg)	Zn (µg/kg)	Pb (µg/kg)	Ni (µg/kg)	Cu (µg/kg)	Cd (µg/kg)	Hg (µg/kg)	PO_4 (µM)	SiO_4 (µM)	NO_3 (µM)	Cl (g/kg)	SO_4 (g/kg)	Na (g/kg)	K (g/kg)	Mg (g/kg)	Ca (g/kg)
Weeks Island																			
	W2	1	<2	.54	<12	.09	0.9	.88	.04	01	.76	8.3	4.6	15.95	2.19	8.8	32	1.08	34
		6	<2	1.9	<12	.04	1.0	.85	.03	03	.93	10.0	3.0	15.83	2.23	8.8	32	1.07	34
		pore	33.	1200.	48.	2.1	7.3	83.	14.4	-	.30	126.	-	15.91	2.74	8.9	.35	1.11	33
	W5	1	<2	1.2	<12	.07	1.4	1.8	.05	.05	1.23	19.0	16.1	7.08	.81	3.9	14	.46	14
		6	<2	2.1	<12	.21	1.1	.93	.05	.04	1.00	9.7	-	15.91	2.19	8.7	32	1.05	33
		pore	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	W8	3(A)	<2	.74	<12	.04	1.9	1.6	.05	.04	1.81	21.3	20.3	6.46	1.06	4.5	16	.54	20
		3(B)	3.4	1.3	<12	.03	1.7	1.5	.05	.04	1.77	21.3	19.9	7.48	96	4.1	.15	.50	19
		pore	37.	150.	120.	.8	4.9	32.	11.0	-	-	85	-	11.27	2.49	6.5	.33	.82	27
	W10	1	193.	18.4	<12	1.8	1.7	1.6	.06	.07	.78	11.8	14.5	12.91	1.76	7.0	25	.85	.27
		6	<12	1.0	<12	.08	1.3	1.2	.03	.04	1.50	15.4	9.9	15.73	2.16	8.6	31	1.04	.33
		pore	265.	1900.	42.	2.1	5.8	36.	4.7	-	.75	122	-	14.97	2.71	8.4	35	1.07	.36
	W15	1	<2	1.2	<12	.06	1.3	1.1	.03	.04	1.43	10.0	5.1	14.61	2.00	8.0	29	.96	.31
		6	<2	.54	<12	.04	1.1	.88	.03	03	1.50	15.6	8.7	14.77	2.10	7.9	27	.96	.31
		pore	88.	1200.	91.	1.1	5.2	56	18.0	-	.70	107	-	15.35	2.60	8.4	32	1.10	.35
	WR3	2	<2	.25	<12	.07	1.6	1.4	.01	-	1.39	80	12.7	1.52	.12	.7	03	08	06
		pore	25	1600.	22.	2.2	5.4	48.	14.6	-	.31	98	-	1.80	1.41	4.6	20	.54	18
Chacahoula																			
	C2	1	<2	.62	<12	.15	1.3	.31	.02	03	1.57	2.9	1.0	17.67	2.47	10.1	36	1.21	.38
		11	<2	.45	<12	.06	1.4	.62	.02	.01	1.64	<2.9	-	17.75	2.49	10.0	36	1.22	.38
		pore	66.	1300.	37.	1.4	8.2	98.	7.6	-	.25	146	-	17.97	2.93	9.9	35	1.25	.41
	C5	1	<2	.70	<12	.08	1.7	.77	.03	.01	68	5.4	0.1	17.31	2.41	10.0	35	1.18	.37
		9	<2	1.3	<12	.08	1.4	.61	02	02	68	7.7	2.9	17.41	2.46	9.9	35	1.19	37
		pore	470.	250.	40	.8	6.3	26	4.7	-	(12.8)	121.	-	16.77	2.30	9.5	35	1.18	.40
	C8	1	<2	.57	<12	.09	1.2	66	02	.05	67	4.6	0.3	16.94	2.40	9.6	34	1.12	35
		8	<2	.50	<12	.03	1.2	65	.02	05	58	4.6	0.4	17.21	2.42	9.7	35	1.17	37
		pore	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C10	1	<2	.77	<12	.11	1.4	.74	02	.06	5.97	4.6	-	17.21	2.44	9.7	34	1.18	37
		8	<2	1.5	<12	.04	1.0	.57	.02	.04	1.34	7.9	1.2	17.51	2.50	9.9	35	1.18	.37
		pore	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
	CR3	1	<2	.57	<12	09	1.2	66	.02	05	67	4.6	0.3	16.94	2.40	9.3	33	1.13	35
		8	<2	.50	<12	.03	1.2	65	02	05	58	4.6	0.4	17.31	2.42	9.3	33	1.13	36
		pore	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	
Weeks Island																			
Mean (Excl. W10-1)		surface	-	.8	-	.06	1.3	1.4	.04	.03									
		deep	-	1.5	-	08	1.2	1.1	05	.04									
		pore	86	1610.	65	1.7	5.7	55	12.5	-									
Range (Excl W10-1)		surface	-	.25-1.2	-	.02-.09	.9-1.9	.9-1.8	.03-.06	.01-.05									
		deep	-	.54-2.1	-	.04-.21	1.0-1.7	.9-1.5	.03-.07	.03-.04									
		pore	33-265	150-3200	22-120	.8-2.2	4.9-7.3	32-83	4.7-18.0	-									
Chacahoula																			
Mean		surface	-	1.3	-	.12	1.5	.8	.03	.04									
		deep	-	1.4	-	.05	1.2	.6	.01	.03									
		pore	268	775	38	1.1	7.2	62	6.2	-									
Range		surface	-	.62-3.8	-	.08-.15	1.2-1.7	.66-.92	.02-.05	.01-.05									
		deep	-	.45-3.0	-	.03-.08	.9-1.4	.57-.66	.02	.01-.05									
		pore	66-470	250-1300	37-40	.8-1.4	6.3-8.1	26-98	4.7-7.6	-									
Standard Sea Water											2.5*	75*	23*	19.35	2.71	10.8	39	1.29	.41
Marine Brine†											82	233	0	149.5	3.66	91.3	63	1.05	1.49

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TABLE G.5-8 Data for relative dissolved and particulate heavy metal burdens - proposed Weeks Island and Chacahoula brine diffuser sites, September 1977.

Site	Station	Depth (m)		TSM (mg/ℓ)	POC (mg C/ℓ)	POC/TSM (%)	DOC (mg C/ℓ)	Fe (μg/ℓ)	Mn (μg/ℓ)	Zn (μg/ℓ)	Pb (μg/ℓ)	Ni (μg/ℓ)	Cu (μg/ℓ)	Cd (μg/ℓ)
Weeks Island														
	W2	1	Dissolved				--	<2.0	.540	<12.0	0.090	0.900	0.880	0.040
			Particulate	15.7	.46	2.9		7500	15.0	3.5	0.52	0.10	0.33	0.0146
		6	Dissolved				1.20	<2.0	1.90	<12.0	0.040	1.000	0.850	0.030
			Particulate	18.5	.54	2.9		130.0	10.0	0.65	0.0973	0.165	0.0611	0.0076
	W5	1	Dissolved				.75	<2.0	1.20	<12.0	0.070	1.400	1.800	0.050
			Particulate	8.5	.51	6.0		370.0	7.7	3.7	0.26	0.514	0.181	0.0062
		6	Dissolved					<2.0	2.10	<12.0	0.210	1.10	0.930	0.050
			Particulate	74.4	.62	0.8	--							
	W8	3(A)	Dissolved				1.93	<2.0	0.740	<12.0	0.040	1.900	1.60	0.050
			Particulate	51.7	.93	1.8		3200.0	62.0	12.0	2.0	3.9	1.7	0.050
		3(B)	Dissolved					3.40	1.300	<12.0	0.030	1.700	1.500	0.050
			Particulate	30.4	.93	3.1	--	1400.0	29.0	4.3	0.49	1.7	0.623	0.0179
	W10	1	Dissolved				1.18	193.0	18.40	<12.0	1.800	1.700	1.600	0.060
			Particulate	3.0	.46	15.3		95.0	2.2	4.2	0.26	<0.126	0.0717	0.0056
		6	Dissolved				1.36	<2.0	1.000	<12.0	0.080	1.300	1.200	0.070
			Particulate	165.4	1.19	0.7		7800.0	180.0	62.0	4.8	8.0	3.1	1.7
	W15	1	Dissolved				1.31	<2.0	1.200	<12.0	0.060	1.300	1.100	0.030
			Particulate	13.6	.44	3.2		5300	12.0	3.2	0.29	6.0	0.27	0.009
		6	Dissolved				1.33	<2.0	0.540	<12.0	0.040	1.100	0.880	0.030
			Particulate	40.7	.51	1.3		4200.0	53.0	31.0	1.0	3.3	1.2	0.057
	WR3	2	Dissolved				2.30	<2.0	0.250	<12.0	0.020	1.400	1.600	0.030
			Particulate	45.1	1.54	3.4		3100.0	20.0	8.5	1.8	4.3	1.6	0.0487
Chacahoula														
	C2	1	Dissolved				--	<2.0	0.620	<12.0	0.150	1.700	0.710	0.020
			Particulate	0.4	.08	20.0		5584	0.163	--	0.00316	--	0.0160	--
		11	Dissolved				.93	<2.0	0.450	<12.0	0.060	1.400	0.620	0.020
			Particulate	2.2	.22	10.0		66.0	1.6	0.24	0.063	--	0.0062	0.0029
	C5	1	Dissolved				1.01	<2.0	0.700	<12.0	0.080	1.700	0.770	0.030
			Particulate	1.3	.22	16.9		47.0	0.66	0.31	0.052	0.073	0.035	0.0036
		9	Dissolved				.80	<2.0	1.300	<12.0	0.080	1.400	0.610	0.020
			Particulate	8.5	.32	3.8		160.0	5.7	1.9	0.18	--	0.097	0.0077
	C8	1	Dissolved				.94	<2.0	0.570	<12.0	0.090	1.200	0.660	0.020
			Particulate	1.4	.22	15.7		52.0	1.5	0.200	0.140	--	0.0235	0.004
		8	Dissolved				.32	<2.0	0.500	<12.0	0.030	1.200	0.650	0.020
			Particulate	1.8	.23	12.8								
	C10	1	Dissolved				--	<2.0	0.770	<12.0	0.110	1.400	0.740	0.020
			Particulate	1.7	--			63.0	1.3	--	0.194	--	0.0631	--
		8	Dissolved				--	<2.0	1.500	<12.0	0.040	1.000	0.570	0.020
			Particulate	(32.7)	--			2200.0	25.0	3.466	51.0	2.9	0.001	0.0386
	CR3	1	Dissolved				.90	<2.0	3.800	<12.0	0.150	1.300	0.920	0.050
			Particulate	3.4	.35	10.3		97.0	3.7	10.269	0.103	--	0.129	0.004
		6	Dissolved				1.11	<2.0	3.000	<12.0	0.060	0.900	0.660	0.020
			Particulate	2.2	.37	16.8		81.0	3.0	--	0.038	--	0.045	0.0033

TABLE G.5-9 Data for heavy metal content of suspended particulates and bottom sediments - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.

Site Station	Depth(m)	P=Particulate S=Sediment	Fe(ppm)	Mn(ppm)	Zn(ppm)	Pb(ppm)	Ni(ppm)	Cu(ppm)	Cd(ppm)
Weeks Island									
W2	1	P-WAS[†]	2170	585	43	6.5	4.8	3.2	.49
		P-Total	47820	984	221	32.9	66.7	20.8	.93
		P-% Leach	4.5	59.5	19.5	19.8	7.2	15.3	52.7
	6	P-WAS	1990	512	26	3.7	3.8	1.3	.35
		P-Total	6793	556	35.3	6.2	8.9	3.3	.41
		P-% Leach	27.8	92.1	73.7	59.7	42.7	54.8	35.4
	7-8	S-WAS[†]	6300	529	31	21	7.2	12	.2
W5	1	P-WAS	2160	569	198	13.0	10.9	3.5	.22
		P-Total	43210	906	435	30.8	60.5	21.5	.73
		P-% Leach	4.9	62.8	45.5	42.2	18.0	16.4	30.1
	6	P-WAS	2110	601	850	5.5	4.3	2.8	1.45
		P-Total	-	-	-	-	-	-	-
		P-% Leach	-	-	-	-	-	-	-
	7-8	S-WAS	6200	627	30	19	7.3	12	.3
W8	3(A)	P-WAS	1920	593	94	6.5	4.1	3.6	.30
		P-Total	62500	1191	234	39.6	75.3	32.3	.96
		P-% Leach	3.1	50.0	40.2	16.4	5.4	11.1	31.2
	3(B)	P-WAS	1710	552	43	4.3	4.8	3.0	[illegible]
		P-Total	46000	943	143	16.0	56.6	20.5	[illegible]
		P-% Leach	3.7	58.5	30.1	26.9	8.5	14.6	13.
	7-8	S-WAS	5900	507	28	18	6.9	11	.2
W10	1	P-WAS	2590	530	477	49	<4	5.3	.67
		P-Total	31840	731	1390	85.8	<42	23.9	1.85
		P-% Leach	8.1	72.5	34.3	57.1	-	22.1	36.2
	6	P-WAS	1350	464	227	1.6	2.1	1.1	.09
		P-Total	47270	1096	376	29.4	48.6	18.6	10.5
		P-% Leach	2.8	42.3	81.4	5.4	4.3	5.5	0.86
	7-8	S-WAS	5700	562	26	18	5.8	10	.2
W15	1	P-WAS	2160	527	72	7.4	4.6	2.7	.10
		P-Total	39320	880	232	20.5	44.0	19.5	.66
		P-% Leach	5.4	60.0	31.0	36.2	10.5	13.8	15.0
	6	P-WAS	1050	560	32	3.6	3.1	1.8	.29
		P-Total	103400	1296	759	24.9	80.9	28.4	1.40
		P-% Leach	1.0	43.2	4.2	14.5	3.8	6.3	20.7
	7-8	S-WAS	5700	594	25	17	6.0	8	.2
WR3	2	P-WAS	1250	468	24	2.5	3.9	1.6	.29
		P-Total	69650	621	189	39.8	95.0	35.6	1.08
		P-% Leach	1.7	75.4	12.7	6.3	4.1	4.4	26.6
	4-6	S-WAS	6300	511	28	19	7.7	13	.2

TABLE G.5-9 continued.

Site Station	Depth(m)	P=Particulate S=Sediment	Fe(ppm)	Mn(ppm)	Zn(ppm)	Pb(ppm)	Ni(ppm)	Cu(ppm)	Cd(ppm)
Chacahoula									
C2	1	P-WAS	1840	279	104	5.4	<7	19.7	4.02
		P-Total	13960	408	300	7.9	<130	39.1	5.
		P-% Leach	13.1	68.4	-	68.3	-	50.3	-
	11	P-WAS	2360	534	63	9.3	<27	1.6	1.06
		P-Total	29860	717	108	28.8	<48	2.9	1.34
		P-% Leach	7.9	74.5	58.2	32.3	-	53.6	78.9
	12-13	S-WAS	5000	384	21	14	4.6	7	.04
C5	1	P-WAS	3260	408	97	13.0	<8	10.0	2.08
		P-Total	36110	508	242	40.0	<56	27.1	2.78
		P-% Leach	9.0	80.3	24.7	32.5	-	36.8	74.8
	9	P-WAS	1830	555	152	8.9	<1.5	3.7	.65
		P-Total	18680	667	224	21.2	<20	11.4	.90
		P-% Leach	9.7	83.2	67.8	42.0	-	32.4	72.2
	10-11	S-WAS	3600	242	18	10	4.0	3	.06
C8	1	P-WAS	2980	894	93	15.0	<11	3.3	2.21
		P-Total	37160	1109	140	97.1	<40	16.8	2.86
		P-% Leach	8.0	80.6	66.3	15.4	-	19.6	77.1
	8	P-WAS	1820	526	61	7.5	<6	1.3	1.22
		P-Total	22494	641	94	58.5	<47	8	1.34
		P-% Leach	8.0	82.1	64.9	12.8	-	-	90.8
	9-10	S-WAS	2400	155	13	6	2.9	1	.03
C10	1	P-WAS	2910	562	96	23.1	<10	10.5	1.50
		P-Total	37040	780	140.0	114.2	<26	28.2	2
		P-% Leach	7.8	72.1	-	20.2	-	37.1	-
	8	P-WAS	1890	534	43	3.8	3.1	2.7	.14
		P-Total	68707	752	106	39.6	78.5	31.6	1.18
		P-% Leach	2.7	71.0	40.5	9.6	4.0	8.5	11.8
	9-10	S-WAS	-	-	-	-	-	-	-
CR3	1	P-WAS	1370	768	70	13.4	<5	11.6	.85
		P-Total	28500	1098	302	30.3	<32	37.97	1.17
		P-% Lead	5.3	69.9	23.2	44.0	-	30.5	72.1
	6	P-WAS	2350	1019	51	10.1	<7	3.6	1.24
		P-Total	36800	1353	100	17.2	<41	20.4	1.52
		P-% Leach	63	75.3	-	58.7	-	17.6	81.4
	7-8	S-WAS	2800	154	14	7	2.9	1	.02
Mississippi Delta Suspended Particulate ≠			46400	1230	244	58	56	56	1.5

† WAS (weak acid soluble) refers to a leach with 25% V/V acetic acid in the case of the suspended particulate (P) and to 1 N HNO_3 in the case of the bottom sediments (S).

≠ From Trefry, 1977; mean of 34 samples.

TABLE G.5-10 Data for surface sediment (0-5 cm) metal contents and metal/iron ratios - proposed Weeks Island and Chacahoula brine diffuser sites, September 1977.

Site Station	Fe(%)	Mn(ppm)	Mn/Fe(x10^{-2})	Zn(ppm)	Zn/Fe(x10^{-4})	Pb(ppm)	Pb/Fe(x10^{-4})	Ni(ppm)	Ni/Fe(x10^{-4})	Cr(ppm)	Cr/Fe(x10^{-4})	Cu(ppm)	Cu/Fe(x10^{-4})	Cd(ppm)	Cd/Fe(x10^{--})	Al(%)	Fe/Al
Weeks Island																	
W2	.63	529.	8.4	30.3	49.1	20.9	33.2	7.2	11.4	3.3	5.2	12.1	19.2	.20	3.2	22	2 9
W5[a]	.62	627.	10.1	29.7	47.9	19.4	31.3	7.3	11.8	2.8	4.5	11.9	19.2	.27	4.4	.20	3.1
W8	.59	507.	8.6	27.3	47.3	18.3	31.0	6.9	11.7	3.0	5.1	11.2	19.0	.22	3.7	.19	3.1
W10	.57	562.	9.9	26.2	46.0	17.7	31.1	5.8	10.2	2.6	4.6	9.7	17.0	.22	3.9	.17	3.4
W15	.57	594.	10.4	24.5	43.2	16.8	29.5	6.0	10.5	2.5	4.4	7.8	13.7	.19	3 3	.15	3.8
WR3[b]	.63	511.	8.1	27.[illegible]	44.0	19.3	30.6	7.7	12.2	2.2	3.5	13.2	21.0	.20	3.2	18	3.5
Chacahoula																	
C2	.50	384.	7.7	21.2	42.4	13.9	27 8	4.6	9.2	2.0	4.0	6.7	13.4	.04	0.8	.11	4.5
C5[a]	.36	242.	6.7	17.7	49.2	10.0	27.8	4.0	11.1	1.5	4.2	2.8	7.8	.06	1 7	09	4.0
C8	.24	155.	6.5	13.[illegible]	54.6	6.4	26.7	2.9	12.1	1.4	5.8	1.0	4.2	.03	1.3	.05	4.8
CR3[b]	.28	154.	5.5	14.4	51.4	6.6	23.6	2.9	10.4	1.0	3.6	1.0	3.6	.02	0.7	.05	5.6
Mean (all stations)	.50±.15	427±181	8.2±1.6	23.3±5.4	47.5±3.8	14.9±5.4	29.3±2.8	5.5±1 8	11.1±1.0	2.2±.8	4.5± .7	7.7±4.7	13.8±6.5	15±.10	2.6±1.4	.14+.06	3.8± 8
Mean (Weeks only)	.60±.03	555± 48	9.3±1.0	27.8±2.3	46.3±2.3	18.7±1.5	31.1±1.2	6.8± .8	11.3± .2	2 7±.4	4.6± .6	11.0±1 9	19.2±2.5	.22±.03	3.6± .5	.19±.02	3.3±.3
Mean (Chacahoula only)	.35±.11	234±108	6.6± .9	16.6±3.6	49.4±5.2	9.2±3.5	26.5±2.0	3.7± 8	10.7±1.2	1.5±.4	4.4±1.0	2.9±2.7	7.3±4.5	.04±.02	1.1± .5	.08± 03	4.7± 7
Metal Content Associated with Organic Matter	No		Only very little		No		Only very little		No		No		Yes		Yes		
Total Metal Content (% leach) Average Mississippi Delta Sediment[c]	3.99(15)	743(75)	1.9	125(22)	31.3	34(55)	8.5	41(17)	10.3	84(3)	21 1	28(39)	7.0	8(27)	2.0	8.11(2)	49

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[a] Proposed diffuser sites

[b] Reference stations

[c] Trefry, 1977

TABLE G.5-11 Data for heavy metal content of selected organism - proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.

Sample #	Sample Description ≠ (Species)/Site-Station	Fe(ppm)	Mn(ppm)	Zn(ppm)	Pb(ppm)	Ni(ppm)	Cu(ppm)	Cd(ppm)	Al(ppm)
1	Croaker (fish) flesh (*M. undulatus*) Weeks Is. - WT3	13.3	3.8	18.7	.05	.01	1.4	.003	2.52
2	White Shrimp flesh (*P. setiferus*) Weeks Is. - WT3	6.4	2.2	56.3	.001	.24	27.3	.04	0.11
3	Zooplankton (chaetognaths) Weeks Is. - WT3	692.	21.9	162.	.55	6.0	15.6	1.56	1020.
4	White Shrimp flesh (*P. setiferus*) Chacahoula - CT2	3.5	1.1	72.6	.005	.09	39.5	.02	0.13
	NW Gulf of Mexico Zooplankton*								
	#1	799.	12.6	155.	15.3	2.0	74.0	2.4	1252.
	#2	288.	9.8	58.	4.3	1.9	6.3	1.3	283.
	#3	2100.	-	120.	20.	6.6	20.	2.9	3100.
	NW Gulf of Mexico Macrobiota§								
	Shrimp	4.	-	63.	.08	.21	.24	.09	-
	Fish Flesh								
	Red Snapper	5.4	-	12.	.03	.06	.80	.03	-
	Winchman	3.8	-	8.2	.04	.08	1.3	.02	-

≠ Sample 1 - 4 fish pool; flesh only
Sample 2 - 5 shrimp pool; flesh only
Sample 3 - Whole sample; mostly chaetognaths
Sample 4 - 1 shrimp; flesh only

* Sims, 1975. #1 - Sample from near-shore off Corpus Christi, Texas.
#2 - Sample from directly offshore of the Atchafalaya, significantly further from land than the sites of this study.

§ Boothe and Presley, 1977.

TABLE G.5-12 Data for gas chromagraphic hydrocarbon concentrations and distributions in sediment samples from the proposed Weeks Island and Chacahoula brine diffuser sites, September, 1977.

Station	Type	Hexane Fraction[4]			Benzene Fraction[4]			OEP[1]	N/B[2]	NPO[3] RD
		Resolved	Unresolved	Ratio R/U	Resolved	Unresolved	Ratio			
W-5	Sediment	0.887	12.879	0.068	1.415	6.389	0.204	3.52	0.64	0.085
W-5	Sediment	1.100	10.242	0.108	1.612	2.563	0.139	4.39	0.67	0.079
W-15	Sediment	1.364	10.656	0.069	0.632	3.836	0.164	3.72	0.59	0.107
W-2	Sediment	0.970	5.666	0.172	0.344	1.973	0.175	3.90	0.65	0.083
W-2	Sediment	1.292	14.270	0.090	0.289	3.629	0.081	4.08	0.67	0.105
W-10	Sediment	1.012	14.327	0.071	0.871	3.878	0.227	3.73	0.64	0.132
W-10	Sediment	0.972	13.625	0.071	0.167	2.222	0.075	4.18	0.68	0.111
WR3	Sediment	0.247	1.640	0.152	0.112	0.612	0.185	4.19	0.81	0.023
WR3	Sediment	0.737	2.629	0.280	0.227	0.865	0.263	3.12	0.77	0.020
W-8	Sediment	0.920	10.313	0.089	0.208	2.546	0.082	2.44	0.71	0.027
C-8	Sediment	0.111	0.720	0.154	0.061	0.331	0.185	2.18	0.65	0.219
C-8	Sediment	0.098	1.555	0.063	0.052	0.572	0.091	3.91	0.51	0.239
C-5	Sediment	0.514	3.187	0.161	0.164	1.354	0.122	3.46	0.53	0.134
C-5	Sediment	0.835	13.54	0.062	0.356	4.180	0.085	3.58	0.51	0.125
C-2	Sediment	0.549	8.880	0.062	0.274	2.682	0.102	3.70	0.55	0.265
C-2	Sediment	0.477	5.02	0.094	0.122	1.031	0.118	3.26	0.56	0.147
CR3	Sediment	0.172	0.714	0.242	0.180	0.361	0.500	2.86	0.47	0.403
WI	Shrimp Tails	0.023	0.649		0.105	0.407				
WI	Whole Shrimp	0.276	12.628		0.245	2.832				
WI	Croaker W/out Gut	0.509	8.16		FAME contamination[5]					
Chacahoula	Croaker W/out Gut	0.246	4.930		FAME Contamination					
Chacahoula	Whole Shrimp	0.046	1.528		0.094	1.037				

[1] OEP = Odd/even preference for the n-alkanes

[2] N/B = Normal/branched ratio for hexane fraction

[3] MPO/RD = The relative dominance of the marine polyolefins (MPO), [illegible]en KOVAT 2030 and 2160, in the hexane fraction.

[4] [illegible]e and [illegible]ne c[illegible]atio[illegible] in [illegible]er m[illegible].

TABLE G.5-13 Gas chromatographic hydrocarbon concentrations in water samples from the proposed Weeks Island and Chacahoula brine diffuser sites.

Station	Type	Hexane Fraction[1]			Benzene Fraction[1]			ppb[2] Total
		Resolved	Unresolved	Ratio	Resolved	Unresolved	Ratio	
W10-S	Water	89.81	3,833.60	0.023	4.25	193.41	0.022	4.12
W10-D	Water	81.71	7,118.30	0.011	16.99	965.06	0.018	8.18
W2-S	Water	28.77	3,510.60	0.008	906.52	1,062.80	0.943	5.51
W2-D	Water	22.00	1,590.50	0.014	347.37	431.63	0.806	2.39
W5-S	Water	1027.34	34,361.15	0.030	73.69	10,447.30	0.007	45.91
W5-D	Water	253.98	8,973.70	0.028	22.10	1,565.28	0.014	10.81
W15-S	Water	42.66	1,348.05	0.034	12.63	428.28	0.029	3.01
W15-D	Water	51.42	3,777.08	0.014	16.59	986.47	0.017	4.83
W8-S	Water	2.67	2,222.87	0.001	---	580.45	0.139	2.81
W8-D	Water	489.01	20,084.79	0.024	33.44	5,659.87	0.017	26.33
WR-3M	Water	32.35	2,157.73	0.015	4.19	813.38	0.005	3.01
C2-S	Water	19.36	1,081.50	0.147	32.54	338.24	0.096	1.48
C2-D	Water	16.83	736.12	0.023	2.94	126.85	0.023	0.88
C5-S	Water	87.45	2,346.9	0.037	74.62	79.44	0.943	2.59
C5-D	Water	48.30	661.08	0.073	3.21	No Unresolved		1.42
CR3-M	Water	43.19	672.60	0.064	209.62	392.15	0.535	1.32

[1] Parts per trillion (ng/liter)

[2] Parts per billion (μg/liter)

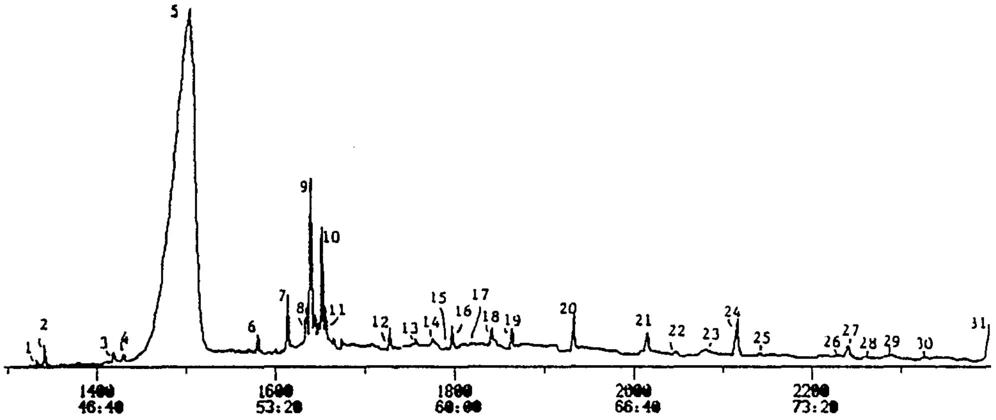

FIGURE G.5-1. Reconstructed gas chromatogram for GCMS analysis of sediment sample 816, hexane fraction, station CR-3.

TABLE G.5-14 GCMS data for #816/station CR3, hexane fraction (sediment).

'eak No.	Base Peak	M+	Characteristic Ions	Compounds	
1					nC_{17}
2	57	268		$C_{19}H_{40}$	pristane
3					nC_{18}
4					phytane
5					sulfur
6	57	282		$C_{20}H_{42}$	nC_{20}
7	83	346	234,262,292	$C_{25}H_{46}$	
8	57	346	223,235,264	$C_{25}H_{46}$	
9	69	348	235,251,267	$C_{25}H_{48}$	
10	55	344	232,248,259	$C_{25}H_{44}$	
11	57	296	156,169,183	$C_{21}H_{44}$	
12					nC_{22}
13	57	239	169,184,198	$C_{18}H_{23}$	
14	57	320	255,270,296	$C_{24}H_{32}$	
15	191	318	263,287,304	$C_{23}H_{42}$	tricyclic diterpane
16					nC_{23}
17	191	332	262,309,318	$C_{24}H_{44}$	tricyclic diterpane
18	55	334	209,223,236	$C_{24}H_{46}$	
19					nC_{24}
20					nC_{25}
21					nC_{26}
22	217	372	288,315,357	$C_{28}H_{36}$	cholestane
23	57	372	189,218,259	$C_{28}H_{36}$	sterane/alkane mixture
24					nC_{27}
25	95	386	329,354,373	$C_{29}H_{38}$	ergostane/methyl cholestan
26	81	400	288,358,371		stigmatane/methyl engostane
27					nC_{28}
28	55	370	302,317,355	$C_{27}H_{46}$	sterane
29	57	400	288,335,371	$C_{29}H_{52}$	sterane

TABLE G.5-14 continued.

