UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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DRAFT

GUIDELINES FOR OCEANOGRAPHIC STUDIES AND FIELD SURVEY REQUIREMENTS

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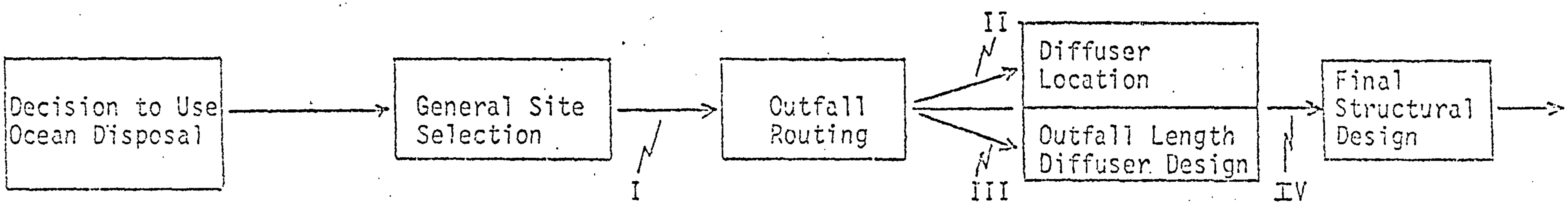
TABLE OF CONTENTS

Flow Chart for Ocean Outfall/Diffuser Design

ign Phase(s):



ta Requirements:

I. Biological Data:
- -sensitive areas
- -reef areas

Geologic Data:
- bottom material(s)
- seismic stability
- sediment characteristics (anchorage)
- construction impediments

Bathymetric Data:
- depth profile
- length of surf zone

II. Bathymetric Data
- level bottom
- depth profile

Biological Data
- proximity to reefs or sensitive biological communities
- proximity to reefs

III. Water Quality Standards

Compliance at
(1) maximum point of rise
(2) SC-SB interface, if applicable

Wastewater Characteristics

required initial dilution for
(1) % occurrence of coli. concentration
(2) acute and chronic toxicity
(3) aesthetics (50:1/200:1 dilution)

Hydrodynamic Data

critical conditions due to
(1) stratification
(2) onshore currents/winds
(3) surface dispersion

IV. Hydrodynamic Data
- longshore currents
- severity of storm event

Geologic Data
- bottom stability
- sediment characteristic

Bathymetric Data
- depth profile
- length of surf zone

A. AVOID:

1. Areas with extensive offshore reefs
2. Zones with shallow depth profiles
3. Embayments with onshore gyres or little flushing and/or dispersive capabilities
4. Zones requiring costly construction needs, eg., across reef areas or lengthy surf zones
5. Areas with existing or potential recreational usage
6. Actual or potential fishery regions
7. Sites exhibiting upwelling
8. Poor offshore bottom stability or soil characteristics
9. Areas with strong alongshore currents
10. Sites with strong onshore winds or surface currents
11. Areas susceptible to adverse ecological impact
12. Locations of aesthetic value

B. LOOK FOR:

1. Areas with steep depth profiles
2. Predominant offshore current or minimum onshore currents
3. Sites near to existing or potential population centers
4. Areas of minimal recreation potential
5. Negligible fishery potential
6. Sandy bottom material offshore
7. Level bottom areas offshore
8. Least costly of alternate sites

C. OTHER CONSIDERATIONS:

1. Disruption of shoreline area by outfall construction
2. Development potential for area
3. Onshore construction impediments
4. Political considerations

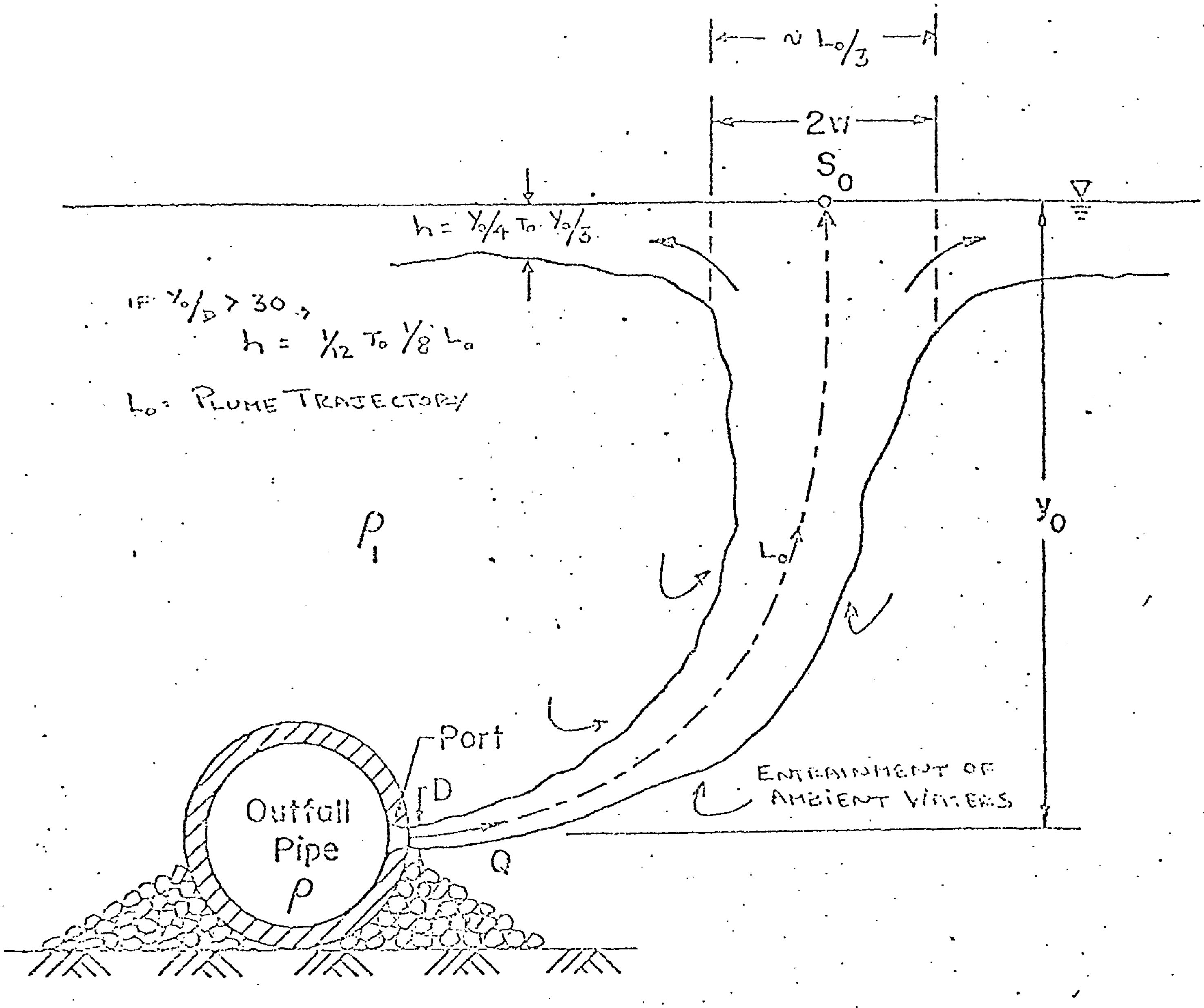


Fig. 1 Definition sketch for rising jet of sewage discharged horizontally from a diffuser port into the ocean.

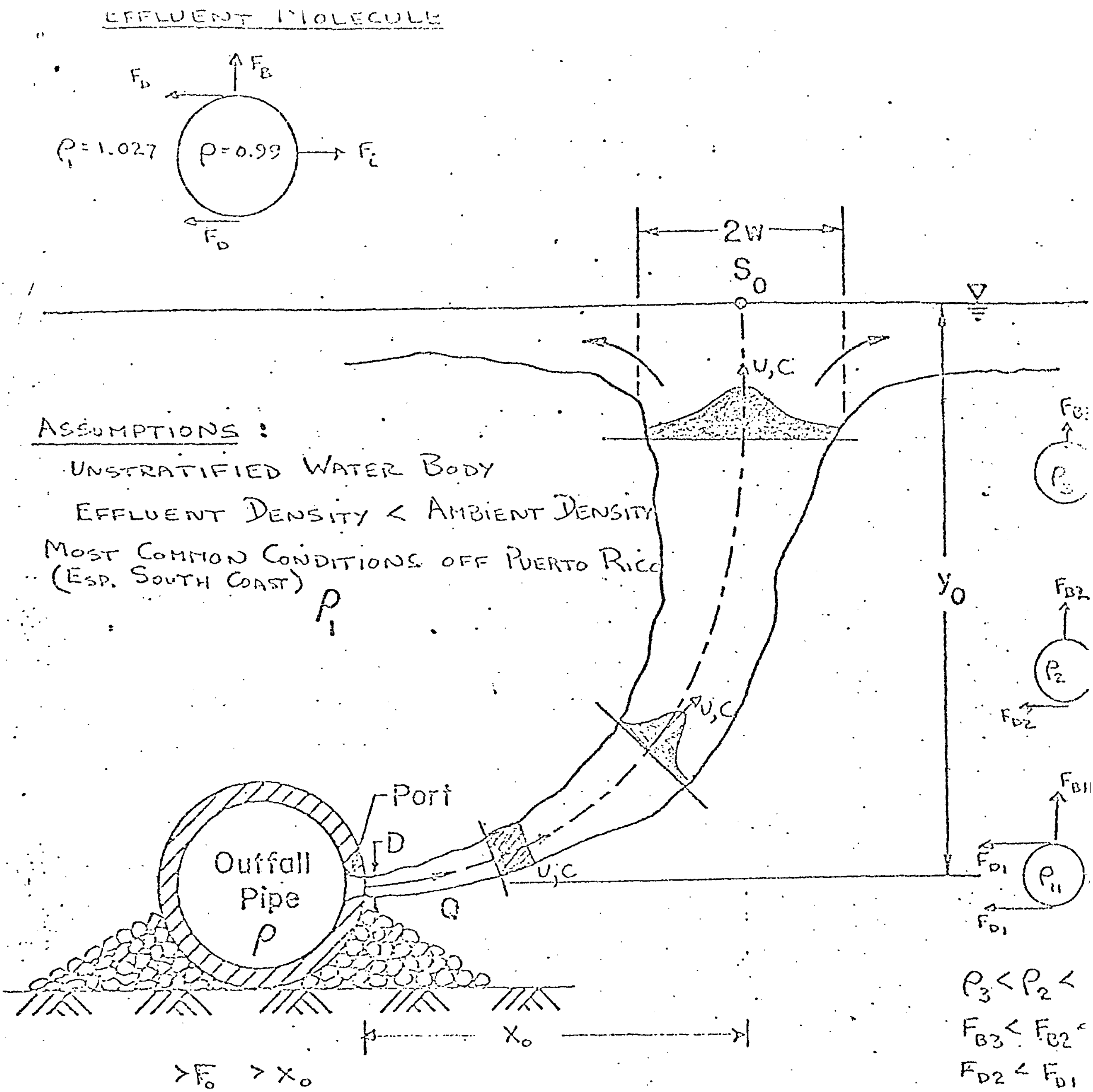


Fig. 2. Definition sketch for rising jet of sewage discharged horizontally from a diffuser port into the ocean.

