Appendix 4.0-A

Scour Analysis

SCOUR ANALYSIS

Proposed Offshore Wind Park

Nantucket Sound, Massachusetts

PREPARED FOR: **Cape Wind Associates, LLC**
75 Arlington Street
Suite 704
Boston, Massachusetts 02116

Prepared By: **ESS Group, Inc.**
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563

E159-003

January 16, 2003 (Updated: 3-17-04)

SCOUR ANALYSIS

Proposed Offshore Wind Park

Nantucket Sound, Massachusetts

Prepared For:
Cape Wind Associates, LLC
75 Arlington Street
Suite 704
Boston, Massachusetts 02116

Prepared By:
ESS Group, Inc.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563

ESS Project No. E159-003

January 16, 2003 (Updated 3-17-04)

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1.0 PURPOSE

This report presents the analysis predicting scour conditions resulting from the offshore wind energy project being proposed by Cape Wind Associates, LLC. The proposed Wind Park will consist of the installation and operation of 130 Wind Turbine Generators (WTGs) on Horseshoe Shoal in Nantucket Sound (see Figure 1). The purpose of the analysis was to evaluate the potential for the Wind Park to affect sediment transport on Horseshoe Shoal based on estimated scour depths and aerial extent of scour. The results of the analysis are not intended to be used for final design of the individual WTGs.

2.0 BACKGROUND

Structures placed in the marine environment may interact with existing forces to contribute to increased local sediment transport that leads to scour. This analysis predicts the potential scour conditions around the monopile foundation structures (referred to as "structures") supporting the WTGs to be placed in specific parallel rows in an array (see Figure 1) perpendicular to prevailing winds, which are generally from the northwest in the winter and southwest in the summer.

Near-field scour conditions may, in time have a detrimental effect on the stability of structures through increased stress or increased exposure to potential damage necessitating costly maintenance. Additionally, far-field scour conditions, if present, could result in an impact on the existing geological conditions of Nantucket Sound in the vicinity of the Wind Park.

3.0 EXISTING CONDITIONS

3.1 General

Nantucket Sound is a shallow open coastal waterbody. The existing conditions study presented by Woods Hole Group (WHG) in a July 2002 report includes approximate values of magnitude and direction of wind, wave, and current conditions for the subject area. The study is based on a combination of existing wind and tidal (heights and currents) data, supplemented with a site-specific current monitoring program and includes sufficient data to provide conservative predictions of scour conditions and an understanding of near and far-field scour impacts.

3.2 Hydrography

Horseshoe Shoal is shaped like a horseshoe, with shallow northern and southern legs separated by a deep-water basin. Depths at Horseshoe Shoal are as shallow as 0.5 feet at Mean Lower Low Water (MLLW). Depths to the north are highly variable, with an average depth of approximately 15 to 20 feet. Water depths within the Project Area range between a minimum depth of 7.7 feet along the southern leg of Horseshoe Shoal and a maximum depth of 62.5 feet near the southwest limit of the Project Area. The geographical features of Nantucket Sound, including the presence of Nantucket and Martha's Vineyard Islands, greatly reduce the ability of an ocean swell to propagate into the Sound without experiencing significant losses of wave height and wave period characteristics.

3.3 Current

Information presented in the WHG report was developed based on a current survey conducted to support analytical modeling and the collection of existing information about currents in Nantucket Sound. For the survey, current data was collected and recorded for use in the modeling. Water mass movement in Nantucket Sound is primarily dominated by strong, reversing, semidiurnal tidal currents. Tidal flood currents flow primarily to the east and are stronger than the westerly-directed ebb currents. The dominant flood currents range between approximately 1.8 ft/sec and 2.0 ft/sec, and are strongest during the spring tide. In contrast to tidal currents, wind-driven currents are only moderate because of the sheltering effect of Nantucket and Martha's Vineyard Islands.

3.4 Sediments

A total of 16 vibracores was advanced/collected from the WTG array area at depths ranging from approximately 14 to 22 feet below the present seabed (see Figure 2). The median sediment grain size, d_{50}, within the array ranged between approximately 0.011 inches (0.279 mm) and 0.020 inches (0.508 mm). In general, the bottom sediments on and surrounding Horseshoe Shoal consist of poorly graded fine to coarse-grained sands, with localized fractions of clay, silt, gravel and/or cobbles.