Peak No.	Base Peak	M+	Characteristic Ions	Compounds	
30	191	368	256,284,232	$C_{27}H_{44}$	
31					nC_{29}
32	191	M+?	249,259,282	-	-
33					nC_{30}
34	191	412	207,218,247	$C_{30}H_{52}$	
35					nC_{31}

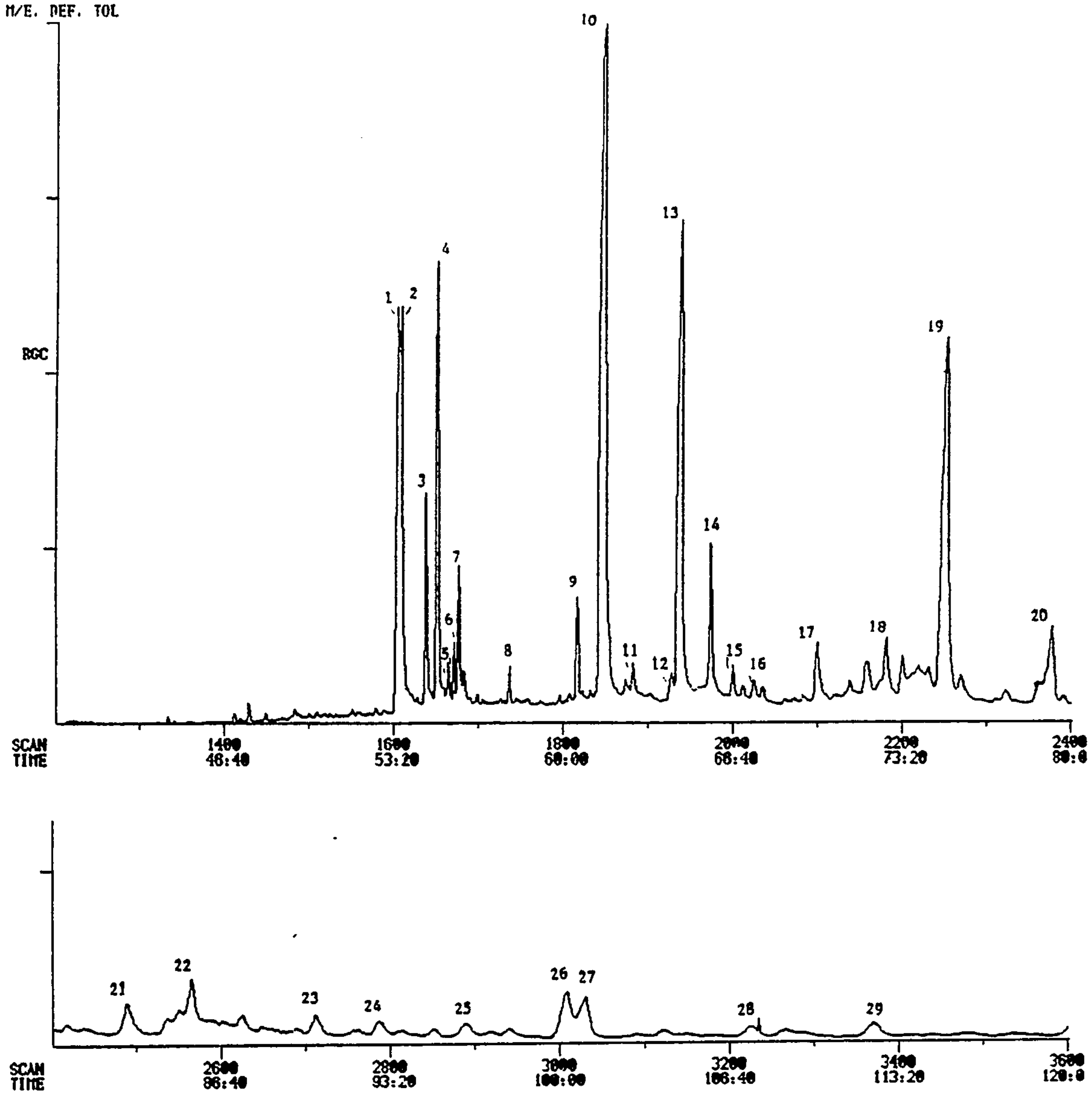

FIGURE G.5-2. Reconstructed gas chromatogram for GSMS analysis of sediment sample 816, benzene fraction, station CR-3.

TABLE G.5-15 GCMS data for #816/station CR3, benzene fraction (sediment).

Peak No.	Base Peak	M+	Characteristic Ions	Compounds			
					4F		
1	80	288	150,190,234	$C_{21}H_{36}$	unknown	unknown	olef
2	91	284	199,213,255	$C_{21}H_{32}$		"	"
3	70	344	234,177,289	$C_{25}H_{44}$		"	
4	55	344	232,247,259	$C_{25}H_{44}$		"	
5	69	274	193,204,218	$C_{20}H_{34}$		"	"
6	69	289?	206,216,232	$C_{21}H_{36}$		"	
7	56	312	214,238,257	$C_{22}H_{36}$		"	
8	55	318?	222,160,279	$C_{23}H_{42}$		"	"
9	57	340	242,267,285	$C_{25}H_{40}$			
10	57	259	241,213,199	$C_{19}H_{31}$		dioctyl ad[illegible]	
11	57	324	293,265,246	$C_{24}H_{36}$			
12	149	266	172,247	$C_{20}H_{36}$			
13	149	?	279,167			dioctyl ph[illegible]ha	
14	55	412	149	$C_{30}H_{52}$		cyclic albene	
15	69	410	265,274,314	$C_{30}H_{50}$			
16	149	294	209,247,265	$C_{22}H30$		phthalate	
17	149	390	265,294,353	$C_{28}H_{54}$			
18	69	414	233,191,173	$C_{30}H_{54}$		unkn. triterp	
19	69	342	175,192,204	$C_{25}H_{42}$		squalene	
20?	69	410		$C_{30}H_{50}$		triterpa[illegible]	
21	57	424	229,202,215	$C_{31}H_{52}$		triterpane?	
22	67	394	214,247,255	$C_{20}H_{46}$		triterpane?	
23	57	438	216,229,244	$C_{32}H_{54}$			
24	149	452	244,294,322	$C_{33}H_{56}$			
25	57	452	257,243,229	$C_{33}H_{56}$		cyclicalkene	
26	57	452	257,244,229	$C_{33}H_{56}$		cyclic alk[illegible]e	
27	204	440	393,269,246	$C_{32}H_{56}$		triterpane	
28	57	466	258,243,229	$C_{34}H_{58}$		cyclic alkane	
29	57	466	229,243,257	$C_{34}H_{58}$		cyclic alk[illegible]e	
30	57	M+?	253,267,281	-		-	

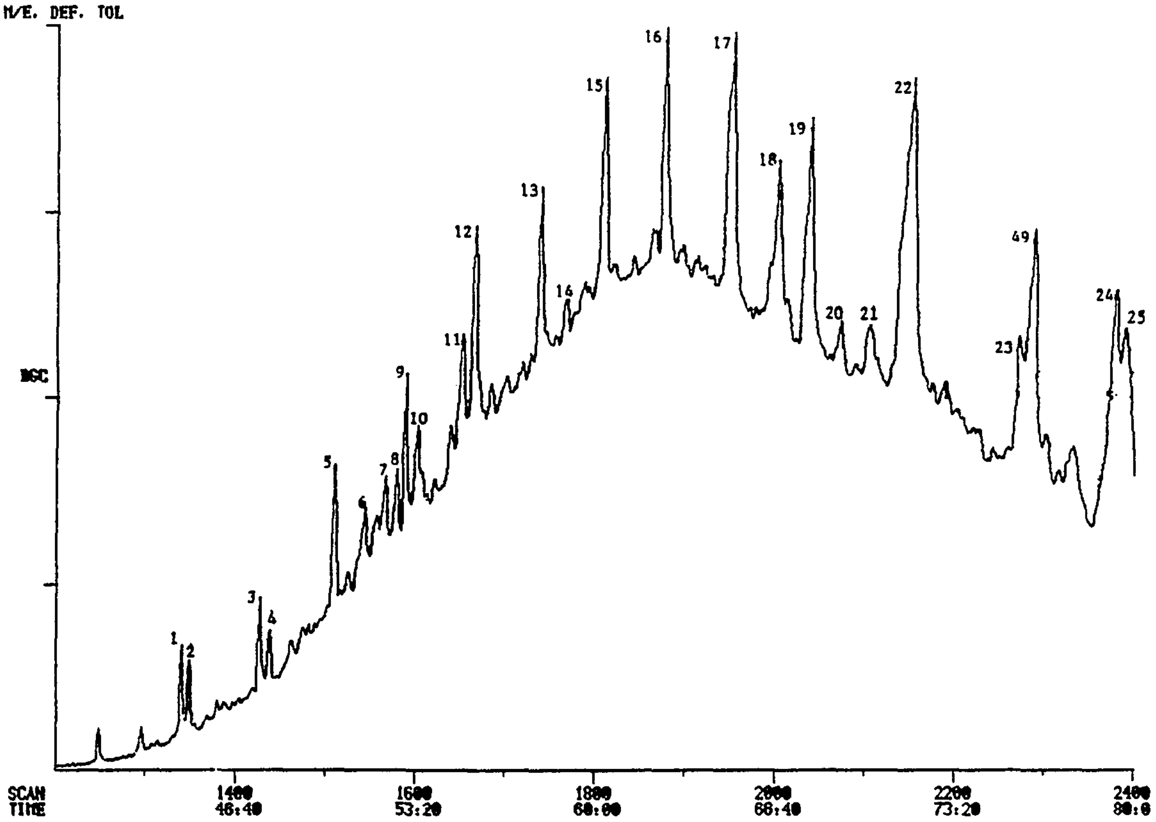

FIGURE G.5-3. Reconstructed gas chromatogram for GCMS analysis of sediment sample 818, hexane fraction, station WR-3.

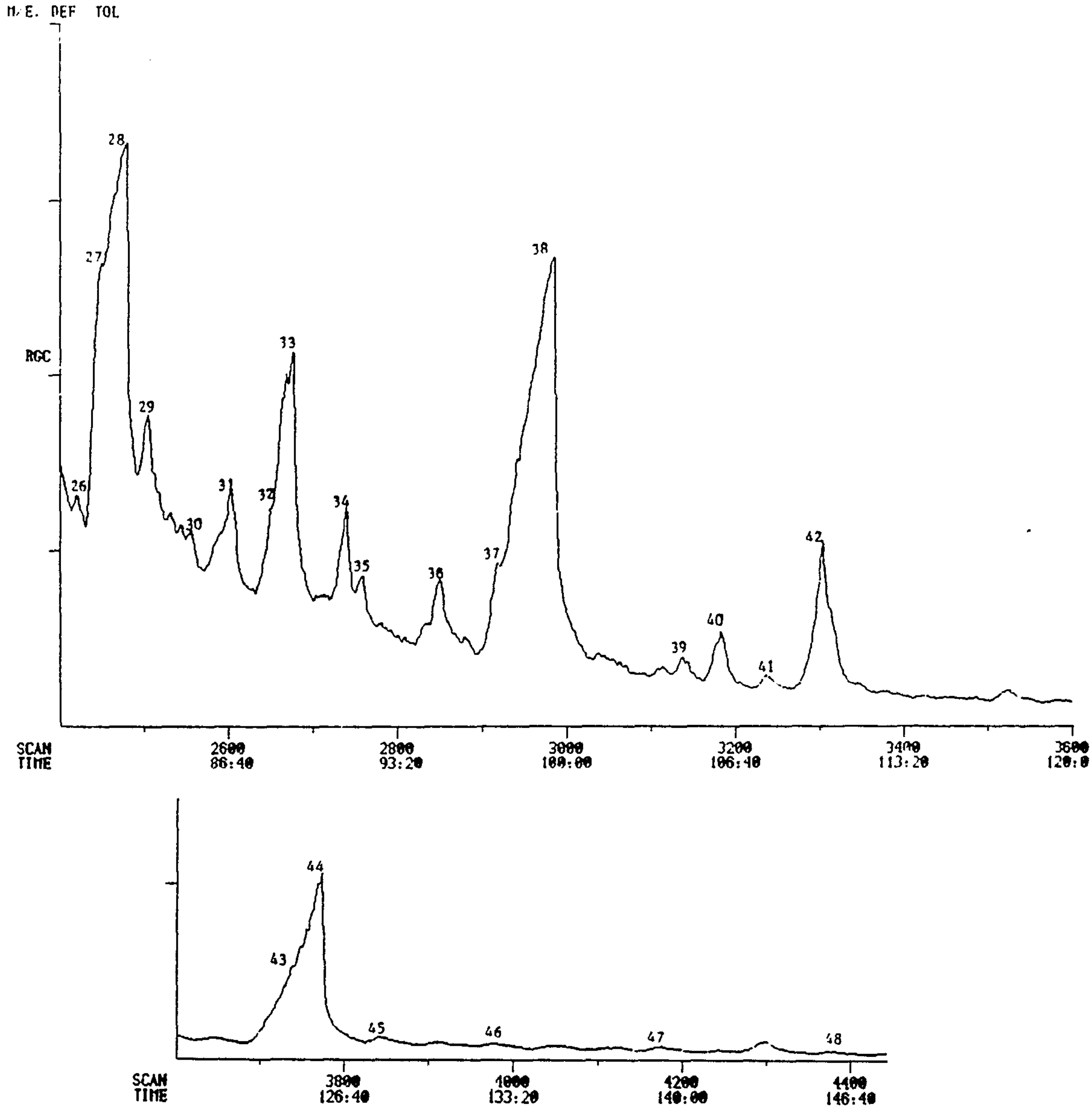

FIGURE G.5-3. continued.

TABLE G.5-16 GCMS data for #818/WR3, hexane fraction (sediment).

Peak No.	Base Peak	M+	Characteristic Ions	Compounds	
1	57	240	127,142,151	$C_{17}H_{36}$	nC_{17}
2	57	268	127,155,183	$C_{19}H_{40}$	pristane
3	57	254	127,142,156	$C_{18}H_{38}$	nC_{18}
4	57	282	169,184,197	$C_{20}H_{42}$	phytane
5	No Data				nC_{19}
6	55	292	180,233,259	$C_{21}H_{40}$	alkane
7	55	292	191,219,242	$C_{21}H_{40}$	alkane ?
8	55	276	261,247,192	$C_{20}H_{36}$	
9	No Data				nC_{20}
10	55	274	191,231,259	$C_{20}H_{34}$	diterpane
11	57	348	235,266,319	$C_{25}H_{48}$	
12					nC_{21}
13					nC_{22}
14	57	332	288,303,318	$C_{24}H_{44}$	
15					nC_{23}
16					nC_{24}
17					nC_{25}
18	55	326	206,219,311	$C_{24}H_{38}$	
19	71	366	253,268,281	$C_{26}H_{54}$	nC_{26}
20	57	372	189,217,259	$C_{27}H_{48}$	C Holestane
21	57	372	218,247,259	$C_{27}H_{48}$	unknown sterane
22					nC_{27}
23	57	400	191,217,259	$C_{29}H_{52}$	Sterane
24	191	368	231,273,353	$C_{27}H_{44}$	Triterpane/ sterane
25	95	414 ?	206,245,382	$C_{30}H_{54}$	unknown mixture
26	57	400	259,354,371	$C_{29}H_{52}$	unknown sterane
27	149	414 ?	191,355,370	$C_{30}H_{54}$	sterane + triterpane
28	57	408	197,211,226	$C_{29}H_{60}$	nC_{29}
29	69	410	299,369,395	$C_{30}H_{50}$	triterpene ?
30	55	428	355,386,400	$C_{31}H_{56}$	mixture w/sterane
31	57	414 ?	383,386,400	$C_{30}H_{54}$	unknown mixture
32	57	398	232,257,344	$C_{29}H_{50}$	triterpane
33					nC_{30}
34	69	410	368,231,395	$C_{30}H_{50}$	triterpene
35	177	398	383,191,205	$C_{29}H_{50}$	adiantane
36	191	412	255,398,408	$C_{30}H_{52}$	hopane ?
37	177	410	204,384,398	$C_{30}H_{50}$	triterpane + triterpene
38					nC_{30}

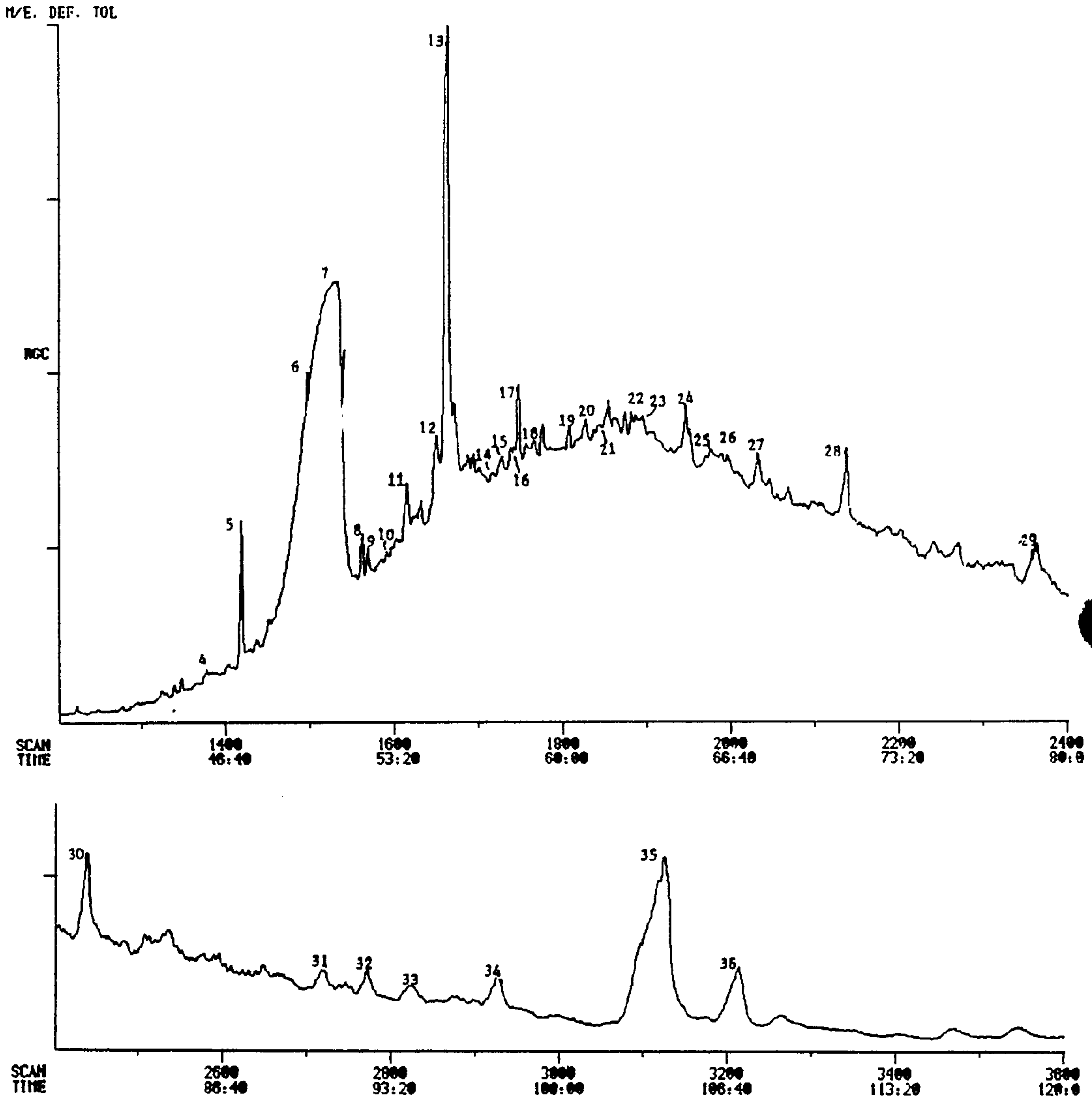

FIGURE G.5-4. Reconstructed gas chromatogram for GCMS analysis of sediment sample 823, benzene fraction, station C-2.

TABLE G.5-17 GCMS data for #823/station C-2, benzene fraction (sediment).

Peak No.	Base Peak	M+	Characteristic Ions	Compounds	
1	70	126(134)	84,97,107	$C_9H_{18}(C_{10}H_{14})$	mono olefin(alkyl benzene)
2	177	192	135,149,159	$C_{14}H_{24}$	unknown aromatic
3	111	180	124,137,152	$C_{13}H_{24}$	di olefin (isoprene
4	178	178	76,89,153	$C_{13}H_{22}$	phenanthrene/ anthracene
5	57	242	101,141,227	$C_{18}H_{26}$	polyolefin (isoprenoid)
6	192	192	192,165,95	$C_{14}H_{24}$	methy phenanthrene?
7	-	-	-	-	sulfur (octahedral)
8	57	?	169,239,255		unknown
9	57	?	192,213,227	$C_{19}H_{40}$	unknown
10	206	272?	165,178,189	$C_{20}H_{32}$	tricyclic diterpene
11	202	270	174,185,255	$C_{20}H_{30}$	unknown aromatic
12	69	268	197,238,254	$C_{19}H_{40}$	unknown
13	55	344	231,247,259	$C_{25}H_{44}$	polyolefin(unknown)
14	216	294	252,267,277	$C_{22}H_{30}$	benzofluorene/ metylpyrene?
15	219	294	234,250,284	$C_{22}H_{30}$	tetramethyl phenanthrene
16	216	358?	240,253,283	$C_{26}H_{46}$	mixture aromatic & alkane
17	81	362	279,292,306	$C_{26}H_{50}$	unknown mixture
18	216	364?	232,279,297	$C_{27}H_{40}$	unknown aromatic
19	230	332	264,280,298	$C_{25}H_{32}$	unkonwn aromatic
20	191	336	230,2460262	$C_{25}H_{36}$	deterpene?
21	235	?	248,267,322		chlorinated HC
22	292	326?	194,221,277	$C_{24}H_{38}$	unkonwn aromatic
23	228	320	244,261,293	$C_{23}H_{44}$	triphenyl benzene?
24	57	352	296,309,324	$C_{26}H_{50}$	nC_{25}?
25	231	352	248,255,275	$C_{26}H_{50}$	4-methyl sterane
26	242	340	309,316,325	$C_{25}H_{40}$	unknown aromatic
27	57	366	202,218,274	$C_{26}H_{54}$	cyclic olefin?
28	57	380	267,281,295	$C_{27}H_{56}$	nC_{27}
29	81	408	335,354,366	$C_{29}H_{60}$	mixture of sterenes
30	57	408	310,324,338	$C_{29}H_{60}$	nC_{29}
31	145	404	188,363,379	$C_{29}H_{56}$	unknown
32	206	440	340,393,425	$C_{32}H_{56}$	triterpane
33	57	422	295,310,365	$C_{30}H_{62}$	nC_{30}?
34	57	436	342,352,365	$C_{31}H_{64}$	nC_{31}
35	204	440	269,301,316	$C_{32}H_{56}$	triterpane unknown
36	189	440	177,189,204	$C_{32}H_{56}$	triterpane unknown

TABLE G.5-17 continued.

Peak No.	Base Peak	M^+	Characteristic Ions	Compounds	
39	191	426	411,369,206	$C_{31}H_{54}$	triterpan
40	191	426	411,369,206	$C_{31}H_{54}$	triterpan
41	191	412	208,397,369	$C_{30}H_{52}$	triterpane
42	57	450	254,266,281	$C_{32}H_{66}$	nC_{32}
43	205	426	411,369,219	$C_{31}H_{54}$	triterpan
44	57	464	352,365,379	$C_{33}H_{68}$	nC_{33}
45	57	454	233,191,208	$C_{33}H_{58}$	triterpane
46	191	454	233,266,283	$C_{33}H_{58}$	triterpan
47	219	440	179,192,370	$C_{32}H_{56}$	triterpane
48	57	468	220,248,262	$C_{34}H_{60}$	triterpane
49					nC_{28}

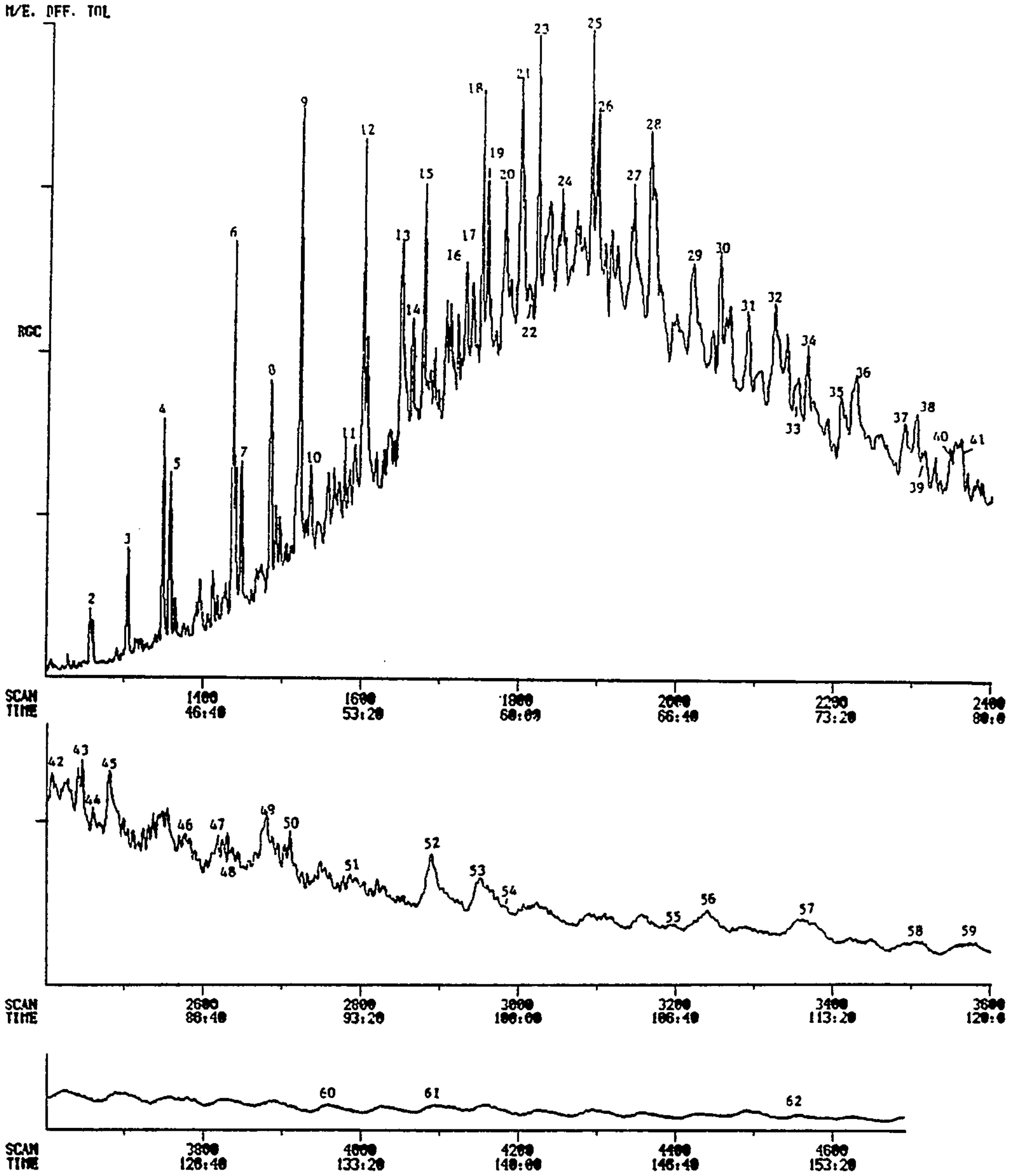

FIGURE G.5-5. Reconstructed gas chromatogram for GCMS analysis of surface water hexane fraction, station C-5.

TABLE G.5-18 GCMS data for #2002/surface water station C-5, hexane fraction.

Peak Number	Base Peak	M+	Characteristic Ions	Compounds
1	57	212	-	nC_{15}
2	57	226	-	nC_{16}
3	57	254?	211,224,196	branched alkane (4 methyl heptadicane)
4	57	240	-	nC_{17}
5	57			pristane
6	57	254	-	nC_{18}
7	57			phytane
8	57	252?	155,239	branched alkane/alkene
9	57	268	-	nC_{19}
10	57	296?	267,224,197	branched alkane
11	57	296?	253,225	branched alkane
12	57	282		nC_{20}
12a	57	?	249,267	unknown
13	57	?	252,267,280	branched alkane
14	57	?	155,169,183,281	
15	57	296		nC_{21}
16	57	324?	281,294,211	
17	57	360	249,296,267	
18	57	310		nC_{22}
19	57	?	267,295,308	
21	57	308	295	unknown
22	91	318	249,291,303	diterpane
23	57	324	-	nC_{23}
24	57	316?	295	unknown
25	57	338	-	nC_{24}
26	57	?	127,295,323	unknown
27	68	336	308	unknown
28	57	352	-	nC_{25}
29	57	?	323,337,253	
30	57	366	-	nC_{26}

TABLE G.5-18 continued.

Peak Number	Base Peak	M+	Charactertistic Ions	Compounds
31	57	372	149,189,217,259	unknown (sterane?)
32	57	?	-	unknown
33	57	372	189,217,275	unknown (sterane?)
34	57	380	-	nC_{27}
35	57			
36	57			
37				sterane-terpane mixture
38		394		nC_{28}
39	69	?	191	weak triterpane spectra
40				
41	191	370		sterane/alkane mixture
42	191	370	M-15	triterpane
43	57			
44	82	386?	218,204,149	sterane (ergostane?)
45	57	408	-	nC_{29}
46	57	400	217	sterane (stigmastane?)
47	57	400	218	sterane
48	57	398/400	218	mixture steranes
49	191	400	191,177,231	triterpane (norhopane)
50	57	400	218	sterane
51	191	398	177	triterpane (adiantane or moretane)
52	191	412	M-15	triterpane (hopane)
53	57	436	-	nC_{31}
54	191	412	205,149	triterpane
55	191	426	411,205,310	$C_{31}H_{54}$ triterpane R&S
56	191	426	411,205,310	$C_{31}H_{54}$ triterpane isomers
57	57	?	191,263	triterpane
58	191	440		$C_{32}H_{56}$ triterpane R&S
59	191	440		$C_{32}H_{56}$ triterpane isomers

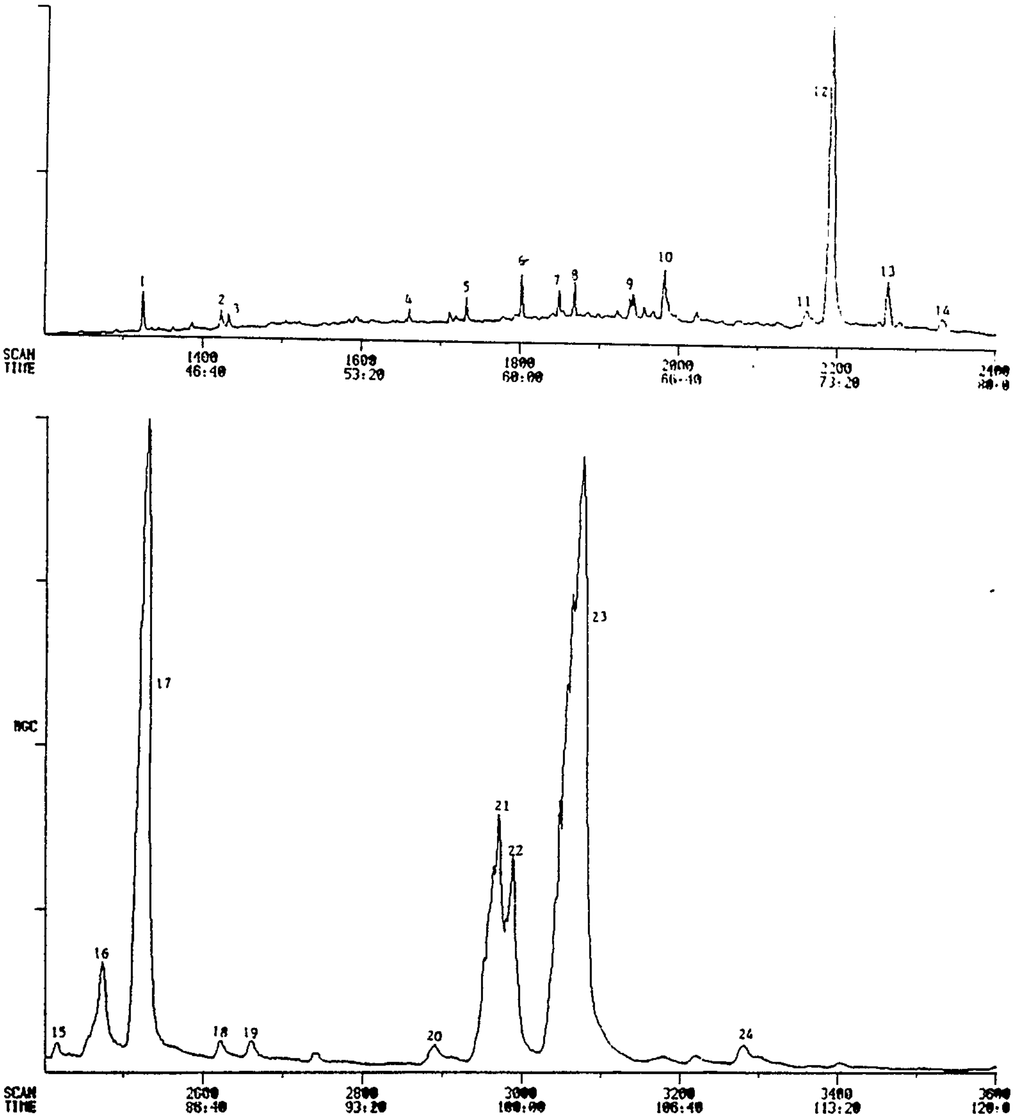

FIGURE G.5-6. Reconstructed gas chromatogram for GCMS analysis of deep water, benzene fraction, station W-2.