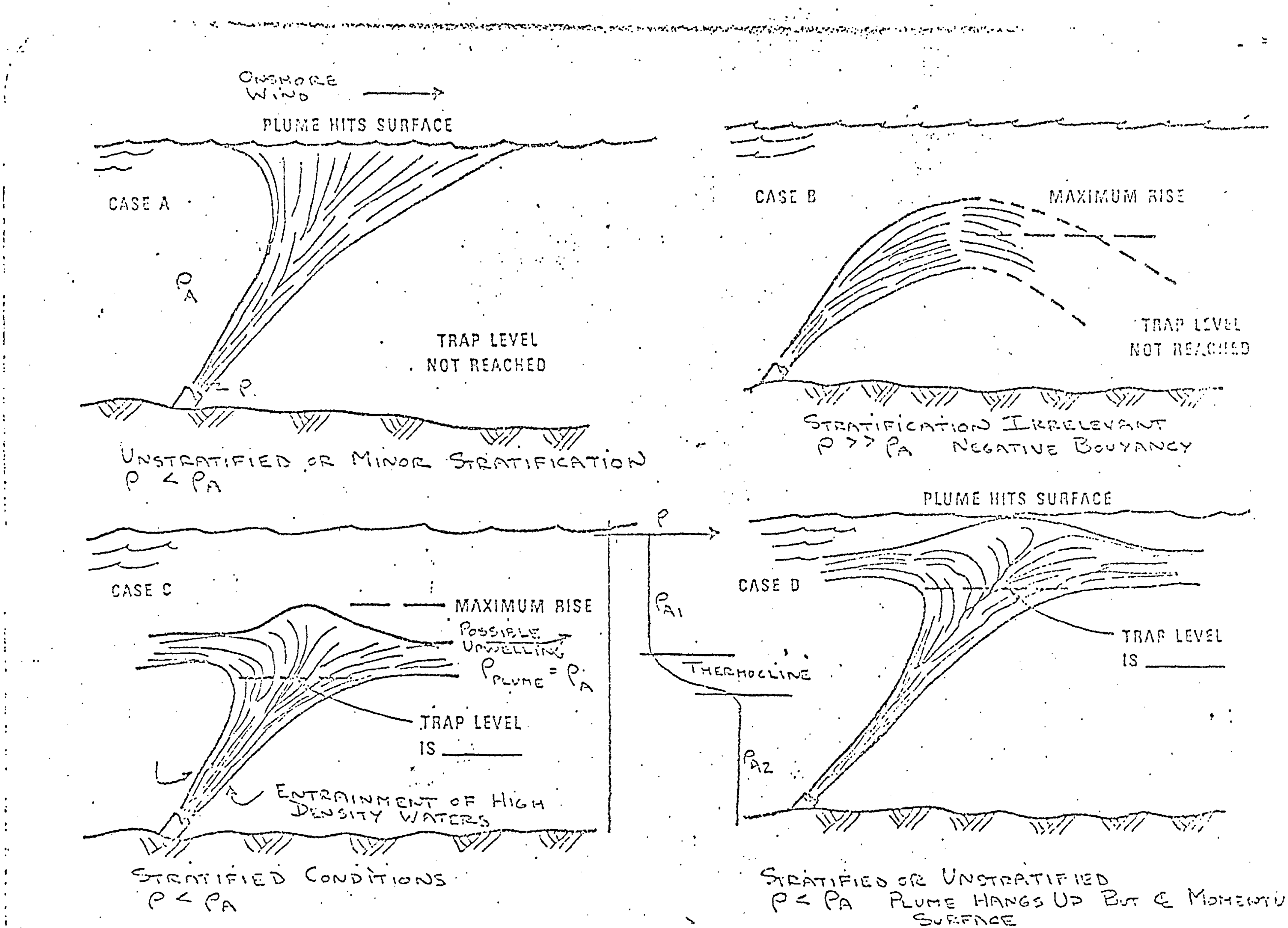
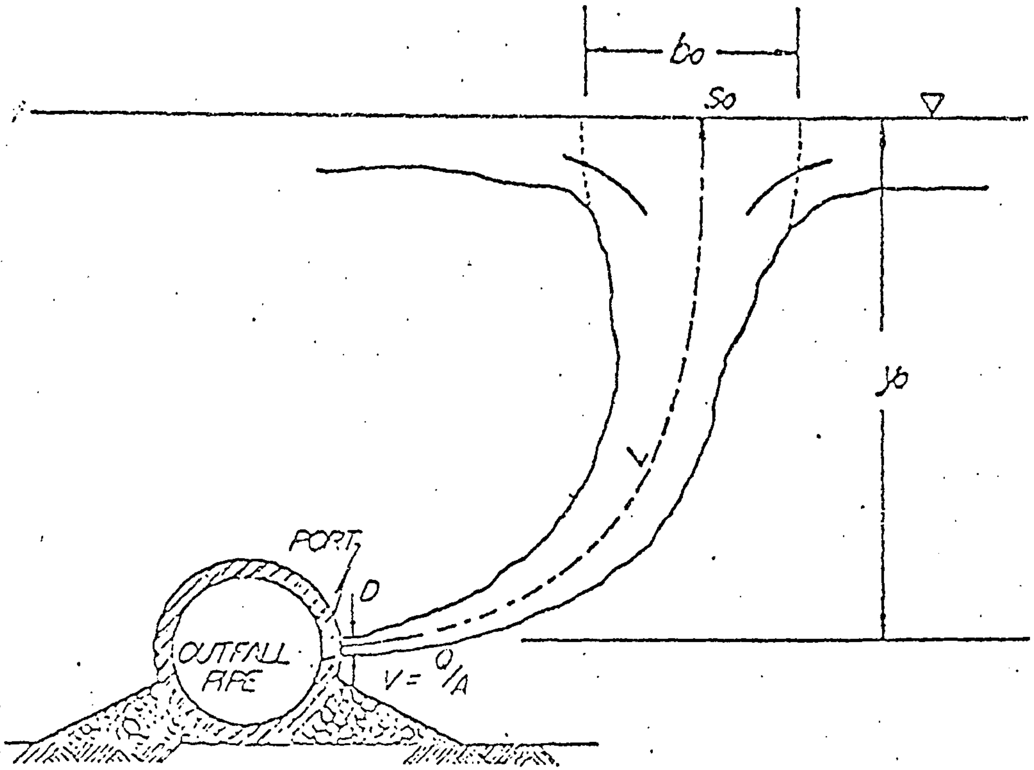


FIG. 4. FOUR POSSIBLE PLUME CONFIGURATIONS ANALYZED BY PROGRAM PLUME

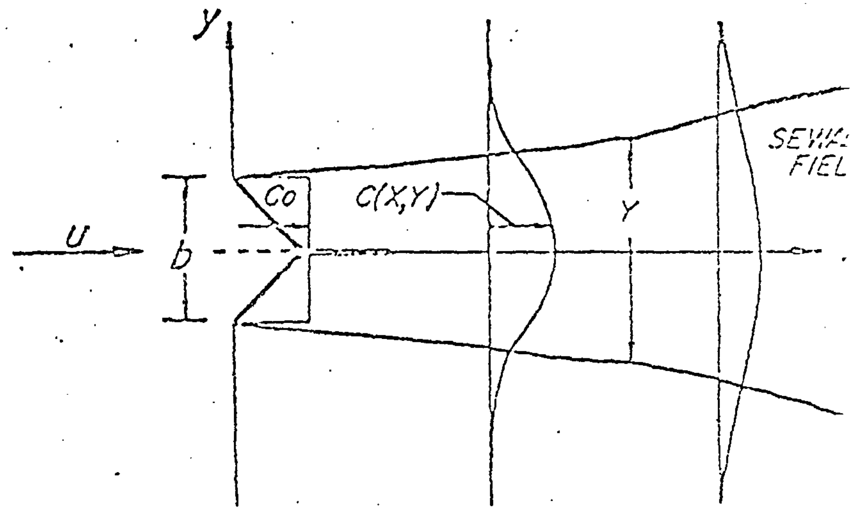


INITIAL DILUTION (S_o)

Dilution Range(s)

S_o 20 - 200:1

D_2 2 - 10:1



PHYSICAL DILUTION (D_2)

Dilution Mechanisms

(1) Initial Dilution (S_o): Calculate from
(a) Rawn et al Plot
(b) Fan & Brooks Plot
(c) Program PLUME

(2) Surface Dispersion (D_2): Calculate from Richardson's 4/3 Law

(3) Bacterial Die-off (D_3): Calculate from $C = C_o e^{-kt} = C_o e^{-Kx/u}$

C_o = coliform concentration after initial dilution (x after growth factor)

Total Dilution = $S_o \times D_2 \times D_3$

FIGURE

DIAGRAM OF INITIAL AND PHYSICAL DILUTION

Factors Affecting Initial Plume Dilution, S_o

(1) Discharge Depth (Y_o)

(2) Initial Jet Velocity (V_J)
Function of: Flow/Port
Port Diameter

(3) Discharge Angle (θ)
Optimum Angle is Horizontal

(4) Ambient Density (p_A)

(5) Effluent Density (p)

(6) Froude Number (F_o)

$$F_o = Q/\frac{\pi D^2}{4}\sqrt{\frac{\Delta p}{p} g D}$$

$$= V_J/\sqrt{g' D}$$

F_o - Indication of Initial Jet Momentum
$>$ F_o $>$ Horizontal Trajectory of Plume

(7) Ambient Stratification
Indicated by Density or Salinity/Temperature Profiles
$>$ Stratification $<$ Chance of Plume Rising to Surface
No Stratification, Plume will Rise Indefinitely

