Appendix E

Water Quality Assessment of Bacterial Indicator Organisms

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I. Background and Existing Requirements

The specific requirements for sampling and reporting of enterococci are specified in the current permit, see "Core Monitoring program, "Appendix J. These requirements, initiated in November 1998, in part, also specify the stations and the sampling frequency. For the purposes of this effort, only enterococci will be addressed. Based on sampling frequency, two sampling regimes exists: regime (1) shoreline (S stations, five sites) and recreational (R stations, three sites) stations, and regime (2) nearshore (C stations, five sites) and offshore (D and E, five sites for D stations and five sites for E stations) stations. Regime (1) is sampled seven days per month while regime (2) is sampled once per month. All sites, obtain grab samples from surface, mid, and bottom depths; except for S stations where only surface grabs are obtained. In addition to the permitted stations, the City has initiated additional stations, starting around October 1999. These include six "Nearshore" stations (C1A, C2A, C3A, C4A, C5A, and C6) and three "Offshore" stations (D3A, D6 and E6) sampled at seven days per month and one per month, respectively for surface/mid/bottom depths; see Figure E for the monitoring station locations. Based on enterococci sampling results, analyses was conducted to evaluate the potential of exceeding the State Water Quality standard for recreational waters of geometric mean 7 cfu/100mL, due to the discharge of primary treated effluent. It is not anticipated that this evaluation will be a definitive study, particularly in light of the Mamala Bay Study. Instead, however, it is hoped that the analyses present here will contribute to the City's position that the discharge of primary treated effluent is not impacting recreational waters.

II. Approach

To evaluate potential impacts, general statistics were applied. This includes the geometric mean value (GM), the sample standard deviation (STDS), the number of data points in a data set (n), the maximum (MAX) value, and the minimum (MIN) value obtained from the data set. The geometric mean value provides the normal tendency, particularly if sufficient data points are available. Because of the complexity of the marine environment, the geometric mean value provides a measurement of what could be anticipated; it is also the statistic used to evaluate public health risk. The sample standard deviation was also considered to provide a sense of data dispersion or distribution. In areas where nonpoint sources are thought to significantly contribute to elevated enterococci concentrations, we anticipate a larger sample standard deviation as opposed to areas not experiencing large nonpoint contributions due to the variability of rainfall events. The number of data points in a data set suggests the reliability of the data set. Finally, the MAX and MIN values also provide a sense of the data distribution or dispersion.

Two transect types were defined: "Alongshore Transects" and "Shoreline Perpendicular Transects." An "Alongshore Transects" is a series of stations having a similar depth contour. The purpose of these transects is to a provide comparison of the tendency along the shoreline. A "Shoreline Perpendicular Transect" is a series of stations that line up perpendicular to the depth contours. See Tables E1 and E2 for the stations that comprise the "Alongshore Transects" and the "Shoreline Perpendicular Transects."

III. Findings

Alongshore Transects:

Shoreline and Receational Waters: See Figures E1, E6, and E11 for shoreline (geometric mean/sample standard deviation), recreational (geometric mean), and recreational (sample standard deviation) enterococci concentrations, respectively. See also Tables E3 and E4. The figures and tables suggest the source of high enterococci in the shoreline areas is associated the Keehi Lagoon/Honolulu Harbor and Ala Wai Canal (nonpoint sources). The higher geometric means and sample standard deviations are associated with surface sample nearest to nonpoint sources. Freshwater discharge, having less density than sea water, tend to remain on the surface of water bodies. Because the geometric mean surface values are much larger than the mid or bottom sample results and because the same pattern is reflected in the sample standard deviation, we conclude that the major contributions are from nonpoint sources. The maximum values, as seen in Table E4, and a comparison of results from stations R2 and R3 versus station R1 support the position that the major sources of enterococci is from nonpoint sources.

Nearshore:
See Figures E2, E3, E7, and E8 for nearshore (permitted and nonpermitted) station enterococci results. See also Tables E5 and E6. Some interesting characteristics can be see from the referenced tables and figures. Stations C1, C2, C3, C1A, C2A, and C3A suggests that a source of enterococci at deep depths and offshore is presents, as seen in the higher geometric mean bottom values for these stations, diminishing as one goes shallower. The highest sample standard deviations from

these stations are of similar magnitude as stations S1 and S8, which we stated was probably caused by variable rainfall. Although the similarity is probably not associated with precipitation, it does suggest that the variability of the nearshore stations at deeper depth is of similar characteristic. For stations C4, C5, C5A and C6, the trend for geometric mean values reversed, with the higher geometric mean values seen at the surface and the bottom geometric means being lower. Lastly, in almost all cases, the geometric mean values for stations farther offshore had a tendency to be higher when compared against stations closer to shore.

Offshore:
See Figures E4, E5, E7, E9, and E10 for offshore (permitted and nonpermitted) station enterococci results. See also Tables E7 and E8. Similar trends exists for the deeper stations as those seen in the nearshore in that stations at and west of the outfall show higher concentrations at depth than station east of the outfall; e.g, stations D4, D5, E4, and E5. It should also be noted that the sample standard deviation shows a reduce values for surface and mid depth results, which supports the position that surfacing, although possible, does not occur routinely.

Shoreline Perpendicular Transects:
The transects show clearly that the plume does influence the waters shoreward of the outfall (see Figures 12 to 14; Transects 1, 2, and 3) at the deeper depths, having a shoreward extent of station C3A. Figure 18 to 21 also show bottom and mid depth values are highly variable.

Transects 4, 5, and 6, however, show virtually no sign of the discharge plume. All bottom stations have comparable enterococci concentrations as the surface and mid depth values.

IV. Conclusions

The compelling figures which demonstrate the discharge of primary treated effluent does not meet recreational waters can be found in the "Shoreline Perpendicular Transects." The "Alongshore Transects" show the contributions of nonpoint sources. Given these two results, we determine the discharge of primary treated effluent does not pose an unacceptable risk at the current treatment and disposal configuration.

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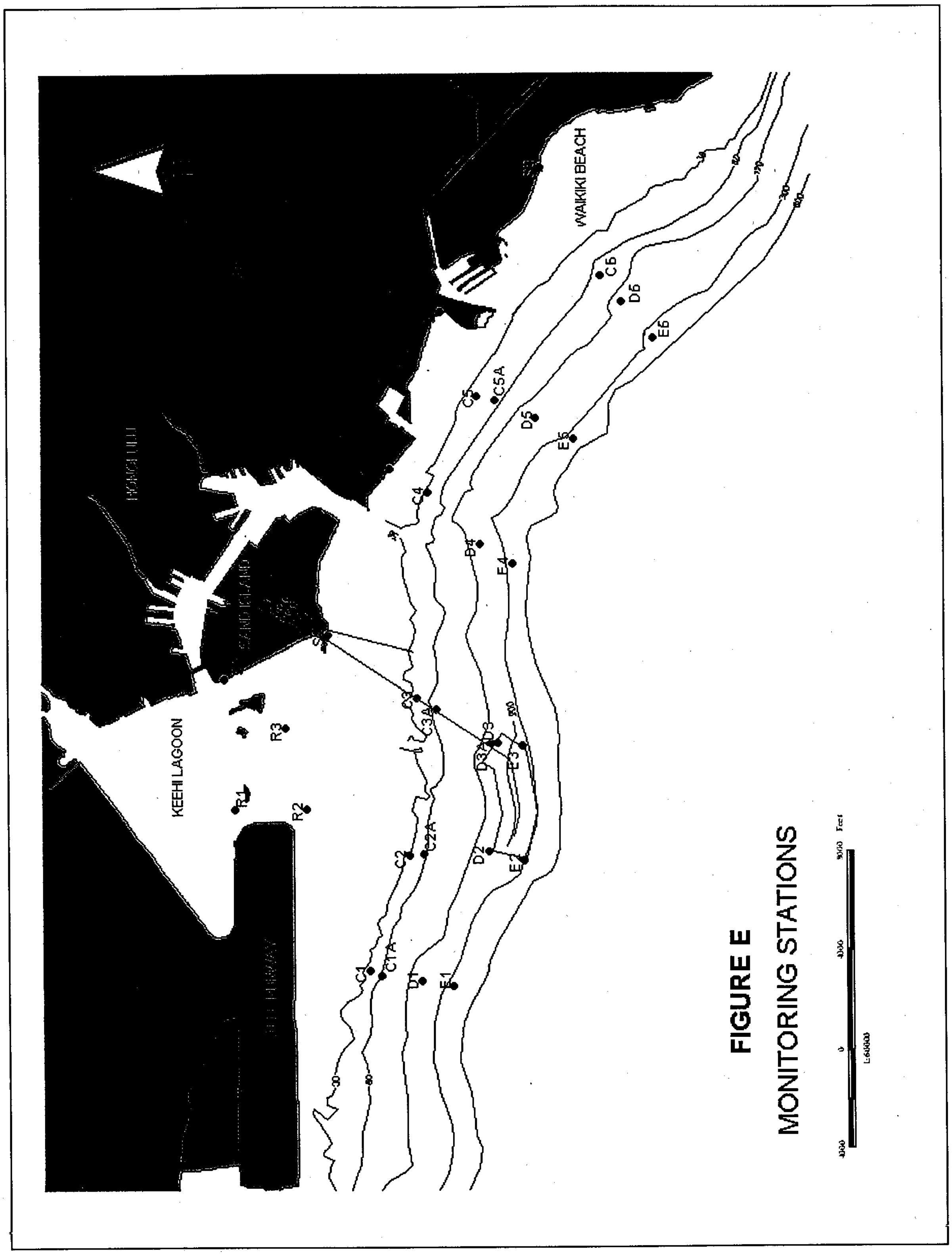