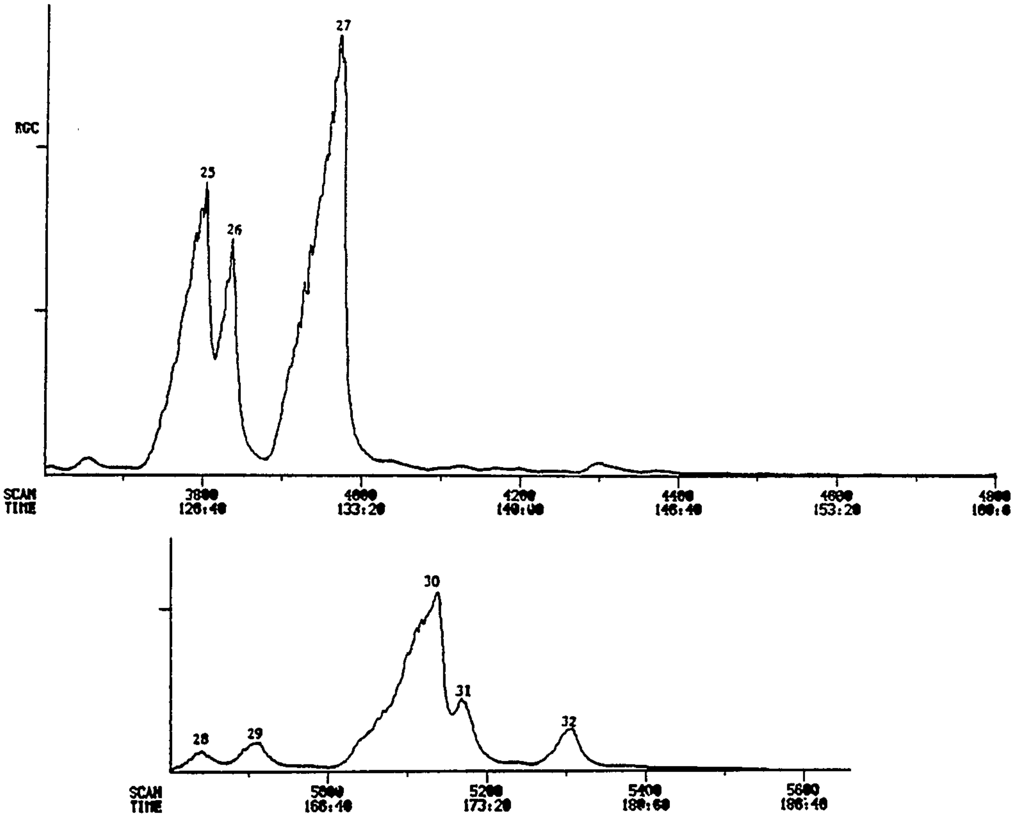

FIGURE G.5-6. continued.

TABLE G.5-19 GCMS data for #2025/deep water station W-2, benzene fraction.

Peak Number	Base Peak	M+	Characteristic Ions	Compounds
1	221	236	91,143	1,1,3-Trimethyl-3-phenylindan
2	143	236	221,91	Trimethyl phenylindan (?) (isomer of Compound (1))
3	57	228?	102,211	Unknown
4	57	252(?)	202,220,237	
5	57	310		nC_{22}
6	57	324		nC_{23}
7	129,57	340		Adipate contaminant
8	57	338		nC_{24}
9	149	390	$C_{24}H_{38}O_4$	Dioctyl phthalate
10	57	368	20,173,196,168	Beginning of Copepod wax serie
11	55	?	181,138,199	Unknown
12	57	396	201,229,168,196	
13	69	410		Squalene $C_{30}H_{50}$
14	365	394,410		Unknown mixture
15	57	408		nC_{29}
16	55	422	365,351,208,236, 222,250	
17	57	424	201,229,257,196, 224	
18	57	422		nC_{30}
19	55	422	199,227	
20	57	436		nC_{31}?
21	55	450	173,201,222,250	
22	57	450	208,236,227,255, 323,351	
23	57	452	229,257,196,224	
24	55(57)	450		
25	55	478(?)	251,223,236,264	
26	57	478	236,255,152,351	
27	57	480	257,229,285,224, 196	
28	55	504	237,250,255	
29	55	504	237,250,255	
30	55	506	250,222,257,264, 236,283,352	
31	57	506	236,264,255,283, 354,489	
32	57	508	257,285,252,224, 356	

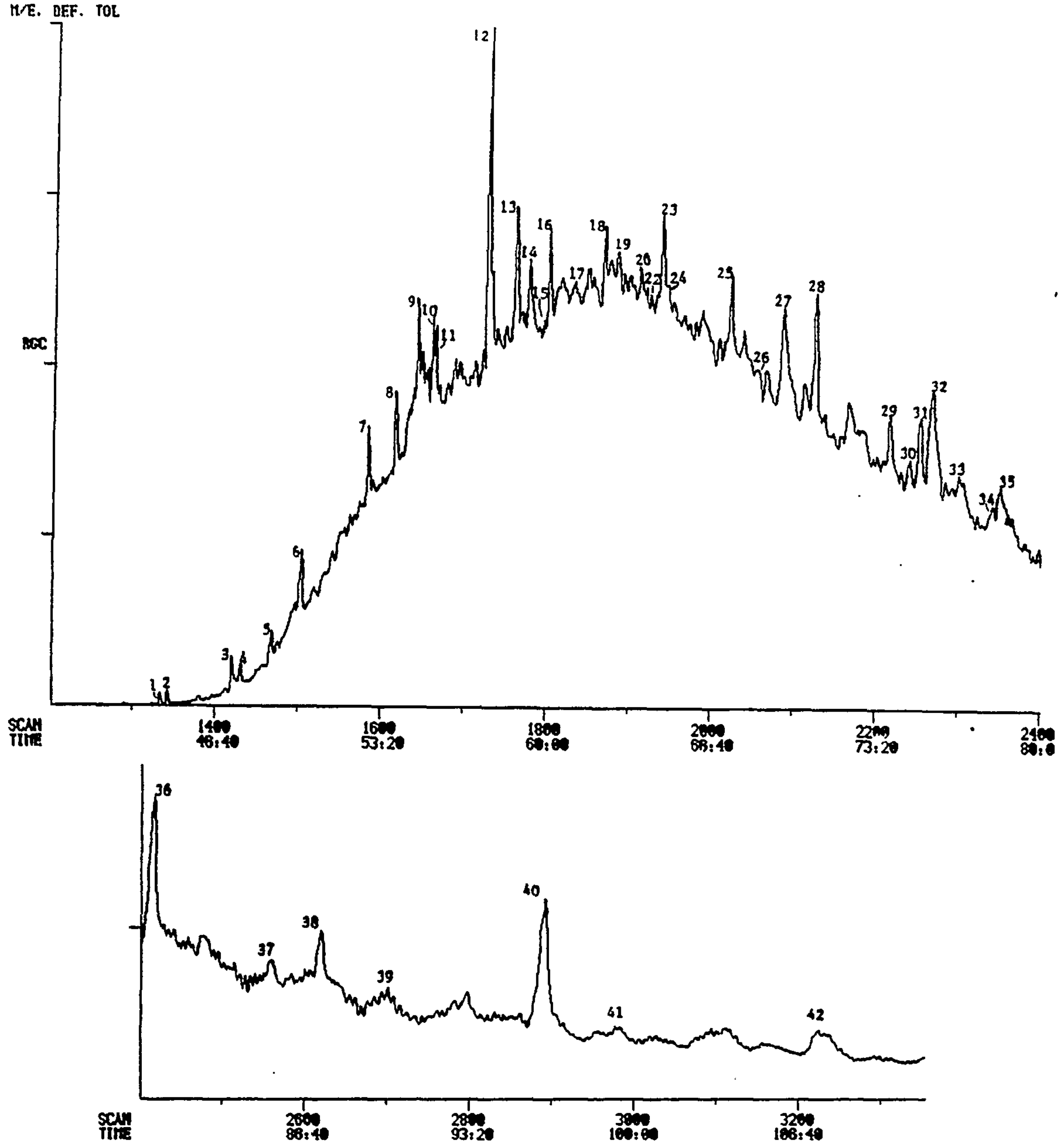

FIGURE G.5-7. Reconstructed gas chromatogram for GCMS analysis of white shrimp, hexane fraction, proposed Weeks Island site.

TABLE G.5-20 GCMS data for Weeks Island shrimp, hexane fraction.

Peak No.	Base Peak	M+	Characteristic Ions	Compounds	
1	57	240	155,169,183	$C_{17}H_{36}$	nC_{17}
2	57	268	142,155,184	$C_{19}H_{40}$	Pristane
3	57	254	155,169,183	$C_{18}H_{38}$	nC_{18}
4	57	280	208,228,253	$C_{21}H_{28}$	phytane
5	57	266	183,209,239	$C_{20}H_{36}$	
6	57	268	183,192,211	$C_{19}H_{40}$	nC_{19}
7	57	282	212,225,239	$C_{20}H_{42}$	nC_{20}
8	57	346	233,261,292	$C_{21}H_{34}$	
9	69	266	208,235,250	$C_{20}H_{26}$	
10	57	296	212,225,239	$C_{21}H_{44}$	
11	69	290	205,234,261	$C_{22}H_{26}$	
12	81	346	233,247,261	$C_{25}H_{46}$	
13	71	268	240,196,183	$C_{20}H_{40}$	cyclic alkane
14	71	308	210,240,231	$C_{23}H_{32}$	
15	191	318	249,272,304	$C_{23}H_{42}$	tricyclic diterp
16	71	324	192,211,225	$C_{23}H_{48}$	nC_{23}
17	57	332	152,165,191	$C_{25}H_{32}$	
18	71	338	211,225,239	$C_{24}H_{50}$	
20	71	338	239,254,309	$C_{24}H_{50}$	
21					nC_{24}
22	71	338	165,179,191	$C_{24}H_{50}$	
23	71	352	268,281,295	$C_{25}H_{52}$	
24	97	394	246,316,327	$C_{28}H_{58}$	
25	71	366	253,268,281	$C_{26}H_{54}$	
26	123	322	288,352,357	$C_{24}H_{34}$	sterane or t
27	71	378	337,281,296		
28	71	380	296,309,324	$C_{27}H_{56}$	nC_{27}
29	57	366	155,169,183	$C_{27}H_{42}$	
30	57	400	218,260,288	$C_{30}H_{40}$	sterane/alkane
31	57	394	309,323,338	$C_{28}H_{58}$	nC_{28}
32	57	394	351,371,379	$C_{28}H_{58}$	
33	57	400	356,287,259	$C_{30}H_{40}$	alkane/triterpane mixture
34	191	414	344,354,369	$C_{31}H_{42}$	triterpane
35	123	414	355,371,399	$C_{31}H_{42}$	triterpane
36	57	408	323,338,351	$C_{29}C_{60}$	nC_{29}
37	no data				
38	57	422	295,309,323	$C_{30}C_{62}$	nC_{30}
39	191	412	218,232,398	$C_{30}H_{52}$	triterpane
40	57	436	323,337,351	$C_{31}H_{64}$	nC_{31}
41	57	?	127,141,155		
42	57	410	218,232,299	$C_{30}H_{50}$	triterpane

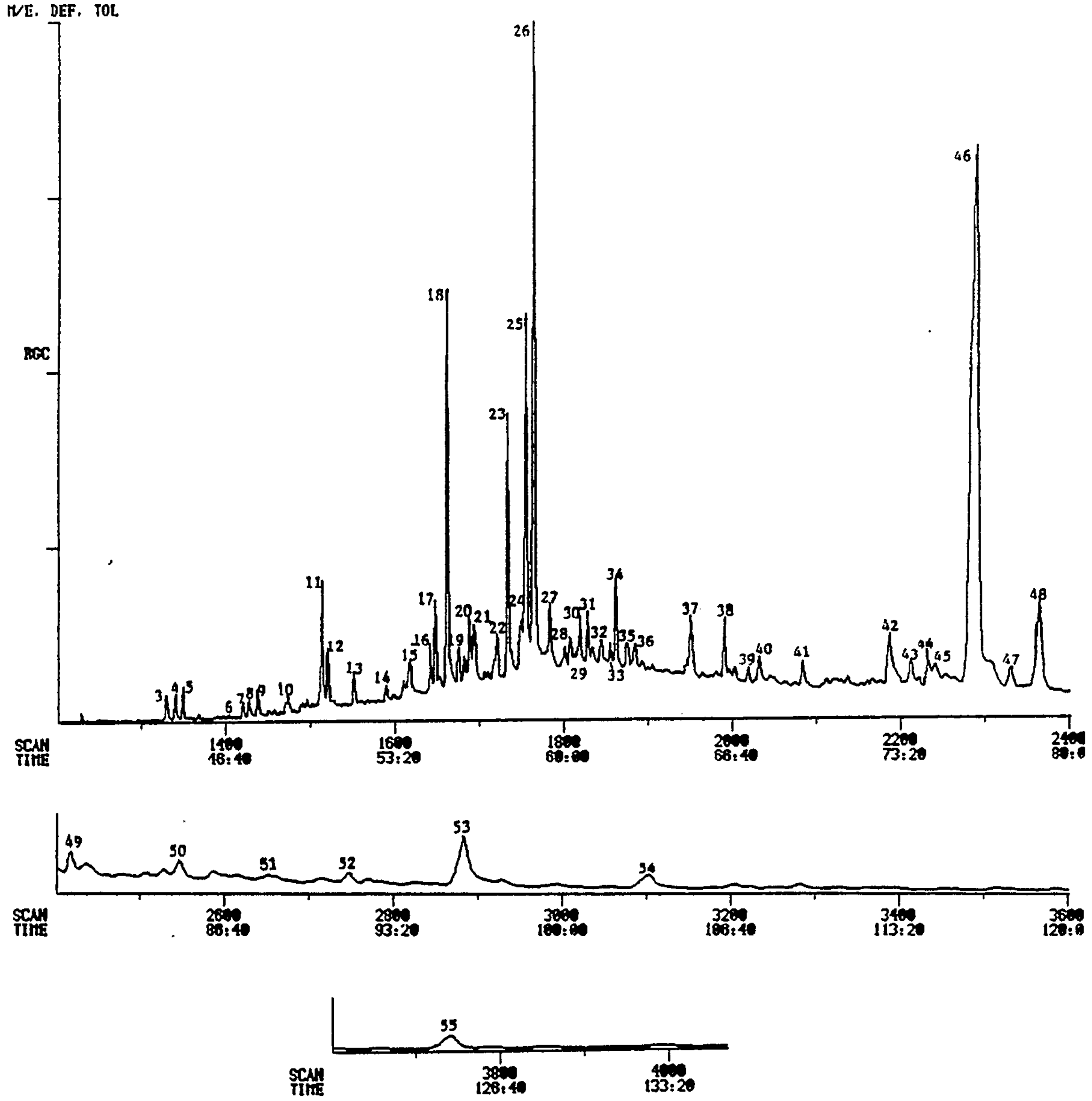

FIGURE G.5-8. Reconstructed gas chromatogram for GCMS analysis of white shrimp, benzene fraction, proposed Weeks Island site.

TABLE G.5-21 GCMS data for Weeks Island shrimp, benzene fraction.

Peak No.	Base Peak	M+	Characteristic Ions	Compounds	
1	68	136	93,107,122	$C_{10}H_{16}$	D-Limonene
2	159	174	128,144,159	$C_{13}H_{18}$	1,6,8-Trimethyl-1,2,3,4-Tetrahydro Naphthale
3	221	236	165,178,192	$C_{18}H_{20}$	1,1,3-Trimethyl 3 phenylindan
4	57	240	113,127,142	$C_{17}H_{36}$	nC_{17}
5	57	268	127,155,183	$C_{19}H_{40}$	pristane
6	178	178	153,119	$C_{14}H_{10}$	phenanthaene ?
7	105	246	141,178,228	$C_{18}H_{30}$	
8	57	254	193,222,237	$C_{18}H_{38}$	C_{13}
9	57	228	172,185,211	$C_{17}H_{24}$	phytane
10	69	274	163,205,232	$C_{20}H_{34}$	
11	69	272	162,203,229	$C_{20}H_{32}$	
12	69	274	136,149,205	$C_{20}H_{34}$	
13	69	272	148,159,191	$C_{20}H_{32}$	
14	57	282	198,212,225	$C_{20}H_{42}$	C_{20}
15	202			$C_{22}H_{36}$	pyrene
16	55	304	152,183,212	$C_{22}H_{40}$	
17	69	344	289,233,219	$C_{25}H_{44}$	
18	55	344	231,247,259	$C_{25}H_{44}$	
19	109	346	205,215,235	$C_{25}H_{36}$	
20	56	312	239,253,216	$C_{23}H_{36}$	
21	69	316	210,233,246	$C_{14}H_{8}$	D.D.E.
22	69	316	147,216,271	$C_{23}H_{40}$	
23	55	346	219,234,248	$C_{25}H_{46}$	
24	216	340	256,272,292	$C_{25}H_{40}$	mixture of alke
25	55	344	175,189,217	$C_{25}H_{44}$	+ chlorinated H
26	55	344	175,210,264	$C_{25}H_{44}$	
27	55	358	301,326,344	$C_{26}H_{46}$	
28	55	360	234,261,276	$C_{26}H_{46}$	
29	57	358	299,314,324	$C_{26}H_{46}$	
30	69	360	218,288,346		chlorinated compound
31	57	340	242,268,285	$C_{26}H_{40}$	
32	69	394	253,324,358		chlorinated HC
33	57	358	268,285,340	$C_{26}H_{46}$	adipate plastic
34	251	362	152,159,170	$C_{26}H_{50}$	pesticide similar Kelthane
35	57	338	211,226,252	$C_{24}H_{50}$	nC_{24} ???
36	175	398	328,292,278	$C_{29}H_{50}$	
37	149	390	113,168,279		Dioclyl phtalat
38	55	412	259,274,315	$C_{30}H_{52}$	
39	69	410	259,266,313	$C_{30}H_{50}$	
40	69	410	191,218,274	$C_{30}H_{50}$	

TABLE G.5-21 continued.

Peak No.	Base Peak	M+	Characteristic Ions	Compounds	
41	69	414	no data	$C_{30}H_{54}$	
42	83	414	247,301,368	$C_{30}H_{54}$	
43	69	414	261,353,368	$C_{30}H_{54}$	
44	69	412	299,330,347	$C_{30}H_{52}$	
45	253	366	199,351,211	$C_{25}H_{42}$	sterene
46	69	410	341,368,299	$C_{30}H_{50}$	squalene
47	149	414	232,255,366	$C_{30}H_{54}$	phthalate
48	81	368	213,247,261	$C_{27}H_{44}$	cholestene type
49	69	366	no data	$C_{26}H_{54}$	
50	81	382	255,261,274	$C_{28}H_{46}$	cholestene type
51	179	444	365,219,231	$C_{33}H_{52}$	
52	81	396	213,255,275	$C_{29}H_{48}$	
53	165	430	178,189,206	$C_{31}H_{58}$	tolophenol acetat
54	189	454	269,301,316	$C_{33}H_{58}$	tritarpene
55	57	464	253,267,282	$C_{33}H_{68}$	nC_{33}

TABLE G.5- 22 Benthic macroinvertebrates collected at the Weeks Island site, September 1977a.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
ANTHOZOA (SEA ANEMONES)	2																		
RHYNCHOCELA (NEMERTEANS)			3	10	5	13			4		9	15	11	10		14	10		
CHAETOGNATHA (ARROW WORMS)																			
Sagitta sp.	3											4			12	6			6
GASTROPODA (SNAILS)																			
Anachis obesa																			
Anachis sp.	1					1				1									
Nassarius acutus		3			2					1	1	1		1		1			1
Tectonatica pussilla										1									
Polinices duplicatus																			2
Epitonium rubicola																			
Epitonium sp.																			2
Prunum apicinum																			1
Prunum sp.																			
Terebra protexa																			
Terebra sp.																			
Neritina sp.																			1
Olivella dealbata																			
Turbonilla sp.																			
Cantharus cancelarius																			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
SCAPHOPODA (TUSK SHELLS)																			
Dentalium texasianum																4			
PELECYPODA (CLAMS)																			
Mulinia lateralis	1	3				1										10		49	
Nuculana concentrica	2	4				9	3			8	4		8	11				1	13
Anadara ovalis																			
Chione sp.	2																		
Noetidae													1						
Semele proficua														1					
Semele belastritta																3		1	
Pandora trilineata																			
Lucina multilineata																1			
Lucina amiantus																			
Tellina sp.																			
Abra aequalis																			
Gemma sp.																			
Mactra sp.																			
Solen viridis																			
Macoma constricta																			
Macoma sp.																			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
POLYCHAETA (BRISTLE WORMS)																			
Spiophanes bombyx	42	13	14	5	18	15	17	12	6	69	34	23	16	43	4	59	6		23
Streblospio benedicti		7	8	6	1	21	5	5		11	39	7	23	7	4		5		15
Cossura longocirrata		9	26	5	28	25	8	49		28	54	24	26	8	29		35		23
Sigambra sp.			4	4	1	1	10	6	3	3	7	2	2	4	2	3	5		
Lumbrineris sp.	2															2			
Lepidasthenia varia						8													
Pseudeurythoe ambigua									25					5			4		
Malmgrenia cf. lunulata														1		1			
Glycera sp.																1			
Lepidonotus sp.	1																		
Gyptis brevipalpa						1					7	2					5		
Clymenella torquata	2									23	1	1		3					
Chaetopterus variopedatus	1																		
Onuphis opalina	3																	1	
Onuphis sp.																			
Diopatra cuprea	1			1	1	1		2	2			1			2				
Megelona rosea																			
Cirratulus sp.																			
Amphictes gunneri																			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Chone infundibuliformis																			
Glycinde solitaria					5		4			1	3	4	2						2
Paraonis fulgens													1						
Neanthes succinea			3	1			1					2	2		1				
Aglaophamus verrilli	5															7			
Syllidae	1			1		2													
Stenolepis sp.																			
Scolupus cf. *elongatus*																2			
Ancistrosyllis spp.		1									1								
OLIGOCHAETA (AQUATIC EARTHWORMS)						16		4		51		1		7					
CRUSTACEA (CRABS, ISOPODS, ETC.)																			
Monoculodes intermedius																			
Corophium sp.																			
Ogyrides limicola	4																		
Campylaspis rubicunda	1																		
Oxyurostylis smithi			2								1	1		4					
Edotea montosa										1									
Paracaprella pusilla	2																		

TABLE G.5- 22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Calidus sp.																			
Mysidopsis bigelowi																			
Lucifer faxoni	1															1			1
Acetes americanus cardinea										1									
Hargeria rapax																			
Xiphipeneus kroyeri			1																
Penaeus setiferus																			
Upobegia affinis		1																	
Callianassa latispina			1													1			
Polyonyx gibbesi	2																		
Euceramus praelongus																2			
Pagurus bullisi																3			
Hepatus pudibundus																1			
Panopeus turgidus	1																		
Panopeus herbstii																			
Portunus sayi		1																	
Pinnixa chaetopterana				1			1			5	1	1	1		2	1		3	
ECHINODERMATA (SEA STARS)																			
Amphipholis sp.	2	1						5	4		1			1		3			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
HEMICHORDATA (ACORN WORMS)																			
Ptychodera bahamensis											18	11		7	38		17		
CEPHALOCHORDATA (LANCELETS)																			
Branchistoma sp.															1	13			
Total Number	82	43	62	34	61	114	49	83	44	204	181	100	93	113	95	139	87	55	90
Density (m^2)	410	430	620	170	610	570	245	830	440	1020	905	500	465	565	475	695	435	550	450
Total Taxa	22	10	9	9	8	13	8	7	6	14	15	16	11	15	10	22	8	5	12

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[a] Collections at each station are based upon two Peterson grabs (0.1 m^2 each), except at Stations W2, W3, W5, W8, W9, and WR3 where only one grab was collected.

TABLE G.5-23 Benthic macroinvertebrates collected at the Weeks Island site, October 1977[a].

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
ANTHOZOA (SEA ANEMONES)	1															3			
RHYNCHOCELA (NEMERTEANS)	3	4	2		21	11	3			3	7	13	3	13	10	15	10		12
CHAETOGNATHA (ARROW WORMS)																			
Sagitta sp.							5	6			1								
GASTROPODA (SNAILS)																			
Anachis obesa	10	1			1											4			
Anachis sp.																			
Nassarius acutus	15		1		1		1	1			2		1		2	19		1	1
Tectonatica pussilla	1				1			1					1		2				1
Polinices duplicatus																1			
Epitonium rubicola																			
Epitonium sp.													2			1			
Prunum apicinum																			
Prunum sp.													1						1
Terebra protexa																			
Terebra sp.																			
Neritina sp.																			
Olivella dealbata	3																		
Turbonilla sp.	4															1			
Cantharus cancelarius																			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
SCAPHOPODA (TUSK SHELLS)																1			
Dentalium texasianum																			
PELECYPODA (CLAMS)																			
Mulinia lateralis	19	2	1		1					1						8		3	
Nuculana concentrica	1	3	3		5	3	2	5		2	6	2	1		2				5
Anadara ovalis	1						1												
Chione sp.																			
Noetidae																			
Semele proficua					1									1					
Semele belastritta																			
Pandora trilineata																			
Lucina multilineata																			
Lucina amiantus																			
Tellina sp.	3									2				1					1
Abra aequalis	3		1									1				8			
Gemma sp.																	1		
Mactra sp.	1																		
Solen viridis																			
Macoma constricta																			
Macoma sp.											2	10				1			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
POLYCHAETA (BRISTLE WORMS)																			
Spiophanes bombyx	53	22	18	10	34	5	24	32	5	48	37	45	10	43	28	172	6	7	53
Streblospio benedicti	5	20	2	22	9	10	55	23	7	17	16	6	5	26	12	14	16	33	17
Cossura longocirrata	3	1		4	13	7	41	28	9	30	58	42	8	24	26	1	48	8	20
Sigambra sp.	4	1	1	2		2	3			2				2	3	1	9		4
Lumbrineris sp.	6		2		1		3									4			
Lepidasthenia varia											1								
Pseudeurythoe ambigua																			
Malmgrenia cf. *lunulata*																			
Glycera sp.	1																		
Lepidonotus sp.																			
Gyptis brevipalpa											4						9		
Clymenella torquata				1			2												
Chaetopterus variopedatus																			
Onuphis opalina																			
Onuphis sp.																			
Diopatra cuprea	1	1							2				2	1	1				
Megelona rosea		1							1							1			
Cirratulus sp.																			
Amphictes gunneri							5												
Chone infundibuliformis																			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Glycinde solitaria							1	1		1									
Paraonis fulgens																			
Neanthes succinea	2	4		2	1		3	2								2	2		2
Aglaophamus verrilli	4															3			
Syllidae			1		1							2	1	2					
Stenolepis sp.	2																		
Scolupus cf. *elongatus*					1														
Ancistrosyllis spp.		1				1													
OLIGOCHAETA (AQUATIC EARTHWORMS)	4				23					7	22	6							
CRUSTACEA (CRABS, ISOPODS, ETC.)																			
Monoculodes intermedius																2			
Corophium sp.																			
Ogyrides limicola																1			
Campylaspis rubicunda																1			
Oxyurostylis smithi							1									1			
Edotea montosa																1			
Paracaprella pusilla																			
Calidus sp.																			
Mysidopsis bigelowi				1		4	1	1	1	1									
Lucifer faxoni																			

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Acetes americanus cardinea			2	1			2					1							
Hargeria rapax																			
Xiphipeneus kroyeri																			
Penaeus setiferus			10	16		19	10	5	55	1	18	17				3	6	130	
Upobegia affinis																			
Callianassa latispina	1															1			
Polyonyx gibbesi																			
Euceramus praelongus																			
Pagurus bullisi	2						9									2			
Hepatus pudibundus																			
Panopeus turgidus																			
Panopeus herbstii							1									1			
Portunus sayi																			
Pinnixa chaetopterana	1		3		3					1	4	10			4	3	10		
ECHINODERMATA (SEA STARS)																			
Amphipholis sp.	5		1					2	4						1	7			4
HEMICHORDATA (ACORN WORMS)																			
Ptychodera bahamensis			10		3						1	6	2	3			11		

TABLE G.5-22 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
CEPHALOCHORDATA (LANCELETS)																			
Branchistoma sp.															1				
Total Number	159	61	58	59	120	62	173	107	84	116	180	161	37	116	92	282	128	182	121
Density (m^2)	795	305	290	295	600	310	865	535	420	580	900	805	185	580	460	1410	640	910	605
Total Taxa	28	12	15	9	17	9	20	12	8	13	14	13	12	10	12	29	11	6	12

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[a] Collections at each station are based upon two Peterson grabs (0.1 m^2 each)

TABLE G.5-24 Benthic macroinvertebrates collected at the Weeks Island site, November 1977[a].

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
ANTHOZOA (SEA ANEMONES)																			
RHYNCHOCELA (NEMERTEANS)	5		3		2	3	2	10	2	6	13	18		9	5	10	10	1	5
CHAETOGNATHA (ARROW WORMS)																			
Sagitta sp.		3	1		7		6	1	1			1	13	28			3	6	
GASTROPODA (SNAILS)																			
Anachis obesa	2			1												1			
Anachis sp.																			
Nassarius acutus	7		1			1	1	2	5					1		1		1	2
Tectonatica pussilla																			
Polinices duplicatus																			
Epitonium rubicola						1													
Epitonium sp.																			
Prunum apicinum																			
Prunum sp.																			
Terebra protexa	1																		
Terebra sp.																			
Neritina sp.																			
Olivella dealbata																			
Turbonilla sp.																			
Cantharus cancelarius						1													

TABLE G.5-24 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
SCAPHOPODA (TUSK SHELLS)																			
Dentalium texasianum																			
PELECYPODA (CLAMS)																			
Mulinia lateralis	19	23	2												2		1	20	3
Nuculana concentrica	2	14	4	3	2	5				2	2	2	1	2	2	1			4
Anadara ovalis	1		1			1													
Chione sp.								1											
Noetidae																			
Semele proficua																			1
Semele belastritta																			
Pandora trilineata																			
Lucina multilineata																			
Lucina amiantus																			
Tellina sp.																			1
Abra aequalis	2																		
Gemma sp.																			
Mactra sp.																			
Solen viridis	1															1			
Macoma constricta	6		4					4			9					1			
Macoma sp.																			