(8) Ambient Currents
Onshore Surface Drift
Upwelling

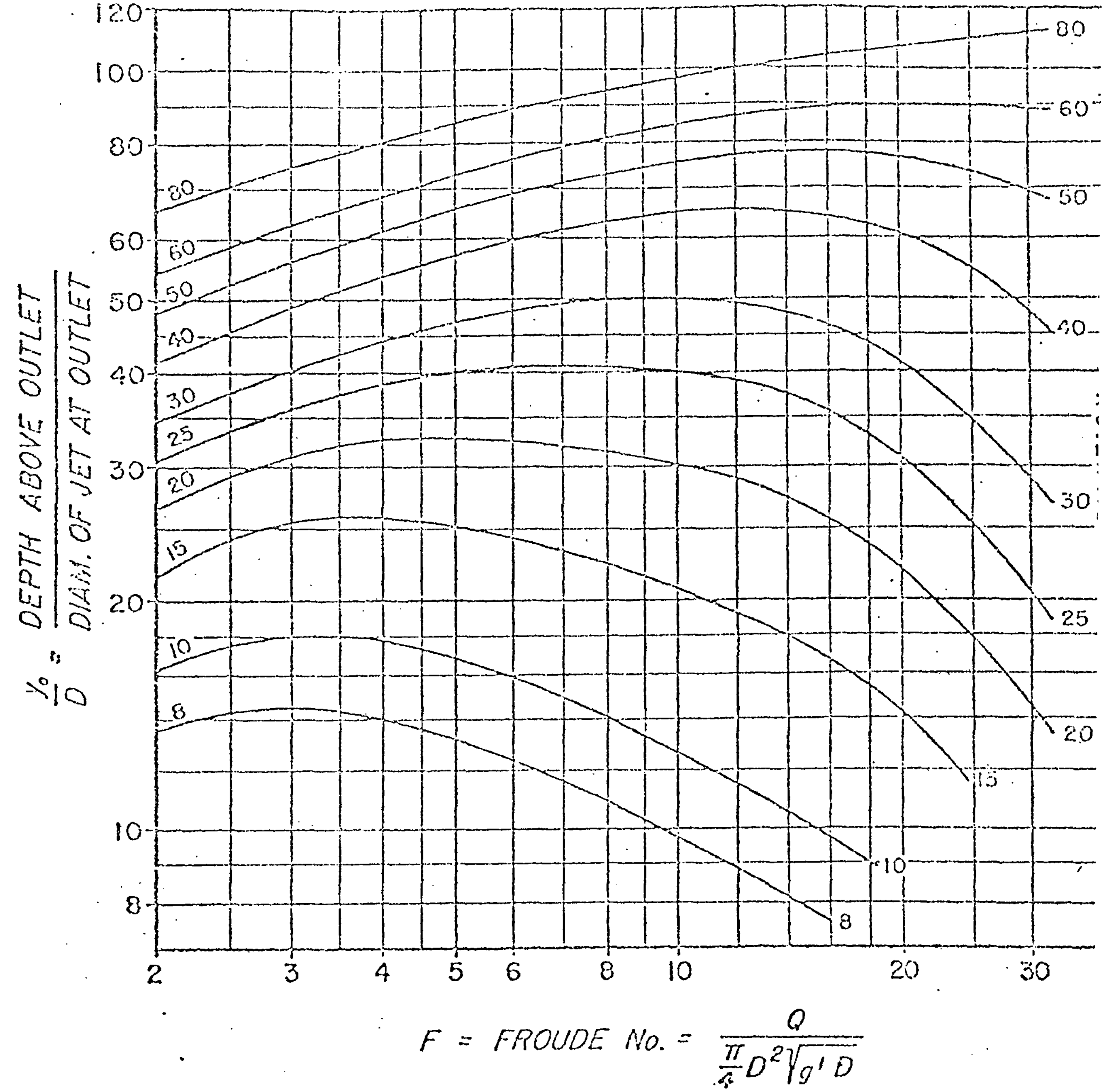
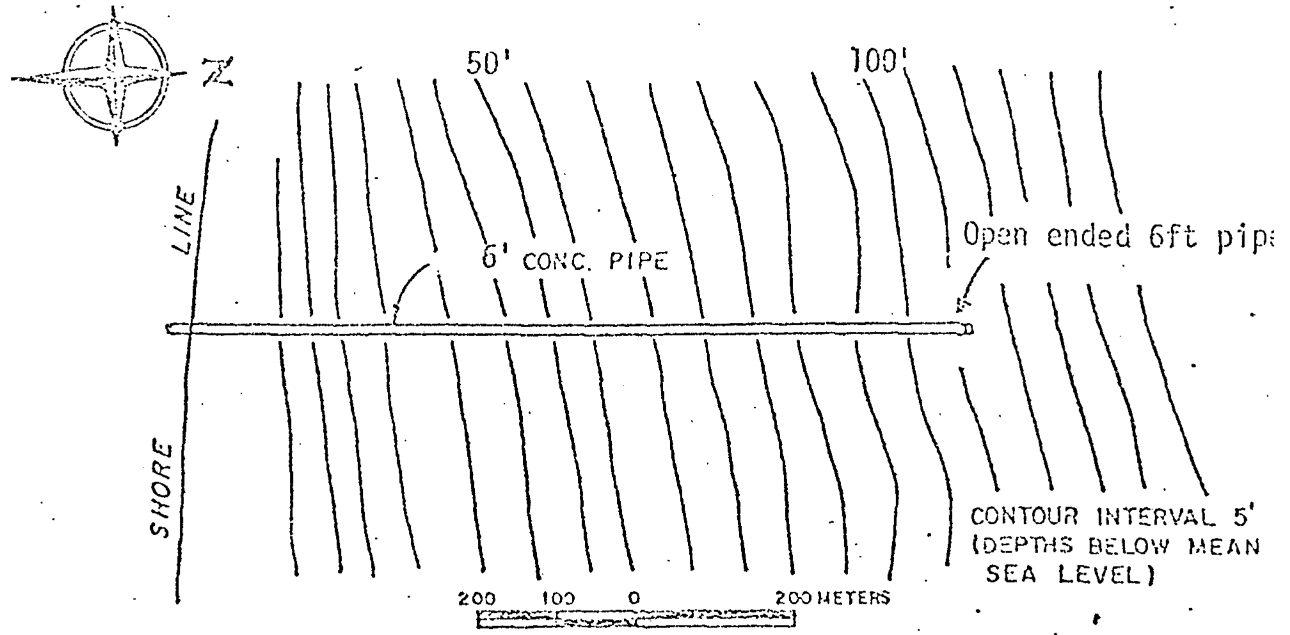
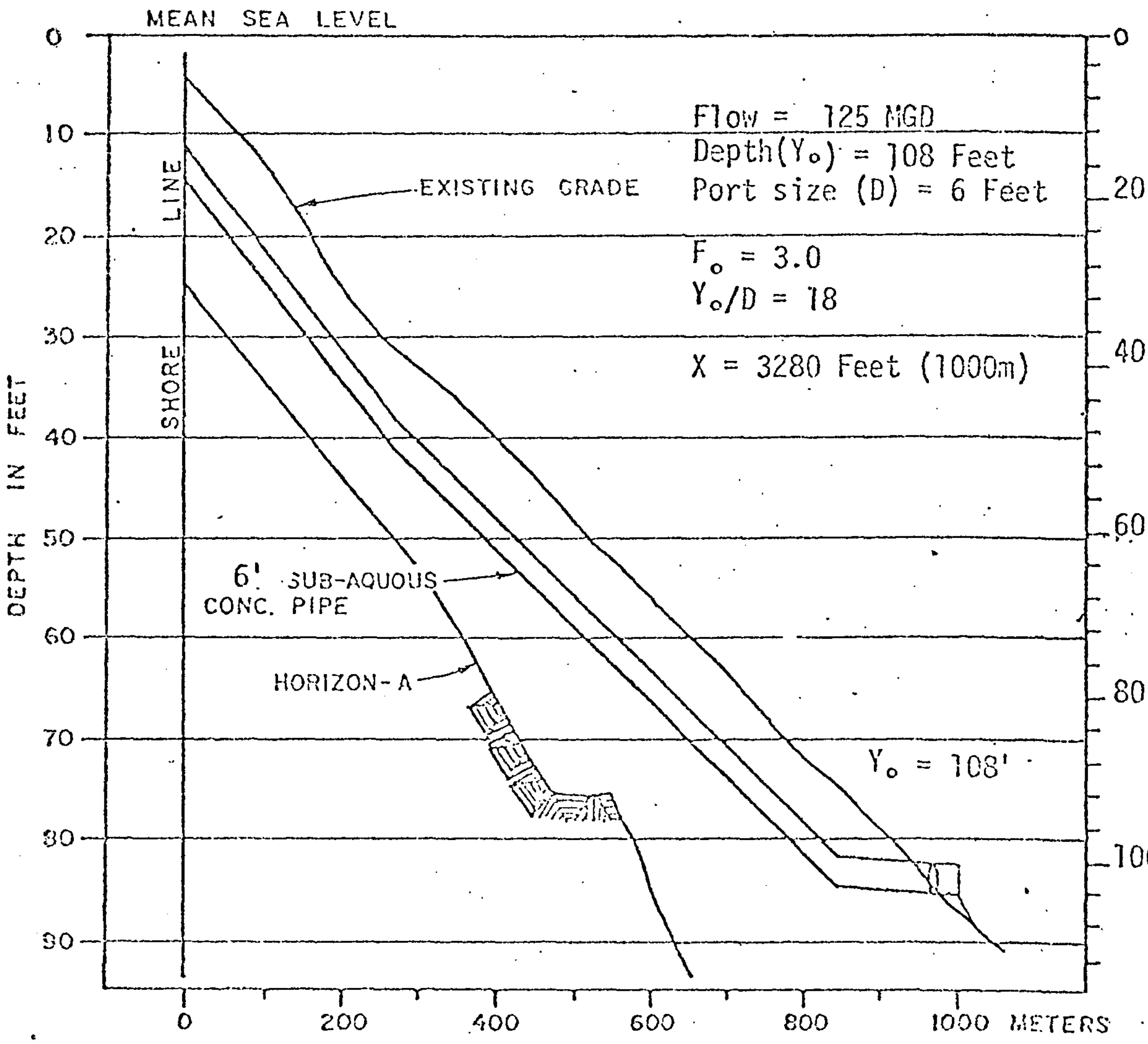


Fig. Dilution S_o on the axis of rising plume at water surface, as function of y_o/D and F, for horizontal round jet into uniform environment (after Rawn, Bowerman and Brooks (28)).



PLAN



PROFILE

Case I: Methods of Increasing Dilution

Data:

$Q = 125$ MGD

$Y_o = 108$ Feet

$D = 6.0$ Feet

$Y_o/_D = 18$

$F_o = 3.0$

} Plot $Y_o/_D$ vs. F_o shows initial dilution $(S_o) = 10:1$

Objective:

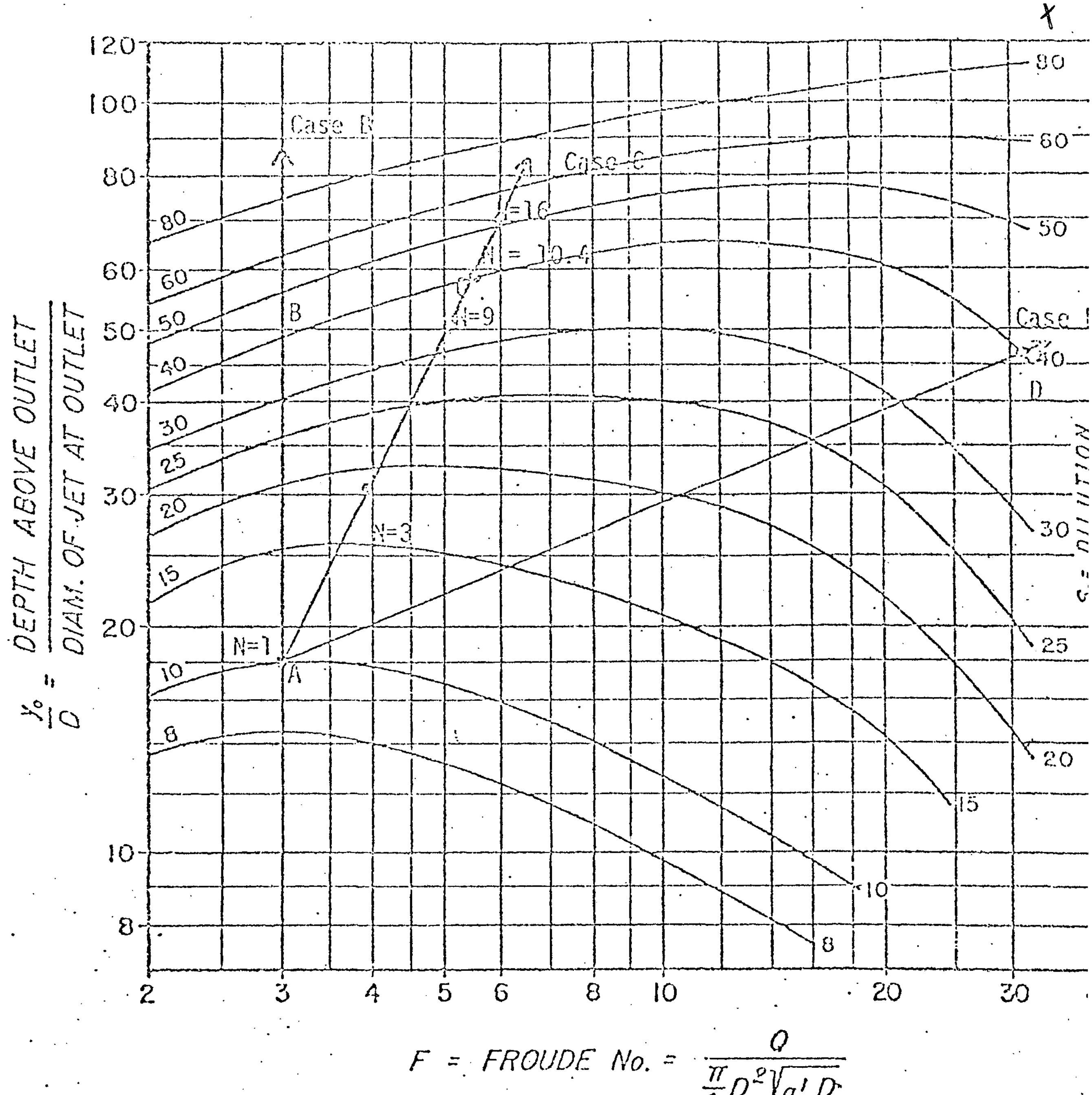
Achieve an initial dilution (S_o) of 40 : 1

Available Options:

(1) Option B: Increase discharge depth with constant design

(2) Option C: Construct A diffuser; increase the number of ports (N) but decrease port diameter to insure constant jet velocity (V_J); all other parameters constant

(3) Option D: No diffuser; decrease outlet diameter (D); all other parameters constant



Case B : Y_o Increasing; Q, V, D Constant
Case C : N Increasing; D Decreasing; V, Y_o Constant
Case D : V Increasing ; D Decreasing; Q, Y_o Constant

Fig. Dilution S_o on the axis of rising plume at water surface, as function of y_o/D and F, for horizontal round jet into uniform environment (after Rawn, Bowerman and Brooks (28)).