4.0 METHODOLOGY

4.1 General

Scour processes are driven by wave action (wind-driven and ocean swell) and currents (tidal and wind-driven). Scour will occur as a result of the amplitude of the orbital motion of water particles at the seabed resulting from wave action and the particle velocity along the seabed resulting from wave action and currents. Analysis of scour processes is a function of the availability of existing data representing the magnitude and direction of currents, wave direction, wave period, wave height, pile diameter, the depth of water, and the soil characteristics of the seabed.

This analysis primarily incorporates information presented in the WHG report and methodologies presented by Sumer & Fredsoe in their 2002 publication titled *The Mechanics of Scour in the Marine Environment*. The analysis was performed for the preferred Wind Park location, Horseshoe Shoal.

The methodology presented by Sumer and Fredsoe (2002) is specific to scour in the marine environment. Sumer and Fredsoe compiled and analyzed detailed hydrodynamic descriptions along with laboratory test results to develop a methodology based on empirical expressions and numerical equations that can be used directly to predict scour conditions.

4.2 Mechanics of Scour

According to Sumer and Fredsoe (2002), scour around a pile in the marine environment can be characterized as one of two kinds of flow regimes: slender- or large-pile. The characterization is based on the diffraction parameter, defined as the ratio of the pile diameter to the wavelength.

The slender-pile regime is defined as having a pile with a diffraction parameter so small (generally less than 0.1) that the flow around the pile is separated, leading to the development of horseshoe and wake vortices (see Figure 3). Horseshoe vortices develop around the entire outside diameter of the pile and are uniform in magnitude. Wake vortices extend outward in the direction of flow until the flow characteristics are no longer affected by the presence of a pile. The acceleration of flow created by the vortices results in the development of a scour hole in the vicinity of the pile. For slender piles, the methodology presented by Sumer and Fredsoe (2002) is based on equations used to predict scour depths around the pile.

The large-pile regime is defined as having a diffraction parameter so large that the flow is not separated. Under these conditions, the wave-induced steady streaming near the seabed will result in the suspension and transport of sediment, resulting in the development of a scour hole around the pile. For structures acting in the large-pile regime, the methodology developed by Sumer and Fredsoe (2002) includes a graphical representation for predicting scour depths having diffraction parameters within a specific range.

The vortices cause the development of an area of scour around a pile including a circular area around the pile having a diameter slightly greater than the diameter of the pile, and a scour shadow extending outward in the direction of flow to a point where the wake vortex no longer exists. The scour hole is a result of the interaction of the horseshoe vortices with the sediment at the base of the pile. The scour shadow is a result of the wake vortices and is also a function of the angle of repose of the sediment present at the base of the pile. Suspended sediments are transported in the water column and deposited along the seabed at a point beyond the effect of the vortices and where flow returns to an equilibrium state.

4.3 Limits of Scour

The aerial extents of the scour hole are based on the magnitude of the vortices developing around the pile, predicted scour hole depths, and sediment characteristics. The extents of the scour hole resulting from horseshoe vortices is predicted based on the relationship developed by Sumer & Fredsoe (2002) as the distance of 1.1 times the value of the pile diameter from the center of the pile combined with a distance from the predicted scour depth and the known angle of repose for the given soil conditions. The outward distance of the scour hole resulting from the horseshoe vortex is also predicted based on the above relationship. For the scour resulting from the wake vortex, the outward distance was predicted by adding the distance resulting from the horseshoe vortex to a distance based on the predicted scour depth and an angle approximately one half that of the angle of repose for the given soil. This approach results in a conservative prediction of the maximum aerial extent of scour conditions surrounding the pile.

4.4 Scenarios for Scour Analysis

Three scenarios, summarized in Table 1 and described below, of wave action and current conditions in the subject area were considered to estimate the overall magnitude of scour that can be anticipated from the construction of the WTGs. For this analysis the subject structures include the one in the shallowest water depth area, the one with the greatest depth, and one from each corner of the array, as identified on Figure 1.

1. The first scenario represents conditions during the dominant flood current during spring tide conditions combined with a coinciding wind and wave propagation direction. The dominant flood current is to the east with a velocity of 2.0 ft/sec. In combination with the dominant flood current, the wind driven current from prevailing westerly winds would be to the east with a velocity of 0.4 ft/sec. Wind-generated waves resulting from the average of the highest 10% of wind velocities in the direction of the currents would have a wave period of 3.1 sec and a significant wave height of 2.5 ft. The approximate direction and magnitude of forces described above were identified in the study prepared by WHG.