TABLE G.5-24 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
POLYCHAETA (BRISTLE WORMS)																			
Spiophanes bombyx	16	16	20	57	17	47	52	54		44	23	34	42	11	37	68	6		34
Streblospio benedicti	2	8	6	28	8	35	45	31	43	4	4	17	29	9	12		30	29	19
Cossura longocirrata			27	20	11	18	50	59	10	28	55	20	4	8	14		79	1	8
Sigambra sp.				1		4		1	2		9		3	1	1	1	9		
Lumbrineris sp.	4		2		1	1									2	5			3
Lepidasthenia varia											1	1							
Pseudeurythoe ambigua						3			1										
Malmgrenia cf. *lunulata*																			
Glycera sp.																			
Lepidonotus sp.																			
Gyptis brevipalpa								1											
Clymenella torquata							2										1		
Chaetopterus variopedatus																			
Onuphis opalina																			
Onuphis sp.								1								1			
Diopatra cuprea			1		1	2		1	4										
Megelona rosea				1		1			3					1					
Cirratulus sp.																			
Amphictes gunneri																			
Chone infundibuliformis																1			
Glycinde solitaria								1			1	1	2		2		1		

TABLE G.5-24 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Paraonis fulgens																			
Neanthes succinea		2	4	1		5	6			3		4			1				1
Aglaophamus verrilli	1															5			
Syllidae					1		1												
Stenolepis sp.																			
Scolupus cf. *elongatus*																			
Ancistrosyllis spp.							1	1		2									
OLIGOCHAETA (AQUATIC EARTHWORMS)			3	3	26	3	2	24	10	9	9	8							9
CRUSTACEA (CRABS, ISOPODS, ETC.)																			
Monoculodes intermedius																			
Corophium sp.	1																		
Ogyrides limicola																			
Campylaspis rubicunda																			
Oxyurostylis smithi																			
Edotea montosa																			
Paracaprella pusilla																	1		
Calidus sp.									1		1								
Mysidopsis bigelowi																			
Lucifer faxoni																			
Acetes americanus cardinea	1						1							1					

TABLE G.5-24 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Hargeria rapax					1														
Xiphipeneus kroyeri																			
Penaeus setiferus																			
Upobegia affinis	1																		
Callianassa latispina		1																	
Polyonyx gibbesi																			
Euceramus praelongus		2																	
Pagurus bullisi	11															5			
Hepatus pudibundus																			
Panopeus turgidus																			
Panopeus herbstii						1													
Portunus sayi																			
Pinnixa chaetopterana	1		2						1										
ECHINODERMATA (SEA STARS)																			
Amphipholis sp.	23					1		2			1			2		10			1
HEMICHORDATA (ACORN WORMS)						1		4		2	8								
Ptychodera bahamensis																			
CEPHALOCHORDATA (LANCELETS)																			
Branchistoma sp.	5															1			

TABLE G.5-24 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Total Number	110	71	81	115	77	134	169	198	83	100	136	106	94	73	78	112	141	58	91
Density (m^2)	550	355	405	575	385	670	845	990	415	500	680	530	470	365	390	560	705	290	455
Total Taxa	19	10	15	9	11	19	12	17	12	9	13	10	7	11	10	15	10	6	13

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[a] Collections at each station are based upon two Peterson grabs (0.1 m^2 each)

TABLE G.5-25 Benthic macroinvertebrates collected at the Weeks Island site, December 1977[a].

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
ANTHOZOA (SEA ANEMONES)	2															2	1		
RHYNCHOCELA (NEMERTEANS)	9	3	3	8	3	17	7	18	4	4	8		3	5	2	26			2
CHAETOGNATHA (ARROW WORMS)	9	2	4		26	1	3						24	8		2			21
Sagitta sp.																			
GASTROPODA (SNAILS)																			
Anachis obesa	2	1							3									2	1
Anachis sp.																			
Nassarius acutus	7	4	1		3	1		3	11			1		2	2	2		2	1
Tectonatica pussilla					1	1		1						1					
Polinices duplicatus																			
Epitonium rubicola																			
Epitonium sp.																			
Prunum apicinum																			
Prunum sp.																			
Terebra protexa																			
Terebra sp.	1																		
Neritina sp.																			
Olivella dealbata																			
Turbonilla sp.	1					1			1			1							2
Cantharus cancelarius																			

TABLE G.5-25 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
SCAPHOPODA (TÜSK SHELLS)																			
Dentalium texasianum																			
PELECYPODA (CLAMS)																			
Mulinia lateralis	1	4							3						1	12		1	
Nuculana concentrica		8		1	3	4	1			2	3	1	1	5					5
Anadara ovalis																			
Chione sp.																			
Noetidae																			
Semele proficua	1					1													1
Semele belastritta																			
Pandora trilineata															1				
Lucina multilineata																			
Lucina amiantus																1			
Tellina sp.						1										2			
Abra aequalis										1						5			
Gemma sp.																			
Mactra sp.	1							1								2			
Solen viridis																			
Macoma constricta				1				5											
Macoma sp.																			

TABLE G.5-25 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
POLYCHAETA (BRISTLE WORMS)																			
Spiophanes bombyx	49	26	30	45	37	40	42	18	2	25	20	36	20	34	28	97	28	2	68
Streblospio benedicti		3	11	15	35	36	21	18	35	5	12	33	14	22	33		8	6	53
Cossura longocirrata			4	14	15	28	11	55	4	30	3	25	12	16	4	1	47		26
Sigambra sp.		2	1	8	2	3	2	4		1	3	1	3	3	4		1		3
Lumbrineris sp.	3			1			1		1						1	1			2
Lepidasthenia varia																			
Pseudeurythoe ambigua		1																	
Malmgrenia cf. lunulata														1		2			
Glycera sp.	1																		
Lepidonotus sp.																			
Gyptis brevipalpa								2									1		
Clymenella torquata		1																	
Chaetopterus variopedatus																			
Onuphis opalina																			
Onuphis sp.	1					2										4			
Diopatra cuprea	2										2			2		1			1
Megelona rosea						1					1					1			
Cirratulus sp.													1						
Amphictes gunneri																			
Chone infundibuliformis																			
Glycinde solitaria												3			2				

TABLE G.5-25 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Paraonis fulgens																			
Neanthes succinea		2			2	2	1	4	1		2	1	1		2	1	1		2
Aglaophamus verrilli	6															9			
Syllidae	1																		
Stenolepis sp.																			
Scolupus cf. *elongatus*																			
Ancistrosyllis spp.			1		1					3		1			1		1		1
OLIGOCHAETA (AQUATIC EARTHWORMS)			5		9	15	8	28	4	12			33	7	11	10	2	20	
CRUSTACEA (CRABS, ISOPODS, ETC.)																			
Monoculodes intermedius																			
Corophium sp.																			
Ogyrides limicola																			
Campylaspis rubicunda																			
Oxyurostylis smithi																			
Edotea montosa																			
Paracaprella pusilla																			
Calidus sp.																			
Mysidopsis bigelowi																			
Lucifer faxoni															2				
Acetes americanus cardinea																			
Hargeria rapax																			
Xiphipeneus kroyeri																			

TABLE G.5-25 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Peneus setiferus																			
Upobegia affinis																			
Callianassa latispina																			
Polyonyx gibbesi																			
Euceramus praelongus																			
Pagurus bullisi																4			
Hepatus pudibundus																			
Panopeus turgidus																			
Panopeus herbstii																			
Portunus sayi																			
Pinnixa chaetopterana		2															3		
ECHINODERMATA (SEA STARS)	7							1			1			1		8			
Amphipholis sp.																			
HEMICHORDATA (ACORN WORMS)								7									3		
Ptychodera bahamensis																			
CEPHALOCHORDATA (LANCELETS)																14			
Branchistoma sp.																			

TABLE G.5-25 continued.

	STATION																		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	WR1	WR2	WR3	WR4
Total Number	104	59	60	93	137	154	97	165	69	83	55	103	112	107	93	207	96	33	189
Density (m^2)	520	295	300	465	685	770	485	825	345	415	275	515	560	535	465	1035	480	165	945
Total Taxa	18	13	9	8	12	16	10	14	11	9	10	10	10	13	14	22	11	6	15

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[a] Collections at each station are based upon two Peterson grabs (0.1 m^2 each)

TABLE G.5-26 Benthic macroinvertebrates collected at the Chacahoula site, Seotember 1977[a].

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
ANTHOZOA (SEA ANEMONES)																	
TURBELLARIA (FLATWORMS)																	
RHYNCHOCOELA (NEMERTEANS)	2	3	7	15	10	6	1	7			17	6					
CHAETOGNATHA (ARROW WORMS)																	
Sagitta sp.	17	1	6	1		13	9	3			1			21		4	4
GASTROPODA (SNAILS)																	
Anachis obesa																	
Anachis sp.					1												
Nassarius acutus							1								1		
Tectonatica pussilla						1			6		5	4					
Epitonium rubicola																	
Oliva sayana																	
Cyclotremiscus sp.																	
Sinum maculatus																	
Sinum perspectivum	1										2						
Turbonilla sp.																	
Cantharus cancelarius					1		1										
PELECYPODA (CLAMS)																	
Mulinia lateralis	1		2	7		15	15		2	1	8	2				1	14
Nuculana concentrica	7	4	5			3			2	2	6						8

TABLE G.5-26 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Nuclana maculatus						2											
Chione sp.							1										
Semele proficua			1													1	
Semele bellastritta						2									1		
Lucina multilineata																	
Tellina sp.			1	17			8	11		11	2	4					4
Abra aequalis				2	4	6	2	2		1		1					2
Eucrassatella speciosa	1																
Solen viridis																	
Macoma sp.																	
POLYCHAETA (BRISTLE WORMS)																	
Spiophanes bombyx	3	4	12	43	17	43	95	81	6		58	12		4	73	3	13
Streblospio benedicti	1	3	6	37	27	39	4	5			16	1			7	6	5
Cossura longocirrata		1	1	10								1					
Sigambra sp.	4	4	1	9	2	5	2				2			2	8		
Lumbrineris sp.	4		2	18	7	9	7	8			9	15		3	3		6
Lepidasthenia varia				1													
Pseudeurythoe ambigua	1	1		1													
Malmgrenia cf. *lunulata*		1	1														
Glycera sp.								1									
Gyptis brevipalpa	1																
Clymenella torquata	1	4	4	10	4	2	2				3			1			

TABLE G.5-26 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Chaetopterus variopedatus																	
Onuphis opalina				1				3				2					
Onuphis sp.																	
Diopatra cuprea												1					1
Megelona rosea			1	1				2									
Cirratulus grandis					1			4	1								
Amphictes gunneri																	
Chone infundibuliformis									42							3	
Glycinde solitaria				3		2	1		1		5	1			1	7	
Neanthes succinea	3		4	21	5	30	10	1			6	5			8		3
Aglaophamus verrilli	4	3	2	25	7	4	40	18			9	4			8	7	4
Syllidae																	
Armandia maculata														1	2		
Stenolepis sp.	2			15	2	2	2	1	1		6	6		1		1	4
Scolupus cf. *elongatus*									20						5		
Ancistrosyllis spp.	1	1				1					1	2					
OLIGOCHAETA (AQUATIC EARTHWORMS)				65		28	10	50	12		12	20			66	87	
CRUSTACEA (CRABS, ISOPODS, ETC.)																	
Monoculodes intermedius			1														
Monoculodes sp.																	
Ampelisca abdita				1													1
Polyonyx gibbesi																	

TABLE G.5-26 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Corophium louisianaum							1										
Priscillina sp.									1								
Ogyrides limicola	1						1	2			2	3			1	12	
Campylaspis rubicunda			1														
Listriella barnardi	1			2													
Speocarcinus lobatus					1	1											
Leptochela serratorbita																	
Oxyurostylis smithi			2	4	2	1	3	16	2		5	1			1		2
Mysidopsis bigelowi							1										
Lucifer faxoni				1		1	3										
Acetes americanus cardinea																	1
Alpheus heterochaelis			1														
Automate kingsleyi					1	6					1						2
Hippolyte pleracantha												1					
Xiphipeneus kroyeri																	
Peneus setiferus	1		2	1		1								1		1	
Upobegia affinis			1			1											
Callianassa latispina	1		1		3	1				1		6					1
Callianassa jamicense																	
Argissa bamatipes																1	
Euceramus praelongus								1									
Pagurus bullisi							1										
Haustoriidae																	
Callinectes similis																	

TABLE G.5-26 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Albunea paretti																	
Chasmocarcinus mississippiensis																	
Squilla empusa																	
Osachila sp.																	
Persephona aquilonaris																1	
Panopeus herbstii																	
Portunus sp.																	
Pinnixa chaetopterana				6		3	2	1			2	1		1			1
Pinnixa retinens										1							
Pinnotheres ostreum							1										
ECHINODERMATA (SEA STARS)																	
Holothuroidea																	
Amphipholis sp.					2	3		9		2	3	5		1			1
HEMICHORDATA (ACORN WORMS)																	
Ptychodera bahamensis					4												
CEPHALOCHORDATA (LANCELETS)																	
Branchistoma sp.	6						2	1									
Total Number	64	30	66	317	101	231	226	227	96	19	181	104		36	185	135	79
Density (m^2)	320	150	660	1585	505	1155	1130	1135	480	95	905	520		180	925	1350	395
Total Taxa	23	13	23	26	19	28	27	21	12	7	23	23		10	14	14	20

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[a] Collections at each station are based upon two Peterson grabs ($0.1m^2$ each) except at Stations C3 and CR3 where only one grab was made. No samples were collected at Station C13.

TABLE G.5-27 Benthic macroinvertebrates collected at the Chacahoula site, October 1977[a].

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
ANTHOZOA (SEA ANEMONES)									2						1		
TURBELLARIA (FLATWORMS)											1						
RHYNCHOCELA (NEMERTEANS)		5	1	8	3	2			2	6	5	14	5	7		4	
CHAETOGNATHA (ARROW WORMS)																	
Sagitta sp.		9	8	5		6	10	2	3	3	6	1		4	3	3	
GASTROPODA (SNAILS)																	
Anachis obesa				2	1		1	7									
Anachis sp.																	
Nassarius acutus	1			1	5	8	11	16	7	2	3	1	1		6	1	1
Tectonatica pussilla						1	1	4			1	4	1		2	7	1
Epitonium rubicola									1							1	
Oliva sayana											1						
Cyclotremiscus sp.																	1
Sinum maculatus																	
Sinum perspectivum																	
Turbonilla sp.																	
Cantharus cancelarius				1				2									

TABLE G.5-27 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
PELECYPODA (CLAMS)																	
Mulinia lateralis	1	4		11	6			3		1		1	1		1		54
Nuculana concentrica	2	3	2		1					1		3	4				4
Nuculana maculatus																	
Chione sp.																	
Semele proficua																	
Semele bellastritta																	
Lucina multilineata						1											
Tellina sp.			5	5	1	10	9	4	1	15	5	8	13		4		1
Abra aequalis			1			1	2		2	2	2	2	2				
Solen viridis						2		1									
Eucrassatella speciosa																	
Macoma sp.															1		
POLYCHAETA (BRISTLE WORMS)																	
Spiophanes bombyx	6	20	17	59	46	35	44	79	11	111	13	49	39	31	13	20	25
Streblospio benedicti	4	9		27	44	31	30	18	2	7	37	62	12	10	2	6	5
Cossura longocirrata					5						1			5			1
Sigambra sp.	1	1			3	1					1	1	4	3			1
Lumbrineris sp.	3	7	12	17	18	11	7		1	16	17	16	13	4			6
Lepidasthenia varia											1						
Pseudeurythoe ambigua																	
Malmgrenia cf. lunulata																	

TABLE G.5-27 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Glycera sp.				2						1							
Gyptis brevipalpa																	
Clymenella torquata			2			2				4	3	4	3	1			3
Onuphis opalina																	
Onuphis sp.								1	2							1	
Diopatra cuprea									4	1		1					
Megelona rosea	1			1	2			4		2		1	1				
Cirratulus grandis								3	1	1	2	1					
Amphictes gunneri																	
Chone infundibuliformis									4							47	
Glycinde solitaria						2			3	1	1			1		2	
Neanthes succinea			1	12	2	12	13	3		5	2	19	3	1	1		1
Aglaophamus verrilli			5	8		8	15	37	6	16	2	4	5	2	46	6	6
Syllidae										1			1	1			10
Armandia maculata																	
Stenolepis sp.				6	5	11	2	8	1	12	8	7	2		7		1
Scolupus cf. *elongatus*						2	1		14							17	
Ancistrosyllis spp.									1				3				
OLIGOCHAETA (AQUATIC EARTHWORMS)					9		2				25	7			71		
CRUSTACEA (CRABS, ISOPODS, ETC.)																	
Monoculodes intermedius																	
Monoculodes sp.								1								2	

TABLE G.5-27 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Ampelisca abdita							1	1									
Polyonyx gibbesi		1															
Corophium louisianaum																	
Priscillina sp.																	
Ogyrides limicola				1		2	1	3			1	2			2	1	
Campylaspis rubicunda																	
Listriella barnardi																	
Speocarcinus lobatus	1			1								2	2				
Leptochela serratorbita						1							1				
Oxyurostylis smithi							4				1	6	1		2	2	1
Mysidopsis bigelowi		2	9	1	1	11				1							
Lucifer faxoni			5		1	4	1			3	1						
Acetes americanus cardinea		1	4		8	3	1							2			
Alpheus heterochaelis																	
Automate kingsleyi										1				1			
Hippolyte pleracantha																	
Xiphipeneus kroyeri																	
Peneus setiferus																	
Upobegia affinis										1		2					
Callianassa latispina						1				1		2	3			1	
Callianassa jamicense	3	1								1							

TABLE G.5-27 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Argissa bamatipes																	
Euceramus praelongus										1							
Pagurus bullisi						4		2			1	2			2	1	
Haustoriidae									1								
Callinectes similis																1	
Albunea paretti															2		
Chasmocarcinus mississippiensis	1												1				
Squilla empusa				1							1	2					
Osachila sp.										5							
Persephona aquilonaris																1	
Panopeus herbstii								1									
Portunus sp.				1													
Pinnixa chaetopterana	1	1		1	3					4		6	14	1	1		29
Pinnixa retinens																	
Pinnotheres ostreum																	
ECHINODERMATA (SEA STARS)																	
Holothuroidea				1										1			
Amphipholis sp.	1	1		1	1					5		3	3		1		2

TABLE G.5-27 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
HEMICHORDATA (ACORN WORMS)																	
Ptychodera bahamensis				1							4						12
CEPHALOCHORDATA (LANCELETS)																	
Branchistoma sp.																	
Total Number	26	65	72	174	165	172	156	200	69	231	146	233	138	75	168	124	165
Density (m^2)	125	325	360	870	825	860	780	1000	345	1155	730	1165	690	375	840	620	825
Total Taxa	13	14	13	24	20	25	19	21	20	30	27	29	25	16	19	19	20

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[a] Collections at each station are based upon two Peterson grabs (0.1 m^2 each).

TABLE G.5-28 Benthic macroinvertebrates collected at the Chacahoula site, December 1977[a].

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
ANTHOZOA (SEA ANEMONES)																	
TURBELLARIA (FLATWORMS)																	
RHYNCHOCELA (NEMERTEANS)					11							9	28	15			12
CHAETOGNATHA (ARROW WORMS)					2							2					
Sagitta sp.																	
GASTROPODA (SNAILS)																	
Anachis obesa																	
Anachis sp.																	
Nassarius acutus					1												
Tectonatica pussilla													1				
Epitonium rubicola																	
Oliva sayana																	
Cyclotremiscus sp.																	
Sinum maculatus													1				
Sinum perspectivum																	
Turbonilla sp.																	
Cantharus cancelarius														1			
PELECYPODA (CLAMS)																	
Mulinia lateralis																	
Nuculana concentrica					1								1				1
Nuculana maculatus																	

TABLE G.5-28 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Chione sp.																	
Semele proficua																	
Semele bellastritta																	
Lucina multilineata																	
Tellina sp.					1								15				1
Abra aequalis					4								7				
Eucrassatella speciosa																	
Solen viridis																	
Macoma sp.																	
POLYCHAETA (BRISTLE WORMS)																	
Spiophanes bombyx					30							16	20	11			3
Streblospio benedicti					15							15	13	2			11
Cossura longocirrata																	4
Sigambra sp.					1								2				1
Lumbrineris sp.					15							14	12	3			13
Lepidasthenia varia																	
Pseudeurythoe ambigua																	
Malmgrenia cf. *lunulata*																	
Glycera sp.												1					1
Gyptis brevipalpa												1					
Clymenella torquata					7							3	24	2			12
Onuphis opalina																	

TABLE G.5-28 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Chaetopterus variopedatus																	
Onuphis sp.																	
Diopatra cuprea					2								1				
Megelona rosea					1								1	1			
Cirratulus grandis																	
Amphictes gunneri													1				
Chone infundibuliformis																	
Glycinde solitaria					3												
Neanthes succinea					1							6	2				3
Aglaophamus verrilli					14							4	8				
Syllidae													1				1
Armandia maculata					1												
Stenolepis sp.					8							5	2				
Scolupus cf. *elongatus*																	
Ancistrosyllis spp.																	
OLIGOCHAETA (AQUATIC EARTHWORMS)													20	10			
CRUSTACEA (CRABS, ISOPODS, ETC.)																	
Monoculodes intermedius																	
Monoculodes sp.																	
Ampelisca abdita					2							1	1				
Polyonyx gibbesi																	
Corophium louisianaum																	
Priscillina sp.																	
Ogyrides limicola													1				

TABLE G.5-28 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Campylaspis rubicunda																	
Listriella barnardi																	
Speocarcinus lobatus																	
Leptochela serratorbita													1				
Oxyurostylis smithi												1	2				
Mysidopsis bigelowi																	
Lucifer faxoni																	
Acetes americanus cardinea																	
Alpheus heterochaelis																	
Automate kingsleyi																	
Hippolyte pleracantha																	
Xiphipeneus kroyeri					1												
Peneus setiferus																	
Upobegia affinis																	
Callianassa latispina													4	1			
Callianassa jamicense																	
Argissa bamatipes																	
Euceramus praelongus					1												
Pagurus bullisi													1				
Haustoriidae																	
Callinectes similis																	
Albunea paretti																	
Chasmocarcinus mississippiensis																	

TABLE G.5-28 continued.

	STATION																
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	CR1	CR2	CR3	CR4
Squilla empusa																	
Osachila sp.																	
Persephona aquilonaris																	
Panopeus aquilonaris																	
Panopeus herbstii																	
Portunus sp.																	
Pinnixa chaetopterana					2							1	6	1			3
Pinnixa retinens																	
Pinnotheres ostreum																	
ECHINODERMATA (SEA STARS)					6								2	1			
Holothuroidea																	
Amphipholis sp.																	
HEMICHORDATA (ACORN WORMS)													1				
Ptychodera bahamensis																	
CEPHALOCHORDATA (LANCELETS)																	
Branchistoma sp.												1					
Total Number					130							81	179	48			66
Density (m^2)					650							810	895	240			330
Total taxa					23							15	28	11			13

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[a] Collections at Stations C5, C13, CR1 and CR4 based upon two Peterson grabs (0.1 m^2 each) and one grab at Station C12. Samples were not collected at other stations.

TABLE G.5-29 Summary of trawl catches of invertebrates and fish collected at Weeks Island survey site, September 17, 1977[a].

Common Name	Relative Abundance (%)	Number Collected	Mean Length (mm)
INVERTEBRATES			
Sea nettle	1.0	6	
Cabbagehead	4.0	24	
Sea anemone	0.3	2	
Moon snail	1.5	9	
Arc shell	0.3	2	
Brief squid	4.7	28	
Mantis shrimp	4.4	26	
White shrimp	14.6	87	
Brown shrimp	4.4	26	
Penaeid shrimp (juvenile)	4.2	25	
Seabob	44.4	264	
Rock shrimp	1.3	8	
Hermit crab	0.3	2	
Purse crab	0.7	4	
Blue crab	2.3	14	
Swimming crabs (juvenile)	11.6	69	
Total Invertebrates		596	
FISH			
Gulf menhaden	0.05	1	160
Bay anchovy[b]	57.9	1439	50
Striped anchovy	0.05	1	88
Sea catfish[b]	7.7	192	98
Gafftopsail catfish[b]	1.1	27	121
Atlantic midshipman[b]	0.8	21	64
Crested cusk-eel[b]	0.3	7	126
Chain pipefish	0.05	1	130
Atlantic bumper	0.3	8	86
Bluntnose jack[b]	0.8	19	43
Atlantic croaker[b]	7.7	191	133
Sand seatrout[b]	15.4	383	45

TABLE G.5-29 continued.

Common Name	Relative Abundance (%)	Number Collected	Mean Length (mm)
Spot	0.05	1	125
Star drum[b]	2.1	53	55
Spadefish	0.15	3	55
Atlantic threadfin	0.4	9	165
Fat sleeper[b]	0.05	1	59
Atlantic cutlassfish	0.1	2	300
Gulf butterfish	0.4	9	99
Blackfin scarobin[b]	0.05	1	68
Fringed flounder[b]	0.20	4	81
Bay whiff[b]	0.2	5	75
Hogchoker[b]	0.15	3	95
Blackcheek toungfish[b]	0.7	18	91
Least puffer[b]	3.3	83	44
Total Fish		2482	

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[a] Data based on composit sample of three trawls of about 45 minutes each

[b] Mean length estimated

TABLE G.5-30 Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, October 14, 1977[a].

Common Name	Relative Abundance (%)	Number Collected[b]	Mean Length (mm)
INVERTEBRATES			
Hydroid colony		P	
ARC shell	0.3	1	
Brief squid	38.8	113	
Mantis shrimp	1.7	5	
White shrimp	53.8	156	
Brown shrimp	1.4	4	
Striped hermit crab	0.3	1	
Purse crab	0.3	1	
Blue crab	0.7	2	
Swimming crabs (juvenile)	2.7	8	
Bryozoan		P	
Total Invertebrates		291	
FISH			
Bay anchovy[c]	96.4	10116	51
Striped anchovy	0.05	5	108
Sea catfish[c]	0.42	44	132
Atlantic midshipman	0.01	1	41
Atlantic moonfish	0.01	1	90
Lookdown	0.01	1	69
Atlantic bumper	0.20	21	66
Crevalle jack	0.01	1	130
Atlantic croaker[c]	0.28	29	121
Sand seatrout[c]	0.61	64	113
Star drum[c]	0.89	92	64
Spadefish	0.06	6	74
Southern stargazer	0.01	1	27
Atlantic cutlassfish[c]	0.70	73	317
Gulf butterfish	0.03	3	155

TABLE G.5-30 continued.

Common Name	Relative Abundance (%)	Number Collected[b]	Mean Length (mm)
Fringed flounder	0.02	2	77
Bay whiff	0.02	2	94
Lined sole	0.01	1	60
Blackcheek toungfish	0.20	20	102
Least puffer	0.06	6	48
Total Fish		10489	

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[a] Data based on composit sample of three trawls of about 38 minutes each

[b] P - Present in trawl

[c] Mean length estimated

TABLE G.5-31 Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, November 12, 1977[a].

Common Name	Relative Abundance (%)	Number Collected[b]	Mean Length (mm)
INVERTEBRATES			
Hydroid Colony		P	
Sea anemone (unidentified)	2.4	16	
Moon snail	0.45	3	
Brief squid	5.5	37	
Mantis shrimp	4.8	32	
White shrimp	22.8	152	
Brown shrimp	2.3	15	
Penaeid shrimp (juvenile)	19.0	127	
Seabob	32.8	219	
Spider crab	0.15	1	
Blue crab	9.5	63	
Swimming crab (juvenile)	0.3	2	
Bryozoan		P	
Total Invertebrates		667	
FISH			
Shrimp eel	0.3	3	340
Gulf menhaden	0.2	2	174
Bay anchovy[c]	44.0	499	68
Sea catfish[c]	7.8	88	86
Crested cusk-eel	0.2	2	166
Chain pipefish	0.3	3	103
Southern kingfish	0.2	2	101
Atlantic croaker	0.7	8	134
Sand seatrout[c]	6.0	67	107
Star drum[c]	36.9	416	61
Banded drum	0.2	2	56
Spadefish	0.4	2	56
Southern stargazer	0.1	1	57

TABLE G.5-31 continued.

Common Name	Relative Abundance (%)	Number Collected[b]	Mean Length (mm)
FISH			
Bighead sea robin	0.1	1	120
Fringed flounder	0.1	1	59
Bay whiff	0.1	1	60
Lined sole	0.2	2	51
Hogchoker	0.9	10	87
Blackcheek toungfish[c]	1.0	11	103
Least puffer	0.3	3	48
Total Fish		1126	

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[a] Data based on composite sample of three trawls of about 38 minutes each

[b] P - Present in trawl

[c] Mean length estimated

TABLE G.5-32 Summary of trawl catches of invertebrates and fish collected at the Weeks Island survey site, December 15, 1977[a].

Common Name	Relative Abundance (%)	Number Collected	Mean Length (m[illegible])
INVERTEBRATES			
Brief squid	3.4	40	
Mantis shrimp	0.15	2	
White shrimp	9.0	106	
Seabob	85.15	1003	
Blue crab	1.3	15	
Swimming crab (Juvenile)	1.0	12	
Total Invertebrates		1178	
FISH			
Bay Anchovy[b]	45.5	150	68
Sea catfish	0.9	3	82
Skilletfish	1.2	4	55
Chain pipefish	0.6	2	133
Atlantic croaker	0.6	2	163
Sand seatrout	16.0	53	88
Spot	3.0	10	139
Star drum[b]	18.4	61	81
Silver perch	1.2	4	116
Spadefish	0.3	1	57
Atlantic cutlassfish	1.2	4	293
Gulf butterfish	2.7	9	47
Bighead sea robin	0.3	1	46
Line sole[b]	0.3	1	30
Hogchoker	3.3	11	83
Blackcheek toungfish	4.2	14	98
Least puffer	0.3	1	78
Total Fish		331	

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[a] Data based on composit sample of three trawls of about 32 minutes eac[illegible]

[b] Mean length estimated.

TABLE G.5-33 Summary of trawl catches of invertebrates and fish collect at the Chacahoula survey site, September 19, 1977[a].

Common Name	Relative Abundance (%)	Number Collected	Mean Length (mm)
INVERTEBRATES			
Sea anemone	21.7	5	
Brief squid	56.9	13	
White shrimp	8.7	2	
Hermit crab	8.7	2	
Swimming crabs (juvenile)	4.0	1	
Total Invertebrates		23	
FISH			
Bay anchovy[b]	40.0	76	45
Striped anchovy	3.0	6	118
Sea catfish	6.5	13	255
Atlantic bumper	4.5	9	164
Lane snapper	0.5	1	85
Atlantic croaker[b]	23.0	44	152
Sand seatrout	16.0	31	154
Spot	0.5	1	150
Star drum	0.5	1	127
Spadefish	0.5	1	120
Atlantic cutlassfish	2.5	5	183
Gulf butterfish	0.5	1	150
Blackfin sea robin	0.5	1	130
Fringed flounder	0.5	1	103
Least puffer	0.5	1	48
Striped burrfish	0.5	1	133
Total Fish		193	

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[a] Data based on composite sample of two trawls of about 66 minutes each

[b] Mean length estimated

TABLE G.5-34 Summary of trawl catches of invertebrates and fish collect
at the Chacahoula survey site, October 15, 1977[a].