Case I: Analysis Results

Methods of Increasing Dilution

Option	Y_o/D	D (Feet)	Y_o (Feet)	No. of Ports (N)	Comments
B	49	6	294	1	Must Increase Depth of Dis charge to 294 Ft.
C	58	1.86	108	10.4 (10 or 11)	Must Design a Diffuser Hav 10 or 11 discharge Ports a Diameter of 1.86 Ft. to the Single Port (Outfall 6.0 Ft. Diameter
D	46	2.35	108	1	Must Decrease D by Trial Error to achieve S_o = 40 Calculated Port Diameter D = 2.35 Ft. Required to this will increase v from ft/sec to 44 ft/sec.

Conclusions:

(1) Option C Appears to be most feasible solution; Involves only the construction of A diffuser

(2) Option B Requires extension of the outfall itself to a depth of 294 feet.

(3) Option D Requires excessive initial jet velocities and associated great head loss and pump capacity.

Case I: Port Spacing Requirements

Data:

$Q = 125$ MGD
$Y_o = 108$ Feet
$D = 1.86$ Feet $Y_o/D = 58$

Objective:

Determine minimum allowable port spacing to prevent plume overlap.

Solution:

(1) From Plot Y_o/D vs. F_o, $F_o = 5.5$

$2\sqrt{2}\alpha\, Y_o/D = 0.23\ (58) = 13.4$

(2) From Plot $2\sqrt{2}\alpha\, Y_o/D$ vs. $2\sqrt{2}\alpha\, X_o/D$,

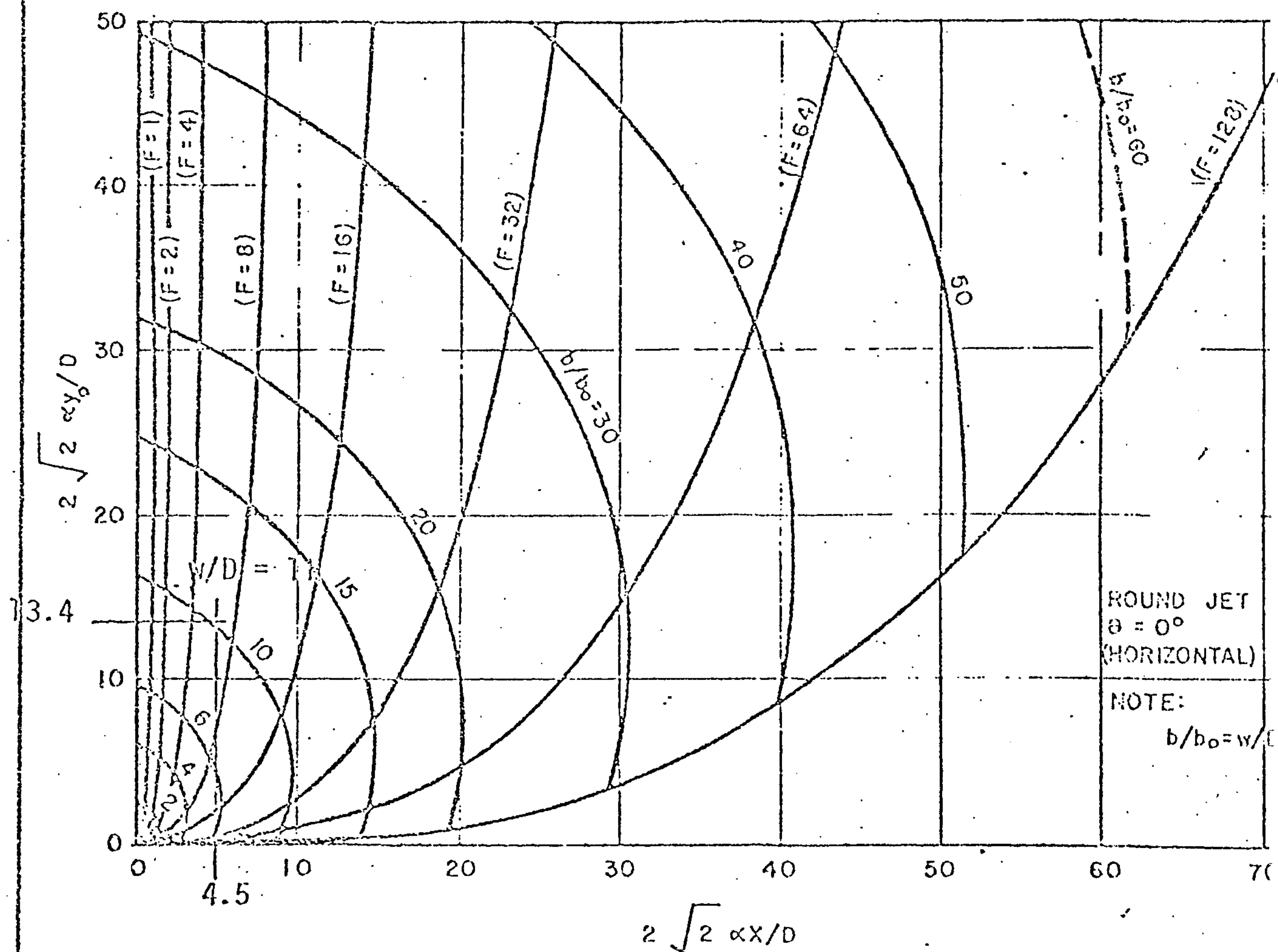
$w/D = 11$

(3) Plume width at surface will be 2w or 2(11)D = 41 Feet

Ports must be spaced a minimum of 41 feet apart on the same side of the diffuser to avoid plume interference

Note: Ports may also be placed on alternate sides of the diffuser at a spacing of 20.5 feet.

X



TRAJECTORIES AND HALF-WIDTHS (W)
FOR HORIZONTAL ROUND JET
INTO STATIONARY UNIFORM ENVIRONMENT
(AFTER BROOKS α = 0.082)

X

Case I: Surface Dispersion

Data: $Q = 125$ MGD

$Y_o = 108$ Feet

Current velocity (v) = 5.0 ft/min. = .083 ft/sec

Diffuser length normal to current = 410 Feet

Objective:

Determine dilution (D_2) provided by surface dispersion

Solution:

Ocean Dispersion Coefficient (E_o):

$E_o = 0.01 \, L^{4/3}$ (CGS Units)

$= 0.01 \, (410 \times 30.5 \text{ cm/ft})^{4/3}$

$= 289.3$ - cm/sec

$= 3.1$ ft/sec

$$B = \frac{12E_o}{ub} = \frac{12\ (3.11)}{.033\ (410)}$$

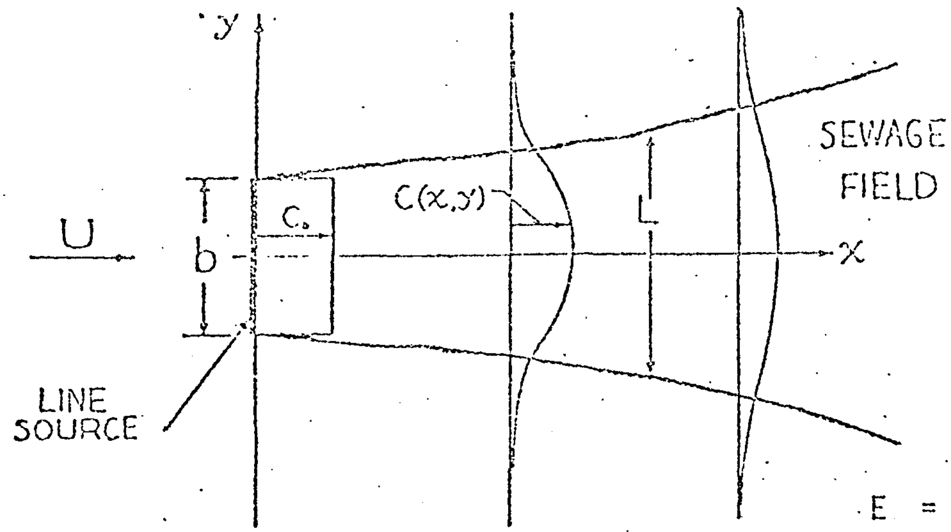
$= 1.09$

$$\frac{Bx}{b} = 1.09 \ \frac{(3280)}{410}$$

$= 8.7$

From Plot C_o/C_{max} vs. Bx/b:

Surface Dispersion = 13:1



$$E_o = 0.01L^{4/3}$$

OCEAN - PLAN VIEW

$$\frac{L}{b} = \left(1 + \frac{2}{3}\frac{Bx}{b}\right)^3$$

Fig.

Schematic diagram of sewage field diffusing laterally in an ocean current (dieoff not considered).