FIGURE E
MONITORING STATIONS

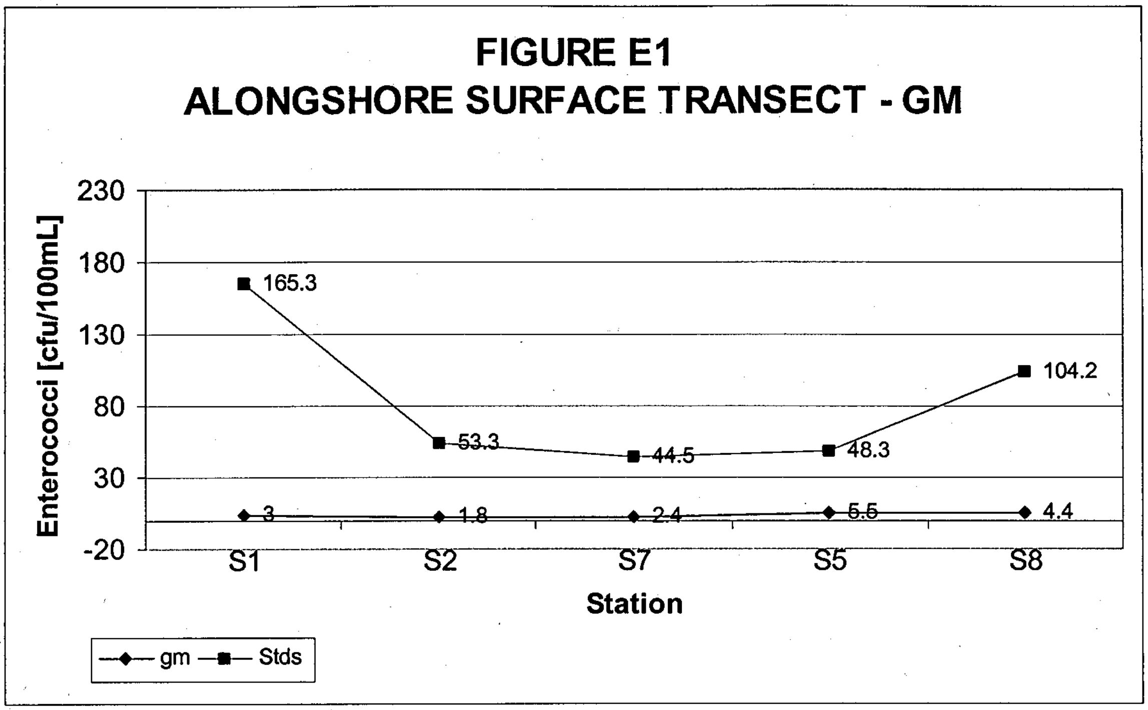


FIGURE E1
ALONGSHORE SURFACE TRANSECT - GM
Enterococci [cfu/100mL]
230
180
130
80
30
-20
165.3
53.3
44.5
48.3
104.2
3
1.8
2.4
5.5
4.4
S1
S2
S7
S5
S8
Station
gm
Stds

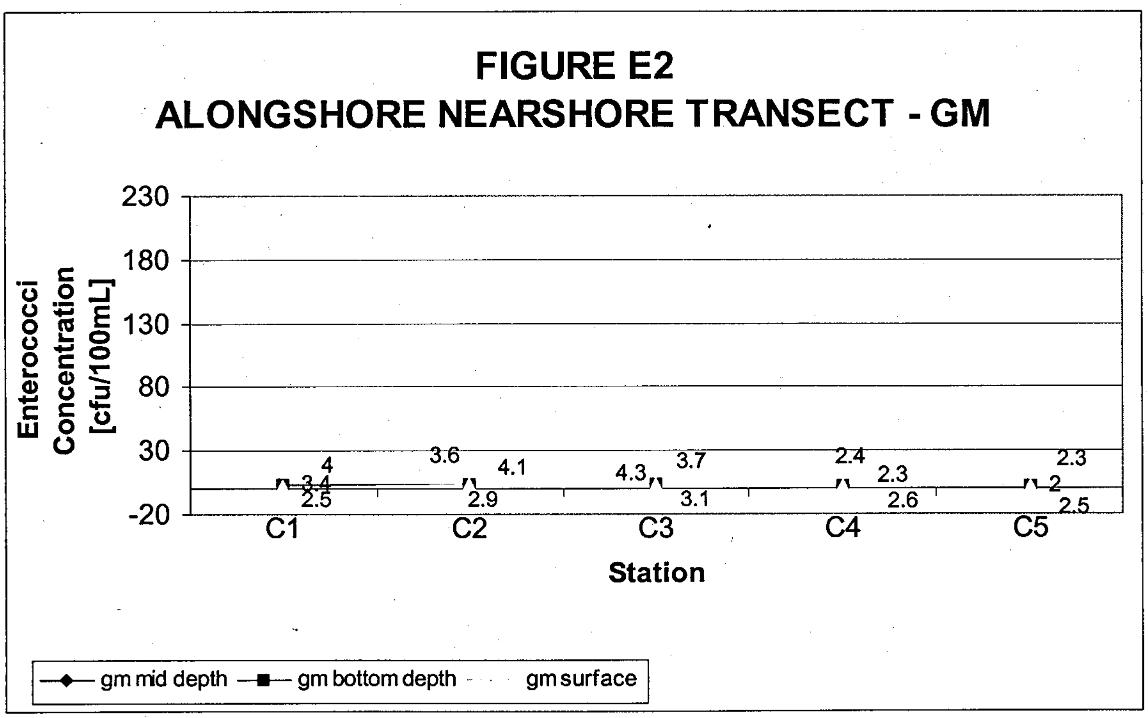


FIGURE E2
ALONGSHORE NEARSHORE TRANSECT - GM
Enterococci Concentration [cfu/100mL]
230
180
130
80
30
-20
4
3.4
2.5
3.6
4.1
2.9
4.3
3.7
3.1
2.4
2.3
2.6
2.3
2
2.5
C1
C2
C3
C4
C5
Station
gm mid depth
gm bottom depth
gm surface

FIGURE E3
ALONGSHORE NEARSHORE-A TRANSECT - GM

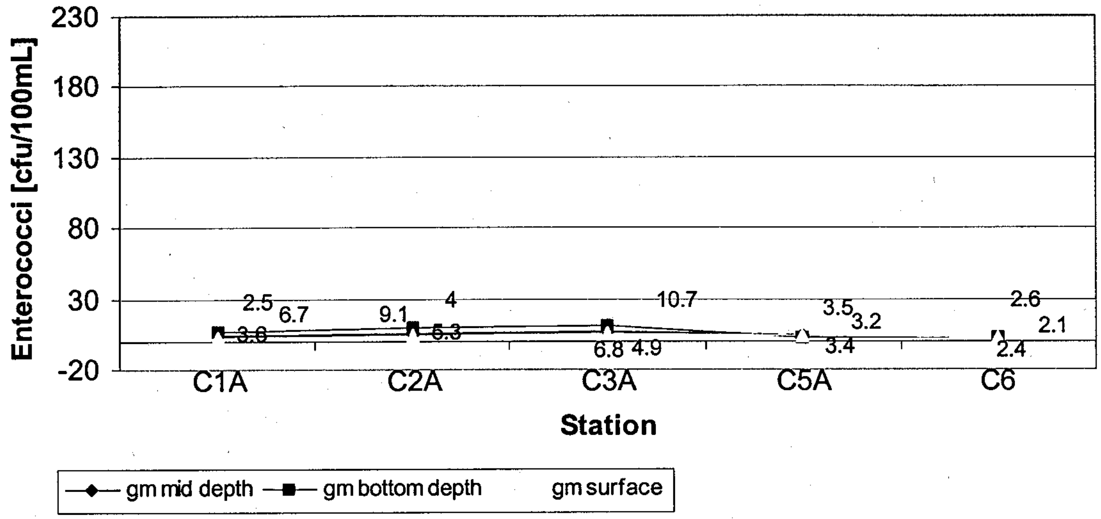
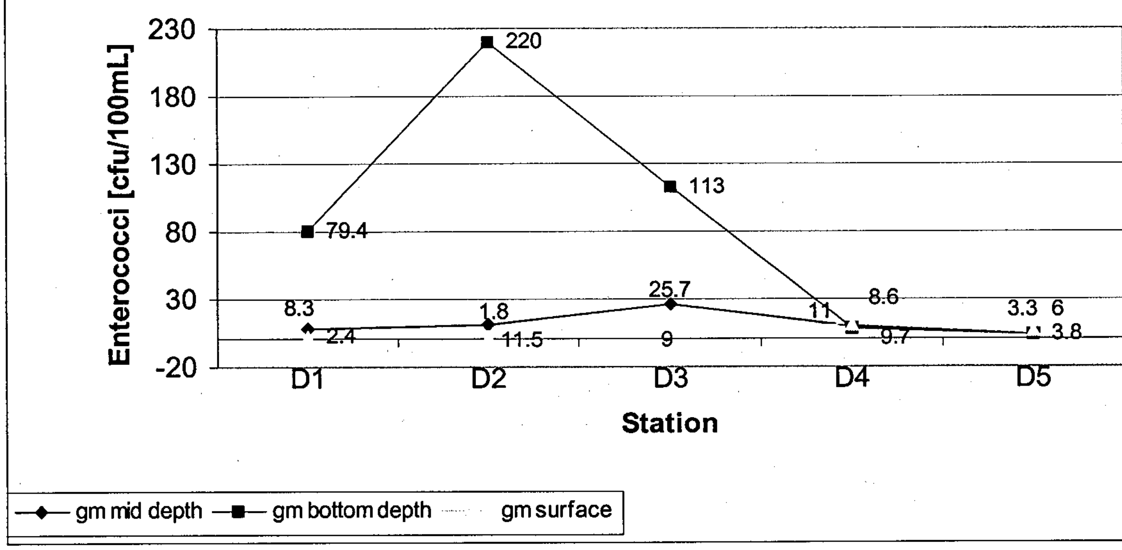