Common Name	Relative Abundance (%)	Number Collected[b]	Mean Length (mm)
INVERTEBRATES			
Hydroid colony		P	
Moon jellyfish	28.0	62	
Sea anemone	3.0	7	
Channeled whelk	0.5	1	
Brief squid	60.5	135	
Mantis shrimp	1.0	2	
White shrimp	2.0	4	
Brown shrimp	1.5	3	
Hermit crab	2.5	6	
Swimming crabs (Juvenile)	0.5	1	
Starfish	0.5	1	
Total Invertebrates		222	
FISH			
Scaled sardine	0.1	1	83
Gulf menhaden	0.1	1	176
Bay anchovy[c]	48.7	414	50
Striped anchovy[c]	20.0	172	115
Offshore lizardfish	0.1	1	278
Sea catfish[c]	5.0	43	271
Atlantic midshipman	0.1	1	104
Atlantic moonfish	0.3	3	121
Atlantic bumper[c]	7.3	63	124
Bluntnose jack	0.1	1	38
Longspine porgy	0.1	1	85
Pinfish	0.2	2	142
Southern kingfish	0.6	5	172
Atlantic croaker	8.6	74	161
Sand seatrout	0.9	8	161
Spot[c]	4.9	42	159

TABLE G.5-34 continued.

Common Name	Relative Abundance (%)	Number Collected[b]	Mean Length (mm)
Atlantic cutlassfish	1.5	13	133
Gulf butterfish	0.3	3	159
Blackfin sea robin	0.3	3	121
Fringed flounder	0.3	3	112
Blackcheek toungfish	0.1	1	57
Least puffer	0.4	4	44
Total Fish		859	

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[a] Data based on composit sample of three trawls of about 60 minutes each.

[b] P - Present in trawl.

[c] Mean length estimated.

TABLE G.5-35 Summary of trawl catches of invertebrates and fish collected at the Chacahoula survey site, December 4, 1977[a].

Common Name	Relative Abundance (%)	Number Collected	Mean Length (mm)
INVERTEBRATES			
Moon jellyfish	0.5	1	
Sea anemone	4.0	8	
Southern oyster drill	0.5	1	
Brief squid	23.0	48	
Mantis shrimp	1.0	2	
White shrimp	25.5	54	
Brown shrimp	2.5	5	
Penaeid shrimp (juvenile)	37.5	80	
Hermit crab	1.5	3	
Spider crab	0.5	1	
Blue crab	1.0	2	
Swimming crab	2.0	4	
Starfish	0.5	1	
Total Invertebrates		210	
FISH			
Bay anchovy[b]	0.9	8	43
Sea catfish	0.4	4	251
Atlantic midshipmen	0.1	1	73
Crested cusk-eel[b]	0.3	3	167
Southern kingfish	1.7	16	190
Atlantic croaker[b]	26.8	246	162
Sand seatrout	0.1	1	140
Silver seatrout[b]	50.8	463	55
Star drum[b]	1.7	16	89
Banded drum[b]	15.0	138	61
Spadefish	0.1	1	45
Atlantic cutlassfish	0.1	1	190

TABLE G.5-35 continued.

Common Name	Relative Abundance (%)	Number Collected	Mean Length (mm)
FISH			
Gulf butterfish	0.2	2	13
Bighead sea robin	0.1	1	34
Blackfin sea robin	0.1	1	25
Fringed flounder	0.2	2	105
Blackcheek toungfish	0.3	3	102
Least puffer[b]	1.1	10	48
Total Fish		917	

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[a] Data based on three trawls of about 30 minutes each

[b] Mean length estimated

TABLE G.5-36 Invertebrates characteristic of the offshore Louisiana coastal region based upon trawl samples.

Scyphozoa: medusae (jellyfish)

Anthozoa: sea anemones

Ctenophora: comb jellies
- *Pleurobranchia* sp.

Gastropoda: snails
- *Polinices duplicatus*
- *Murex* sp.
- *Thais haemostoma*
- *Busyon* sp.
- *Oliva sayana*
- *Cancellaria reticulata*
- other gastropods

Pelecypoda: clams
- *Rangia cuneata*
- *Nuculana acuta*
- *Dinocardium robustrum*
- *Dosinis discus*
- other pelecypods

Cephalopoda: squid
- *Lolliguncula brevis*

Crustacea: shrimp and crabs
- *Acetes americanus*
- *Squilla* sp.
- *Penaeus setiferus*
- *Penaeus duorarum*
- *Penaeus aztecus*
- *Xiphopeneus* sp.
- *Trachypenaeus* sp.
- Unidentified shrimp
- *Palaemonetes vulgaris*
- *Crangon* sp.

TABLE G.5-36 continued.

- *Sicyonia* sp.
- *Clibinarius vitatus*
- Unidentified hermit crab
- *Hepatus epheliticus*
- *Leiolambrus nitidus*
- *Persephona crinata*
- *Libinia emarginata*
- *Portunus spihocarpus*
- *Portunus gibbesii*
- *Callinectes sapidus*
- *Callinectes similis*
- *Calappa sulcata*
- *Ovalipes* sp.
- *Panopeus* sp.

Asteriodea: starfish

Ophiuroidea: brittle star

Perret, 1971; Ragan and Harris, 1975

TABLE G.5-37 Fish characteristic of the Louisiana coastal region base
upon trawl samples.

Common Name	Scientific Name
CLASS CHONDRICTHYS (sharks and rays)	
Smooth dogfish	*Mustelus canis*
Atlantic sharpnose shark	*Rhizoprionodon terraenova*
Bonnethead	*Sphyrna tiburo*
Lesser electric ray	*Narcine brasiliensis*
Roundel skate	*Raja texana*
Atlantic stingray	*Dasyatis sabina*
Smooth butterfly ray	*Gymnura micrura*
Cownose ray	*Rhinoptera bonasus*
CLASS OSTEICHTHYS (bonyfish)	
Skipjack herring	*Alosa chrysochloris*
Gulf menhaden	*Brevoortia patronus*
Atlantic herring	*Clupea harengus*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorsoma petenense*
Scaled sardine	*Harengula pensacolae*
Atlantic thread herring	*Opisthonema oglinum*
Striped anchovy	*Anchoa hepsetus*
Bay anchovy	*Anchoa mitchilli*
Inshore lizardfish	*Synodus foetens*
Blue catfish	*Ictalurus furcatus*
Sea catfish	*Arius felis*
Gafftopsail catfish	*Bagre marinus*
Oyster toadfish	*Opsanus tau*
Atlantic midshipman	*Porichthys porosissimus*
Singlespot frogfish	*Antennarius radiosus*
Sargassumfish	*Histrio histrio*
Pancake batfish	*Halieutichthys aculeatus*
Batfish	*Ogcocephalus* sp.
Bearded brotula	*Brotula barbata*

TABLE G.5-37 continued.

Crested cusk eel	_Ophidion welshi_
Unidentified cusk eel	
Longnose killifish	_Fundulus similis_
Rough silverside	_Membras martinica_
Tidewater silverside	_Menidia beryllia_
Pipefish	_Syngnathus_ sp.
Snook	_Centropomus undecimalis_
Rock sea bass	_Centropristis philadelphica_
Sand perch	_Diplectrum formosum_
Bluefish	_Pomatomus saltatrix_
Sharksucker	_Echeneis naucrates_
Crevalle jack	_Caranx hippos_
Jack	_Caranx_ sp.
Atlantic bumper	_Chloroscombrus chrysurus_
Leatherjacket	_Oligoplites saurus_
Greater Amberjack	_Seriola dumerili_
Look down	_Selene vomer_
Florida pompano	_Trachinotus carolinus_
Rough scad	_Trachurus lathami_
Atlantic moonfish	_Vomer setapinnis_
Red snapper	_Lutjanus campechanus_
Gray snapper	_Lutjanus griseus_
Lane snapper	_Lutjanus synagris_
Tripletail	_Lobotes surinamensis_
Silver jenny	_Eucinostomus gula_
Pigfish	_Orthopristis chrysoptera_
Sheepshead	_Archosargus probatocephalus_
Pinfish	_Lagodon rhomboides_
Longspine porgy	_Stenotomus caprinus_
Silver perch	_Bairdiella chrysura_
Sand seatrout	_Cynoscion arenarius_
Spotted seatrout	_Cynoscion nebulosus_
Silver seatrout	_Cynoscion nothus_

TABLE G.5-37 continued.

High hat	Equetus acuminatus
Banded drum	Larimus fasciatus
Spot	Leiostomus xanthurus
Southern kingfish	Menticirrhus americanus
Gulf kingfish	Menticirrhus littoralis
Atlantic croaker	Micropogon undulatus
Black drum	Pogonias cromis
Red drum	Sciaenops ocellata
Star drum	Stellifer lanceolatus
Atlantic spadefish	Chaetodipterus faber
Striped mullet	Mugil cephalus
Great barracuda	Sphyraena barracuda
Atlantic threadfin	Polydactylus octonemus
Southern stargazer	Astroscopus y-graecum
Gobies	
Atlantic cutlassfish	Trichiurus lepturus
King mackerel	Scomberomorus cavalla
Spanish mackerel	Scomberomorus maculatus
Harvestfish	Peprilus alepidotus
Gulf butterfish	Peprilus burti
Barbfish	Scorpaena brasiliensis
Horned searobin	Bellator militaris
Bluespotted searobin	Prionotus roseus
Blackfin searobin	Prionotus rubio
Bighead searobin	Prionotus tribulus
Searobins	Prionotus sp.
Ocellated flounder	Ancylopsetta quadrocellata
Spotted whiff	Citharichthys macrops
Bay whiff	Citharichthys spilopterus
Mexican flounder	Cyclopsetta chittendeni
Spotfin flounder	Cyclopsetta fimbriata
Fringed flounder	Etropus crossotus

TABLE G.5-37 continued.

Gulf flounder	Paralichthys albigutta
Souther flounder	Paralichthys lethostigma
Shoal flounder	Syacium gunteri
Lined sole	Achirus lineatus
Hogchocker	Trinectes maculatus
Blackcheek tonguefish	Symphurus plagiusa
Gray triggerfish	Balistes capriscus
Planehead filefish	Monocanthus hispidus
Northern puffer	Sphoeroides maculatus
Southern puffer	Sphoeroides nephelus
Least puffer	Sphoeroides parvus
Striped burrfish	Chilomycterus schoepfi

(Perret, 1971; Ragan and Harris, 1975)

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APPENDIX H

DEEP WELL INJECTION OF BRINE

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DEEP WELL INJECTION OF BRINE

An alternate method of disposing of brines displaced from the Strategic Petroleum Reserve (SPR) caverns during oil fill and cavern leaching is by deep well injection. Disposal is accomplished by injecting brines under pressure into wells completed in deep sand reservoirs.

Certain physical conditions are prerequisite to successful subsurface disposal operations. A reservoir having sufficient volume and three-dimensional continunity to accommodate injected brine must exist. Further, the hydraulic characteristics of the reservoir must be such that it will readily transmit injected brines. Finally, the reservoir must be isolated hydraulically to preclude contamination of fresh water aquifers.

The potential impacts associated with subsurface injection of brines are:

- contamination of ground water aquifers
- aquifer fracture
- chemical and physical problems of fluid incompatibility
- interference with oil and gas reservoirs
- earthquake inducement

Contamination of Ground Water Aquifers

Contamination of overlying fresh water aquifers can occur by direct influx of deep-injected brines into shallower horizons, aquiclude fracture, leakage through permeable beds separating the deeper zones from shallower zones, leakage through improperly cased wells, abandoned wells, or wells which are open to both the injection zone, and to the fresh water aquifers.

The geologic section which was considered for disposal is characterized by poorly consolidated sediments, consisting primarily of sands, silts, clays and partially indurated shales. Sand units comprise an estimated 40% of the total section, while the remaining portion of the section consists of relatively impermeable silts, clays, and shales, which have characteristically poor transmitting properties, and may serve to preclude the vertical movement of the injected brines. Brines will be injected into deep (greater than 3,000 feet) saline reservoirs well below the lowermost usable fresh water aquifer.

Assurances that no contamination will result from leakage through wells requires that all wells within the area of influence of the injection field be identified, and properly sealed where necessary. Because the brine disposal reservoirs may be uplifted in the vicinity of the dome, it is essential that abandoned wells completed at depths shallower than the disposal reservoir also be checked. If any wells are found to be improperly plugged, they would be replugged in accordance with accepte procedures. If a substantial number of the wells appear to need replugging, it may be necessary to move the injection site.

Aquifer Fracture

A satisfactory reservoir for subsurface waste disposal must possess adequate volume and have impermeable strata such as shale aquicludes above and below the storage layer. Excessive pressure buildup could lead to aquiclude fracture and loss of containment. Pressure buildup depends upon:

- aquifer size
- injection rate
- quantity of waste fluid
- aquifer porosity
- aquifer permeability
- clogging agents in the waste such as colloids or materials which support bacterial growth

The potential for aquifer fracture exists whenever the pressure conditions within a reservoir exceed the prevailing stress field. The prevailing stress field in the reservoir is the result of the lithostatic weight of overburden materials and the hydrostatic weight of the fluid column existing within and above the reservoir. Experience in the Gulf Coast sediments suggests gradients of 1.0 and 0.5 pounds per square inch per foot of depth (psi/ft) for the lithostatic and hydrostatic gradients, respectively. Fracture gradients in the Gulf Coast sediments have been observed in the range of 0.54 to 0.8 psi/ft. Careful monitoring of well-head and bottom hole pressures during injection will be required to insure that fracture pressures are not exceeded.

Chemical and Physical Problems of Fluid Incompatibility

Impacts associated with chemical and physical incompatibility of injected brines with respect to native formation fluids will be confined to the vicinity of the injection well bore where it penetrates the receiving disposal reservoir. Analyses of brines injected at other SPR sites have indicated no significant compatibility problems. The reservoirs considered for injection contain moderately to highly saline waters (on the order of 30,000 to 100,000 ppm total dissolved solids) and should therefore pose no problems with respect to receiving SPR brines, which will range in concentration from 90,000 ppm to an effectively saturated brine (264,000 ppm).

Interference with Oil and Gas Reservoirs

Impacts on oil and gas reservoirs and production can result directly from the influx and flushing of these reservoirs by injected brines. The oil and gas reservoirs can also be impacted indirectly, by the effects of reservoir pressurization attendant to the injection operations. In order that these impacts are minimized or avoided, injection wells must be located such that the area of influence of the disposal operation does not impinge on the oil and gas reservoirs. Vertical and stratigraphic separations between injection depths and the oil and gas reservoirs will further insure that no impacts result from the disposal operation. However, it is possible that pressure buildup in the disposal sands would be accompanied by slight pressure increases in oil and gas strata. This could benefit overall hydrocarbon production by reducing the effect of pressure loss due to oil and gas depletion.

Earthquake Inducement

Earthquakes may be induced when faults are lubricated by injected fluids. There is documented evidence of earthquakes being triggered as a result of subsurface injection of fluid accompanied by an increase in injection reservoir pressure. The two known cases of this phenomenon have occurred in Colorado in an area of high natural rock stresses. One occurred near Denver and was associated with a disposal well containi liquid waste from the Rocky Mountain Arsenal. The other occurred near Rangely, Colorado and was associated with water injection into wells of the Rangely oil field. The mechanisms causing the earthquake are not well understood; however, one possible explanation is that stresses on opposite sides of existing fault planes were not sufficiently large to overcome frictional forces along the plane and cause movement until the waste fluids were injected and acted as a lubricant. Stresses are relieved by plastic deformation or rupture of rocks. If the plasticity of a rock is relatively low, the stress continues to increase until rupture (faulting) occurs. In the Gulf Coast area, the unconsolidated sediments, as opposed to the consolidated rock in Colorado, are very plastic and stress relief comes in the form of plastic deformation. Although faults do exist in the Gulf Coast, movement along these planes due to lubrication by injected brine seems unlikely. Numerous flood water and liquid waste injection sites have been in operation along the Louisiana-Texas Gulf Coast for many years without reported occurrences of earthquakes. In addition, the National Oceanic and Atmospheric Administration has classified this area as having no reasonable expect of surface earthquake damage (Figure B.2-7).

APPENDIX I

HYDROCARBON EMISSIONS AND MODEL TO CALCULATE GROUND-LEVEL CONCENTRATIONS

Part I	Summary of Emissions from Tanker and Barge Transfers and Model Used to Calculate Downwind Ground-Level Concentrations
Part II	Description of the Physical and Chemical Basis for Emissions from Marine Vessel Transfer of Crude Oil

APPENDIX
Part I

ESTIMATES OF EMISSIONS FROM TANKER AND BARGE TRANSFERS AND MODEL USED TO CALCULATE DOWNWIND GROUND-LEVEL CONCENTRATIONS

I.1 EMISSIONS FROM BARGE AND TANKER TRANSFERS

Hydrocarbon emission factors for petroleum loading/unloading were based upon American Petroleum Institute (API) publication 2514-A (1976) and Appendix I, Part II. A summary of average and maximum emission factors at three crude oil temperatures are set forth below:

		Emission Factors (lb/1000 gal transferred)					
		Average			Maximum		
		70°F	100°F	120°F	70°F	100°F	120°F
Ship Loading:	Cleaned	0.30	0.38	0.48	0.33	0.45	0.56
	Uncleaned	0.79	0.88	0.97	0.83	0.94	1.05
	Average	0.55	0.63	0.73	0.58	0.70	0.81
Barge Loading:	Cleaned	0.48	0.57	0.68	0.52	0.65	0.77
	Uncleaned	1.54	1.65	1.75	1.59	1.71	1.84
	Average	1.01	1.11	1.22	1.06	1.18	1.31
Ship Ballasting:	Cleaned	0.17	0.17	0.17	0.17	0.17	0.17
	Uncleaned	0.66	0.66	0.66	0.66	0.66	0.66
	Average	0.42	0.42	0.42	0.42	0.42	0.42

Average emission factors were based on a Reid vapor pressure (RVP) of 4 psia, while maximum emission factors were based on a RVP of 5 psia. The crude oil temperature was assumed to be 70°F during fill and 120°F during withdrawal operations (except 100°F for crude oil stored at Weeks Island). The specific emission factors used for the transfer operations in Section C.3.2.2.3 are as follows (lb/1000 gal):

1) Transfer of oil between VLCC and 45 MDWT tankers 12 miles offshore: 0.30 (loading) + 0.42 (ballasting) = 0.72
2) Transfer from 45 MDWT tankers to 20,000 barrel barges at Port Allen: 1.54 (loading) + 0.42 (ballasting) = 1.96
3) Offloading 45 MDWT tankers at the St. James docks: (ballasting) = 0.42

4) Loading 20,000 barrel barges at Bull Bay: 1.75 (loading) + 0 = 1.75

5) Loading 80 MDWT tankers at the St. James docks: 0.73 (loading) + 0 = 0.73 (except 0.63 for Weeks Island oil)

An average value of 0.42 lb/1000 gal was used for all ballasting emissions.

Maximum emission factors used in Section C.3.2.2.3 were based upon uncleaned tankers and barges. These factors are as follows (lb/1000 gal):

1) VLCC transfer to 45 MDWT tankers in the Gulf: 0.83 (loading) + 0.66 (ballasting) = 1.49

2) Loading 80 MDWT tankers at the St. James docks: 1.05 (loading) + 0 = 1.05

A description of the physical and chemical basis for these emission factors is provided in Appendix I, Part II.

I.2 LOSSES IN TRANSIT

Transit losses are estimated at 0.01 percent per psia true vapor pressure (TVP) per week in transit (EPA, 1976e). Transit emission factors were based on a RVP of 4 psia and are 0.0067 lb/hr/1000 gal at 70°F, 0[illegible] lb/hr/1000 gal at 100°F and 0.01674 lb/hr/1000 gal at 120°F. Transit times for the Capline oil distribution are as follows:

45 MDWT Tanker transit from 12 miles offshore to Port Allen	44 hours
Barge transit from Port Allen to Bull Bay	2 hours
45 MDWT Tanker transit from 12 miles offshore to St. James	32 hours
45 MDWT Tanker transit from 12 miles offshore to Nordix	41 hours
Barge transit from Bull Bay to Baton Rouge	3 hours
80 MDWT Tanker transit from St. James to 12 miles offshore	33 hours
80 MDWT tanker transit from Nordix to 12 miles offshore	42 hours

I.3 MODEL USED TO CALCULATE DOWNWIND GROUND-LEVEL CONCENTRATIONS

Downwind concentrations of effluents were calculated using methods recommended by the U.S. Environmental Protection Agency (Turner, 1969).

The equation used for "worst case" concentrations (averaging periods up to 24 hours) is:

$$\chi = \frac{Q \times 10^6}{\pi \sigma_y \sigma_z u} \exp \left(- \frac{1}{2} \left(\frac{H}{\sigma_z} \right)^2 \right) \qquad (1)$$

where: χ = downwind concentration ($\mu g/m^3$)
Q = effluent source term (g/sec)
σ_y = horizontal dispersion coefficient (m)
σ_z = vertical dispersion coefficient (m)
u = wind speed (m/sec)
H = stack height (m)

Except for storage tank, brine pond and construction vehicle emissions, continuous point source release was assumed. Ground-level release (H=0) was assumed except for storage tank and power plant emissions. In addition, the model is based upon the following assumptions: The effluents are normally distributed along the plume centerline; there is no removel of pollutants from the plume; and there is complete reflection at the ground. Worst-case assumptions were for stability class "D" and a wind speed of one meter per second (m/sec) except two m/sec offshore. These conditions occur very infrequently at the site, particularly for durations longer than about one hour.

Values calculated by Equation 1 are peak concentrations assumed to be 10-minute averages. Extrapolation of the peak concentrations to various averaging periods up to 24 hours are determined by a power law correction (Turner, 1969). The equation used is:

$$\chi(t) = \chi(10\text{-minute}) \times \left(\frac{t}{10} \right)^{-0.17} \qquad (2)$$

where t is the averaging interval in minutes.

Equation 2 is applicable only when the average wind direction is constant. Therefore, extrapolation confidence is much less for 24 hours than for 1 hour.

The equation used for annual average concentrations is:

$$\chi = \sum_i \frac{2.032 \times Q}{u_i \sigma_z X} f_i \times 10^6 \exp \left(- \frac{1}{2} \left(\frac{H}{\sigma_z} \right)^2 \right) \qquad (3)$$

where: χ = annual average concentration ($\mu g/m^3$)
Q = effluent source term (g/s)

σ_z = vertical dispersion coefficient (m)

X = downwind distance (m)

u_i = wind speed for speed class i (m/sec)

f_i = fraction of the time the wind is blowing in the most frequent wind direction sector in wind speed class i

H = stack height (meters)

Based upon the New Orleans wind rose (USDC, 1971), the values of u_i and f_i are as follows:

u_i (m/sec)	f_i (%)
0.83	2.10
2.63	2.77
4.33	3.84
6.55	2.57
9.28	0.21
14.43	0.00

The wind speed for a given wind speed class was taken to be the average speed for that class independent of wind direction. Values of f_i above are for north winds, the most frequent wind direction at New Orleans.

Since the storage tanks and construction vehicles are multiple point sources, an area source correction was applied. To allow for an area source, a virtual distance X_1 is found that approximates the distance required for a point source to disperse into an area equivalent to that of the area source. The total distance $(X + X_1)$ is then used to determine revised dispersion coefficients (σ_y and σ_z). To maximize storage tank calculations, the wind was assumed to blow parallel to the longer axis of the tanks.

APPENDIX I
Part II
DESCRIPTION OF THE PHYSICAL AND CHEMICAL BASIS FOR EMISSIONS FROM MARINE VESSEL TRANSFER OF CRUDE OIL

I.1 INTRODUCTION

Ships and barges will be used to deliver crude oil to and from the marine terminals for the Strategic Petroleum Reserve (SPR) facility. Hydrocarbon emissions are generated at marine terminals when volatile hydrocarbon liquids are either loaded onto or unloaded from ships and barges.

The magnitude of crude oil transfer emissions are dependent on many factors. Industry testing programs have been conducted recently to evaluate the interrelationship of these and other important factors in developing up-to-date emission factors for ship and barge loading and ballasting emissions. Most of those studies completed have developed emission factors for gasoline. Crude oil transferring operations are under study by the Western Oil and Gas Association (WOGA) (Chevron Research Co., 1976).

This appendix evaluates the existing emission data and proposes an analytical procedure for estimating the probable crude oil emission factors for the SPR facility.[a]

Section I.2 presents the general nature and characteristics of marine transfer emissions. Sources testing data compiled by many industry sources concerning marine transfer emissions are presented in Section I.3. Description of a proposed procedure and assumption required to estimate emission factors for crude oil are presented in Section I.4. The final section concludes the emission factor analysis and presents a summary of emission factors proposed to be used for the SPR facility.

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[a] This appendix derives emission factors for crude handling operations which represent a reduction in emission factors presented in earlier FEA environmental reports. The results reported here represent the best approximations possible with currently existing data.

I.2 EMISSION SOURCES AND CHARACTERISTICS

I.2.1 Loading Emissions

Loading emissions are attributable to the displacement to the atmosphere of hydrocarbon vapors residing in empty vessel tanks by volatile hydrocarbon liquids being loaded into the vessel tanks. Loading emissions can be separated into (1) the arrival component and (2) the generated component. The arrival component of loading emissions consists of hydrocarbon vapors left in the empty vessel tanks from previous cargos. The generated component of loading emissions consists of hydrocarbon vapors evaporated in the vessel tanks as hydrocarbon liquids are being loaded.

The arrival component of loading emissions is directly dependent on the true vapor pressure of the previous cargo, the unloading rate of the previous cargo, and the cruise history of the cargo tank on the retu voyage. The cruise history of a cargo tank may include heel washing, ballasting, butterworthing, vapor freeing, or no action at all.

The generated component of loading emissions is produced by the evaporation of hydrocarbon liquid being loaded into the vessel tank. quantity of hydrocarbons evaporated is dependent on both the true vapor pressure of the hydrocarbons and the loading and unloading practices. The loading practice which has the greatest impact on the generated component is the loading and unloading rate.

A typical profile of gasoline concentration in a ship tank during loading is presented in Figure I-1 (American Petroleum Institute, 1976). As indicated in the figure, the hydrocarbons present throughout most of the vessel tank vapor space are contributed to by the arrival vapor component and the concentration is almost uniform. There is a sharp rise in hydrocarbon vapor concentration just above the liquid surface. This is the generated component. The generated component, also called a "vapor blanket," is attributable to evaporation of the hydrocarbon liquid.

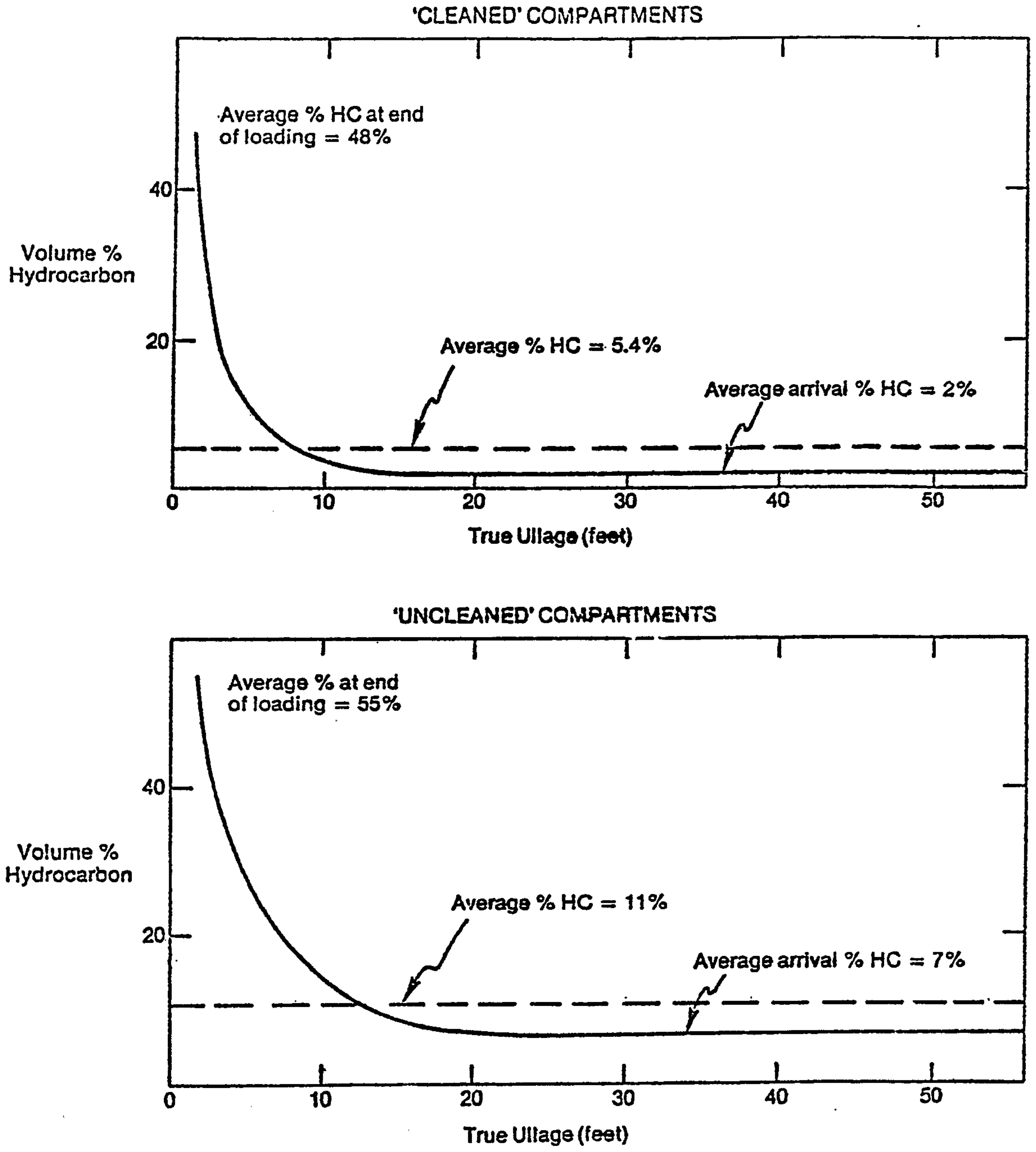

FIGURE I-1 Typical ship emission profiles.

From Figure I-1 it is apparent that for large vessels with 55 foot ullages,[a] the average hydrocarbon concentration of vapors vented during loading operations is primarily dependent on the arrival component. For smaller vessels such as barges with 12 foot ullages, the average hydrocarbon concentration in the vented loading vapors is dependent on both the generated component and the arrival component.

I.2.2 Unloading Emissions

Unloading emissions are hydrocarbon emissions displaced during ballasting operations at the unloading dock subsequent to unloading a volatile hydrocarbon liquid such as gasoline or crude oil. During the unloading of a volatile hydrocarbon liquid, air drawn into the emptying tank absorbs hydrocarbons evaporating from the liquid surface. The greater part of the hydrocarbon vapors normally lies along the liquid surface in a vapor blanket. However, throughout the unloading operation, hydrocarbon liquid clinging to the vessel walls will continue to evaporate and to contribute to the hydrocarbon concentration in the upper levels of the emptying vessel tank.

Before sailing, an empty marine vessel must take on ballast water maintain trim and stability. Normally, on vessels that are not fitted with segregated ballast tanks, this water is pumped into the empty vessel tanks. As ballast water enters tanks, it displaces the residual hydrocarbon vapors to the atmosphere generating the so termed "unloading emissions."

I.2.3 Parameters Affecting Emissions

Emission testing results indicate that many factors affect the magnitude of crude oil loading and unloading emissions. Due to the interrelated nature of these parameters, it is difficult to quantify the emission impacts. This section qualitatively presents the effects of the following parameters on marine loading and unloading emissions:

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[a] The term "ullage" refers to the distance between the cargo liquid level and the rim of the ullage cap.