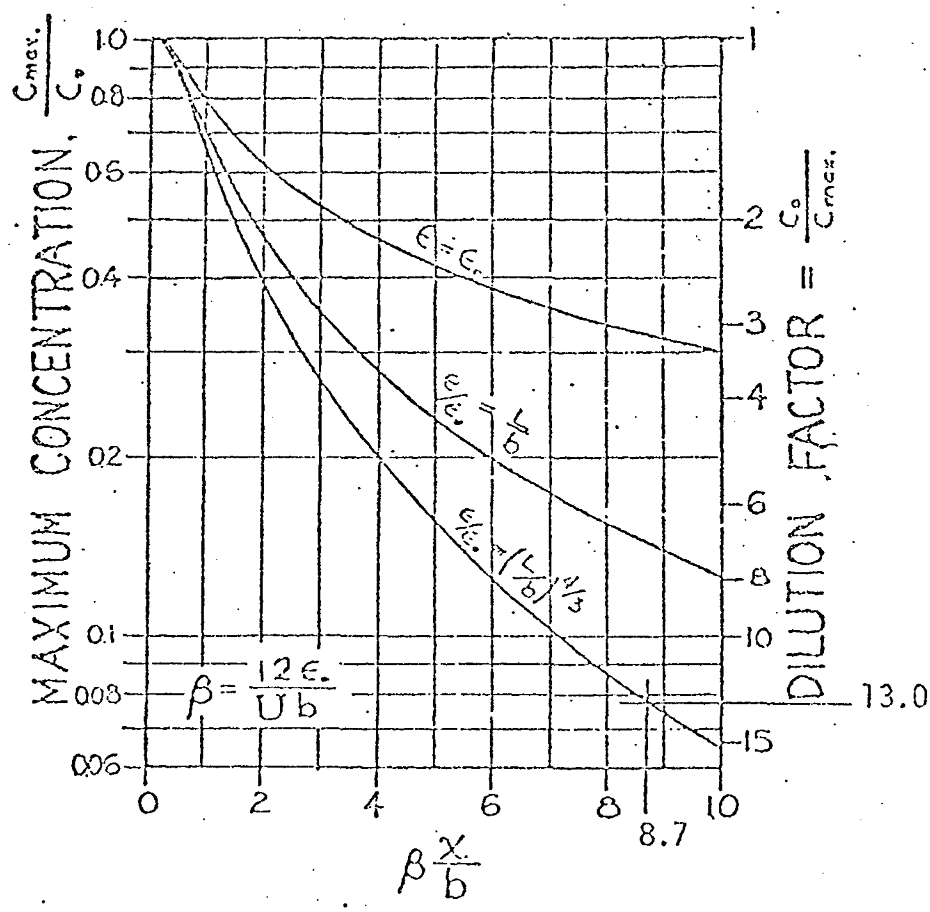


Fig. Dilution along the centerline of a sewage field in an ocean current according to various diffusion laws. Lowest curve is for Richardson's 4/3 law, with solution given by equation 19.

INPUT DESCRIPTION (IBM 360)

Data input for program P L U M E consists of the followin records (see Figure 1):

Initial Conditions

Format: (2L1, I3, F5.0, 7F10.0)

Field	Column	Description
1	1	Leave blank.
2	2	Logical: T (true)=MKS units; Blank=FPS un
3	3-5	Number of ambient density points to be entered, ≤ 50, right justify (do not use a decimal point).
4	6-10	Angle of port orientation from horizontal, degrees.
5	11-20	Port diameter.
6	21-30	Vertical distance between water surface ar outfall port centerline (port depth).
7	31-40	Density of effluent in grams per cubic centimeter.
8	41-50	Leave blank.
9	51-60	Total volumetric flow rate.
10	61-70	Number of ports.
11	71-80	Desired data printout interval along plume centerline.

Density (s) Profile Cards

The program needs a profile of either density or temperature and salinity. If density is input, the units must be gram

One set of paired depth and density values is entered on each ca
starting at the surface. If ambient density is constant with de
use only one card.

Format: (3F10.0)

Field	Column	Description
1	1-10	Depth (distance measured from surface=0)
2	11-20	Density (or temperature, in degrees Celsi
3	21-30	Salinity (in parts per thousand) but ente only if temperature is entered in columns 11-20. Otherwise, blank. You must use a non-zero salinity if temperature is used.

Any number of additional cases may be run by providing addi sets of input data cards as described above.

*********A BUOYANT PLUME IN A DENSITY STRATIFIED MEDIA******

CASE NO. [illegible] INITIAL CONDITIONS ......:

UNITS: FPS

PORT ANGLE	0
FROUDE NUMBER	356.1
LENGTH FOR FLOW ESTABLISHMENT . . .	1.40
INTEGRATION STEP LENGTH	.755
PRINTOUT INTERVAL	3.50
XO	1.40
ZO	39.97
DISCHARGE DENSITY	1.00000
PORT DEPTH	40.00
FLOWRATE	1.08000E 01
NUMBER OF PORTS	26
DISCHARGE VELOCITY	8.46
PORT DIAMETER.	2.50000E-01

DENSITY STRATIFICATION DEPTH RHO

DEPTH	RHO
0	1.02499
40.00	1.02500

S	X	Z	ELEV	THETA	DILN
4.42	4.41	39.74	.26	8.8	3.1131
8.20	8.00	38.62	1.38	27.1	6.0814
11.98	11.01	36.36	3.64	45.9	10.0493
15.75	13.28	33.36	6.64	58.9	15.3324
19.53	14.98	29.99	10.01	66.9	21.8036
23.31	16.30	26.45	13.55	72.0	29.3221
27.08	17.35	22.82	17.18	75.4	37.7670
30.86	18.22	19.15	20.85	77.8	47.0715
34.64	18.96	15.44	24.56	79.6	57.1827
38.41	19.59	11.72	28.28	81.0	68.0580
42.19	20.14	7.99	32.01	82.1	79.6514
45.97	20.63	4.24	35.76	83.0	91.9613
49.74	21.07	.49	39.51	83.7	104.9265
PLUME HITS SURFACE					
50.24	21.12	.00	40.00	83.8	106.6648

LAST LINE ABOVE IS FOR MAXIMUM HEIGHT OF RISE.

TRAPPING LEVEL NOT REACHED

III. Oceanographic Study Requirements

A. Basic Objectives: To determine the physical/chemical, biological and hydrodynamic conditions at either an existing or proposed disposal site in order to access critical conditions with respect outfall/diffuser design and to establish baseline conditions for future trend analyses.

B. General Requirements:

1. Determination of critical conditions for ocean outfall/ diffuser deisgn by consideration of
   - degree of stratification
   - upwelling
   - frequency and magnitude of onshore winds
   - frequency and magnitude of onshore currents
   - seasonal or periodic changes in any of the above

2. Analysis of plume transport and dilution mechanisms under critical conditions including an evaluation of
   adverse biological effects
   compliance with water quality standards at

   (a) the maximum point of plume rise above the discharge point
   (b) the Class SB-SC interface (if applicable)
   effects on designated water usage

3. Optimization of diffuser design to maximize initial dilution at the proposed discharge location.

4. A recommended outfall and diffuser design with the rationale for the proposed outfall length, routing, discharge depth and diffuser type, orientation and design.

5. An assessment of the existing (baseline) ecological commun including a determination of the following:
   - benthic biota
   - water column biota
   - surface (photic zone) biota
   - sensitive indigenous organisms
   - indigenous biota of economic importance
   - general interrelationship(s) of major indigenous
   - seasonal changes or natural progressions in biolc system.

6. An analysis of wastewater characteristics including an evaluation of chemical properties
   potential for acute and/or chronic toxicity to indigenous biota
   potential for aesthetic degradation

7. An overall assessment of the effects of the proposed discharge and construction activity on indigenous biota, general water quality and aesthetic conditions in the study area.

8. Field surveys, data analysis and literature research to determine
   - hydrodynamic characteristics of study area
   - meteorologic conditions immediately prior to and during surveys.
   - baseline biological conditions
   - local bathymetry
   - bottom geology

C. Waste Characterization

1. General Considerations

a. The waste characterization program should provide a set of minimum initial dilution (S_o) requirements to preclude water quality standards contravention acute or chronic toxicity to indigenous biota unacceptable aesthetic degradation

b. Where no existing discharge is available use samples from similar municipality and/or literature research to estimate effluent characteristics

c. Toxicity studies should be run with both primary and secondary chlorinated effluent on sensitive and/or economically important species determined from the biological survey

2. Chemical Characteristics

a. Samples routine chemical parameters, eg.,

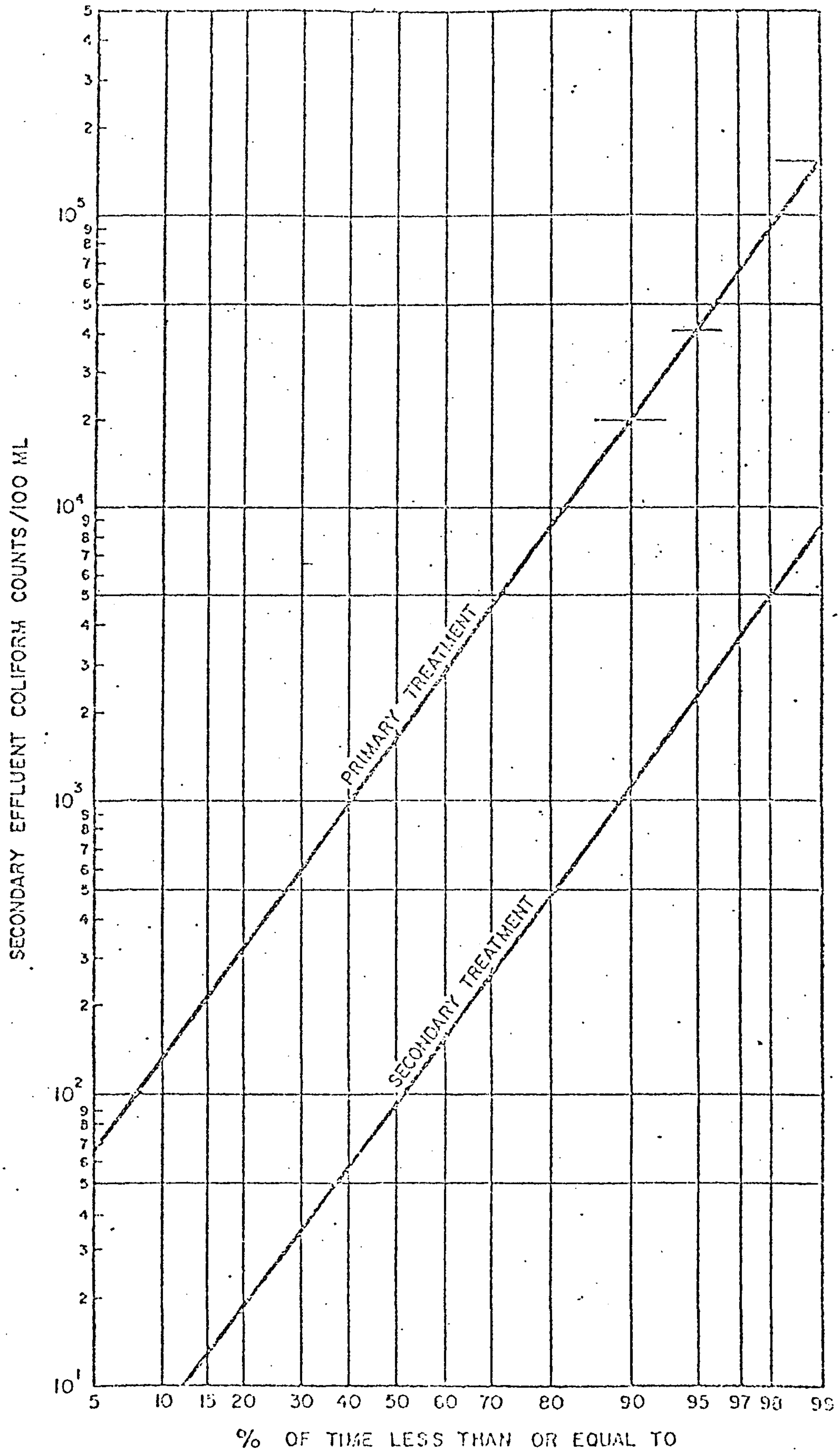
BOD_5	Kjedahl - N
COD	Nitrogen series
pH	total phosphorus
Color	orthophosphates
total solids	total phosphates
volatile solids	total coliform
turbidity	fecal coliform
metals	dissolved oxygen
transparency	suspended solids

and all parameters for which there are water quality standards in the disposal zone

b. Develop and/or utilize past research to determine a statistical frequency record of effluent total and fecal coliform concentrations for both primary and secondary chlorinated effluent (see plot of effluent coli. vs. % time $\leq$)

c. Estimate coliform aftergrowth factor from actual analysis or past research; ranges usually from 1.5 to 3.0 times the initial concentration

d. Determine initial dilution(S_o) required to meet E. coli. or fecal coli. standard at both the
(1) maximum point of plume rise and
(2) Class SB-SC interface (if applicable) under 90%, 95% and 99% occurrences



FREQUENCY OF OCCURRENCE EFFLUENT COLIFORM CONCENTRATION FOR PRIMARY AND SECONDARY TREATMENT AND POST CHLORINATION

3. Biological Toxicity

a. Select sensitive or important indigenous species as noted in the Biological Survey section for bioassay studies; recommends minimum of 3 species.

b. Perform short-term (acute) toxicity tests with primary and secondary chlorinated effluent under varying dilutions to determine the 96-hour median tolerance limits (TL_m)

c. Acute Toxicity - develop plot(s) of effluent dilution vs. % dieoff for each bioassay species and research literature to determine actual 96 hr. - TL_m to quantify the acute toxicity of the proposed effluent to each of the control species.

d. Chronic Toxicity - adjust the initial dilution(s) (S_o) required for the 96 hr - TL_m by the following biological "safety factors" to insure against long-term (chronic) toxicity:

Substance	Factor
Heavy Metals	1:100
Ammonia	1:20
Cyanide	1:10
Sulfide	1:20
Non-cumulative	1:10
Cumulative	1:20 -- 1:100

The most stringent initial dilution requirement determined from this procedure should provide an additional minimal dilution constraint for the diffuser design and location.