2. The second scenario represents conditions based on the propagation of what the WHG report considers an average ocean swell approaching from the east with a wave period of 8.0 sec and a wave height of 4.5 ft, combined with coinciding tidal current and wind directions. The resulting ebb current to the west would have a velocity of 1.8 ft/sec with a wind-driven current of 0.36 ft/sec resulting from the easterly winds over Nantucket Sound.

3. The third scenario represents predicted conditions associated with the 100-year storm event without considering the sheltering effect provided by Nantucket and Martha's Vineyard Islands. Open ocean conditions, as experienced along the south shore of Nantucket Island, can include an ocean swell having a wave period of 12.5 sec and a significant wave height of 19.0 ft. These wave conditions were used to compute the wave crest associated with the 100-year storm surge published in the November 6, 1996, Flood Insurance Study for the Town of Nantucket. In combination with the open ocean swell, an ebb current to the west with a velocity of 1.8 ft/sec will act with a wind-driven current having a velocity of 0.36 ft/sec resulting from easterly winds. It should be noted that it is likely that a wave of this magnitude would break as it propagates into Nantucket Sound due to the relative depths along the south and east edges of the Sound and the existing hydrographic conditions in Nantucket Sound do not support the development of a wind-generated wave of this magnitude.

Table 1:Summary of Conditions

Scenario	Tidal Current (ft/sec)	Wind Current (ft/sec)	Wave Period (sec)	Wave Height (ft)
1	2.0	0.40	3.1	2.5
2	1.8	0.36	8.0	4.5
3	1.8	0.36	12.5	19.0

5.0 PREDICTED SCOUR DEPTH

The foundations for each WTG in the Wind Park will have a pile diameter that is dependent on the water depth at each structure. The water depth at structure locations within the array varies between approximately 12 feet and 50 feet. WTGs located in water depths of up to 40 feet at MLLW will have 16.75 foot diameter foundations, and WTGs located in 40 to 50 feet of water at MLLW will have 18 foot diameter foundations. Each of the three scenarios in Table 1 was applied to the aforementioned subject structures. The values for seabed grain size (d_{50}), shown on Table 2, were taken from the vibracore sample location closest to each subject structure. The locations of the vibracore samples are shown on Figure 2.

The results, as related to each of the three scenarios, are as follows:

1. Under conditions when the wind-driven current and wind-driven waves coincide with the maximum dominant tidal current, the structures act as large piles. This occurs as a result of the relatively short wavelength when compared to the diameter of the piles. Specifically, the diffraction parameter, as defined in Section 4.2, is greater than 0.1. The methodology presented by Sumer and Fredsoe (2002) is not valid. Specifically, the wind-driven wave characteristics are not significant enough to accurately predict scour depths. Predicted scour depths for this scenario would be less than the depths predicted based on more significant wave characteristics identified in scenarios 2 and 3. The results presented in Table 2 for this scenario represent approximate predictions based on interpolation of graphical data presented by Sumer and Fredsoe (2002).
2. Under conditions with a propagating ocean swell combined with coinciding tidal and wind-driven currents, the structures act as slender piles, and scour depths range from 2.7 feet to 4.0 feet, and the scour hole extends a maximum of between 26 feet and 33 feet away from the edge of the pile in the downstream direction. These predicted scour conditions should be considered the most reasonable representation resulting from the existence of the proposed structures.
3. Under conditions associated with the propagation of an unaltered large ocean wave into Nantucket Sound combined with coinciding tidal and wind-driven currents, the structures act as slender piles, and scour depths range from 6.0 feet to 8.5 feet, and the scour hole extends a maximum of between 46 feet and 59 feet away from the edge of the pile in the downstream direction. The conditions for this scenario are conservative given the Nantucket Sound environment, and scour conditions of this magnitude are not likely to occur.