- o loading and unloading rate
- o true vapor pressure
- o cruise history
- o previous cargo
- o chemical and physical properties

I.2.3.1 Loading and Unloading Rate

During the loading operation, the initial loading and unloading rate has a significant effect on hydrocarbon emissions due to the splashing and turbulence caused by higher initial loading or withdrawing rates. This splashing and turbulence results in rapid hydrocarbon evaporation and the formation of a vapor blanket. By reducing the initial velocity of entering or withdrawing rates, it is possible to reduce the turbulence and consequently, to reduce the size and concentration of the vapor blanket. Slow final loading rate can also lower the quantity of emissions. This is because when the hydrocarbon level in a marine vessel tank approaches the tank roof, the action of vapors flowing towards the ullage cap vent begins to disrupt the quiescent vapor blanket. Disruption of the vapor blanket results in noticeably higher hydrocarbon concentrations in the vented vapor (Environmental Protection Agency, 1976).

I.2.3.2 True Vapor Pressure

The true vapor pressure (TVP) of a hydrocarbon liquid has a marked impact on the hydrocarbon content of its loading and unloading emissions. TVP is an indicator of a liquid's volatility and is a function of the liquid's Reid Vapor Pressure (RVP) and temperature. Compounds with high TVP exhibit high evaporation rates and consequently, contain high hydrocarbon concentrations in their loading and ballasting vapors. The monographs presented in Figures I-2 and I-3 correlate the TVP for crude oil and gasoline. The RVP of gasoline loaded in the Houston-Galveston area range from 9.5 to 13.6 psia in the winter season, while the RVP of crude oils unloaded normally range from 2 to 7 psia. For the purpose of assessing a SPR facility, the crude oil is assumed to have a maximum RVP of 5 psia and an average RVP of 4 psia at a temperature of 70°F.

I.2.3.3 Cruise History

The cruise history of a marine vessel includes all of the activities which a cargo tank experiences during the voyage prior to a loading or

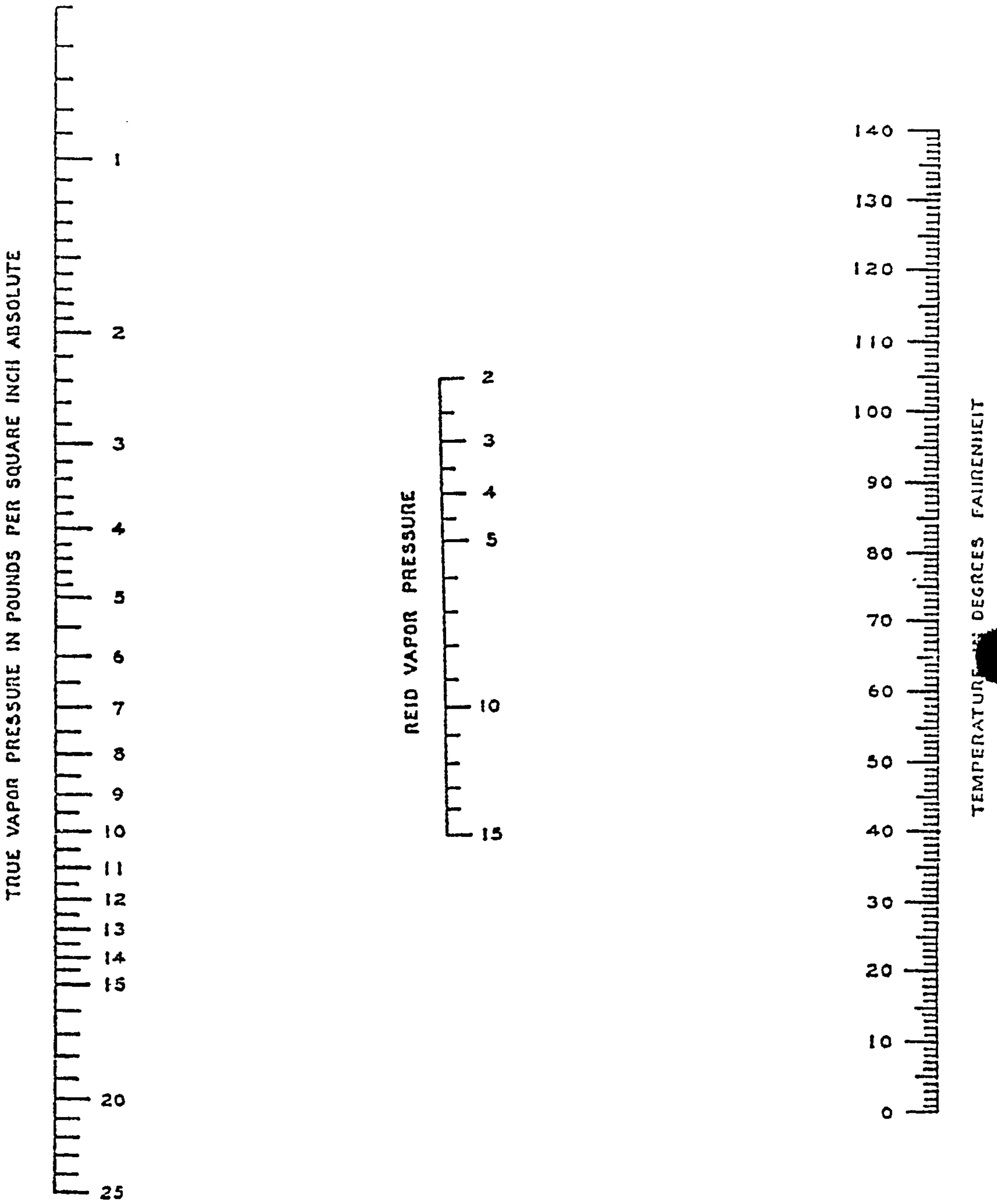
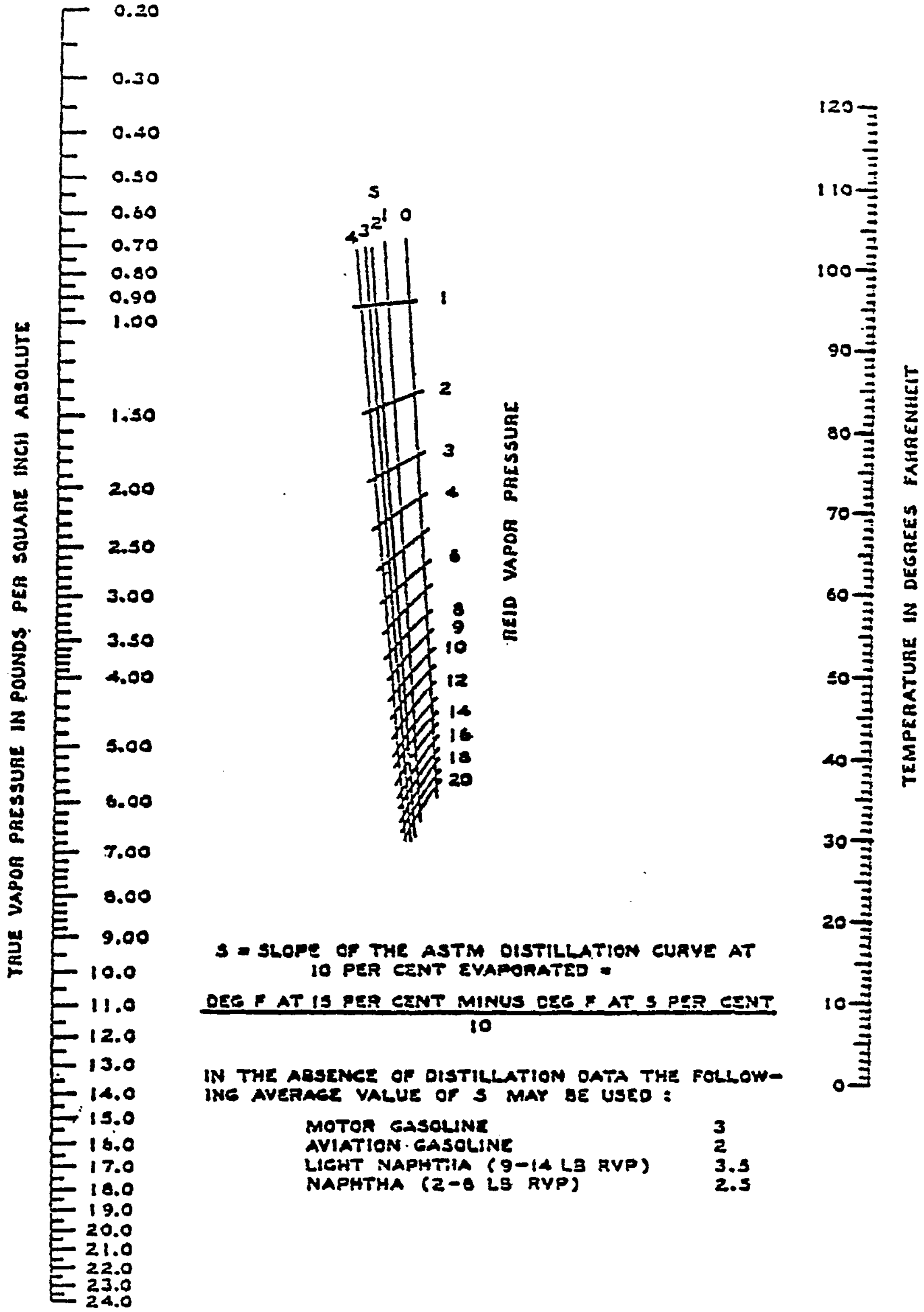


FIGURE I-2 Vapor pressures of crude oil.



S = SLOPE OF THE ASTM DISTILLATION CURVE AT 10 PER CENT EVAPORATED =

$$\frac{\text{DEG F AT 15 PER CENT MINUS DEG F AT 5 PER CENT}}{10}$$

IN THE ABSENCE OF DISTILLATION DATA THE FOLLOWING AVERAGE VALUE OF S MAY BE USED :

MOTOR GASOLINE	3
AVIATION GASOLINE	2
LIGHT NAPHTHA (9-14 LB RVP)	3.5
NAPHTHA (2-8 LB RVP)	2.5

FIGURE I-3 Vapor pressures of gasolines and finished petroleum products.

unloading operation. Examples of significant cruise history activities are ballasting, heel washing, butterworthing, and gas freeing. Cruise Cruise history impacts marine transfer emissions by directly affecting the arrival vapor component. Barges normally do not have significant cruise histories because they rarely take on ballast and do not usually have the manpower to clean cargo tanks.

Ballasting is the act of partially filling empty cargo tanks with water to maintain a ship's stability and trim. Recent testing results indicate that prior to ballasting, empty cargo tanks normally contain an almost homogeneous concentration of residual hydrocarbon vapors. When ballast water is taken into the empty tank, hydrocarbon vapors are vented, but the remaining vapors not displaced retain their original hydrocarbon concentration. Upon arrival at a loading dock, a ship discharges its ballast water and draws fresh air into the tank. The fresh air dilutes the arrival vapor concentration and lowers the effective arrival vapor concentration by an amount proportional to the volume of ballast used. Although ballasting practices vary from vessel to vessel, the average vessel is ballasted approximately 40 percent.

The heel of a tank is the residual puddles of hydrocarbon liquids remaining in tanks after emptying. These residual liquids will eventually evaporate and contribute to the arrival component of subsequent vessel-filling vapors. By washing out this heel with water, AMOCO Oil Company found that they were able to reduce the hydrocarbon emissions from subsequent filling operations from 5.7 volume percent to 2.7 volume percent hydrocarbons (Environmental Protection Agency, 1976). Butterworthing is the washing down of tank walls in addition to washing out tank heels. Butterworthing also reduces loading emissions by reducing the arrival component concentration. The hydrocarbon liquids washed from the tanks are stored in a slops tank for dosposal onshore (Environmentla Protection Agency, 1976).

In addition to heel washing and butterworthing, marine vessels can purge the hydrocarbon vapors from empty and ballasted tanks during the voyage by several gas freeing techniques which include air blowing and emission factor (lb/1000 gal) is derived from the average HC volume concentration. The hydrocarbon volume concentration is then converted into a total hydrocarbon mass by multiplying an average vapor molecular weight and a correction factor accounting for vapor generation factor. These are:

$$H_f = \frac{Xv}{100} \quad \frac{K.W_m}{V_k} \quad \frac{100+F}{100} \tag{1}$$

and

$$F = \frac{(1-X_T) \quad \frac{U_i}{U_i-U_f} \quad -(1-X_r) \quad \frac{U_i}{U_i-U_f}}{(1 - X_v)} \quad -1 \tag{2}$$

where:

H_f = hydrocarbon emission factors, lb/1000 gal

X_v = volumetric average of HC concentration of vented vapor, percent

K = constant, 133.7 ft^3/1000 gal

W_m = molecular weight of HC vapor, lb/lb-mole

V_k = molar volume of perfect gas, 379.44 ft^3/lb mole at STP conditions

F = vapor generation factor, see Equation (3)

X_T = volumetric average HC concentration of arrival vapor, percent

X_r = volumetric average HC concentration of remaining vapor, percent

U_i = total tank depth, ft

U_f = final ullage, ft

According to API calculation, a maximum volume increase (vapor generation factor F) of 6 percent for both ships and barge was determined. Thus, if we combine the constants K and V_k with a conservative value of F equivalent to 6 percent, equation (1) can be simplified to:

$$H_f = 0.3735 \,.\, (X_v) \,.\, (W_m) \tag{3}$$

TABLE I-1 Summary of petroleum industry testing programs on marine loading emissions.

Company	Types of Marine Testing	Location	Date	Extent of Testing	Emission Factors
WOGA	tanker loading and ballasting emissions for crude oil and natural gasoline	Ventura County Union Oil Terminal Getty Oil Terminal California	May 1976 (tests are ongoing)	6 tests to date	preliminary data indicates that emissions from loading a nonvolatile crude into ballasted tanks which previously carried more volatile crude and not gasoline are 0.9 to 1.0 lb/1000 gallons
EXXON	primarily gasoline loading, but also averages and crude loading	Exxon Terminal Baytown Texas Karg Island, Iran	winter 1974-1975 summer 1975	100 ship tests 30 barge tests	<u>Gasoline Loading</u> tanker - gas free 3.24 vol % tanker - ballasted 6.96 vol % tanker - uncleaned 10.26 vol % average Exxon tanker 6.41 vol % (1.47 lb/mgal) ocean barge -gas free 5.69 vol % ocean barge -ballasted 9.08 vol % ocean barge -uncleaned 14.40 vol % avg. EXXON ocean barge 11.71 vol % (2.66 lb/mgal) barge 18.35 vol % (4.14 lb/mgal) <u>Aviation Gasoline Loading</u> tanker - gas free 1.63 vol % tanker - unclean (av. gas prev.) 6. 65 vol % tanker - unclean (no gas prev.) 10.64 vol % average EXXON tanker 5.35 vol % (1.47 lb/mgal) average military tanker 4.13 vol % (1.13 lb/mgal) barge 18.35 vol % (4.25 lb/mgal) <u>Weighted Average Dock</u> 1.8 lb/mgal Also have a TVP dependent correlation (see text)
American Petroleum Institute	motor gasoline loading	predominantly in Houston-Galveston area	1974-1976		clean tankers 1.3 lb/mgal clean barges 1.2 lb/mgal uncleaned tankers 2.5 lb/mgal uncleaned barges 3.8 lb/mgal
Arco	motor gasoline loading of tankers	Houston Refinery	Nov. 1974, Feb. and April 1975	11 tests	<u>Gasoline Loading on Tanker</u> fast load, low TVP, clean 2.1 vol % (0.4 lb/mgal) fast load, med TVP, clean 2.6 vol % (0.5 lb/mgal) slow load, high TVP, clean 4.2 vol % (0.9 lb/mgal) slow load, high TVP, part clean part lcean 6.9 vol % (1.5 lb/mgal) avg. ARCO tanker 3.9 vol % (0.84 lb/mgal)
AMOCO	primarily motor gasoline loading	Whiting, Ill	2/26/74-7/22/75	40-50 tests	none developed
	crude barge unloading	Texas City, Texas	5/29/74-8/5/75	9 tests	none developed AMOCO did state that average emissions for AMOCO ship less than 10.2 vol %
Shell	gasoline loading on tanker	Deer Park, Texas	Oct. 1974	5-10 tests	none developed
British Petroleum	crude oil loading on tanker	Middle East	1973	Unknown	none developed

The total volume of HC concentration vented at loading conditions (X_v is equal to the sum of arrival HC concentration (X_a) and the generation vapor concentration (X_g). Thus,

$$X_v = X_a + X_g \tag{4}$$

Based on the above relation, EXXON has further derived the following loading emission correlation:

$$X_v = \frac{E}{V} = \frac{C}{100} + \frac{P \cdot (G - U) \cdot A}{V} \tag{5}$$

where:

E = total volume of HC emitted at the loading condition, CF

C = arrival HC concentration, percent

V = HC liquid loaded, ft^3

P = true vapor pressure of the HC liquid, psia

A = surface area of the HC liquid, ft^2

G = HC generation coefficient value of 0.36 $ft^3/(ft^2\text{-psia})$

U = final true ullage correction in $ft^3(ft^2\text{-psia})$ from Figure I-4

Assuming $V = A\ (U_i - U_f)$, Equation (5) becomes

$$X_v = \frac{C}{100} + \frac{P \cdot (G - U)}{(U_i - U_f)} \tag{6}$$

The EXXON correlation of equation (6) is based principally upon gasol[illegible]e loading data (Environmental Protection Agency, 1976). For the loading of crude oil, SAI has proposed to adjust the first and second terms by multip[illegible]i correction factors α_1 and α_2, respectively. Thus, for crude oil ship load[illegible] operation:

$$X_v = \alpha_1 \frac{C}{100} + \alpha_2 \frac{P \cdot (G - U)}{(U_i - U_f)} \tag{7}$$

In the above correlation, α_1 is principally affected by the characteristics of the previous cargo, whereas the value of α_2 is independent to the condi[illegible] of previous cargo. For barge loading operation, it is further assumed t[illegible]r

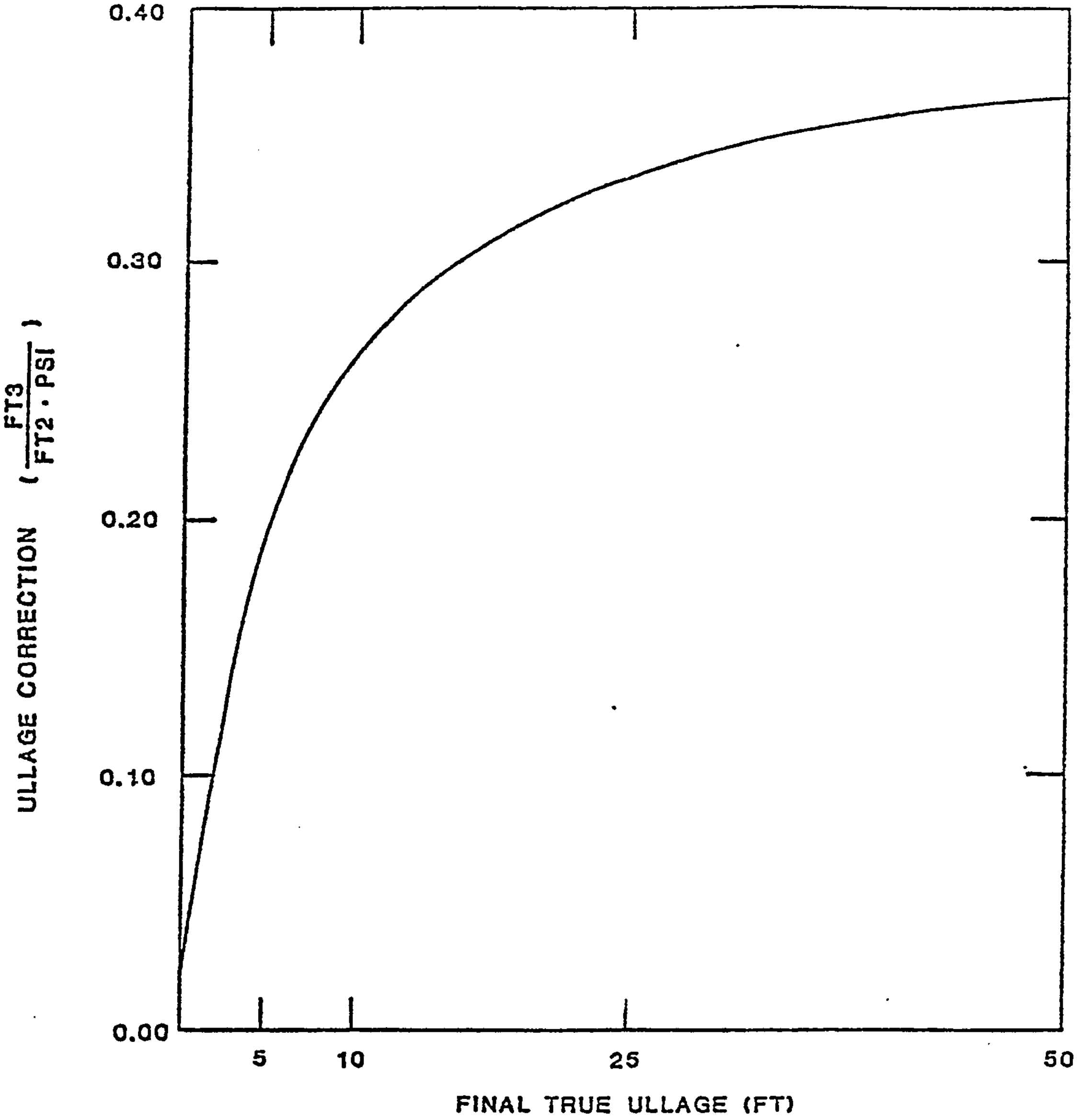


FIGURE I-4 Hydrocarbon generation coefficient, final ullage correction to the EXXON Corporation.

correction factor α_2 for vapor generation terms is necessary. That is because barge loadings are usually operated in short duration and the majority of hydrocarbon vapor generated during this period would be those volatile hydrocarbons with very light molecular weights.

Thus, the basic difference between vapor characteristics for gasoline and crude oil would be slight for a short barge loading duration.

For the purpose of SPR facility analysis, it is further assumed that no correction factor on C is necessary when previous cargo is a volatile hydrocarbon such as gasoline. Thus,

- $\alpha_1 = 1$, when previous cargo is gasoline
- $\alpha_1 = \alpha_2$, when previous cargo is crude oil.

The correction factor α_2 can be interpreted as the ratios of evaporation mass transfer coefficients between crude oil and gasoline. Mackay and Matsuger (1973) have correlated the mass transfer coefficient (K) based on wind tunnel studies of evaporative hydrocarbon liquids. They found that th mass transfer coefficient is inversely proportional to the vapor phase Schmidt number (S_c) as follows:

$$K = f(U \cdot A) \cdot (S_c)^{-0.67}$$

where U is wind speed, and A is the oil surface area.

The α_2 thus can be determined by:

$$\alpha_2 = \frac{K_c}{K_g} = \frac{S_c^{-0.67} \text{ crude oil}}{S_c^{-0.67} \text{ gasoline}}$$

Since the Schmidt number (S_c) is defined by the mass transport properties $\mu/\rho\mathcal{D}_{AB}$ (Bird, et al., 1960).

α_2 can then be calculated by the following equations:

$$\alpha_2 = \frac{(\mu/\rho_{\mathcal{D}}\ AB)^{-0.67} \text{ crude oil}}{(\mu/\rho_{\mathcal{D}}\ AB)^{-0.67} \text{ gasoline}} \qquad (8)$$

and

$$\mathcal{D}_{AB} = 0.0018583 \frac{T^3 \frac{1}{M_A} + \frac{1}{M_B}}{P\sigma_{AB}{}^2\ \Omega_{\mathcal{D},AB}} \qquad (9)$$

$$\mu = 2.6693 \times 10^{-5} \frac{\sqrt{MT}}{\sigma_{2}\,\Omega_{\mu_{AB}}} \qquad (10)$$

μ = viscosity of vapor

ρ = density of vapor

$\mathcal{D}_{AB}$ = binary diffusivity for system A (air) and B (hydrocarbon)

M_A, M_B = molecular weight of A, B, respectively

P = fluid pressure, atmosphere

σ_{AB} = collision diameter, A

$\Omega\mathcal{D}$, AB = collision integral for mass diffusivity

$\Omega\mu,_{AB}$ = collision integral for viscosity

The pertinent intermolecular properties and functions for prediction of transport properties of hydrocarbon gases at low densities are presented in Table I-2 and Table I-3, respectively. Table I-4 presents the comparative analysis of hydrocarbon vapor emitted by loading gasoline and crude oil. As can be seen, due to the difference in chemical compositions between gasoline and crude oil, the gasoline generally exhibits higher transport properties and thus results in a higher evaporation mass diffusity coefficient (i.e., 1.345 for gasoline versus 0.513 for crude oil). Based on this analysis, the value of α_2 can be determined as 0.381.

The appropriate arrival HC hydrocarbon concentration, (C), can be calculated based on API gasoline emission factors as follows:

Vessels	Arrival Conditions	Emission Factors (lb/1000 gal)	Generation Vapor $\frac{P \cdot (G - U)}{(U_i - U_f)}$, %	Calculated Arrival Vapor (C), %
Ships	Cleaned	1.3	$\frac{7.5\ (0.36-0.10)}{(55-1.5)} = 3.64$	1.71 (2.50)
	Uncleaned	2.5	3.64	6.65 (8.00)
Barges	Cleaned	1.2	$\frac{7.5\ (0.36-0.27)}{(55-12)} = 1.57$	3.37
	Uncleaned	3.8	1.57	14.10

TABLE I-2 Intermolecular parameters of hydrocarbons.

Substance	Molecular Weight M	Lennard-Jones Parameters[a]	
		σ (Å)	ϵ/κ (° K)
CH_4	16.04	3.822	137.
C_2H_2	26.04	4.221	185.
C_2H_4	28.05	4.232	205.
C_2H_6	30.07	4.418	230.
C_3H_6	42.08	—	—
C_3H_8	44.09	5.061	254.
n-C_4H_{10}	58.12	—	—
i-C_4H_{10}	58.12	5.341	313.
n-C_5H_{12}	72.15	5.769	345.
n-C_6H_{14}	86.17	5.909	413.
n-C_7H_{16}	100.20	—	—
n-C_8H_{18}	114.22	7.451	320.
n-C_9H_{20}	128.25	—	—
Cyclohexane	84.16	6.093	324.
C_6H_6	78.11	5.270	440.
Other organic compounds:			
CH_4	16.04	3.822	137.
CH_3Cl	50.49	3.375	855.
CH_2Cl_2	84.94	4.759	406.
$CHCl_3$	119.39	5.430	327.
CCl_4	153.84	5.881	327.
C_2N_2	52.04	4.38	339.
COS	60.08	4.13	335.
CS_2	76.14	4.438	488.

Source: Bird et al, 1960.

TABLE I-3 Functions for prediction of transport properties of gases at low densities.

$\kappa T/\epsilon$ or $\kappa T/\epsilon_{AB}$	$\Omega_\mu = \Omega_k$ (For viscosity and thermal conductivity)	$\Omega_{\mathcal{D},AB}$ (For mass diffusivity)	$\kappa T/\epsilon$ or $\kappa T/\epsilon_{AB}$	$\Omega_\mu = \Omega_k$ (For viscosity and thermal conductivity)	$\Omega_{\mathcal{D},AB}$ (For mass diffusivity)
			2.50	1.093	0.9996
0.30	2.785	2.662	2.60	1.081	0.9878
0.35	2.628	2.476	2.70	1.069	0.9770
0.40	2.492	2.318	2.80	1.058	0.9672
0.45	2.368	2.184	2.90	1.048	0.9576
0.50	2.257	2.066	3.00	1.039	0.9490
0.55	2.156	1.966	3.10	1.030	0.9406
0.60	2.065	1.877	3.20	1.022	0.9328
0.65	1.982	1.798	3.30	1.014	0.9256
0.70	1.908	1.729	3.40	1.007	0.9186
0.75	1.841	1.667	3.50	0.9999	0.9120
0.80	1.780	1.612	3.60	0.9932	0.9058
0.85	1.725	1.562	3.70	0.9870	0.8998
0.90	1.675	1.517	3.80	0.9811	0.8942
0.95	1.629	1.476	3.90	0.9755	0.8888
1.00	1.587	1.439	4.00	0.9700	0.8836
1.05	1.549	1.406	4.10	0.9649	0.8788
1.10	1.514	1.375	4.20	0.9600	0.8740
1.15	1.482	1.346	4.30	0.9553	0.8694
1.20	1.452	1.320	4.40	0.9507	0.8652
1.25	1.424	1.296	4.50	0.9464	0.8610
1.30	1.399	1.273	4.60	0.9422	0.8568
1.35	1.375	1.253	4.70	0.9382	0.8530
1.40	1.353	1.233	4.80	0.9343	0.8492
1.45	1.333	1.215	4.90	0.9305	0.8456
1.50	1.314	1.198	5.0	0.9269	0.8422
1.55	1.296	1.182	6.0	0.8963	0.8124
1.60	1.279	1.167	7.0	0.8727	0.7896
1.65	1.264	1.153	8.0	0.8538	0.7712
1.70	1.248	1.140	9.0	0.8379	0.7556
1.75	1.234	1.128	10.0	0.8242	0.7424
1.80	1.221	1.116	20.0	0.7432	0.6640
1.85	1.209	1.105	30.0	0.7005	0.6232
1.90	1.197	1.094	40.0	0.6718	0.5960
1.95	1.186	1.084	50.0	0.6504	0.5756
2.00	1.175	1.075	60.0	0.6335	0.5596
2.10	1.156	1.057	70.0	0.6194	0.5464
2.20	1.138	1.041	80.0	0.6076	0.5352
2.30	1.122	1.026	90.0	0.5973	0.5256
2.40	1.107	1.012	100.0	0.5882	0.5170

[a] Taken from J. O. Hirschfelder, R. B. Bird, and E. L. Spotz, *Chem. Revs.*, 44, 205 (1949).

TABLE I-4 Comparison of chemical compositions and mass transport propertie
between gasoline and crude oil.

Chemical Composition, Volume % of Loading Vapors	Gasoline[a]	Crude Oil[b]
$C_1 + C_2$	0.02	0.12
C_3	0.02	0.15
C_4	2.36	1.33
C_5	1.07	2.05
C_6	0.19	0.63
C_7	0.19	0.32
C_8	0.15	0.03
C_9	---	0.02
C_{10}	---	0.01
C_{11}	---	0.01
Air	96.0	95.35
$\Sigma \epsilon/K$	302.1	331.6
$\Sigma KT/\epsilon$	1.039	1.055
$\Omega_{D,AB}$	1.42	1.40
$\Omega_{\mu,AB}$	1.56	1.54
σA (Air)	3.681	3.681
σB	5.28	5.21
σAB	4.48	4.45
M_B	67	77
μ	6.919×10^{-4}	7.516×10^{-4}
D_{AB}	0.36	0.081
ρ	2.99×10^{-3}	3.43×10^{-3}
$(\mu/\rho D_{AB})^{-0.67}$	1.345	0.513

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[a] Shell Oil Company, Ship Valley Forge, test date 10/19/74
[b] Avila Terminal, Lion of California, test data 5/8/76

Source: Environmental Protection Agency, 1976.

The calculated arrival HC vapor concentration for ships using API emission factor seems to be in close agreement with the EXXON reported value (value in parentheses).

By substituting the appropriate values of C, α_2, and P, Equation (7) also compares well with the latest available WOGA test data. The WOGA test on September 5, 1976 estimated the overall crude oil emission factor to be 0.62 lb/1000 gallons which falls in the middle of the calculated emission factors. The calculated emission factors using Equation (7) are 0.35 lb/1000 gallons and 0.85 lb/1000 gallons for cleaned and uncleaned ships, respectively.

Similarly, the emission from ship ballasting operation can be correlated based on arrival vapor concentrations during loading operations. Since the ballasting potentially dilutes tank arrival concentration by approximately the same percentage as that of ballasting volume, for a ship with 40 percent ballasting volume the emission factor can be calculated by dividing the arrival HC concentration (C) by 0.4.