4. Aesthetic Consideration

a. Perform laboratory dilution tests with ambient waters to determine initial dilution (S_o) required for

   a. Plume indiscernibility
   b. Secchi disk visibility at 1 meter depth

TOXICITY AND REQUIRED DILUTION FOR MUNICIPAL WASTEWATERS AFTER TREATMENT

Process Effluent	Mean Toxicity Toxic Units[a]	Relative Dilution Required
Primary	2.21	1.0
Activated Sludge, Std. rate	<0.52 (0.78)	<0.24 (0.35)
Chemical Precipitation	1.28	0.6
Chemical Precipitation + Ammonia Removal or Sorption	<0.8 (≈1.0)	<0.35 (0.45)
Chemical Precipitation + Ammonia Removal + Sorption	<0.52 (0.83)	<0.24 (0.4)
Chlorination (Primary Eff.) (5 mg/ℓ)[b]	10.0	4.5
Chlorination (Primary Eff.) (2 mg/ℓ)[b]	5.0	2.3
Chlorination-Dechlorination (Primary Eff.)	1.93	0.87
Chlorination-Dechlorination (Chemical Ppt. Eff.)	~1.0	0.45

[a]Toxicities below one toxic unit were estimated from observed mortalities using the binomial function and Figure 27. The two values are the most probable toxicity concentration (MPTC) and the value for the upper 95% confidence limit.

[b]Residual chlorine controlled at this level before contact.

TOXICITY OF CHLORINATED EFFLUENTS

Effluent	Toxicity, 96 hr TL_m		Total Residual Chlorine Before Contact (mg/l)	Toxicity, Toxic Units, T_c =	
	Before Chlorination Range	After Chlorination		Before Chlorination Range	After Chlorination
imary	0.56-0.33	0.35 0.06	1 8	1.8-3.0	2.9 16
tivated Sludge	1.0	0.17 0.05	2 5.5	0.48-1.2	6 19
emical Precipitation	0.84-0.68	0.72 0.06	2 5	1.2-1.5	1.4 20

te: Table from Reference (6).

b. Past studies indicate that generally 50:1 dilution is required for secondary effluent and 200:1 dilution is required for primary effluent to render plumes indiscernable.

D. Field Survey Requirements

1. General Considerations

a. The selection of a specific field survey program should consider at least the
   - magnitude and toxicity of the discharge
   - sensitivity and economic importance of local biota
   - proximity of recreational areas
   - general hydrology of the area
   - overall budget constraints for such work

   Examples:
   - local reef or phosphorescent bay areas --- more intensive biological surveys and bioassay work
   - upwelling or strong onshore currents --- more intensive hydrodynamic work

b. At least one(1) survey should be undertaken during the critical period of the year, i.e., when
   - expected initial dilution is minimal
   - onshore currents are strongest or when
   - local biota is most vulnerable to adverse effects

c. In all cases, major items of importance are the definition of the
   - degree of stratification (and seasonal changes, if any)
   - local hydrodynamics
   - most sensitive indigenous species and the
   - general baseline biological community

d. Generally, for any significant discharges recommend a minimum of
   - 2 hydrodynamic (current meter) studies
   - 2 water quality studies
   - 1 benthic biological study
   - 1-4 water column biological studies
   - 1 bathymetric survey
   - 1 geologic survey
   - 2 meteorlogic surveys (concurrent with hydrodynamic work)

   for the field survey requirements

2. Water Quality Study

a. Routine Chemical Survey

(1) Recommended baseline parameters and sample depths are as follows:

Temperature (vertical profile)**
Salinity (vertical profile)**
Secchi Depth*
Dissolved Oxygen*
pH*
Biochemical Oxygen Demand*
Suspended Solids*
Turbidity*
Total Organic Carbon*
Nitrogen Series (Organic N, NH_3 - N, NO_3-N)*
Phosphorus (Total - Filtered and Unfiltered)*
Coliform Bacteria (Total and Fecal)*
Chlorophyll "a"*
Inorganic Nitrogen*
Total and Fecal Coliform*

*Measurements Below Surface Above Bottom and at Mid-depth
**Measurements at 10 feet intervals

(2) Chemical surveys generally include
grid sampling pattern
3 to 6 transects perpendicular to shoreline
15 to 25 sample stations, or more

b. Stratification Survey

(1) In addition to routine chemical samples, further collection of salinity and temperature data should undertaken at as many additional stations as possible at 10 ft depth intervals

c. Metals Survey

(1) Recommended baseline parameters are as follows

mercury	zinc	nickel
cadmium	lead	pesticides
copper	arsenic	petroleum hydrocarbons
chromium	selenium	organohalogens
beryllium	vanadium	

(2) Sample at a minimum of 1 station in study area at the surface, mid-depth and bottom

3. Hydrodynamic Survey

a. General Considerations

(1) The study should define the major transport mechanisms which will act on the discharge plume. Study should determine specifics concerning
- vertical velocity gradients
- prevailing current patterns both at surface and in the water column
- frequency and magnitude of onshore current(s)
- existence of upwelling phenomena
- surface dispersion characteristics

(2) Each survey should include, as a minimum,
- continuous current meter studies
- surface drifter studies
- bottom droque studies

over a 30 to 35 day period
recommends frequency: 2 surveys, all discharges
$\geq$ 3 surveys for major discharges

b. Survey Specifics

(1) Current meters

self-operating; anchored to bottom
records apprxoimately every 5 minutes
recommended minimum program:
- 3 current meter stations
- 2 current meters per station: 1 at - 5 meter MWL
  1 at 5 meters off bottom
- continuous operation for 30 to 35 days
- locate 1 meter sufficiently offshore to avoid local effects
- repeat for 2 surveys

(2) Surface drifters

short-term (1 to 3 day) studies
record on approx. hourly intervals
usually 5 gallon bouyant jugs
can correlate results with wind studies
recommended minimum program:
- 1 or 2 releases at a few stations
- do during current meter operation
- preferably release concurrently with bottom droques
- repeat for 2 surveys

(3) Bottom drogues

short term (1 to 5 day) studies
provide large scale mass movement of water
can be suspended from surface float and recorded hourly
recommended minimum program:
Same as surface drifters

(4) Dye Studies

optional
can be used to determine surface dispersion and wind effects

c. Miscellaneous Review Items

The oceanographic report, should include the following items

(1) Discussion of general circulation patterns in study area

(2) Discussion of most critical onshore current conditions with magnitude(s) and expected duration(s)

(3) Discussion of seasonal and shorter term periodicity, eg., day-night surface current reversals, in current measurements.

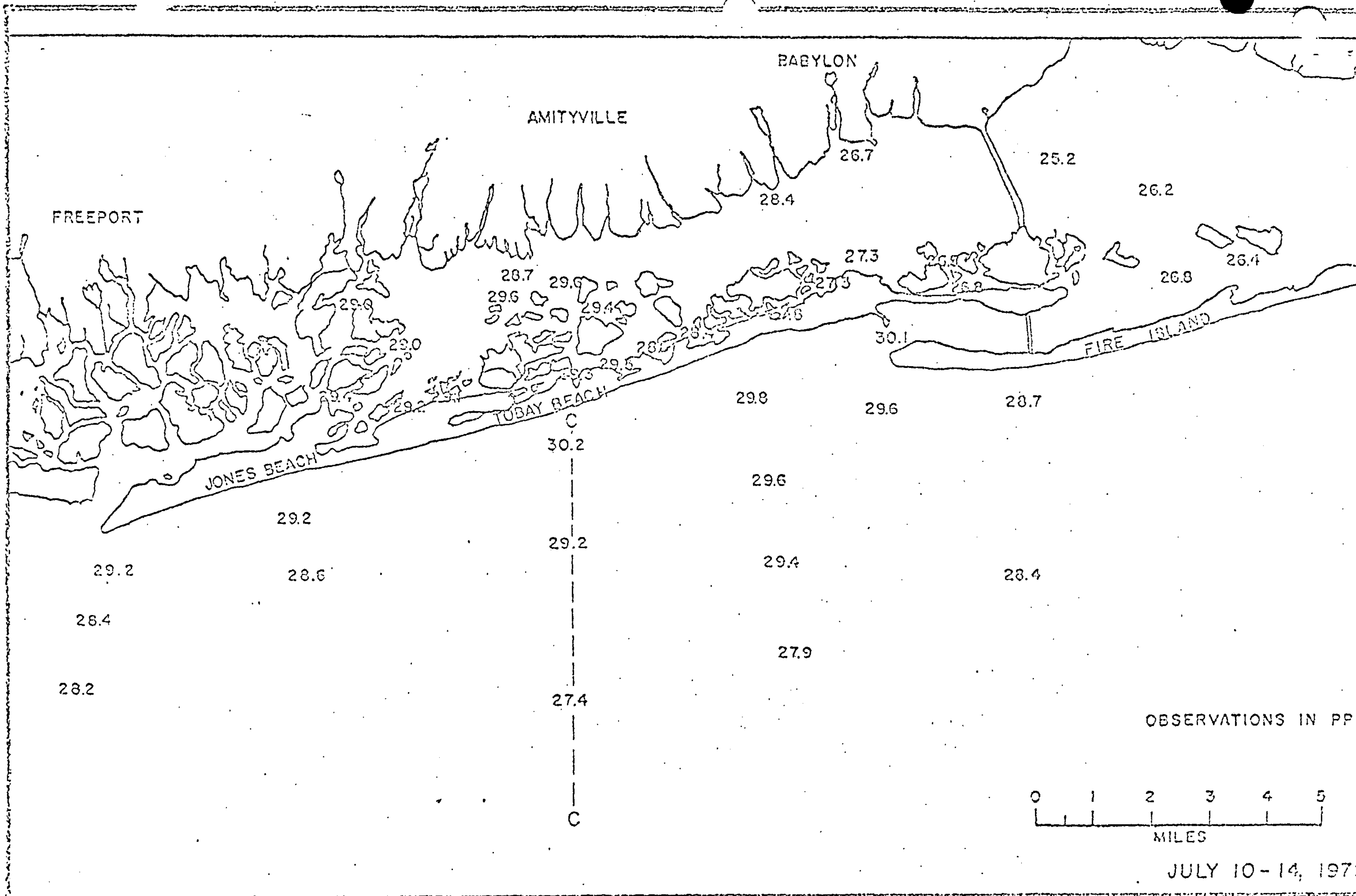
(4) Progressive vector diagrams for each current meter during each survey