FIGURE E4
ALONGSHORE OFFSHORE TRANSECT - GM



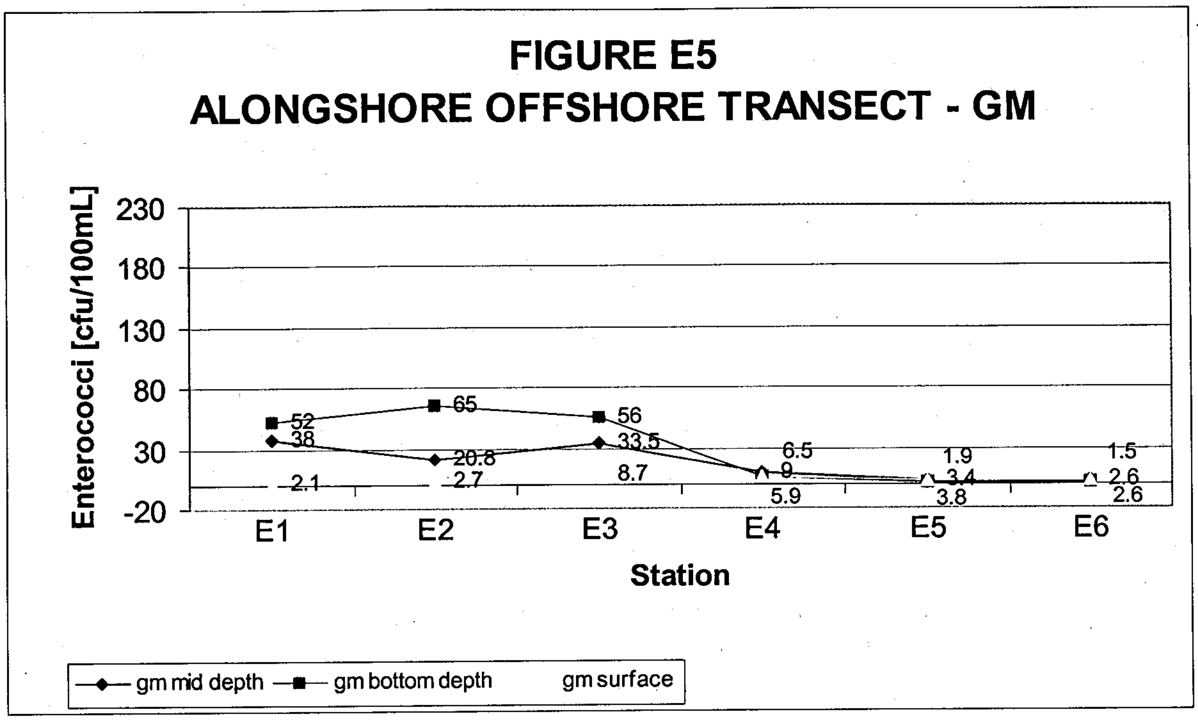


FIGURE E5
ALONGSHORE OFFSHORE TRANSECT - GM
Enterococci [cfu/100mL]
230
180
130
80
30
-20
52
38
2.1
65
20.8
2.7
56
33.5
8.7
6.5
9
5.9
1.9
3.4
3.8
1.5
2.6
2.6
E1
E2
E3
E4
E5
E6
Station
gm mid depth
gm bottom depth
gm surface

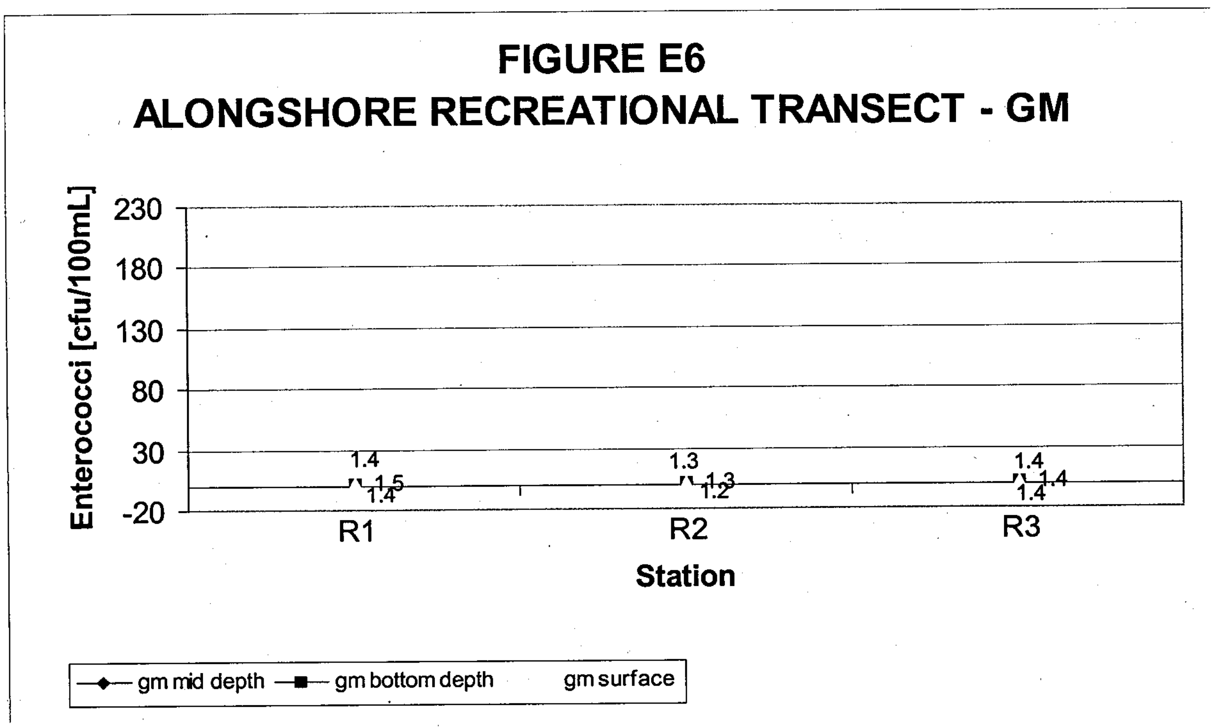


FIGURE E6
ALONGSHORE RECREATIONAL TRANSECT - GM
Enterococci [cfu/100mL]
230
180
130
80
30
-20
1.4
1.5
1.4
1.3
1.3
1.2
1.4
1.4
1.4
R1
R2
R3
Station
gm mid depth
gm bottom depth
gm surface