Table 2: Summary of Results

	Structure	Depth (ft)	d_{50} (ft)	Scour Depth (ft)	Maximum Scour Distance (ft from pile)
Scenario 1	C-10	20	0.0011	1.6	18.7
	H-8	56	0.0012	0.2	9.7
	D-1	22	0.0016	0.2	9.7
	L-1	25	0.0007	0.2	9.7
	A-12	30	0.0010	0.1	9.7
	K-16	32	0.0010	0.1	9.7
Scenario 2	C-10	20	0.0011	2.7	25.5
	H-8	56	0.0012	3.0	28.0
	D-1	22	0.0016	3.8	31.6
	L-1	25	0.0007	3.9	32.5
	A-12	30	0.0010	3.8	32.2
	K-16	32	0.0010	4.0	32.7
Scenario 3	C-10	20	0.0011	7.1	50.4
	H-8	56	0.0012	6.0	45.1
	D-1	22	0.0016	8.5	58.5
	L-1	25	0.0007	8.2	56.7
	A-12	30	0.0010	7.1	51.2
	K-16	32	0.0010	8.0	55.5

The structural design of the WTGs is based on no scour occurring around the WTG. The design calculations must use a fixed point for analysis, and the existing mudline was selected as this fixed point for design calculations. Therefore, any amount of scour around the WTG will be significant. Since scour around the WTGs must be eliminated, the mitigation measures described in Section 7.0 will be implemented.

6.0 ELECTRICAL SERVICE PLATFORM

The methodology was also applied to complete an analysis of the anticipated scour conditions around the piles that will support the Electrical Service Platform (ESP) to be located within the array. The ESP will be a 100-foot by 200-foot platform supported by 6 piles. Each pile will have a diameter of 3.5 feet. According to the methodology presented by Sumer and Fredsoe (2002), for adjacent piles to act as a group of piles by generating significant proximity or wake interference, they must be located within a distance approximately equal to five times the pile diameter. Based on this methodology and the known spacing and diameter for the piles, each pile will act as a single pile. Similar to the individual WTGs, for scenario 1, the supporting piles will act as large piles. For scenarios 2 and 3, they will act as slender piles.

Table 3: Scour Conditions for Electrical Service Platform

Scenario	Depth (ft)	d_{50} (ft)	Scour Depth (ft)	Maximum Scour Distance (ft from pile)
1	28	0.0012	< 0.1	2.1
2	28	0.0012	5.0	30.8
3	28	0.0012	6.9	41.2

7.0 MITIGATION

There are several methods for mitigating the effects of scour around piles. They include placement of large stones, concrete mats, and artificial seaweed.

Seabed Scour Control Systems (SSCS) has researched and developed a unique system, which incorporated into a cost-effective and internationally proven method, provides a permanent solution to the problem of scour without any necessity for future maintenance. Ocean and Coastal Consultants, Inc., the United States representative for SSCS, has provided a proposal for the mitigation of scour. Information in support of this proposed scour mitigation can be found in Appendix B.

The SSCS system includes a grouping of seabed scour control mats anchored below the seabed. The existence of fronds serves to reduce the water particle velocity at the seabed. Suspended sediments settle on the mats as a result of the decreased velocity. To reduce the risk of undermining of the mats and localized scour resulting from any gaps in coverage around the structure, the mats can be placed and anchored in orientations and shapes that allow for complete coverage of the area affected by scour (see Figure 4). In addition to being effective in both shallow and deep water, and providing damage protection, the SSCS viscous drag frond system has been proven to eliminate scour conditions immediately upon installation.

Although not necessary to eliminate any long-term, far-field effects, the incorporation of the SSCS system in the design of the array would completely mitigate the effects of local scour at each individual structure.

8.0 CONCLUSION

The analysis demonstrates that structure-induced scour will be localized around each WTG and that there is no potential for the Wind Park to adversely affect sediment transport on Horseshoe Shoal based on estimated scour depths and aerial extent of scour for individual WTGs. Results using the methodology presented by Sumer & Fredsoe (2002) support the conclusion that scour conditions around the structures will be limited to local scour. Localized effects to sediment transport patterns may occur immediately around the foundation base. However, it is expected that a localized sediment transport equilibrium condition will be reached shortly after construction of the Wind Park given the cyclic nature of both the tidal regime and scour. The structures in the Wind Park are no less than 2,100 feet apart, and the maximum estimated scour distance from a WTG is approximately 60 feet (2.9% of the minimum distance between WTGs). Considering the spacing between adjacent structures, the cyclic nature of marine scour, the predicted range of scour depths and aerial extent, and the determination in the WHG report that there is near zero sediment transport in the vicinity of Horseshoe Shoal, it is not realistic to conclude the presence of the array will have any long-term, far-field effects on the composition of Horseshoe Shoal. Similarly, based on the results of the analysis and spacing under the ESP, there will be no long-term, far-field effects on the composition of Horseshoe Shoal due to the construction or operation of the ESP. Furthermore, localized scour will be fully mitigated trough the use of proposed scour countermeasure devices previously presented. As a result, the proposed Wind Park will have no near or far field impacts on sediment transport within Nantucket Sound.