I.5 CONCLUSION

A modified analytical procedure based on API and EXXON gasoline data enables quantitative estimation of hydrocarbon emission factors from crude oil transferring operations under various arrival conditions. The procedure employs correction factors to both arrival and generation components of the hydrocarbon vapors concentration previously derived from gasoline data. An emission reduction factor of 0.38 is derived for crude oil when comparing the evaporation mass diffusivity of crude oil with gasoline. The final hydrocarbon emission factors for crude oil loading operations are summarized in Table I-5. As can be seen, the average emission factors from ship loading operations range from 0.55 to 0.58 lb/1000 gallons. Similar hydrocarbon emission factors range from 1.01 to 1.06 lb/1000 gallons for barge crude oil loading operations. The ballasting emission factors are calculated to range from 0.17 to 0.66 lb/1000 gallons.

① 0.17
0.66
.83 .83 ÷ 2 = 0.42 #/1,000 gal Avg. (BALLASTIN

② $\frac{0.55+0.58}{2}$ = 0.565 #/1,000 gal – loading out during withdraw

TABLE I-5 Summary of maximum and average hydrocarbon emission factors (lb/1000 gallon) for crude oil transport operation.

essels	Arrival[a] Conditions	Maximum Emission Factor[b]		Average Emission Factor[c]	
		Previous Cargo		Previous Cargo	
		Gasoline	Crude Oil	Gasoline	Crude Oil
Ship Loading					
	Cleaned	--	0.33	--	0.30
	Uncleaned	1.90	0.83	1.86	0.79
	Average	--	0.58	--	0.55
Barge Loading					
	Cleaned	--	0.52	--	0.48
	Uncleaned	3.87	1.59	3.83	1.54
	Average	--	1.06	--	1.01
Ship Ballasting					
	Cleaned	--	0.17	--	0.17
	Uncleaned	--	0.66	--	0.66
	Average	--	0.42	--	0.42

– See Page I-1
for 120°F

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[a] Average condition lies between cleaned and uncleaned conditions. The cleaned is defined as the arrival conditions where vessels had been subjected to any cleaning process prior to loading, as well as compartments which had previously contained a nonvolatile hydrocarbon.

[b] Based on RVP = 5.0 and temperature of 70° F.

[c] Based on RVP = 4.0 and temperature of 70° F.

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APPENDIX J

OIL TEMPERATURES DURING WITHDRAWAL

APPENDIX J

OIL TEMPERATURES DURING WITHDRAWAL

J.1 INTRODUCTION

The temperature of the oil being handled is an important factor in determining the emission of hydrocarbon vapors from storage tanks, tankers and barges in transit, and during transfers to and from carrier vessels. The oil temperature during oil fill operations will tend to average about 70°F, the average ambient temperature. During storage, however, heat transfer from the salt dome structure to the oil in the cavities could heat the oil to temperatures approaching that of the rock salt. Therefore, the hydrocarbon emissions from this higher temperature oil will be greater during withdrawal than during fill.

To determine the hydrocarbon emission factors during oil withdrawal, estimates must be made of the heat transfer rates during oil movement The temperature of the storage cavity walls is a critical parameter; temperatures may range from 90° to 100°F at 1000 foot depths to 150°F at 4000 to 5000 foot depths. The oil in storage, which is able to circulate in free convection, will tend to reach the temperature of the warmest portion of the cavity. Heat transfer analyses to estimate the temperature of the oil withdrawn must consider the following: (1) heat exchange from the warm oil to the incoming fresh water flowing through the fill pipe (not applicable to Weeks Island conventional mine storage caverns); (2) heat loss from buried pipelines during transport to the distribution terminal; and (3) frictional heating of the oil during pipeline transport. Oil temperatures calculated at terminal delivery can then be used to determine oil properties for calculation of hydrocarbon vapor losses during tank storage, tanker transfer, and tanker transit.

The following subsections develop the method used for estimating the heat transfer rates which are applied to withdrawals from the Capline Group storage sites. Controlling equations, oil properties, and physical configurations are developed and applied to the conditions of withdrawal at these sites.

J.2 PROPERTIES OF THE OIL AND BRINE

The oil is assumed to be characterized by an average U.S. crude, API 26° (Perry, 1963).

Density - 316 lbm/barrel, (56.03 lbm/cu.ft.)
Specific heat - 0.45 BTU/lbm°F
Thermal conductivity - 0.08 BTU/hr-ft-°F.

Variation of properties with temperature and pressure can be neglected, except for viscosity. Viscosity values (Brown, 1967; Frick, 1962) are:

6 centipoise = 14.5 lbm/ft.hr. at 140°F
13 centipoise = 31.5 lbm/ft.hr. at 120°F
19 centipoise = 46.0 lbm/ft.hr. at 100°F
30 centipoise = 72.6 lbm/ft.hr. at 80°F

The brine solution is characterized as 5.1 molal, or 300 ppt salt. The heat capacity and thermal conductivity of the salt in solution may be neglected, so that the thermal properties per unit volume are equivalent to those for water.

Density - 75 lbm/cu.ft.
Thermal conductivity - 0.38 BTU/hr-ft-°F
Specific heat - 0.77 BTU/lbm°F = 62.4 BTU/cu.ft.°F
Viscosity - 0.3 centipoise = 0.73 lbm/ft.hr.

J.3 HEAT EXCHANGE DURING OIL DISPLACEMENT

The heat exchange between the oil and displacement water can be described by standard heat transfer equations for heating or cooling of fluids flowing in tubes.

The heating of a fluid during flow between points 1 and 2 along a tube is defined by

$$\begin{aligned} WC(T_2-T_1) &= h\pi DL(\Delta t) \\ &= h_L L(\Delta t) \end{aligned} \qquad (1)$$

where h is the heat transfer coefficient per unit area

h_L is the heat transfer coefficient per unit length

W is the mass flow rate

C is the specific heat

T_2, T_1 are the fluid temperatures at points 1, 2

(Δt) is the average temperature difference between the fluid and tube wall

L is the tube length

D is tube diameter or hydraulic diameter.

To simplify the problem, it is noted that the potential rate of heat release or uptake into the water is much more rapid than that for oil; consequently it is assumed that the wall temperature is identical to the temperature of the water in the inner pipe. The heat exchange between oil and water is balanced:

$$W_o C_o (T_{01} - T_{02}) = W_w C_w (T_{w2} - T_{w1}) \qquad (2)$$

The average temperature differential between points 1 and 2 is:

$$(\Delta t) = 1/2[(T_{w2} - T_{02}) + (T_{w1} - T_{01})] \qquad (3)$$

The heat transfer coefficient of the oil in turbulent flow is given by a well-known Nusselt correlation (Perry, 1963):

$$(Nu) = \frac{hD}{K} = 0.023\ (Re)^{0.8} (Pr)^{1/3} \qquad (4)$$

and for flow regimes transitional between turbulent and laminar (Sieder & Tate, 1936),

$$(Nu) = \frac{hD}{K} = 0.027\ (Re)^{0.8} (Pr)^{1/3} (\mu/\mu_w)^{.14} \qquad (5)$$

where (Nu) is Nusselt number

(Re) is the Reynold's number $[4W/\pi D\mu]$

(Pr) is Prandtl number $[\mu C/K]$

μ_w is fluid viscosity at the wall temperature

μ, C, K are, respectively, the fluid viscosity, specific heat, and thermal conductivity.

The system of four equations with four unknowns (T_{oil}, $T_{water\ at\ exit}$, (Δt), h) is solved iteratively because the viscosity varies enough with temperature to prevent treatment as a constant.

J.4 OIL COOLING IN PIPELINE FLOW

Warm oil flowing in a pipeline in cooler soil will release heat to the soil. Davenport and Conti (1971) give an approximate formula for the heat transfer coefficient per unit length of pipeline, based upon the method of images:

$$h_p = 2\pi K_s / \ln\,(4H/D)$$

where K_s is the thermal conductivity of the soil
H is the burial depth to pipeline centerline
D is the pipe diameter
ln refers to the natural logarithm.

The formula assumes a homogeneous soil. About 10% more heat may be dissipated to the air for shallow-buried lines, and with air and soil near temperature equilibrium. The thermal conductivity of a typical soil (90% sand, with 10% clay) ranges from 0.7 to 1.5 BTU/hr-ft°F (from dry soil at 0.7 to wet soil at 1.5). (Makowski & Mochlinski, 1956). Thermal conductivity decreases with further water percentage increases until the mixture is sufficiently fluid to permit convective movement of the water around the pipe.

In contrast to the oil-water heat exchange in the fill pipe, where the heat transfer in the pipe wall can be neglected, the pipeline may be coated with insulating materials or concrete. Such coatings will have a thermal resistance per unit length of

$$h_i = \frac{\pi D K_i}{X_i} \qquad (7)$$

where X is the coating thickness and K is the conductivity of the covering material. Typical values for coatings are:

corrosion coating X_i = 1/2 inch = .042 ft; K_i = 0.09
concrete X_i = 3 inches = .25 ft; K_i = 0.7

Further, the oil heat transfer to the pipe wall, as given in Section D.3, must be included. An approximate value of the heat transfer coefficient, conveniently expressed per unit length of pipeline instead of per unit area, is derived from Perry (1963).

$$h_L = S\pi\,(VD')^{0.8}/\,\mu^{0.467} \qquad (8)$$

where the units are selected to have the following dimensions:

V in ft/sec, D′ in inches, and μ is the viscosity in centipoise.

The reciprocals of the heat transfer coefficients, $R = \frac{1}{h}$, define thermal resistances which are additive. The cooling of the line is then given by (see equation (1)):

$$\frac{T_2 - T_1}{L} = \frac{\Delta t}{WC} [\Sigma R]^{-1} = \frac{\Delta t}{WC} \left[\frac{1}{h_L} + \frac{1}{h_i} + \frac{1}{h_p}\right]^{-1}$$

J.5 OIL FRICTIONAL HEATING IN PIPELINE FLOW

The frictional heating of the oil is a strong function of fluid velocity; it is generally negligible below 5 ft/sec but significant at 10 feet/sec. The heating may be expressed by (Szilas, 1975):

$$\frac{\Delta T}{L} = \frac{\Pi}{8} e\, f\, r \frac{V^3 D}{WC} \qquad (9)$$

where r is the fluid density,

v is the fluid velocity,

e is a roughness factor (adding 2% to 10% to the friction)

f is the friction factor in the Blasius or Nikuradse form:

$$f = \frac{.316}{(Re)}.25 \text{ , for } (Re) < 10^5$$

$$\text{and } f = .0032 + \frac{.221}{(Re)}.237 \text{ , for } (Re) > 10^5$$

In calculating the heating in °F/mile, conversion factors of 777.6 ft-lbf per BTU and 32.2 lbm ft/sec^2 per lbf are used. The roughness factor varies from 1.02 at (Re) of 50,000, to 1.10 at (Re) of 250,000, and can be obtained from standard piping handbooks. (There is no functional expression for e).

J.6 ESTIMATION OF OIL TEMPERATURE

The following section illustrates calculations required to estimate temperatures for oil received at the terminals. Bayou Choctaw early storage site and the DOE terminal near St. James are used in the calculations detailed in this section. Section J.7 and Table J.1 summarize analogous oil temperature estimates for all Capline Group SPR sites.

TABLE J-1. Oil Temperatures During Withdrawal

Storage Site	Oil Temperature at Depth (°F)	Temperature Change During Displacement (°F)	Net Temperature Change During Pipeline Transfer (°F)	Oil Temperature as Received at Terminal (°F)
1) Napoleonville	150	-26	-1 to -3	121 - 123
2) Weeks Island	110	-5	-5	100
3) Bayou Choctaw	150	-26	-4	120
4) Iberia	150	-26	-7	117
5) Chacahoula	150	-26	0 to 4	120 - 124

J.6.1 Water-Oil Heat Exchange

The fill pipe for each cavern is annular with oil in the outer annulus. The flow rate is about 5600 barrels per hour through an annulus of 143 square inches. Dimensions are ID of 19" and OD of 13-3/8" (hydraulic diameter 0.47 ft.), with a nominal length of 2500 feet. The water flows in a tubing of area 123 square inches and 12-1/2" ID.

Water flow is 2.1 x 10^6 lbm/hr, at 10.3 ft/sec. (Re) is 3.5 x 10^6. Oil flow is 1.8 x 10^6 lbm/hr at 8.9 ft/sec. Reynolds numbers are 11,800; 18,600; 27,200; and 59,000 at 80°F, 100°F, 120°F, and 140°F, respectively.

The worst case assumption of cavern temperatures is 150°F; water intake can be expected to average 70°F. Thus $\Delta t = 40 + 1/2\ (T_{02} - T_{W1})$, where T_{02} and T_{W1} are unknown.

The Nusselt correlation, expressed as a function of average cooling temperature differential gives:

T_2-T_1	Δt	(Nu)	(Pr)	(Re)
5.1°F	10°F	654	82	59,000
9.5°F	20°F	612	100	50,000
12.9°F	30°F	555	120	41,000
16.3°F	40°F	526	160	34,000
17.7°F	50°F	455	177	27,200
20.5°F	60°F	441	180	26,000

The solution of the problem, obtained by matching the oil exit temperature and the wall/oil differential temperature in the equation for (Δt) and the above table, gives

oil - cooled from 150° to 124° at the surface
water - heated from 70° to 80° at the salt dome cavity.

Other solutions, assuming alternate cavern temperatures, are:

- oil cooled from 140° to 120°; water heated from 70° to 77.5°
- oil cooled from 130° to 114°; water heated from 70° to 76°
- oil cooled from 120° to 107°; water heated from 70° to 75°

J.6.2 Pipeline Cooling

The pipeline conditions assumed are cover of 3 feet, moist sandy soil, and 1/2 inch of corrosion wrapping. Concrete sections are ignored over the 39 mile pipeline length, although there may be substantial length of weighted sections. Maximum flow is 577 MBD in a 36" line. The thermal resistances are:

soil: $H/D = 1.5$; $K_s = 1.5$: therefore, $R = .19$

wrapping: $R = \frac{x}{\pi D K_i}$ $K_i = 0.09$; $x = 0.042$; $D = 3$:

therefore, $R = .05$

Oil internal thermal resistance at 577,000 barrels per day in the 36" line, with $V = 5.3$ ft/sec, is:

$R = .0032$ at 120°F

$R = .0038$ at 100°F

The total pipeline thermal resistance is thus about .244 in wet soil and 40 percent greater in dry soil. The cooling per mile for 120°F oil would be 0.32°F to an ambient of 70°F and 0.19°F for 100°F oil. Cooling in dry soil would be about 40 percent less.

J.6.3 Heating in the Pipeline

With a flow of 577 MBD, velocity is 5.3 feet per second, mass flow is 7.6×10^6 lbm/hr,

	(Re)	(f)	(e)
80°F	44,400	.0218	1.03
100°F	70,100	.0194	1.05
120°F	102,000	.0176	1.06

Heating is 0.05°F per mile at 80°F; 0.04°F per mile at 100°F and 120°F.

J.6.4 Summary of Thermal Effects

The existing cavities at Bayou Choctaw may reach a temperature, estima from their depth, of 120°F. Heat exchange with incoming water at 70° would reduce this temperature to about 107°F. Net cooling in the 39 mile pipeline would average .16°F per mile, or 6.2°F. Resultant oil temperatures at St. James would be about 100°F.

However, temperatures as high as 140°F to 150°F could occur in one or more cavities. Oil temperature at the surface would then be 120°F to 124°F, with cooling in the line to about 110°F to 115°F at St. James under wet soil conditions and to 115°F to 120°F under dry soil conditions. This latter case could constitute worst case conditions and is used for calculation of hydrocarbon emissions during withdrawal handling of Bayou Choctaw oil.

J.7 SUMMARY OF OIL TEMPERATURE ESTIMATES FOR CAPLINE GROUP STORAGE SITES

Controlling equations, oil properties, and physical configurations applicable to oil withdrawal at the Capline Group storage sites were developed in Sections J.1 through J.5. Their application to a particular site (Bayou Choctaw early storage) was illustrated in Section J.6.

This section summarizes the results of the application of the methodology developed in Sections J.1 through J.5 to each of the five SPR storage sites. Table J.1 presents the temperatures estimated for oil received at terminal facilities from each of the storage sites.

The temperature of oil stored at Napoleonville is expected to reach 150°F at depth within the caverns. Displacement water would reduce this temperature to about 124°F during withdrawal (see Section J.3). The output oil at 124 degrees would be further cooled during pipeline transfer and would arrive at the terminal at temperatures ranging from 121°F - 123°F, depending on transfer flow rate. (Cooling during pipeline transfer is the result of a net heat loss from the combined effects of pipeline cooling and pipeline heating due to flow resistance (see Section J.4).

At Weeks Island, oil temperatures at depth are expected to reach 110°F in leached storaged caverns. Cooling during withdrawal to the surface would reduce this temperature to approximately 105°F, and pipeline cooling (at a distribution rate of 1 MMGD) would reduce this temperature to about 100°F.

Oil temperatures for Bayou Choctaw are expected to reach 150°F in cavern storage and to be reduced to 124°F during withdrawal operations. Cooling during pipeline transfer would result in a temperature of 120°F at the terminal, assuming a pipeline flow of 930 MBD.

Oil stored at Iberia is expected to reach a temperature of 150°F, with cooling during withdrawal reducing this temperature to approximately 124°F. Transferring this oil by pipeline to the terminal at a rate of 930 MBD would further reduce the temperature to about 117°F.

At Chacahoula dome, stored oil is expected to reach a temperature of 150°F at depth. Cooling during withdrawal would reduce this temperature to about 124°F, and cooling during pipeline transfer to the terminal at rates ranging from 780 MBD to 1.2 MMBD would result in temperatures ranging from 120° - 124°F at the terminal.

J.8 REFERENCES

Brown, K.E., 1967, Gas Lift Theory and Practice, Prentice - Hall.

Davenport, T.C. and V.J. Conti, 1971, Heat transfer problems encountered in the handling of waxy crude oils in large pipelines, J. Inst. Petrol., Vol. 57, p. 147

Frick, 1962, In Petroleum production handbook, McGraw-Hill.

Makowski, M.W. and K. Mochlinski, 1956, In Proc. Inst. Electr. Engr., Vol. 103A, p. 453

Perry, J.H. and others, 1963, Chemical engineers handbook, New York, McGraw-Hill.

Sieder and Tate, 1936, In Ind. Eng. Chem., Vol. 28, p. 1429

Szilas, A.P., 1975, Production and transportation of oil and gas, Elsevier.

APPENDIX K

COMMENTS RECEIVED

Department of the Army, New Orleans District Corps of Engineers K-1

U.S. Department of Agriculture, Soil Conservation Service K-5

U.S. Department of Commerce, National Oceanic and Atmospheric Administration K-6

U.S. Environmental Protection Agency K-8

U.S. Nuclear Regulatory Commission K-16

Advisory Council on Historic Preservation K-17

State of Louisiana, Department of Urban and Community Affairs K-18

Morton-Norwich Products, Inc. K-20

Dow Chemical Company K-24

DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60267
NEW ORLEANS, LOUISIANA 70160

IN REPLY REFER TO
LMNPD-RE

22 November 1977

Mr. Michael E. Carosella
Executive Communications
Room 3309
Federal Energy Administration
Washington, DC 20461

Dear Mr. Carosella:

Your draft environmental impact statement (EIS), with cover letter dated 21 September 1977, concerning the Capline Group of salt domes was referred to this office from the Office of the Chief of Engineers, Washington, DC, for review and comments.

We have reviewed the draft EIS in accordance with our areas of reponsibility and expertise as outlined in the Council on Environmental Quality guidelines, Title 40, CFR, Part 1500, published in the "Federal Register" dated 1 August 1973; and US Army Corps of Engineers administrative procedures for permit activities in navigable waters or ocean waters, Title 33, CFR, Parts 320-329, published in the "Federal Register" dated 19 July 1977.

We offer the following comments regarding the draft EIS:

a. General comments:

(1) Water quality and species composition data in the document were obtained from literature reviews pertaining to the the regional environmental setting. The scope of this project and the potential adverse environmental impacts are of such magnitude to suggest that specific onsite sampling, analyses, and impact evaluations should be conducted to update existing conditions in the proposed project areas and to adequately assess project impacts. Some of the most significant adverse impacts which would occur as a result of the proposed project are those which would affect the water quality and dependent aquatic

organisms of the numerous streams and wetlands of the project areas. These problems should be addressed first hand, rather than relying entirely on data and discussions taken from available publications.

(2) The references to rare and endangered species should be changed to threatened or endangered. The American alligator is considered threatened in the project areas.

(3) The environmental setting should include a discussion of the vector problems and potentials which exist in the area of project influence. The impact sections should provide discussions as to how the proposed project and alternatives would affect these vector problems. Construction activities would produce habitat for vectors of public health significance, especially mosquitoes. Project completion probably would impede normal surface drainage and also would create temporary and permanent impoundments suitable for vector production.

b. Detailed comments:

(1) Page 3.2-13. The source reference should be included for table 3.2-1.

(2) Page 3.3-6, paragraph 4. Add water hyacinth to the list of plants in this paragraph, since it is a codominant aquatic herb located in the area.

(3) Page 3.47-7, paragraph 1. The referenced table (table 3.4-1) is not included in the text.

(4) Page 4.1-4, paragraph 3. Change the paragraph as follows: "At least three potentially significant. . . may occur: 1) changes in the benthic communities, 2) disruption of migration routes, and 3) denial of valuable inshore habitat to many pelagic species incapable of utilizin waters of higher salinities."

(5) Page 4.1-5. The source reference for figure 4.4-1 should be included.

(6) Page 4.1-7, paragraph 1. There would be a greater reduction in suitable habitat for aquatic organisms if the combined effects of all brine releases associated with the entire SPR program were considered.

(7) Page 4.1-10, paragraph 1. The statement in this paragraph appears many times in the text. Regardless of the amount of nutrients

that are added to the organic system, photosynthetic productivity would be significantly curtailed due to the reduction in light levels.

(8) <u>Page 4.1-11, paragraph 3</u>. The research reference should be provided to substantiate the stated recovery times.

(9) <u>Page 4.1-12, paragraph 1</u>. Utilization of the push-ditch method of pipeline construction, where feasible, would significantly reduce construction impacts.

(10) <u>Page 4.3-2, paragraph 1 and 2</u>. The site specific environmental settings for the Koch and Nordix sites are not provided in the text.

(11) <u>Page 4.5-4, paragraph 1</u>. The total habitat area involved is not presented in section 3.4.2.5, as stated in this paragraph.

(12) <u>Page 5.2-1, paragraph 5.2.1.3</u>. Low-flow conditions are the worst conditions from a water quality standpoint, and dredging during these periods could aggravate an already bad situation.

(13) <u>Page 5.2-3, paragraph 5.2.2.2</u>. Add a statement that a program of monitoring dikes of brine reservoirs, the brine diffusors, and brine and oil pipelines would be monitored.

(14) <u>Page 5.3-2, paragraph 1</u>. State the approximate number of cubic yards of material that would be excavated for the pipeline.

(15) <u>Page 6.3-1</u>. It is necessary that paragraph 6.3.4 "Impacts on Biological Productivity" be added. It should include a discussion of the biological activity that would be affected by the cumulative impacts from construction and operation of the proposed project and those of the considered alternatives.

(16) <u>Page 9.2-2, table 9.2-1</u>. The reference to 33 CFR 209 should be updated. Our regulatory program regulations were revised on 19 July 1977, and the proper reference is now Title 33, CFR, Parts 320-329.

(17) <u>Volume II, page A.3-24, paragraph A.3.4.3</u>. The flotation canal method is the least acceptable method of pipeline construction discussed. The reasons other methods cannot be used must be well documented before the flotation method can be considered acceptable.

(18) <u>Volume II, page B.2-73, paragraph 2</u>. There are no shrub species listed in this paragraph, as indicated.

LMNPD-RE
Mr. Michael E. Carosella 22 November 1977

Representatives of your organization have been maintaining close coordination with our representatives concerning permit requirements and have been providing all necessary information required for permit processing. We appreciate your efforts in maintaining this close coordination. Thank you for the opportunity to review and comment on the draft EIS.

Sincerely yours,

EARLY J. RUSH III
Colonel, CE
District Engineer

Copy furnished:

Mr. Charles Warren, Chairman
Council on Environmental Quality
Washington, DC 20506

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Post Office Box 1630, Alexandria, La. 71301

November 16, 1977

Executive Communications
Room 3309
Federal Energy Administration
Washington, D.C. 20461

Dear Sir:

Re: Capline Group Salt Domes, St. James, Louisiana
Review draft EIS

The following comments concerning the referenced EIS are offered for your consideration. The EIS contained a thorough description of project impacts of the proposed plan and various alternatives. However, there was no mention of prime farmland during characterization of existing resources or impacts. Prime farmlands are those whose value derives from their general advantage as cropland due to soil and water conditions. Prime farmland can be pastureland, cropland, forestland, or open land but not urban or industrial built-up land. If the project will result in the irreversible conversion of this prime farmland to other uses, this should be addressed in the appropriate impact section.

The following information is provided for your use in making determinations as to the impact of the project on prime farmland. Approximately 75 percent of the soils in the Napoleonville dome site area are classified as prime farmland. Approximately 30 percent of the soils in Weeks Island site are considered prime farmland. All the soils in the Iberia and Bayou Choctaw site areas are classified as prime farmland. None of the soils within the Chacahoula site area are considered prime farmland. A determination should be made as to the amount of land not presently in industrial use within the storage site areas that is classified as prime farmland.

We appreciate the opportunity to review this draft statement.

Sincerely,

Alton Mangum

Alton Mangum
State Conservationist

cc: Council on Environmental Quality, Washington, D.C.
R. M. Davis, Administrator, SCS, Washington, D.C.
Office of Coordinator of Environmental Quality Activities,
Office of the Secretary, USDA, Washington, D.C.
Director, Environmental Services Division, SCS, Washington, D.C.
J. Vernon Martin, Director, TSC, SCS, Fort Worth, Texas

UNITED STATES DEPARTMENT OF COMMERC
The Assistant Secretary for Science and Techn[illegible]y
Washington, D.C. 20230
(202) 377-3111

November 18, 1977

Mr. Michael E. Carosella
Associate Assistant Administrator
Special Programs, Strategic Petroleum
  Reserve
Executive Communications, Room 3309
Federal Energy Administration
Washington, D.C. 20461

Dear Mr. Carosella:

This is in reference to your draft environmental impact statement entitled, "Capline Group Salt Domes/Bayou Choctaw Expansion, Chacahoula, Iberia, Napoleonville, Weeks Island Expansion." The enclosed comments from the National Oceanic and Atmospheric Administration are forward[illegible] for your consideration.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving ten (10) copies of the final statement.

Sincerely,

Sidney R Galler

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosure--Memo from: National Oceanic and Atmospheric
Administration-National Ocean Survey

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Rockville, Maryland 20852
National Ocean Survey

C52/JLR

November 4, 1977

TO: William Aron
Director
Office of Ecology and Environmental Conservation

G. C. [illegible] for,
FROM: Gordon Lill
Deputy Director
National Ocean Survey

SUBJ: DEIS #7710.10 - Bayou Choctaw Expansion

The subject statement has been reviewed within the areas of NOS responsibility and expertise, and in terms of the impact of the proposed action on NOS activities and projects.

The following comments are offered for your consideration.

Appendix B - Detailed Description of the Environment-
There are no adequate site specific physical oceanographic or meteorological data for the potential brine disposal sites along the Louisiana coast now in existence. This should be brought out.

Appendix E - Oil and Brine Spill Risk Analysis
The present state-of-the-art for oil spill analysis includes models which provide lines of probabilistic impact and probabilistic time to impact in this area. This information, missing in the subject DEIS, would improve the plan for containment and removal of spilled oil.

Appendix G - Brine Dispersion Modeling-
The modeling approach used to characterize the dispersion of brine into surrounding waters may suffer from assumptive mathematical simplifications. The assumptions of constant depth and vertically constant current would appear to be weaknesses in the MIT model.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
FIRST INTERNATIONAL BUILDING
1201 ELM STREET
DALLAS, TEXAS 75270

November 30, 1977

Mr. Thomas A. Noel
Acting Assistant Secretary
Resource Application
Department of Energy
1725 M Street N.W.
Washington, D.C. 20461

Dear Mr. Noel:

We have reviewed the Draft Environmental Impact Statement (EIS) for the proposed Capline Group Salt Domes of the Strategic Petroleum Reserve (SPR) located in the Gulf Coast Region of south central Louisiana. The proposed development for approximately 300 million barrels (MMB) of oil storage requires use of salt dome facilities developed for the Early Storage Reserve (ESR) at Bayou Choctaw and Weeks Island located in Iberville and Iberia Parishes, Louisiana. Each will respectively provide 94 MMB and 89 MMB of crude oil storage capacity. In addition, the project proposes construction of a new 150 MMB salt dome storage facility at Napoleonville salt dome located in Assumption Parish. Four other candidates for possible development of additional capacity for the Capline Group include two new sites at Chachoula salt dome in La Fourche Parish and Iberia salt dome in Iberia Parish. The other two possibilities are the expansion of either Bayou Choctaw or Weeks Island. One or a combination of these four candidates may be developed as alternatives to the development of the Napoleonville salt dome.

The following comments are provided for your consideration in preparation of the Final EIS:

1. In assessing environmental impacts of the Capline Group proposed and alternative SPR salt dome expansion sites, it appears that impacts regarding utilization and loss of wetlands could be minimized if appropriate measures are taken. In reviewing wetland impacts contributed by each of the alternatives as presented on page 4.9-5 of the draft statement, it appears expansion development of either Iberia salt dome or Chachoula salt dome would contribute to the greatest amount of wetland destruction and permanent loss. The wetland policy as expresse and emphasized by the Environmental Protection Agency, published in the <u>Federal Register</u> (40 CFR 230, September 5, 1975), and presented by <u>The President in</u> Executive Order 11990 (Protection of Wetlands),

requires that particular cognizance and consideration be given any proposal that has potential to damage or destroy wetlands. Therefore, the applicant should provide substantive evaluation of all proposed and alternate actions in regard to their potential to adversely impact the wetlands. The selected project action should be shown to be the most practicable of all alternative actions and will provide possible mitigative measures to minimize harm to the wetlands. In the selection of any right-of-way, every effort should be made to avoid wetlands utilization. Mitigative measures are available to minimize the environmental impacts and we will be happy to work with you to define these areas. As possible alternate salt dome crude oil storage sites for future storage and expansion, the Final should consider using off-shore domes and other sites inland away from Gulf Coast wetland areas.

We recognize that The President's Executive Order 11990 (Protection of Wetlands) does not apply directly to this project because of the exemptions allowed in Section 8 of this Order. However, for future projects of this nature, the applicant is advised that EPA will implement this Order to its fullest degree to preserve and protect the wetlands and will take appropriate actions to carry out its mandates. The applicant's consideration and response on this matter should be provided in the Final EIS.

2. Proposed expansion activities for the SPR for the Capline Group involves hydrocarbon storage by emplacement of crude oil into salt domes, solution mining of the salt domes to create or enlarge existing storage capacity, and, in some cases, disposal of the produced or displaced brines by deep well injection. All these types of operations will be regulated under the Underground Injection Control (UIC) program of the Safe Drinking Water Act (Public Law 93-523), as per Draft regulations, August 31, 1976.