FIGURE E7
ALONGSHORE NEARSHORE TRANSECT - STDS

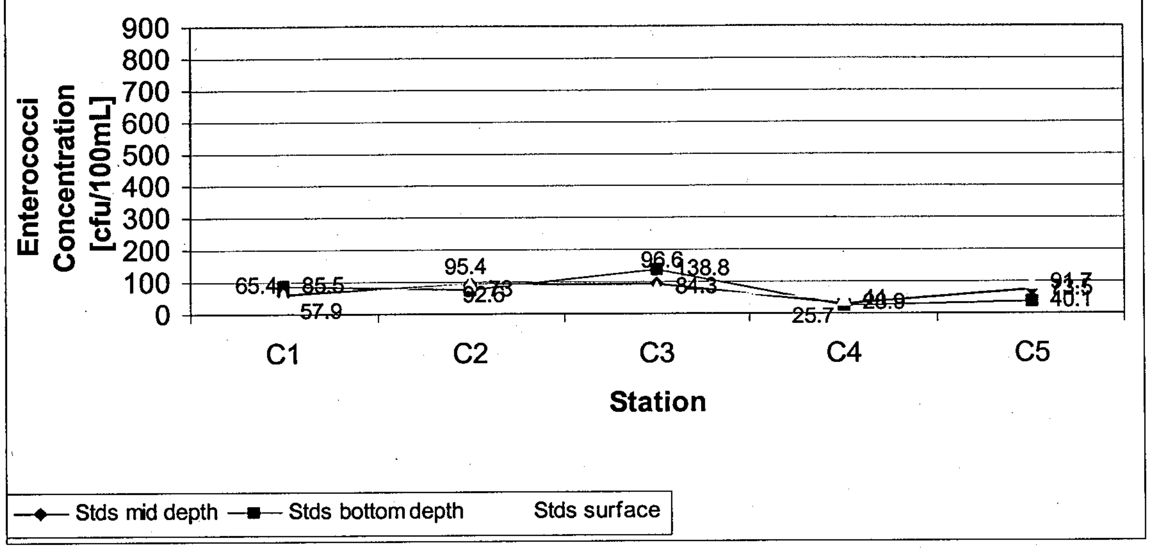


FIGURE E8
ALONGSHORE NEARSHORE-A TRANSECT - STDS

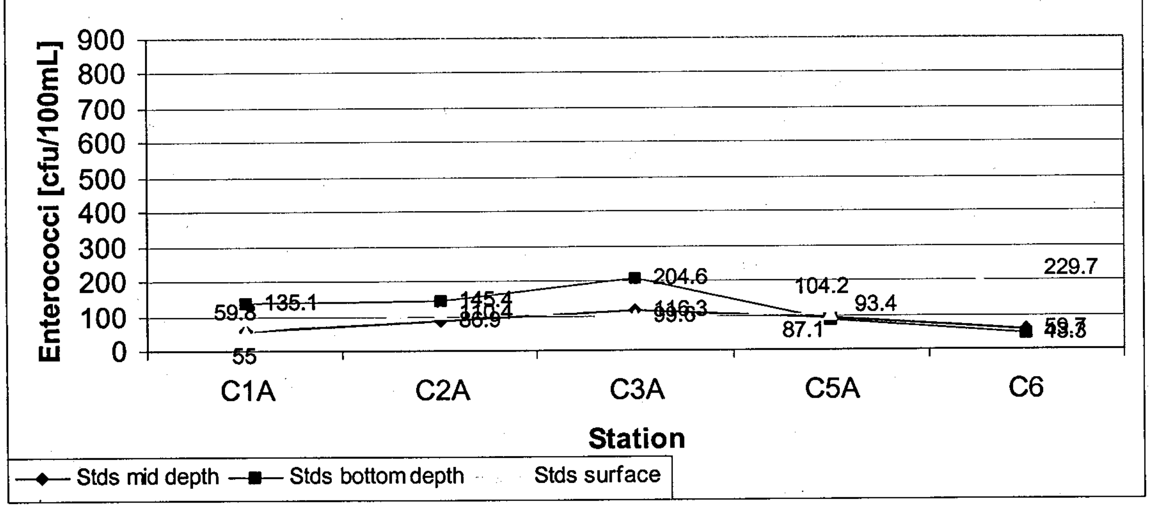


FIGURE E9
ALONGSHORE OFFSHORE TRANSECT - STDS

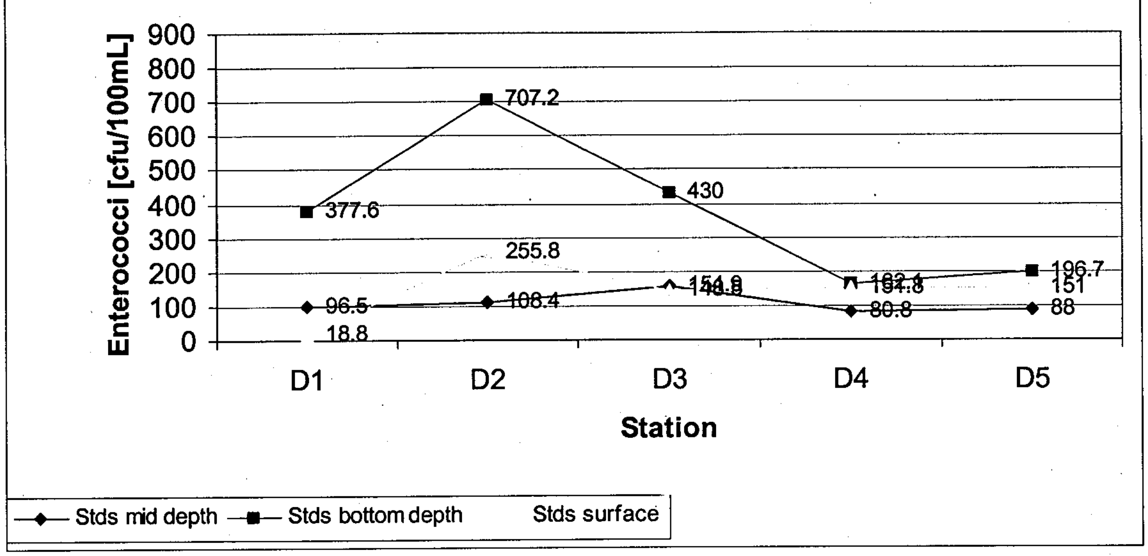


FIGURE E10
ALONGSHORE OFFSHORE TRANSECT - STDS

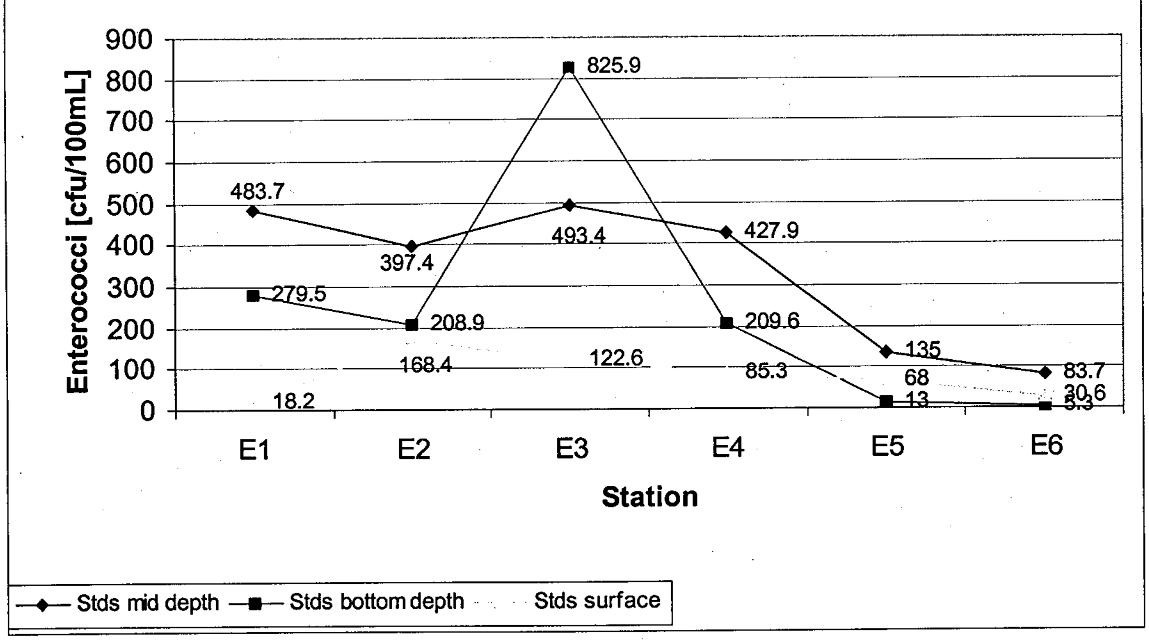


FIGURE E11
ALONGSHORE RECREATIONAL TRANSECT - STDS

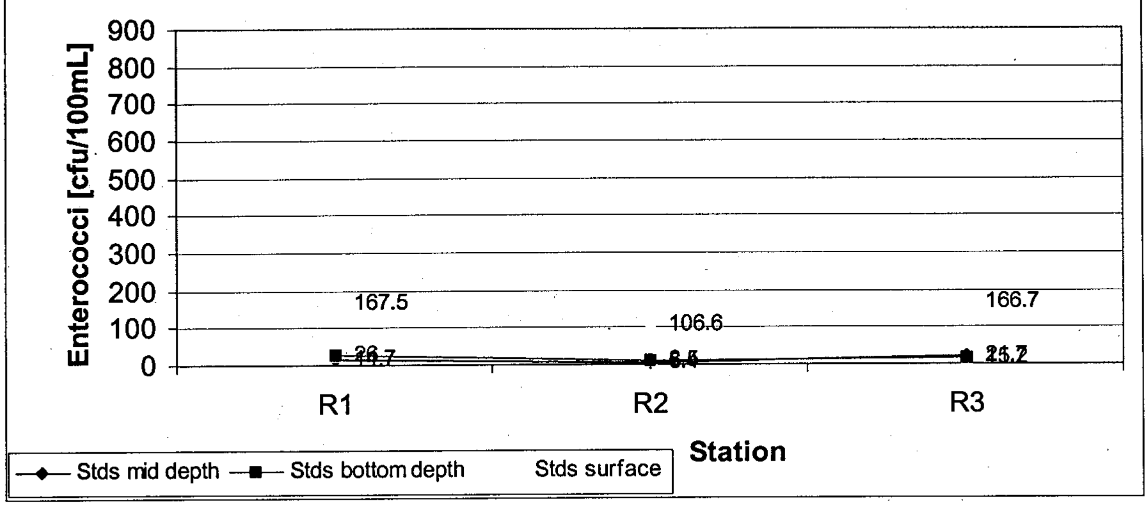


FIGURE E12
TRANSECT 1 - GM

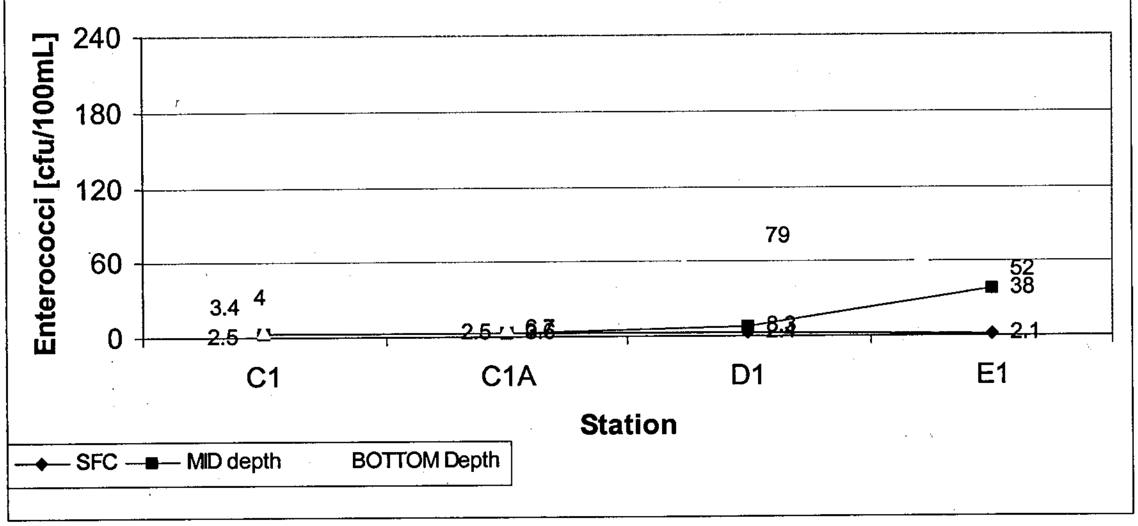


FIGURE E13