9.0 REFERENCES

Breusers, H.N.C., Nicollet, G. and Shen, H.W. 1977. Local Scour Around Cylindrical Piles. J. Hyd. Res., Vol. 15, No. 3, 211-252.

Das, Braja M. 2000. Principles of Geotechnical Engineering, Second Edition. PWS-KENT Publishing Company, Boston.

Environmental Science Services, Inc. November 21, 2001. U.S. Army Corps of Engineers Section 10/404 Individual Permit Application.

Federal Emergency Management Agency. November 6, 1996. Flood Insurance Study, Town of Nantucket, Massachusetts, Nantucket County.

Ocean Surveys, Inc. July 25, 2002. Report: Marine Geophysical Survey and Sediment Sampling Program. Prepared for ESS.

Sorensen, Robert M. 1997. Basic Coastal Engineering, Second Edition. Chapman & Hall, New York.

Sumer, B. Mutlu, and Fredsoe, Jorgen. 2002. The Mechanics of Scour in the Marine Environment. World Scientific, New Jersey.

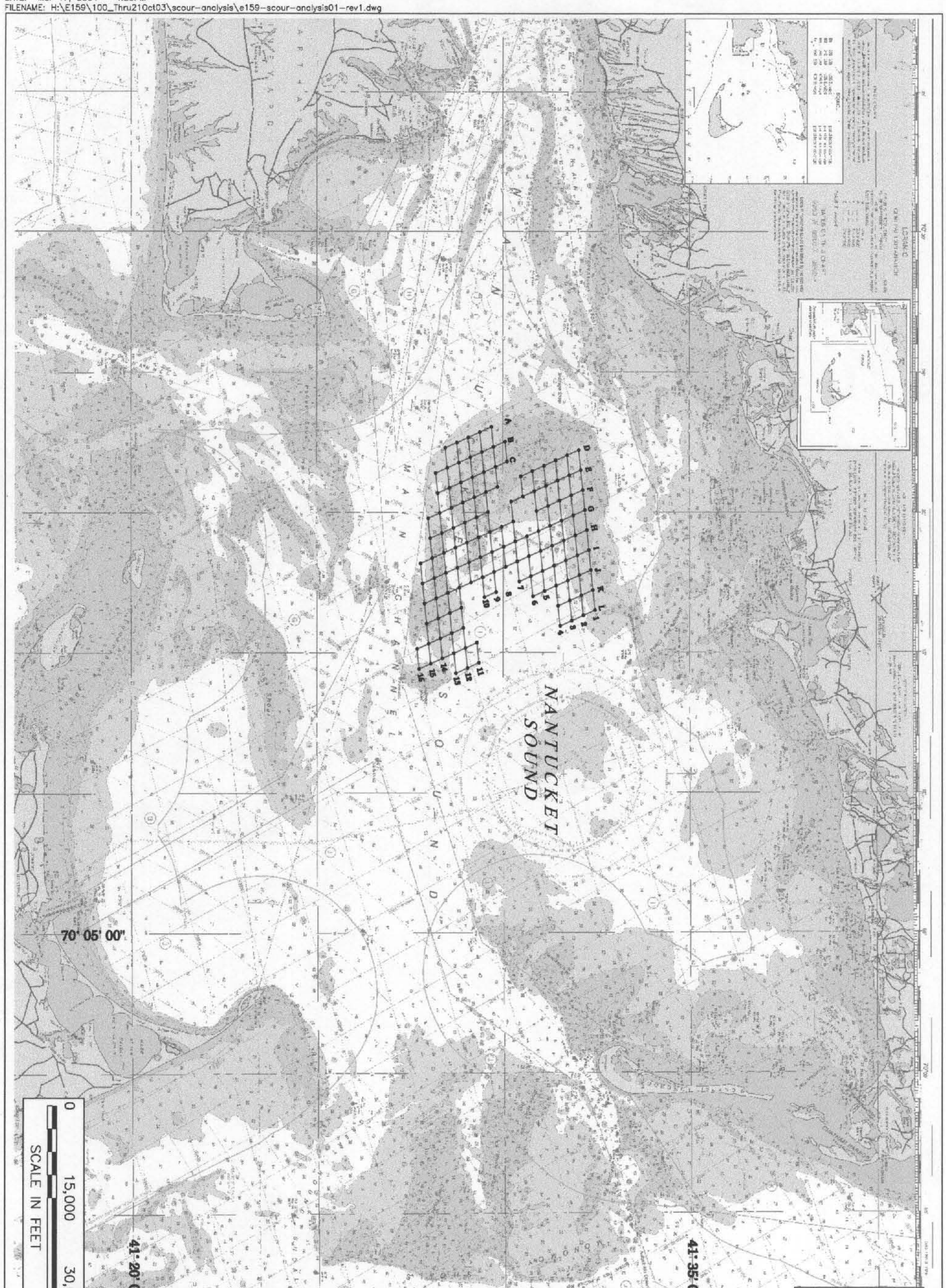
U.S. Army Corps of Engineers. 1984. Shore Protection Manual, Volume 2.