(5) Polar coordinate histogram for all meters

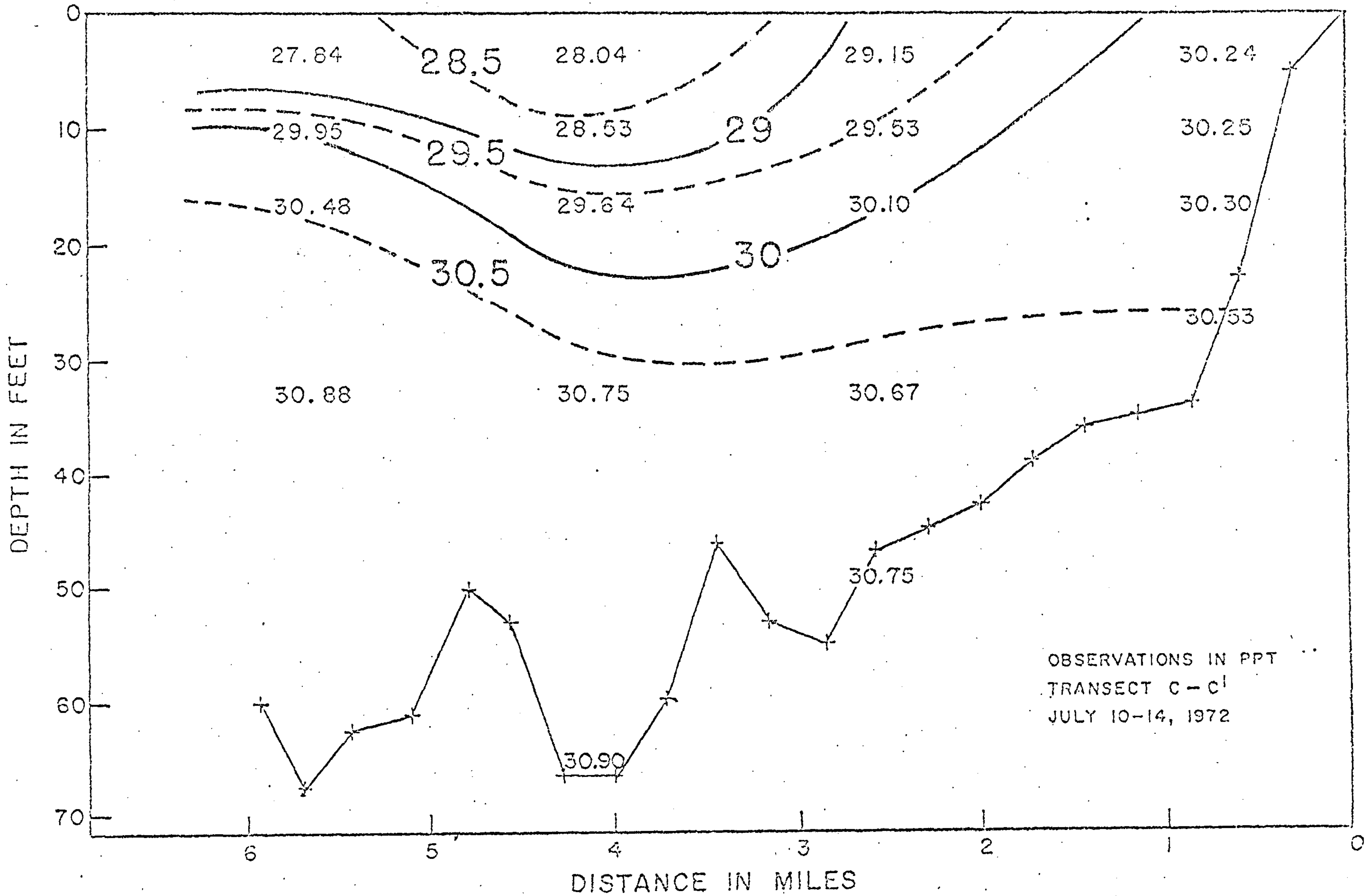
(6) Map(s) with drogue/drifter transport patterns

(7) Dye dispersion plots (c/c_o vs. distance) if studied

(8) Tidal stage readings for survey period(s)



OBSERVED SURFACE SALINITY DISTRIBUTION



OFFSHORE VERTICAL SALINITY

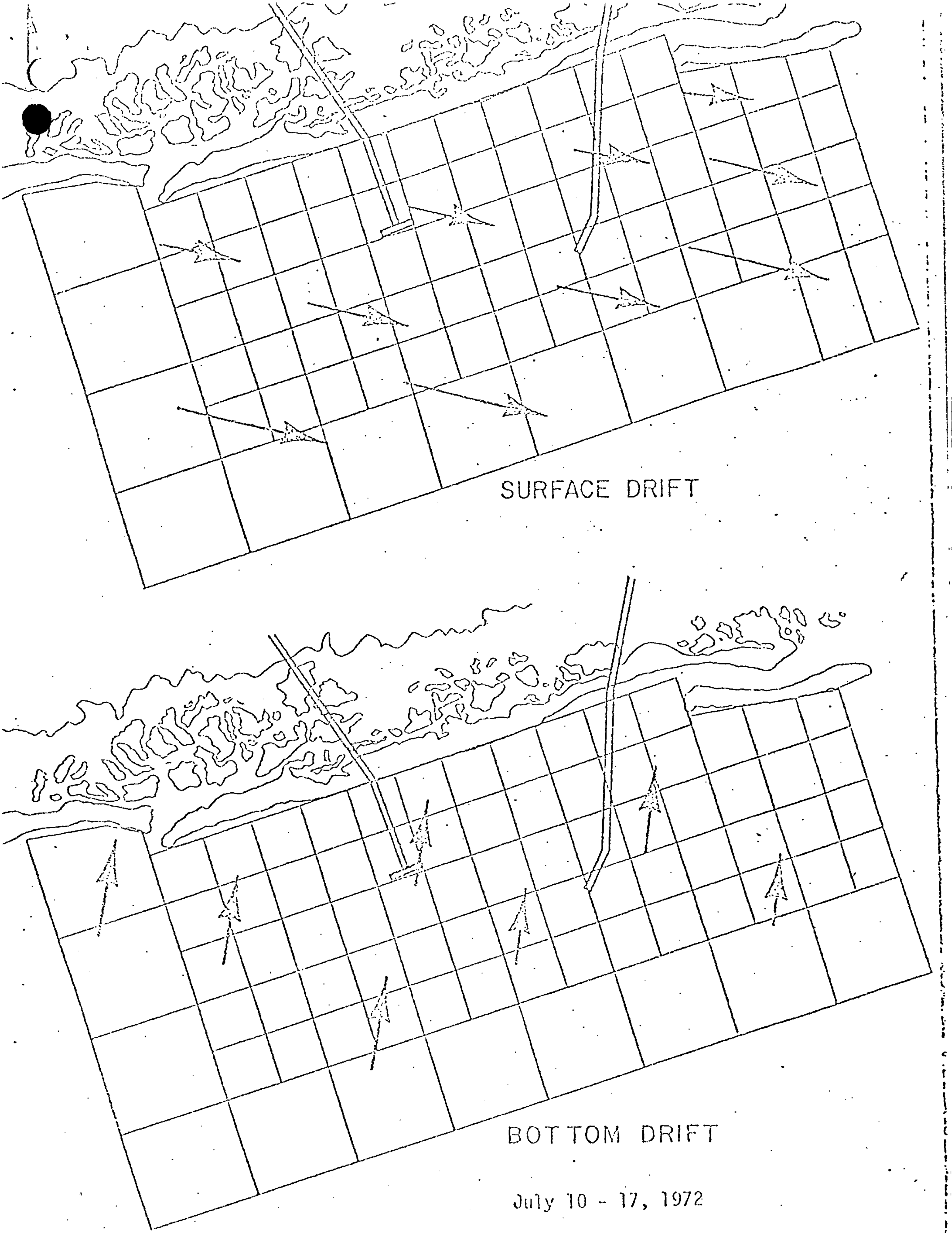


FIGURE V-22

4. Biological Survey

a. General Considerations

(1) The study should determine the characteristics of the existing biological community in both the water column and the benthic region. Specific items to be defined are

- sensitive indigenous species
- indigenous biota of economic importance
- location of sensitive biological communities
- interdependence of observed species
- seasonal progressions of biological organisms
- baseline biological conditions for future trend analysis.

b. Determination of Bioassay Organism(s):

(1) Generally select at least
- 1 benthic organism (if reef area, consider coral)
- 1 water column organism (usually zoo-on phytoplankton)
- 1 surface organism (≤ 30 ft. depth) and
- possibly 1 finfish species

(2) Consider the following items in selection
- overall expected sensitivity of species
- economic importance of species itself
- significance as a food source species
- reef building organism(s)
- most sensitive life stage, eg., larva, egg, juvenile forms

c. Water Column Survey

(1) Collection depths: surface
mid-depth
above bottom

(2) Equipment and parameters:
- plankton met - phytoplankton
- bongo met - zooplankton
- Niksin bottle - phytoplankton, zooplankton and chemical sample

(3) Frequency:
- 1 run per season
- 3 to 4 runs may be needed to define seasonal changes

d. Benthic Survey

(1) Number of Stations: minimum 5 stations adequate

(2) Frequency: 1 run usually adequate especially
if reef area; probably static community

(3) Equipment: biological box-corer
tow dredge
grab sampler - Van Veen, McIntyre

5. Geologic Survey

a. General Considerations

(1) The geologic study should determine the
physical characteristics of the overlying bottom materia
depth of overlying deposits
location(s) of reef areas
general bottom stability
outfall anchorage requirements
general desirability of alternate outfall routings

b. Survey Specifics

(1) Recommended sediment parameters to be evaluated are as follows:

grain size distribution	TOC
volatile solids	BOD
trace metals	COD
synthetic organics, eg., DDT	sulfides

(2) Sonar ("boomer") soundings may be used to determine the depth of bottom deposits; soundings should be undertaken along as many transects as possible

(3) Core samples may be taken to verify sonar readings (optional)

6. Bathymetry Survey

a. General Considerations

(1) Depth soundings should be taken along as many transects as possible in study area

(2) Bathymetric map scale: 1:25,000 to 1:10,000
5 meter contour intervals

7. Meteorology Study

a. General Considerations

(1) The meteorologic study should include
correlation of wind and surface current patterns
discussion of general meteorlogic conditions in the study area and effect on hydrodynamic regime

(2) Frequency: 2 or more gage periods
30-35 days each
operation during current meter studies

IV. Oceanographic Study Requirements - Review Checklist*

A. Existing Study Area Characteristics

1. Were surveys undertaken for
   instream water quality?
   water column biota?
   benthic biota?
   sediment chemical characteristics?
   sediment physical characteristics?
   hydrodynamic characteristics? surface currents? bottom currents
   bathymetry
   geologic characteristics

2. Did the instream water quality surveys define
   routine chemical characteristics at the surface, mid-depth and bottom?
   degree of stratification?
   baseline metal concentrations?
   salinity and temperature at 10 ft. depth intervals at as many stations as possible?