TRANSECT 2 - GM

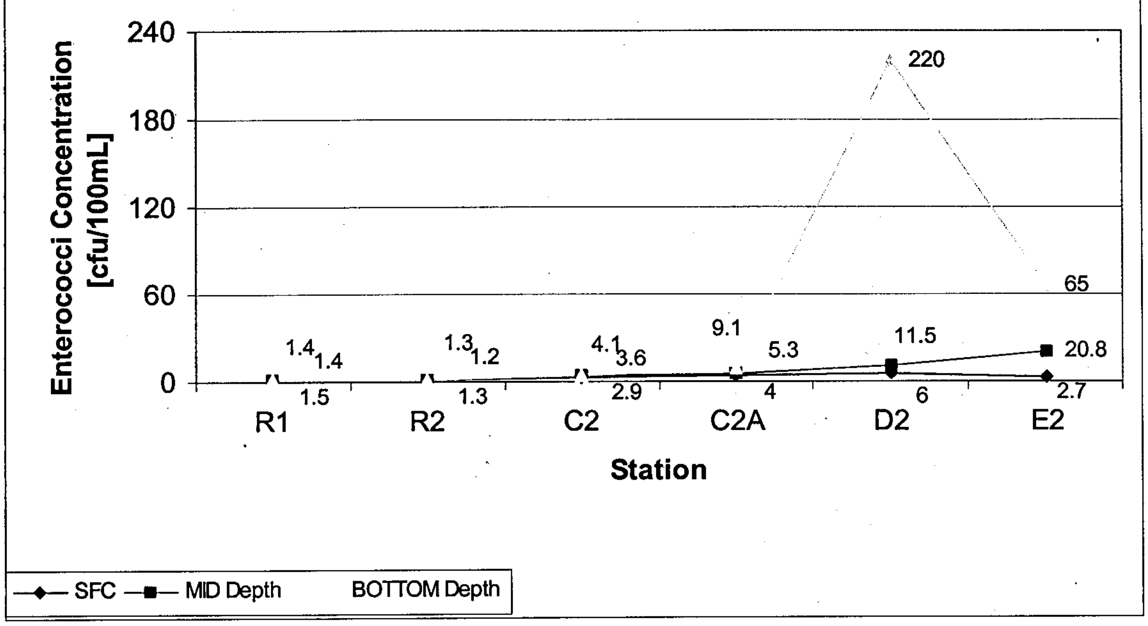
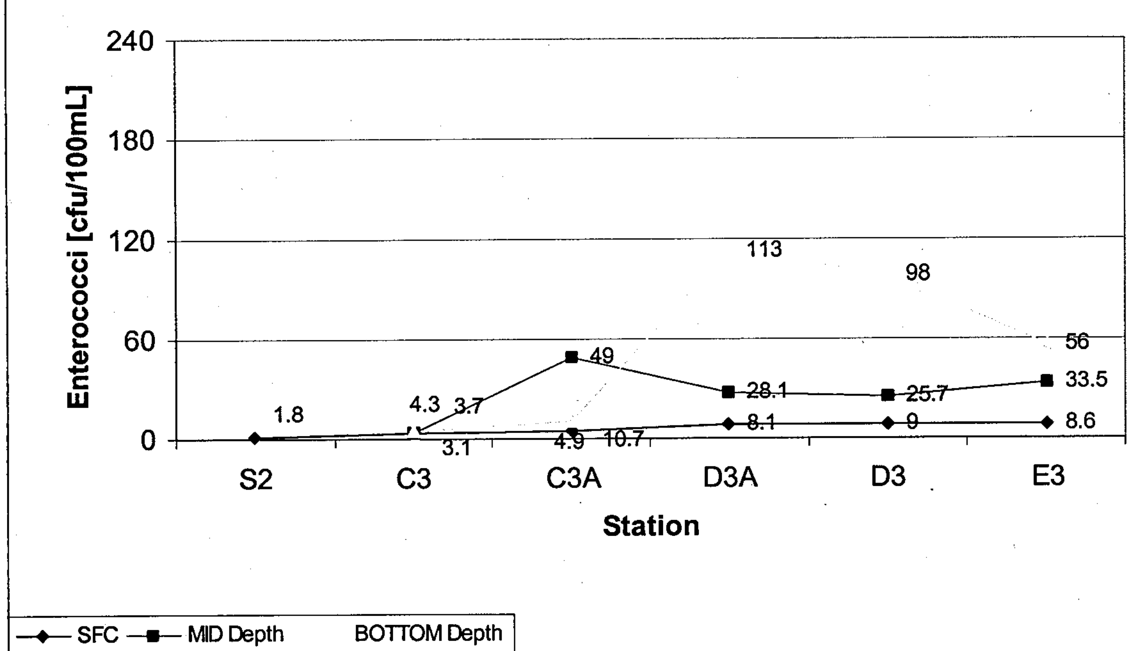


FIGURE E14
TRANSECT 3 - GM



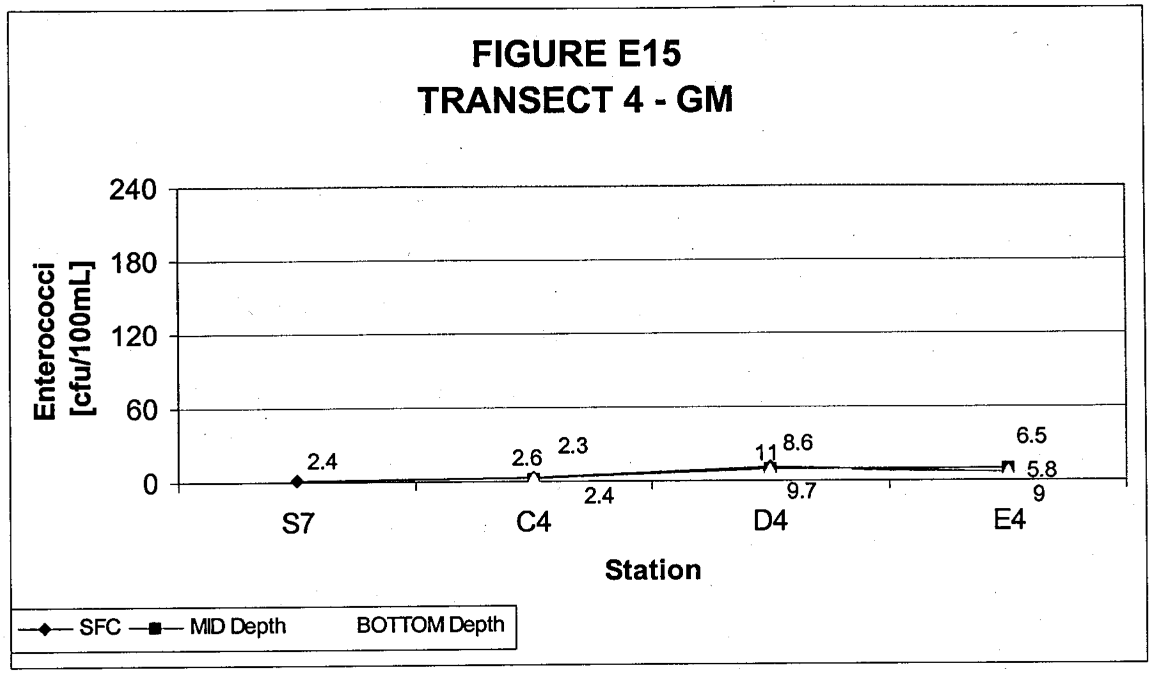


FIGURE E15
TRANSECT 4 - GM
Enterococci [cfu/100mL]
240
180
120
60
0
2.4
2.6
2.3
2.4
11
8.6
9.7
6.5
5.8
9
S7
C4
D4
E4
Station
SFC
MID Depth
BOTTOM Depth

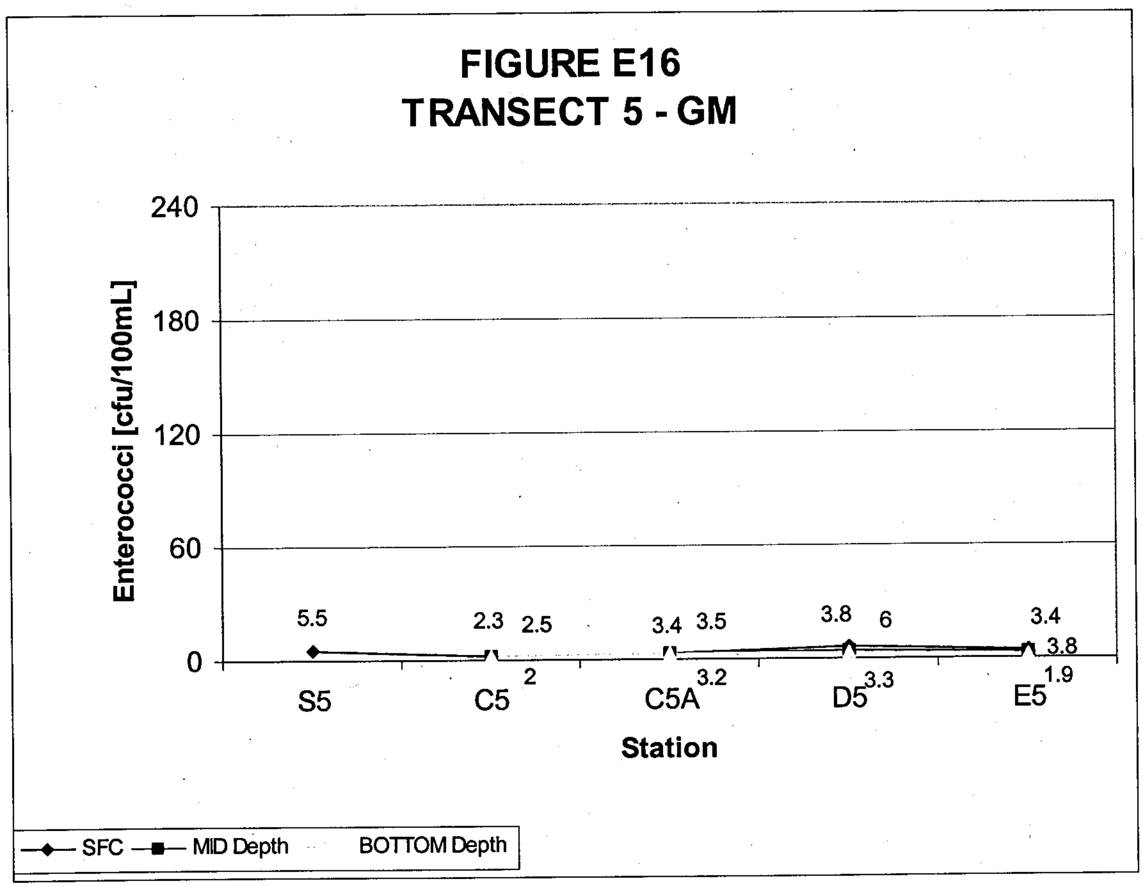


FIGURE E16
TRANSECT 5 - GM
Enterococci [cfu/100mL]
240
180
120
60
0
5.5
2.3
2.5
2
3.4
3.5
3.2
3.8
6
3.3
3.4
3.8
1.9
S5
C5
C5A
D5
E5
Station
SFC
MID Depth
BOTTOM Depth