U.S. Army Corps of Engineers. May 2001. Evaluating Scour at Bridges (Hydrologic Engineering Circular No. 18).

Woods Hole Group. July 2002. Report: Analytical Modeling of Alternative Wind Park Sites, Existing Conditions.

Figures

DATE: Mar 17, 2004 - 4:23PM
FILENAME: H:\E159\100_Thru21Oct03\scour-analysis\e159-scour-analysis01-rev1.dwg



ESS Group, Inc.

Engineers
Scientists
Consultants

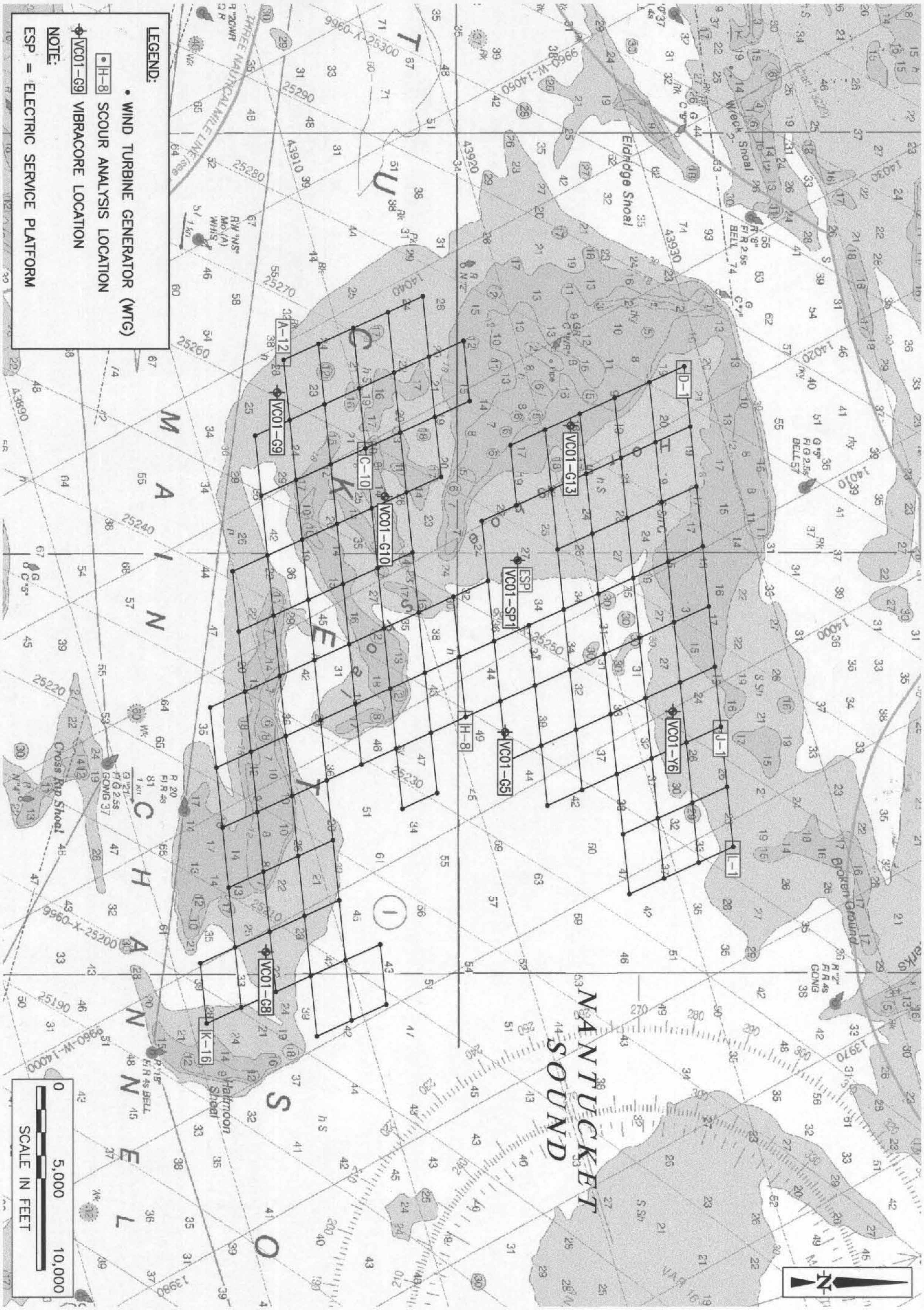
CAPE WIND PROJECT
Cape Wind Associates, LLC