Under these Draft regulations, the data presented in the draft statement needs to be strengthened to support an effective evaluation of the environmental impact of these operations. The applicant should provide sufficient data to EPA from the on-going testing and analysis program before initiating any of the emplacement, mining, or disposal operations. Since the State of Louisiana is expected to assume primary enforcement authority of the Underground Injection Control Program, the data and analyses provided should be consistent both with those requirements proposed in EPA Administrator's Decision Statement #5 (39 CFR:69), or those required under the superseding UIC regulations, when they become applicable, and those required for permit application under Statewide Order 29-B of the Louisiana Department of Conservation, Oil and Gas Division. In addition, close coordination should be afforded both EPA and the Louisiana Department of Conservation by DOE in all phases of data requirements, collection, and presentation. Also, selected technical data should be provided to the public in a form of a "by request" appendix to the Final EIS. We are requesting that the intentions of the applicant to comply with the above recommendations be adequately addressed in the Final EIS.

3. It is recommended that the method of brine disposal involving use of the displaced brine as a chemical feed stock be adopted wherever practicable. Discussion of this alternative should be included in the Final EIS.

4. The statement indicates that pipelines for the SPR salt domes will be coated externally with an asphalt-sand mixture or coal tar enamel for corrosion protection. The pipeline will also contain sacrificial zinc anodes to lessen internal corrosion. The Final EIS should discuss whether these corrosion preventive measures could cause any adverse impacts to groundwater quality in the project area.

5. On page B.2-57, in the discussion of the interpretative ruling of December 21, 1977, regarding the Federal Clean Air Act, the name "Emission Trade-Off" is incorrectly used since it is more commonly referred to as "Emission Offset." This discrepancy in terminology should be corrected in the final statement. Furthermore, based upon the extrapolation of regional air quality data taken from ambient air monitoring studies conducted in 1975, the statement indicates that levels of non-methane hydrocarbons and photochemical oxidants were exceeding Federal air standards quite frequently in southern Louisiana. Therefore, the emission offset policy may be applicable to this project. In addition, the final statement should note that the exclusion of new sources, which emit less than 100 tons per year, as required under the emission offset policy, is based on "potential" instead of "actual" emissions. These matters and their effect on this project should be adequately considered and addressed in the final statement.

6. In addressing the ambient air quality standards, the final statement should recognize that the Clean Air Act, amended on August 7, 1977, has changed past Prevention of Significant Deterioration (PSD) Regulations. These changes that are significant to this project are that PSD designated source categories have been expanded from 19 to 28 sources, one of which is petroleum storage and transfer facilities. Also, PSD regulations no longer apply only to particulate and sulphur dioxide emisisons but instead to all criteria pollutants, (i.e., Sulphur Dioxide (SO_2), Total Suspended Particulates (TSP), Non-Methane Hydrocarbons (NMHC), Nitrous Oxides (NO_x), Carbon Monoxide (CO), and Photochemical Oxidants (O_3). These changes and their effect upon the project should be addressed in the final statement.

7. In discussing possible mitigative measures in eliminating hydrocarbon emission venting from the underground storage caverns, we suggest that condensation units in lieu of a flare system be used. The condensation unit would not only provide less potential for possible explosion of the volatile gases within storage but would also provide fuel conservation by allowing the condensed emissions be returned to storage.

8. No sewage discharges for any of the Capline Group sites are mentioned in the Draft EIS. If such discharges will exist, discharge points, type of treatment, and possible impacts to the receivng stream should be discussed. In addition, National Pollutant Discharge Elimination System (NPDES) permit application for such discharges should be addressed.

9. The discussion of the Spill Prevention Control and Countermeasure (SPCC) Plan as required under Coded Federal Regulations at 40 CFR 112 (Oil Pollution Prevention; Non-Transportation Related Onshore and Offshore Facilities) needs to be strengthened. The Final EIS should state that an SPCC Plan, which will meet the requirements of 40 CFR 112, will be prepared within six months after the facility begins operation and shall be fully implemented no later than one year after operation begins.

10. The levels of environmental noise tabulated on page B.2-66 of the Draft EIS have been labeled as "established guidelines," from EPA. However, this table reflects only "identified levels" which are requisites to protect public health and welfare with an adequate margin of safety for both activity interference and hearing loss. The noise levels cited in this table do not constitute a regulation, specification, or standard.

These comments classify your Draft Environmental Impact Statement as ER-2. Specifically, based upon the information contained in the statement, we have environmental reservations concerning the destruction of valuable wetlands and also the possible environmental impacts that brine disposal could induce on underground aquifers. In addition, we are requesting more information on air, noise, underground injection, wastewater treatment, and other areas as specifically addressed in the above comments. Furthermore, we do want to reemphasize that EPA, in the future, will review projects of this nature with the fullest intent to protect and preserve the wetlands as mandated by Executive Order 11990, and in doing so, would consider an environmental unsatisfactory determination for projects of this nature. Our classification and a summary of our comments will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions, under Section 309 of the Clean Air Act.

Definitions of the categories are provided on the enclosure. Our procedure is to categorize the EIS on both the Environmental consequences of the proposed action and on the adequacy of the impact statement at the draft stage, whenever possible.

We appreciate the opportunity to review the Draft Environmental Impa Statement. Please send us two copies of the Final Environmental Impac Statement at the same time it is sent to the Council on Environmental Quality.

Sincerely,

Adlene Harrison

Adlene Harrison
Regional Administrator

Enclosures

ant Administrator for Pesticide Programs (36 FR 9038).

Dated: April 3, 1974.

HENRY J. KORP,
Deputy Assistant Administrator for Pesticide Programs.

[FR Doc.74-8016 Filed 4-8-74;8:45 am]

SHELL CHEMICAL CO.

Notice of Filing of Petition for Food Additive

Pursuant to provisions of the Federal Food, Drug, and Cosmetic Act (sec. 409 (b)(5), 72 Stat. 1786; 21 U.S.C. 348(b)(5)), notice is given that a petition (FAP 4H5046) has been filed by the Shell Chemical Co., Suite 300, 1700 K Street, NW., Washington, D.C. 20006, proposing establishment of a food additive regulation (21 CFR Part 121) permitting the safe use of the insecticide 2,2-dichlorovinyl dimethyl phosphate in space, spot and/or crack and crevice treatments of food service, manufacturing, and processing establishments including, but not limited to, restaurants, flour mills, supermarkets, and plants handling dairy products, vegetables, oils, candy, macaroni/spaghetti, soft drinks, cake mixes, and cookies.

Dated: March 29, 1974.

JOHN B. RITCH, Jr.,
Director, Registration Division.

[FR Doc.74-8017 Filed 4-8-74;8:45 am]

SUBSURFACE EMPLACEMENT OF FLUIDS

Administrator's Decision Statement #5

The Environmental Protection Agency, in concert with the objectives of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq.; 86 Stat. 816 et seq.; Pub. L. 92-500) " . . . to restore and maintain the chemical, physical, and biological integrity of the Nation's water" has established an EPA policy on Subsurface Emplacement of Fluids by Well Injection" which was issued internally as Administrator's Decision Statement No. 5. The purpose of the policy is to establish the Agency's concern with this technique for use in fluid storage and disposal and its position of considering such fluid emplacement only where it is demonstrated to be the most environmentally acceptable available method of handling fluid storage or disposal. Publication of the Policy as information establishes the Agency's position and provides guidance to other Federal Agencies, the States, and other interested parties.

Accompanying the policy statement are "Recommended Data Requirements for Environmental Evaluation of Subsurface Emplacement of Fluids by Well. injection well system; and to insure ments is to provide guidance for potential injectors and regulatory agencies concerning the kinds of information required to evaluate the prospective injections well system; and to insure protection of the environment. The Recommended Data Requirements require sufficient information to evaluate complex injection operations for hazardous materials, but may be modified in scope by a regulatory agency for other types of injection operations.

The EPA recognizes that for certain industries and in certain locations the disposal of wastes and the storage of fluids in the subsurface by use of well injection may be the most environmentally acceptable practice available. However, adherence to the policy requires the potential injector to clearly demonstrate acceptability by the provision of technical analyses and data justifying the proposal. Such demonstration requires conventional engineering and other analyses which indicate beyond a reasonable doubt the efficacy of the proposed injection well operation.

Several issues within the policy should be highlighted and explained to avoid confusion. One of the goals of the policy is to protect the integrity of the subsurface environment. In the context of the policy statement, integrity means the prevention of unplanned fracturing or other physical impairment of the geologic formations and the avoidance of undesirable changes in aquifers, mineral deposits or other resources. It is recognized that fluid emplacement by well injection may cause some change in the environment and, to some extent, may preempt other uses.

Emplacement is intended to include both disposal and storage. The difference between the two terms is that storage implies the existence of a plan for recovery of the material within a reasonable time whereas disposal implies that no recovery of the material is planned at a given site. Either operation would require essentially the same type of information prior to injection. However, the attitude of the appropriate regulatory agency toward evaluation of the proposals would be different for each type operation. The EPA policy recognizes the need for injection wells in certain oil and mineral extraction and fluid storage operations but requires sufficient environmental safeguards to protect other uses of the subsurface, both during the actual injection operation and after the injection has ceased.

The policy considers waste disposal by well injection to be a temporary means of disposal in the sense that it is approved only for the life of an issued permit. Should more environmentally acceptable disposal technology become available, a change to such technology would be required. The term "temporary" is not intended to imply subsequent recovery of injected waste for processing by another technology.

Paragraph 5 of the policy and program guidance provides that EPA will apply the policy to the extent of its authorities in conducting all EPA program activities. The applicability of the policy to participation by the several States in the NPDES permit program under section 402 of the Federal Water Pollution Control Act as amended has been established previously by § 124.80(d) of Part 124 entitled "State Program Elements Necessary for Participation in the National Pollutant Discharge Elimination System," 37 FR 28390 (December 22, 1972). These guidelines provide that each EPA Regional Administrator must distribute the policy to the Director of a State water discharge permit issuing agency, and must utilize the policy in his own review of any permits for disposal of pollutants into wells that are proposed to be issued by States participating in the NPDES.

Dated: April 2, 1974.

JOHN QUARLES,
Acting Administrator.

ADMINISTRATOR'S DECISION STATEMENT No. 5

EPA POLICY ON SUBSURFACE EMPLACEMENT OF FLUIDS BY WELL INJECTION

This ADS records the EPA's position on injection wells and subsurface emplacement of fluids by well injection, and supersedes the Federal Water Quality Administration's order COM 5040.10 of October 15, 1970..

Goals. The EPA Policy on Subsurface Emplacement of Fluids by Well Injection is designed to:

(1) Protect the subsurface from pollution or other environmental hazards attributable to improper injection or ill-sited injection wells.

(2) Ensure that engineering and geological safeguards adequate to protect the integrity of the subsurface environment are adhered to in the preliminary investigation, design, construction, operation, monitoring and abandonment phases of injection well projects.

(3) Encourage development of alternative means of disposal which afford greater environmental protection.

Principal findings and policy rationale. The available evidence concerning injection wells and subsurface emplacement of fluids indicates that:

(1) The emplacement of fluids by subsurface injection often is considered by government and private agencies as an attractive mechanism for final disposal or storage owing to: (a) the diminishing capabilities of surface waters to receive effluents without violation of quality standards, and (b) the apparent lower costs of this method of disposal or storage over conventional and advanced waste management techniques. Subsurface storage capacity is a natural resource of considerable value and like any other natural resource its use must be conserved for maximal benefits to all people.

(2) Improper injection of municipal or industrial wastes or injection of other fluids for storage or disposal to the subsurface environment could result in serious pollution of water supplies or other environmental hazards.

(3) The effects of subsurface injection and the fate of injected materials are uncertain with today's knowledge and could result in serious pollution or environmental damage requiring complex and costly solutions on a long-term basis.

Policy and program guidance. To ensure accomplishment of the subsurface protection goals established above it is the policy of the Environmental Protection Agency that:

(1) The EPA will oppose emplacement of materials by subsurface injection without strict controls and a clear demonstration that such emplacement will not interfere with present or potential use of the subsurface environment, contaminate ground water resources or otherwise damage the environment.

(2) All proposals for subsurface injection should be critically evaluated to determine that:

(a) All reasonable alternative measures have been explored and found less satisfactory in terms of environmental protection;

(b) Adequate preinjection tests have been made for predicting the fate of materials injected;

(c) There is conclusive technical evidence to demonstrate that such injection will not interfere with present or potential use of water resources nor result in other environmental hazards;

(d) The subsurface injection system has been designed and constructed to provide maximal environmental protection;

(e) Provisions have been made for monitoring both the injection operation and the resulting effects on the environment;

(f) Contingency plans that will obviate any environmental degradation have been prepared to cope with all well shut-ins or any well failures;

(g) Provision will be made for supervised plugging of injection wells when abandoned and for monitoring to ensure continuing environmental protection.

(3) Where subsurface injection is practiced for waste disposal, it will be recognized as a temporary means of disposal until new technology becomes available enabling more assured environmental protection.

(4) Where subsurface injection is practiced for underground storage or for recycling of natural fluids, it will be recognized that such practice will cease or be modified when a hazard to natural resources or the environment appears imminent.

(5) The EPA will apply this policy to the extent of its authorities in conducting all program activities, including regulatory activities, research and development, technical assistance to the States, and the administration of the construction grants, state program grants, and basin planning grants programs and control of pollution at Federal facilities in accordance with Executive Order 11752.

WILLIAM D. RUCKELSHAUS,
Administrator.

FEBRUARY 6, 1973.

RECOMMENDED DATA REQUIREMENTS FOR ENVIRONMENTAL EVALUATION OF SUBSURFACE EMPLACEMENT OF FLUIDS BY WELL INJECTION

The Administrator's Decision Statement No. 5 on subsurface employment of fluids by well injection has been prepared to establish the Agency's position on the use of this disposal and storage technique. To aid in implementation of the policy a recommended data base for environmental evaluation has been developed.

The following parameters describe the information which should be provided by the injector and are designed to provide regulatory agencies sufficient information to evaluate the environmental acceptability of any proposed well injection. A potential injector should initially contact the regulatory authority to determine the preliminary investigative and data requirements for a particular injection well as these may vary for different kinds of injection operations. The appropriate regulatory authority will specify the exact data requirements on a case by case basis.

(a) An accurate plat showing location and surface elevation of proposed injection well site, surface features, property boundaries, and surface and mineral ownership at an approved scale.

(b) Maps indicating location of water wells and all other wells, mines or artificial penetrations, including but not limited to oil and gas wells and exploratory or test wells, showing depths, elevations and the deepest formation penetrated within twice the calculated zone of influence of the proposed project. Plugging and abandonment records for all oil and gas tests, and water wells should accompany the map.

(c) Maps indicating vertical and lateral limits of potable water supplies which would include both short- and long-term variations in surface water supplies and subsurface aquifers containing water with less than 10,000 mg/l total dissolved solids. Available amounts and present and potential uses of these waters, as well as projections of public water supply requirements must be considered.

(d) Descriptions of mineral resources present or believed to be present in area of project and the effect of this project on present or potential mineral resources in the area.

(e) Maps and cross sections at approved scales illustrating detailed geologic structure and a stratigraphic section (including formations, lithology, and physical characteristics) for the local area, and generalized maps and cross sections illustrating the *regional* geologic setting of the project.

(f) Description of chemical, physical, and biological properties and characteristics of the fluids to be injected.

(g) Potentiometric maps at approved scales and isopleth intervals of the proposed injection horizon and of those aquifers immediately above and below the injection horizon, with copies of all drill-stem test charts, extrapolations, and data used in compiling such maps.

(h) Description of the location and nature of present or potentially useable minerals from the zone of influence.

(i) Volume, rate, and injection pressure of the fluid.

(j) The following geological and physical characteristics of the injection interval and the overlying and underlying confining beds should be determined and submitted:

(1) Thickness;
(2) areal extent;
(3) lithology;
(4) grain mineralogy;
(5) type and mineralogy *of* matrix;
(6) clay content;
(7) clay mineralogy;
(8) effective porosity (including an explanation of how determined);
(9) permeability (including an explanation of how determined);
(10) coefficient of aquifer storage;
(11) amount and extent of natural fracturing;
(12) location, extent, and effects of known or suspected faulting indicating whether faults are sealed, or fractured avenues for fluid movement;
(13) extent and effetcs of natural solution channels;
(14) degree of fluid saturation;
(15) formation fluid chemistry (including local and regional variations);
(16) temperature of formation (including an explanation of how determined);
(17) formation and fluid pressure (including original and modifications resulting from fluid withdrawal or injection);
(18) fracturing gradients;
(19) *diffusion and dispersion characteristics* of the waste and the formation fluid including effect of gravity segregation;
(20) compatibility of injected waste with the physical, chemical and biological characteristics of the reservoir; and
(21) injectivity profiles.

(k) The following engineering data should be supplied:

(1) Diameter of hole and total depth of well;
(2) type, size, weight, and strength, of all surface, *intermediate, and injectio* [illegible] strings;
(3) specifications and proposed i[illegible]ation of tubing and packers;
(4) proposed *cementing procedures* [illegible] type of cement;
(5) proposed coring program;
(6) proposed formation testing program;
(7) proposed logging program;
(8) proposed artificial fracturing or st[illegible]ulation program;
(9) proposed injection procedure;
(10) plans of the surface and subsurface construction details of the system including engineering drawings and specifications of the system (including but not limited [illegible] pumps, well head construction, and ca[illegible]g depth);
(11) plans for monitoring including a multipoint fluid pressure monitoring system constructed to monitor pressures above as well as within the injection zones; desc[illegible]tion of annular fluid; and plans for m[illegible]taining a complete operational history [illegible] the well;
(12) expected changes in pressure, rate of native fluid displacement by injected fluid, directions of dispersion and zone affecte[illegible] the project;
(13) contingency plans to cope with [illegible] shut-ins or well failures in a manner that will obviate any environmental degradation.

(l) Preparation of a report thoroughly investigating the effects of the proposed s[illegible]surface injection well should be a prere[illegible]site for evaluation of a project. Such a st[illegible]ment should include a thorough assessment of: (1) the alternative disposal schemes in terms of maximum environmental protection; (2) projection of fluid pressure respo[illegible]e with time both in the injection zones [illegible] overlying formations, with particular at[illegible]tion to acquifers which may be used for fresh water supplies in the future; and (3) problems associated with possible chemical interactions between injected was[illegible]mation fluids, and mineralogical con[illegible].

[FR Doc.74–8021 Filed 4–8–74;8:46 [illegible]

FEDERAL MARITIME COMMISSION

AMERICAN WEST AFRICAN FREIGH[illegible] CONFERENCE

Notice of Petition Filed

Notice is hereby given that the following petition has been filed with the Co[illegible]mission for approval pursuant to sect[illegible]n 14b of the Shipping Act, 1916, as amen[illegible]d (75 Stat. 762, 46 U.S.C. 813a).

Interested parties may inspect a copy of the current contract form and of [illegible]e petition, reflecting the changes propo[illegible]d to be made in the language of said c[illegible]tract, at the Washington office of the Federal Maritime Commission, 1100 L Street NW., Room 10126 or at the F[illegible]d Offices located at New York, N.Y., N[illegible] Orleans, Louisiana, San Francisco, C[illegible]fornia, and Old San Juan, Puerto Rico. Comments with reference to the proposed changes and the petition, including a request for hearing, if desired, may [illegible]e submitted to the Secretary, Federal M[illegible]itime Commission, 1100 L Street NW., Washington, D.C. 20573, on or before April 19, 1974. Any person desiring a hearing on the proposed modification [illegible] the contract form and/or the appro[illegible]d contract system shall provide a clear [illegible] concise statement of the matters upon which they desire to adduce evidence.

ENVIRONMENTAL IMPACT OF THE ACTION

LO - Lack of Objections

EPA has no objections to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER - Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to re-assess these aspects.

EU - Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

ADEQUACY OF THE IMPACT STATEMENT

Category 1 - Adequate

The draft impact statement adequately sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 - Insufficient Information

EPA believes the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3 - Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement. If a draft statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make such a determination.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 18 1977

419001

Executive Communications
Room 3309
Department of Energy
1726 M Street, N. W.
Washington, D. C. 20461

PR

Gentlemen:

This is in response to your request for comments on the Draft Environmental Impact Statements for the Capline Group Salt Domes and the Seaway Group Salt Domes.

We have reviewed the statements and determined that the proposed action have no significant radiological health and safety impacts nor will they adversely affect any activities subject to regulation by the Nuclear Regulatory Commission. Accordingly, we have no substantive comments to make.

Thank you for providing us with the opportunity to review the Capline Group Salt Domes and the Seaway Group Salt Domes Draft Environmental Impact Statements.

Sincerely,

Voss A. Moore

Voss A. Moore, Assistant Director
for Environmental Projects
Division of Site Safety and
Environmental Analysis

cc: CEQ (5)

Advisory Council on
Historic Preservation
1522 K Street N.W.
Washington, D.C. 20005

October 28, 1977

Mr. Michael E. Carosella
Associate Assistant Administrator
Special Programs
Strategic Petroleum Reserve
Federal Energy Administration
Washington, D. C. 20461

Dear Mr. Carosella:

This is in response to your request of September 23, 1977, for comments on the draft environmental statement (DES) for the Capline Group of salt dome crude oil storage sites located in the Gulf Coast region of south central Louisiana.

The Council notes from its review that while cultural resource studies to date indicate no properties included in or known to be eligible for inclusion in the National Register of Historic Places will be affected additional studies are necessary before final determinations can be made. Accordingly, the Federal Energy Administration is reminded that should those additional studies identify cultural resources eligible for inclusion in the National Register which will be affected by the undertaking, it should delay further processing of the undertaking and afford the Council an opportunity to comment pursuant to the "Procedures for the Protection of Historic and Cultural Properties" (36 C.F.R. Part 800).

Should you have any questions or require additional assistance in this matter, please contact Michael H. Bureman of the Council staff at P. O. Box 25085, Denver, Colorado 80225, or at (303) 234-4946, an FTS number.

Sincerely yours,

Louis S. Wall
Assistant Director, Office
of Review and Compliance, Denver

The Council is an independent unit of the Executive Branch of the Federal Government charged by the Act of October 15, 1966 to advise the President and Congress in the field of Historic Preservation.

STATE OF LOUISIANA
DEPARTMENT OF URBAN AND COMMUNITY AFFAIRS

EDWIN EDWARDS
GOVERNOR
LEON R. TARVER, JR.
SECRETARY

P. O. BOX 44455
BATON ROUGE, LOUISIANA 7[illegible]C
389-5664

November 10, 1977

Federal Energy Administration
Washington, D.C. 20461

RE: Draft EIS - Capline Group of Salt Dome Crude Oil Storate Sites-Strategic
Petroleum Reserves - Volume I-II-III

Dear Sir:

We have reviewed the referenced environmental statement with respect to agency impact and responsibility.

APPLICABLE STATEMENTS ARE CHECKED BELOW:

____ This is to notify you that we concur with your selection of state agencies requested to review and comment on the document. We recommend no addit[illegible].

__X__ A copy of the document has been forwarded for review and comment to the Louisiana state agencies listed on Attachment A. Any comments forthcoming from these agencies will be forwarded to you by December 8, 1977

____ We request that you forward a copy of the document for review and comment to the Louisiana state agencies listed on Attachment B. Any comments forthcoming from these agencies should be forwarded to you with a copy to DUCA by ____________________.

____ Additional Louisiana state agencies have been informed of the contents of the document and notified where a copy may be obtained.

A copy of the statement will be retained in our office and is available for publ[illegible]c inspection, and a notice of availability will be published in our newsletter.

Sincerely,

George P. Gullett

George P. Gullett
Environmental Coordinator

GPG:se

Attachment: 1

Mr. William Mollere
Manager
Governor's Council on Environmental Quality
Office of Science, Technology and Environmental
Policy
Post Office Box 44066
Baton Rouge, Louisiana 70804

Mr. Robert LeFleur
Executive Secretary
Stream Control Commission
Post Office Drawer FC
Baton Rouge, Louisiana 70893

Mr. William C. Hulls
Secretary
Department of Natural Resources
Post Office Box 44396
Baton Rouge, Louisiana 70804

Mr. Paul Hartwig
Assistant Secretary
Division of Archeology and Historic Preservation
Old State Capitol
Baton Rouge, Louisiana 70801

MORTON-NORWICH PRODUCTS, INC.

110 NORTH WACKER DRIVE · CHICAGO, ILLINOIS 60606
(312) 621-5200

LEGAL DEPARTMENT

November 4, 1977

Executive Communications
Box PR, Room 3317
Federal Energy Administration
12th & Pennsylvania, N. W.
Washington, D. C. 20461

Re: CAPLINE DRAFT EIS (DES 77-9)

TO WHOM IT MAY CONCERN:

The Federal Energy Administration published a Notice in the Federal Register of September 23, 1977, concerning the availability of the Draft Environmenta Impact Statement for the Capline Group of Storage Sites in connection with the Strategic Petroleum Reserve Program.

The Federal Energy Administration invited comments and requested that they submitted by November 7, 1977, although it would endeavor to comply with any request for extension of the review period.

Morton-Norwich Products, Inc. is the owner and lessee of real property in an around Weeks Island, Louisiana and, through its Morton Salt and Morton Chemical Divisions, owns and operates mining, production and transportation facilities at Weeks Island. Weeks Island is one of the alternative sites discussed in the Draft Environmental Impact Statement.

Accordingly, Morton-Norwich has a substantial and vital interest in the subj t matter of the Draft Environmental Impact Statement and does desire to commen However, the comment period is inadequate and an additional twenty-one days is needed to finalize and submit comments on the Draft Environmental Impact Statement.

Wherefore, an extension of twenty-one days, to November 28, 1977, is hereby requested for commenting on the Draft Environmental Impact Statement.

Respectfully submitted,

Raymond P. Buschmann

Raymond P. Buschmann
Division Counsel
Morton Salt Division of
Morton-Norwich Products, Inc.

MORTON-NORWICH PRODUCTS, INC.
110 NORTH WACKER DRIVE • CHICAGO, ILLINOIS 60606
(312) 621-5200

November 18, 1977

Executive Communications
Room 3317
Federal Energy Administration
Strategic Petroleum Reserve Program
12th & Pennsylvania, N. W.
Washington, D. C. 20461

Re: Capline Draft Environmental
Impact Statement (DES 77-9)

Gentlemen:

By notice in the Federal Register of September 23, 1977, the Federal Energy Administration invited comments to the Draft Environmental Impact Statement (DES 77-9) on the Proposed Storage of Crude Oil at the Capline Group of Salt Domes in connection with the Strategic Petroleum Reserve Program. One of the proposed Capline Group storage sites is Weeks Island, Louisiana.

Morton-Norwich Products, Inc., is a Delaware corporation with its principal place of business at 110 North Wacker Drive, Chicago, Illinois 60606 ("MORTON"). MORTON is the owner and lessee of real property in and around Weeks Island, Louisiana, and, through its Morton Salt and Morton Chemical Divisions, owns and operates mining, production, and transportation facilities at Weeks Island. Accordingly, MORTON has a substantial and vital interest in the subject matter of the Draft Environmental Impact Statement.

MORTON, by letter dated November 4, 1977, requested an extension of time in which to comment, and within said extended time period now submits fifteen copies of its comments as follows:

(1) The expanded use of the Weeks Island, Louisiana salt dome for oil storage wastes a valuable and irreplaceable natural resource. MORTON, the owner of the salt reserves in the Weeks Island salt dome, has determined that the dome is ideally suited for the underground mining of rock salt, in that the following criteria are all met:

  (a) The salt is close to the surface;

  (b) The reserves are large enough to justify the high capital requirements of a mine;

  (c) The dome is solid, free from any significant fissures, water seepage or gas entrapments;

(d) The salt is of high purity;

(e) The crystal size is large; and

(f) The dome is located adjacent to water transportation, for economical and efficient handling and distribution.

The Draft Environmental Impact Statement identifies other salt domes which would not meet the above criteria, but would appear suitable for oil storage by solution mining. Such other domes should be preferred so as not to waste a valuable natural resource.

(2) The suggested significant expansion of Weeks Island salt dome for oil storage through rapid solution mining may impact the stress forces in the dome. Such change could result in significant adverse environmental consequences, if it should affect the seal or structural integrity of the existing or proposed rock salt mining shaft collars. For example, it has been reported that one dome subject to rapid mining was uplifted by six inches. Such a movement at Weeks Island could force an abandonment of the rock salt operations and irreparably impact the community and the salt industry.

(3) The expanded use of Weeks Island for oil storage would require additional government facilities and operations on the surface of Weeks Island. Such additional facilities could interfere with MORTON'S ability to continue its present operations, and may well prevent MORTON from expanding its present facilities, thereby resulting in a socio-economic adverse impact on the community.

(4) As recognized in the Draft Environmental Impact Statement, the expanded use of Weeks Island for oil storage will have a potential adverse impact on the environment, which, in turn, could interfere with and circumvent the operational needs of MORTON'S present facilities at Weeks Island.

Wherefore, MORTON submits that, based upon the above, the Draft Environmen[illegible]a Impact Statement fails to appropriately recognize the environmental and the socio-economic impacts which the proposed expanded use of Weeks Island would have on MORTON'S employees, the local community, and the environs. In th[illegible] opinion of MORTON, the expanded use of Weeks Island as an alternate storag[illegible] site for the Capline Group for purposes of the Strategic Petroleum Reserve Program should be withdrawn because of such potential adverse environmental impact, in addition to other reasons.

Moreover, our national environmental policy, declared by Congress in the National Environmental Policy Act of 1969, provides that all practical means and measures be used "to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans." The expansion of Weeks Island, proposed in the Draft Environmental Impact Statement, would be in conflict with this policy.

Respectfully submitted:

H. W. Diamond

H. W. Diamond
Director of Engineering
Morton Salt Division of
Morton-Norwich Products, Inc.

EVHBK WSH

DOWCHEM A PLAQ

NOV. 11, 1977

EXECUTIVE COMMUNICATIONS
ROOM 3309, DEPARTMENT OF ENERGY
WASHINGTON, D. C. 20461

ALTHOUGH DOW'S POSITION WAS IGNORED COMPLETELY, WE FEEL COMPELLED TO COMMENT ON YOUR DRAFT ENVIRONMENTAL IMPACT STATEMENT, DES 77-9 CAPLINE GROUP SALT DOMES SEPTEMBER 1977.

ON PAGE C.4-3, VOLUME III, QUOTE DELIVERY OF A PORTION OF THE BRINE TO DOW CHEMICAL COMPANY UNQUOTE IS MENTIONED AS A SYSTEM ALTERNATIVE. THIS CANNOT BE A SYSTEM ALTERNATIVE BECAUSE THERE IS A SEVER LIMITATION ON THE VOLUME THAT CAN BE PROCESSED BY DOW DUE TO PLAN SIZE. ALSO, THERE ARE SERIOUS QUESTIONS CONCERNING THE QUALITY OF THE BRINE MADE FROM BAYOU LAFOURCHE OR GRAND BAYOU RAW WATER.

ON PAGE C.4-46, VOLUME III, THE THIRD PARAGRAPH SPEAKS OF DISPLACING, AT LEAST TEMPORARILY, DOW EMPLOYEES CURRENTLY WORKING IN THE BRINE FIELDS. IF DOW'S BRINE PRODUCTION AT NAPOLEONVILLE IS INTERRUPTED AT ALL, A MAJOR SOCIO-ECONOMIC IMPACT ON OVER 2,000 EMPLOYEE WILL OCCUR AT DOW'S PLANT AT PLAQUEMINE, LOUISIANA WHICH DEPENDS ENTIRELY ON NAPOLEONVILLE BRINE RAW MATERIAL. THE ABILITY TO STORE LARGE QUANTITIES OF PRODUCT IS ESSENTIAL FOR STABLE AND ECONOMIC OPERATION OF THE PLAQUEMINE PLANT. IF THIS STORAGE CAPACITY RESULTING FROM DOW'S BRINING OPERATION IS NOT AVAILABLE, IT WILL ALSO HAV A MAJOR SOCIO-ECONOMIC IMPACT ON OUR EMPLOYEES.

G. H. WATKINS
GENERAL MANAGER
LOUISIANA DIVISION
DOW CHEMICAL COMPANY
AWT
END

EVHBK WSH
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DOWCHEM A PLAQ