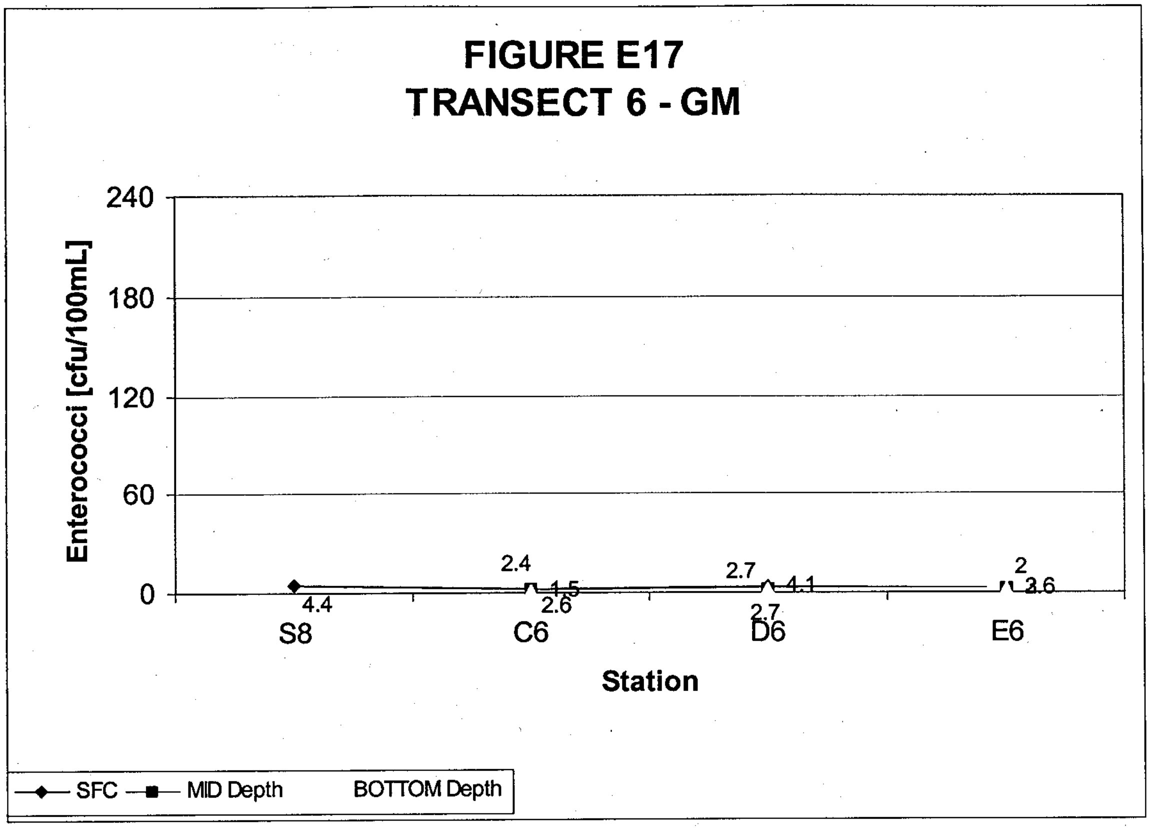


FIGURE E17
TRANSECT 6 - GM
240
180
120
60
0
Enterococci [cfu/100mL]
2.4
2.7
2
1.5
4.1
3.6
4.4
2.6
2.7
S8
C6
D6
E6
Station
SFC
MID Depth
BOTTOM Depth

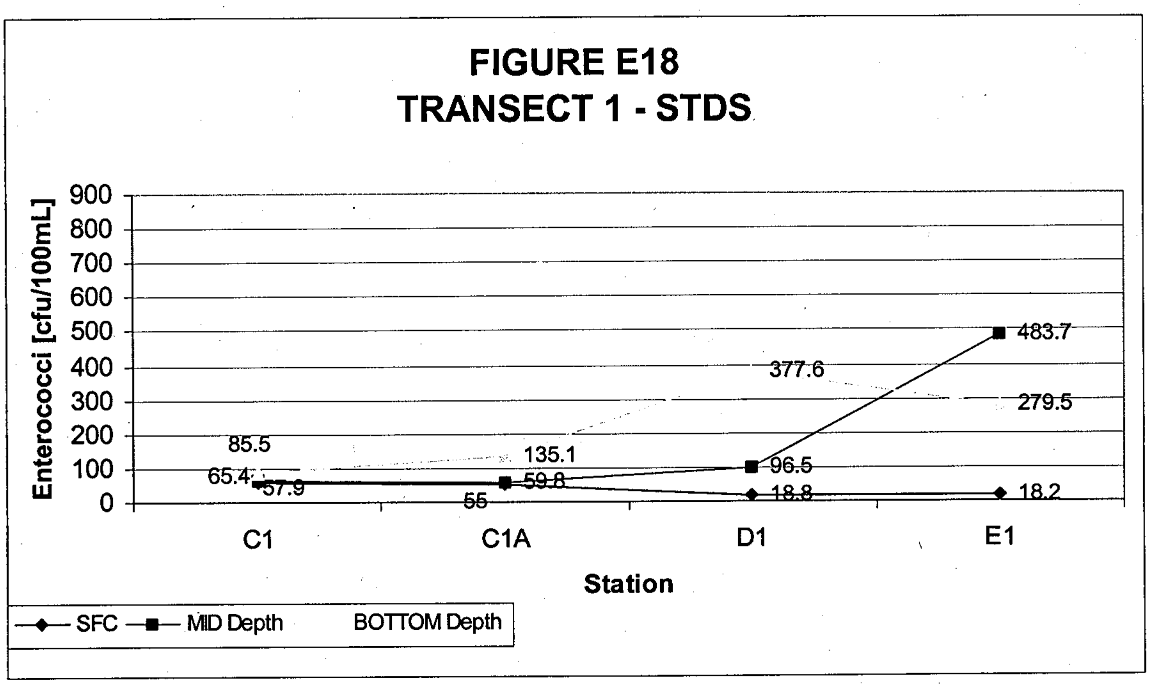


FIGURE E18
TRANSECT 1 - STDS
900
800
700
600
500
400
300
200
100
0
Enterococci [cfu/100mL]
483.7
377.6
279.5
85.5
135.1
65.4
57.9
59.8
96.5
55
18.8
18.2
C1
C1A
D1
E1
Station
SFC
MID Depth
BOTTOM Depth