3. Did the biological surveys define
   sensitive and/or economically important species?
   phyto - and zooplankton populations? diversity indices?
   benthic organisms? diversity indices? identification of specie
   water column and benthic species density?
   major indigenous finfish?
   major indigenous bottom fish?
   seasonal changes in biota?
   general predator-prey relationships?

4. Did the sediment studies determine
   grain size distribution?
   trace metals concentrations?
   volatile solids concentration?
   pesticides? synthetic organics?
   TOC? BOD? COD? sulfides?

5. Did the hydrodynamic studies include
   continuous current meters at a minimum of 3 stations with surface and bottom meters for a duration of at least 30 days?
   surface drifter and bottom and mid-depth drogue studies?
   progressive ector diagrams for all current matters?
   maps of drifter/drogue releases and retrievals?
   current histograms for all meters?
   a minimum of 2 survey periods for meters, drogue and drifter studies
   consideration of local onshore gyres or upwelling phenomena?

coordination of drogue/drifter studies with meter operation?
consideration of most probable critical period in the year?
tidal stage readings?
definition of most prevalent and most critical current conditions for diffuser design?
definition of most desirable diffuser location from probable plume transport considerations?
the overall desirability of the study area for outfall siting based upon existing hydrodynamic conditions?

6. Did the geologic studies define
location of all reef areas?
possible impediments to outfall construction?
potential anchorage problems?
most desirable outfall routing(s) and diffuser location(s) from geologic considerations?
depth and stability overlying bottom materials?

B. Miscellaneous

Did the study include

1. A recommendation for a specific diffuser/outfall routing, design and location justification?
2. Diffuser optimization by varying portage, flow/port, discharge depth, etc?
3. Use of Program PLUME?
4. Definition critical conditions with respect to stratification onshore winds and currents
5. Definition of seasonal changes in stratification and hydrodynamics
6. Calculation of plume dilution under critical conditions
7. Compliance with coliform standards at the maximum point of plume rise? at the SB-SC interface (where applicable)?
8. Consideration of effluent toxicity and aesthetic requirements? Compliance with these requirements at maximum point of plume rise?
9. Consideration of coliform aftergrowth in analyses?
10. Statistical plot of coliform concentration vs. % of time
11. Chemical analysis of existing discharge or a similar wastewater?
12. A meterologic study during surveys with wind histograms and progressive wind vector diagrams?
13. A bathmetric survey and a map of depth profiles in study area?
14. A discussion of probable construction effects on local biota?
15. Toxicity bioassays on sensitive or economically important specie
16. Determination of 96 hr - TL_m for each test species?
17. Plot of effluent dilution vs. % dieoff for each test species for both primary and secondary chlorinated effluent?
18. Definition of the most sensitive test species?
19. Definition of the projected critical effluent characteristics and hydrodynamic conditions used in the determination of the required outfall length and diffuser design?

V. Diffuser Design Considerations

A. Basic Objectives

1. The diffuser should be designed to maximize the initial dilution(s) in order to comply with water quality standards and meet biological and aesthetic requirements at both

a. the maximum point of plume rise above the diffuser and
b. the SB-SC interface (where applicable)

with minimal capital cost, head loss and jet interference.

2. Optimization techniques using Program PLUME should be employed to evaluate variable diffuser designs to meet above objective.

B. General Review Considerations

1. Diffuser should be oriented perpendicular to the predominant onshore current vector(s) in order to provide maximum effective plume width normal to such currents; appropriate diffuser types are as follows:

Y-shaped	random current pattern(s)
T-shaped	predominant onshore current
I or split Y	predominant longshore current

2. Diffuser site should be as level as possible

3. Diffuser design should maximize flow uniformity between ports

4. All ports should flow full to prevent seawater intrusion

5. All ports should discharge horizontally but may be alternately located on different sides of the diffuser

6. All ports should be circular and bell-mouthed on interior edges to minimize head losses

7. Port spacing should be large enough to prevent any jet merging and resultant reduced dilution(s) in the zone of plume bouyancy.

8. Diffuser ends should be removable for general maintenance and sediment flushing.

9. Tapered diffusers and variable port sizes can be used to provide both minimum desired interior velocities and flow uniformity

10. Usually, greater initial Froude numbers(F_0) for the discharge induce more entrainment of ambient waters into the effluent plume, a greater horizontal trajectory of the plume and a smaller plume rise at any given distance along the arc of the plume trajectory.

C. Specific Design Criteria

1. The sum of all diffuser port areas must be less than the cross-section area of the outfall itself in order to insure no intrustion of sea water into the diffuser structure; the optimum ratio of total port area/outfall cross-section has been shown to be between 1/2 and 2/3.

port area = (1/2 to 2/3) x (outfall cross-section)

2. The sum of the port areas offshore at any point in the diffuser must be less than the diffuser cross-section area at that point.

3. All circular ports must have an $F_0 \geq 0.59$ in order to flow full; an $F_0 \geq 1.0$ is generally adequate for design at low flow periods.

4. Minimum velocities of 2 to 3 fps are required for settled sewage at average design flows to preclude sedimentation in either the outfall or diffuser structure.

5. Required jet velocities are as follows:

$V_j \geq$ 1.0 ft/sec (for all flows)
$\leq$ 20. ft/sec (for concrete diffusers under maximum daily design flows).

6. Port diameter (D) criteria are as follows:

a. Port diameter(D) $\leq$ 1/4 manifold cross-section at any point along diffuser

$\geq$ 2 to 3 inches in all cases

b. Typical range is 4 to 9 inches
c. Port diameters are usually larger for primary effluent to prevent clogging and excessive maintenace

d. If diffuser is tapered port diameters generally increase in size towards the diffuser end (bulkhead) to insure flow uniformity.

7. Port spacing(l) criteria to preclude jet interference (merging)

a. Port spacing(l) $\geq$ 10 x (port diameter)
$\geq$ jet trajectory (L)/6
b. Typical spacing range is 8 to 15 feet (c. to c.); average is 10 feet
c. When ports are on the same side of the diffuser, jet interference has been observed at a distance along trajectory of 2.5 to 3.1 L.
d. For ports on alternate sides of the diffuser, merging has been observed above diffuser when the Froude number (F_o) was in range 10 to 40; generally, greater Froude numbers prevent jet merging above the diffuser or increase distance above diffuser that such merging might occur.

Parameter Definition:

F_o = Froude number
D = Port diameter
L = Trajectory length along plume ℄ to maximum point of rise
l = Port spacing
Vj = Jet velocity

V. Ocean Outfall Design and Construction Considerations

A. General Considerations

1. Basic items to be considered in the design of an outfall are as follows:

a. Structural

wave pressure effects
longshore current effects
anchorage need (esp. in the surf zone)
ballast (flotation) requirements
bottom sand movement (esp. in surf zone)
compressability of bottom material along routing
need for "thrust" blocks at alignment changes
need for support piles (esp. at thrust blocks)
effect of storm conditions on all of the above

b. Hydraulic

minimum velocity requirements
peak plant flow(s)
roughness coefficient(s) and head losses
economic analysis of gravity vs pump flow
head requirements
water hammer analysis

2. Outfall design should provide

a. Inspection manholes along entire length

b. Access chambers for cleaning equipment

c. Removable bulkheads on the diffuser for flushing line

3. Scheduling for outfall construction (marine portion) should consider periods of low biological vulnerability for instream biota.

4. Design and construction requirements differ according to

a. Plant to shoreline portion

b. Surf zone portion (out to -20 to -30 feet MLW depth)

c. Offshore portion (beyond -30 feet MLW depth)

B. Surf Zone Considerations

1. Bottom materials move during all conditions

2. In most cases, outfall placement below ocean flow is desirable especially if bottom is sandy. (≥5 feet cover over outfall with sand and quarry stone is common).

3. Should consult historic bathymetry data to evaluate long-term bottom transport.

4. On sandy bottom, open trench construction is often impossible; possible construction technique is as follows:

   a. Drive 2 parallel rows of sheet piles

   b. Remove material to provide approx. 5 to 8 ft. cover over outfall

   c. Install outfall; longer outfall sections desirable

   d. Backfill to approx. + 1 ft. above outfall with sand

   e. Fill remainder to ocean floor level with quarry grade stone (50 to 150#)

   Benefits of such placement are as follows:

   a. No damage due to sand movement

   b. No damage due to lateral currents

   c. No anchorage requirements

   d. No ballast considerations

5. Consider use of pilings (preferably pipe piling) to provide support and lateral constraints

C. Offshore Zone Considerations

1. Outfall may be on or below ocean floor

2. Bottom materials generally move only during storm events

3. Storm events generally felt to approx. - 50 ft. MWL depth

4. Generally, ≥ 5 ft cover for sub-terrestial outfalls is common

5. If exposed, ballast all outfall sections to prevent erosion

RECOMMENDED MONITORING PROGRAM

A. Physical Measurements

1. Temperature[1]
2. Salinity[1]
3. Secchi Depth
4. Turbidity[2]
5. Incident and reflected light[1]

B. Chemical Measurements

1. Dissolved Oxygen[2]
2. pH[2]
3. Nitrogen (organic, ammonia, nitrate)[2]
4. Phosphorus (total, ortho)[2]
5. Biochemical Oxygen Demand - 5 day[2]
6. Total organic carbon[2]
7. Reactive-Silica[2]
8. Heavy Metals[2]

C. Biological Measurement

1. Chlorophyll "a"[2]
2. Algal Counts[2]
3. Zooplankton Counts[2]
4. Total and Fecal Coliform[2]

D. Benthos

1. Total Kjeldahl Nitrogen
2. Total organic carbon
3. Biochemical Oxygen Demand - 5 day
4. Grain size distribution
5. Heavy Metals
6. Benthic trawl in outfall region (classification and enumeration or organisms)

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[1]Surface and 5 meter intervals to bottom
[2]Surface and bottom

Total 15 - 20 stations, 3-4 transects perpendicular to shoreline

VIII. General Comments

A. Puerto Rico Coastal Water Characteristics:

Literature research indicated the following general characteristics:

1. No significant thermal or salinity stratification along the south shore

2. Usually on the north shore, stratification is insignificant in nearshore areas where depths are $\leq$ 40 meters; exception(s): Dorado area

3. No upwelling noted along any coastal areas

4. Due to diurnal offshore/onshore wind changes, critical hydrodynamic conditions may often be during periods of

   a. minimal stratification and

   b. onshore surface winds (often daytime periods)

B. Possible Future Policy Decisions

Possible future policy decisions which might be considered by the Puerto Rico Commonwealth are as follows:

1. Prohibiting discharge into SB waters ($\leq$ 500 meters offshore)

2. Requiring diffusers on all outfalls

3. Requiring outfall and diffuser designs to meet standards using primary effluent characteristics if the facility is to operate for an interim period at this level

4. Requiring that the coliform, aesthetic and biological chronic toxicity standards be met at the maximum point of plume rise above the discharge point; requiring, in addition, that the SB coliform standard be met at the SB-SC interface (if applicable)

5. Requiring Program PLUME be used in all future oceanographic studies for diffuser analysis and optimization

6. Establishing a maximum allowable chlorine residual for coastal discharges to reduce biological toxicity of the effluent.

7. For outfall construction:

   a. Require trenched outfall for all discharges into south coast waters

   b. Require trenched emplacement for all outfall sections into $\leq$ 30 to 50 feet MLW depth on north shore waters or

   c. Require all coastal outfall sections constructed in surf zone areas ($\leq$ 30 to 50 feet) in Puerto Rico to be placed in trenches with a minimum of 5 feet cover.