FIGURE E19
TRANSECT 2 - STDS

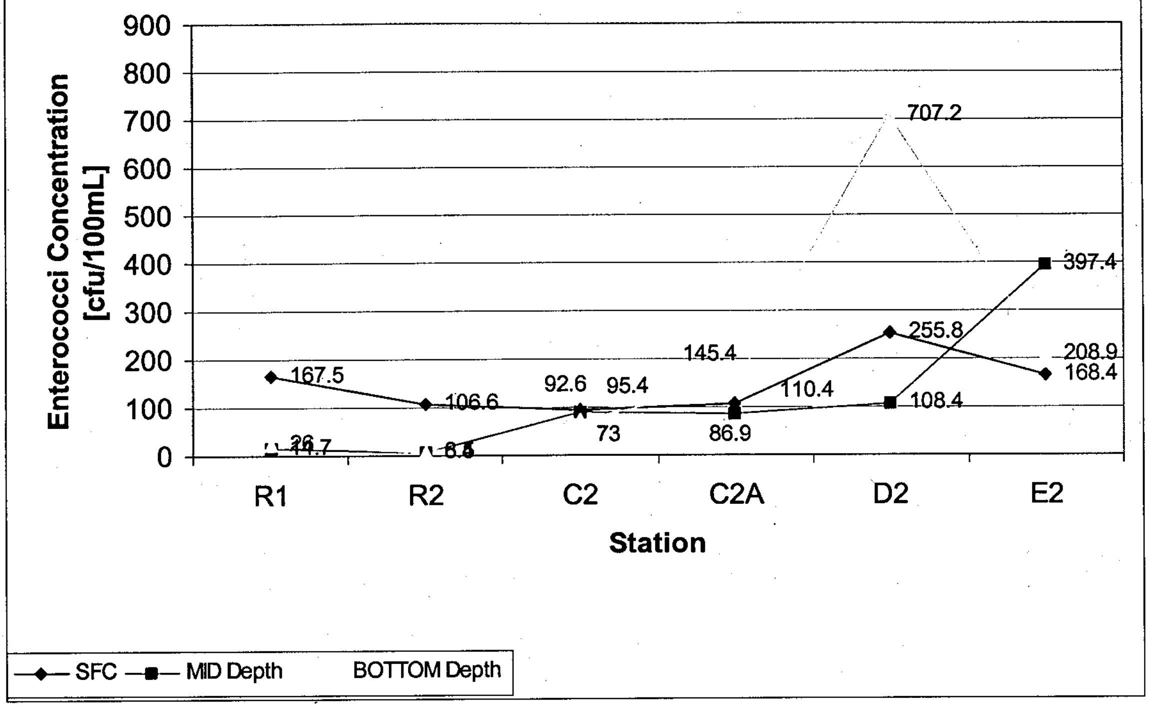
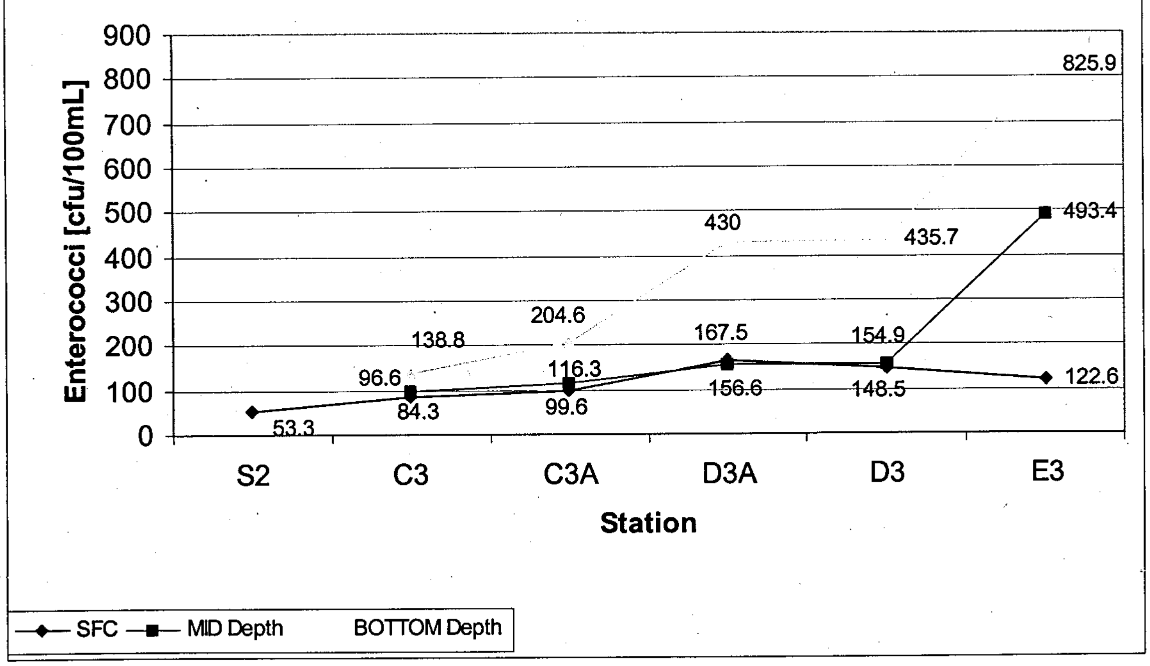


FIGURE E20
TRANSECT 3 - STDS



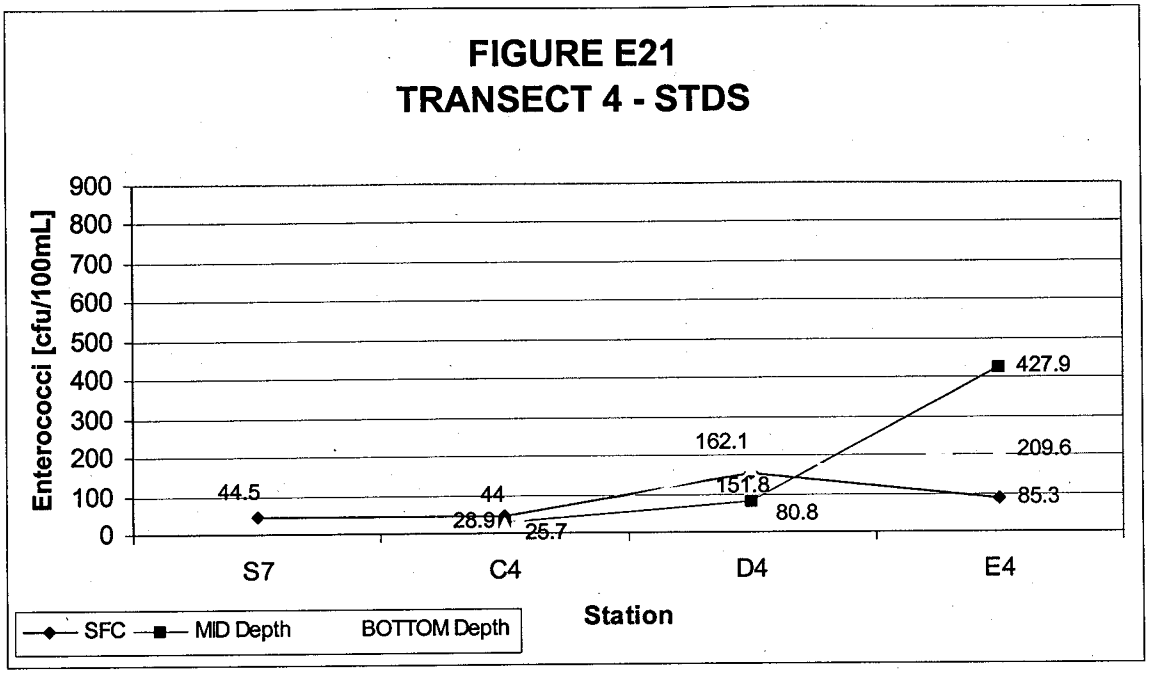


FIGURE E21
TRANSECT 4 - STDS
Enterococci [cfu/100mL]
900
800
700
600
500
400
300
200
100
0
44.5
44
28.9
25.7
162.1
151.8
80.8
427.9
209.6
85.3
S7
C4
D4
E4
Station
SFC
MID Depth
BOTTOM Depth

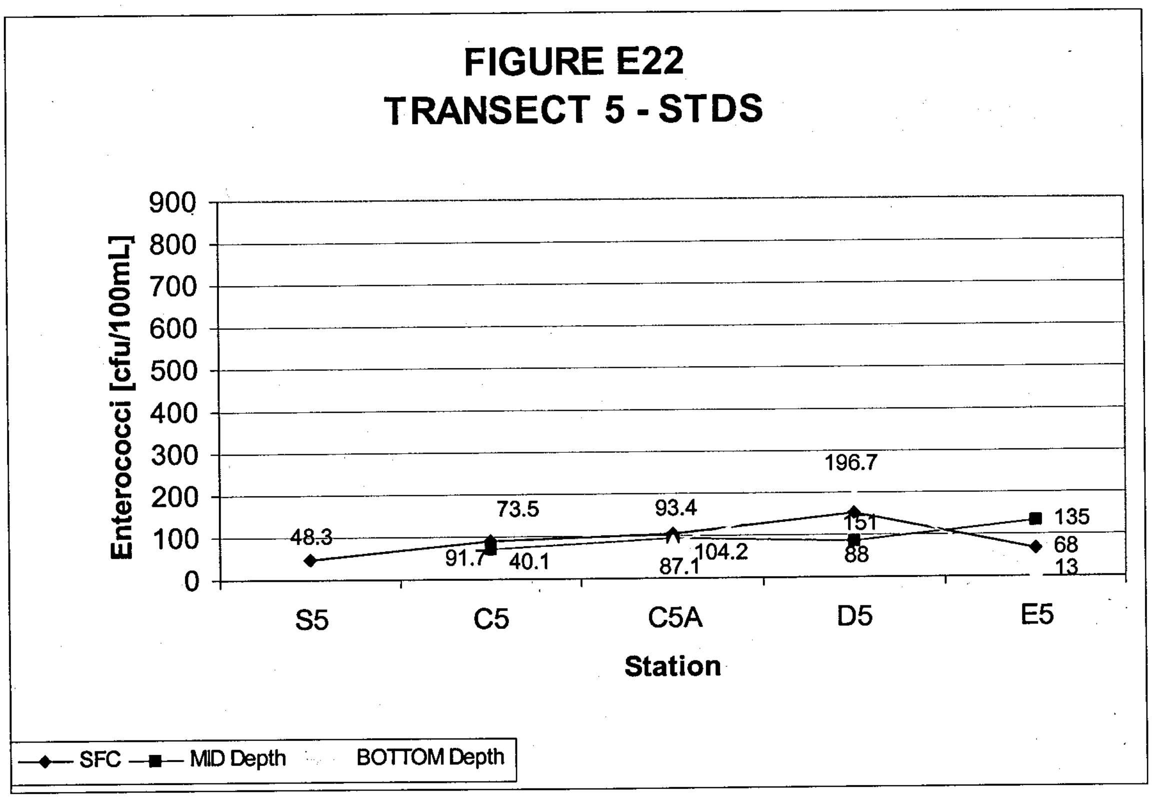


FIGURE E22
TRANSECT 5 - STDS
Enterococci [cfu/100mL]
900
800
700
600
500
400
300
200
100
0
48.3
73.5
91.7
40.1
93.4
87.1
104.2
196.7
151
88
135
68
13
S5
C5
C5A
D5
E5
Station
SFC
MID Depth
BOTTOM Depth

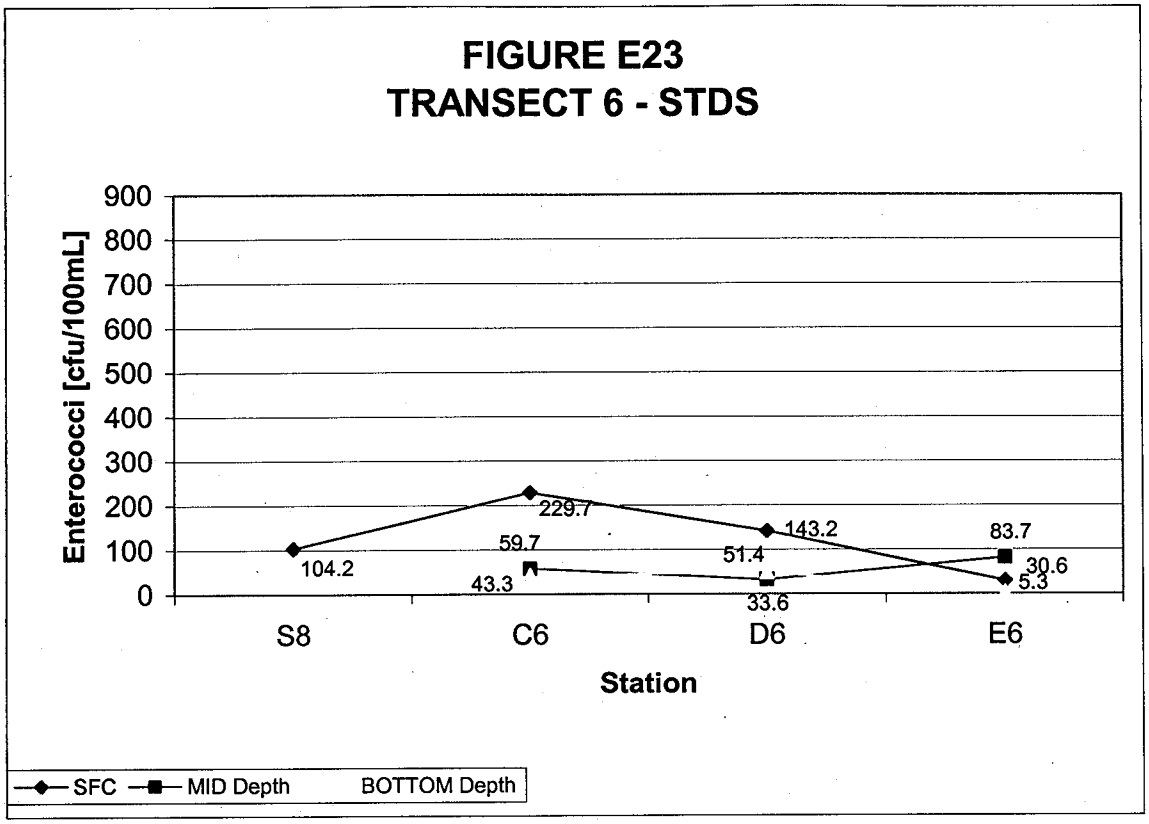


FIGURE E23
TRANSECT 6 - STDS
Enterococci [cfu/100mL]
900
800
700
600
500
400
300
200
100
0
229.7
143.2
83.7
59.7
51.4
104.2
43.3
30.6
5.3
33.6
S8
C6
D6
E6
Station
SFC
MID Depth
BOTTOM Depth

TABLE E1 ALONGSHORE TRANSECTS	
TRANSECT	STATIONS
SURFACE TRANSECT	S1, S2, S7, S5, and S8
NEARSHORE TRANSECT	C1, C2, C3, C4, and C5
NEARSHORE – A TRANSECT	C1A, C2A, C3A, C5A, and C6
OFFSHORE TRANSECT	D1, D2, D3, D4, and D5
OFFSHORE TRANSECT	E1, E2, E3, E4, E5, and E6
RECREATIONAL TRANSECTS	R1, R2, and R3

TABLE E2 SHORELINE PERPENDICULAR TRANSECTS	
TRANSECT	STATIONS
TRANSECT 1	C1, C1A, D1, and E1
TRANSECT 2	R1, R2, C2, C2A, D2, and E2
TRANSECT 3	S2, C3, C3A, D3A, D3, and E3
TRANSECT 4	S7, C4, D4, and E4
TRANSECT 5	S5, C5, C5A, D5, and E5
TRANSECTS 6	S8, C6, D6, and E6

TABLE E3 GENERAL STATISTICS - SHORELINE STATIONS					
STATION	GEOMETRIC MEAN	STDS	n	MAX	MIN
S1	3.0	165.3	308	2000	0.9
S2	1.8	53.3	308	790	0.9
S7	2.4	44.5	308	650	0.9
S5	5.5	48.3	308	630	0.9
S8	4.4	104.2	308	1600	0.9

TABLE E4

GENERAL STATISTICS - RECREATIONAL WATERS STATIONS

STATION	Depth [meter]	GEOMETRIC MEAN	STDS	n	MAX	MIN
R1b	14	1.4	26.0	335	460	0.9
R1m	7	1.4	14.7	335	240	0.9
R1s	Sfc	1.5	167.5	334	1700	0.9
R2b	14	1.3	8.5	335	79	0.9
R2m	7	1.2	6.4	335	63	0.9
R2s	Sfc	1.3	106.6	335	1200	0.9
R3b	9	1.4	15.2	334	180	0.9
R3m	5	1.4	21.7	335	270	0.9
R3s	Sfc	1.4	166.7	335	1900	0.9

TABLE E5

GENERAL STATISTICS PERMITTED NEARSHORE STATIONS

STATION	Depth [meter]	GEOMETRIC MEAN	STDS	n	MAX	MIN
C1b	12	4.0	85.5	336	950	0.9
C1m	6	3.4	65.4	336	630	0.9
C1s	Sfc	2.5	57.9	336	490	0.9
C2b	12	4.1	73.0	336	780	0.9
C2m	6	3.6	92.6	336	900	0.9
C2s	Sfc	2.9	95.4	336	960	0.9
C3b	12	4.3	138.8	336	1800	0.9
C3m	6	3.7	96.6	336	990	0.9
C3s	Sfc	3.1	84.3	336	830	0.9
C4b	12	2.3	25.7	336	330	0.9
C4m	6	2.4	28.9	336	220	0.9
C4s	Sfc	2.6	44.0	336	430	0.9
C5b	12	2.0	40.1	336	400	0.9
C5m	6	2.3	73.5	336	760	0.9
C5s	Sfc	2.1	91.7	336	1100	0.9

TABLE E6

GENERAL STATISTICS
NONPERMITTED NEARSHORE STATIONS

STATION	Depth [meter]	GEOMETRIC MEAN	STDS	n	MAX	MIN
C1Ab	19	6.7	135.1	258	1300	0.9
C1Am	9	3.6	59.8	258	620	0.9
C1As	Sfc	2.5	55.0	258	510	0.9
C2Ab	18	9.1	145.4	258	1300	0.9
C2Am	9	5.3	86.9	258	1000	0.6
C2As	Sfc	4.0	110.4	258	1100	0.9
C3Ab	19	10.7	204.6	258	2100	0.5
C3Am	9	6.8	116.3	258	800	0.2
C3As	Sfc	4.9	99.6	258	780	0.9
C5Ab	21	3.2	87.1	258	740	0.9
C5Am	10	3.4	93.4	258	890	0.9
C5As	Sfc	3.5	104.2	258	800	0.9
C6b	49	2.1	43.3	256	530	0.9
C6m	25	2.4	59.7	258	820	0.4
C6s	Sfc	2.6	229.7	258	3000	0.2

TABLE E7

GENERAL STATISTICS - OFFSHORE WATERS STATION

STATION	Depth [meter]	GEOMETRIC MEAN	STDS	n	MAX	MIN
D1b	50	79.4	377.6	36	1400	0.9
D1m	25	8.3	96.5	36	460	0.9
D1s	Sfc	2.4	18.8	36	99	0.9
D2b	50	220	707.2	36	2800	0.9
D2m	25	11.5	108.4	36	500	0.9
D2s	Sfc	6.0	255.8	36	1200	0.9
D3b	50	113.0	430.0	36	2100	0.9
D3m	25	25.7	154.9	36	770	0.9
D3s	Sfc	9.0	148.5	36	740	0.9
D4b	50	8.6	162.1	36	780	0.9
D4m	25	9.7	80.8	36	320	0.9
D4s	Sfc	11.0	151.8	36	710	0.9
D5b	50	3.3	196.7	36	1100	0.9
D5m	25	3.8	88.0	36	510	0.9
D5s	Sfc	6.1	151.0	36	740	0.9
E1b	100	52	279.5	36	1100	0.9
E1m	50	38.2	483.7	36	2200	0.9
E1s	Sfc	2.1	18.2	36	92	0.9
E2b	100	65.8	208.9	36	780	2
E2m	50	20.8	397.4	36	2000	0.9
E2s	Sfc	2.7	168.4	36	880	0.9
E3b	82	56.1	825.9	36	4300	0.9
E3m	41	33.5	493.4	36	2400	0.9
E3s	Sfc	8.6	122.6	36	540	0.9
E4b	100	6.5	209.6	36	1200	0.9
E4m	50	9.0	427.9	36	2200	0.9
E4s	Sfc	5.9	85.3	36	470	0.9
E5b	100	1.9	13.0	36	74	0.9
E5m	50	3.4	135.0	36	700	0.9
E5s	Sfc	3.8	68.0	36	380	0.9

TABLE E8

GENERAL STATISTICS

UNPERMITTED OFFSHORE STATIONS

STATION	Depth [meter]	GEOMETRIC MEAN	STDS	n	MAX	MIN
E6b	101	1.50	5.3	37	28	0.9
E6m	50	2.6	83.7	37	370	0.9
E6s	Sfc	2.0	30.6	37	170	0.9
D6b	49	2.7	51.4	37	220	0.9
D6m	25	2.7	33.6	37	140	0.9
D6s	Sfc	4.1	143.2	37	850	0.9
D3Ab	51	98.0	435.7	37	2100	0.9
D3Am	25	28.1	156.6	37	670	0.9
D3As	sfc	8.1	167.5	37	960	0.9