Source: NOAA Chart #13237, Nantucket Sound & Approaches

Proposed Wind Turbine Array

Figure 1

DATE: Mar 17, 2004 - 4:23PM
FILENAME: H:\E159\100_Thru21Oct03\scour-analysis\e159-scour-analysis02-rev1.dwg



ESS Group, Inc.
Engineers
Scientists
Consultants

CAPE WIND PROJECT
Cape Wind Associates, LLC

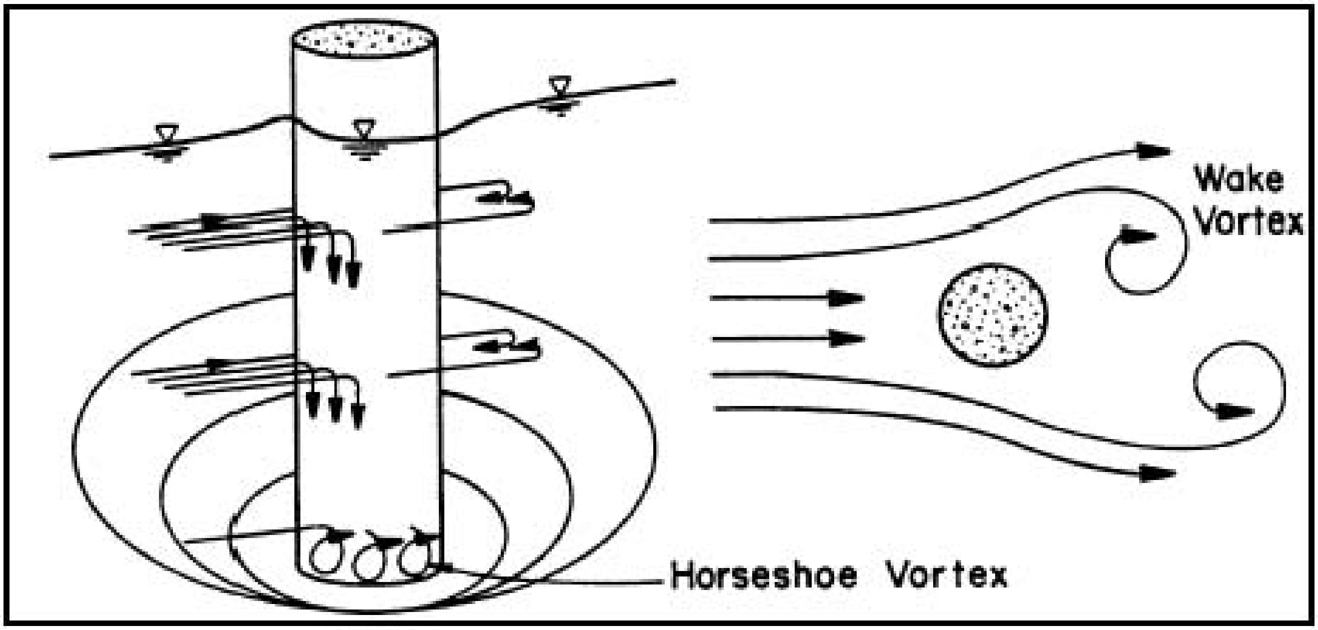
Modeled Wind Turbine and Vibracore Sample Locations

Source: NOAA Chart #13237, Nantucket Sound & Approaches

Figure 2

Appendix A

Engineering Calculations

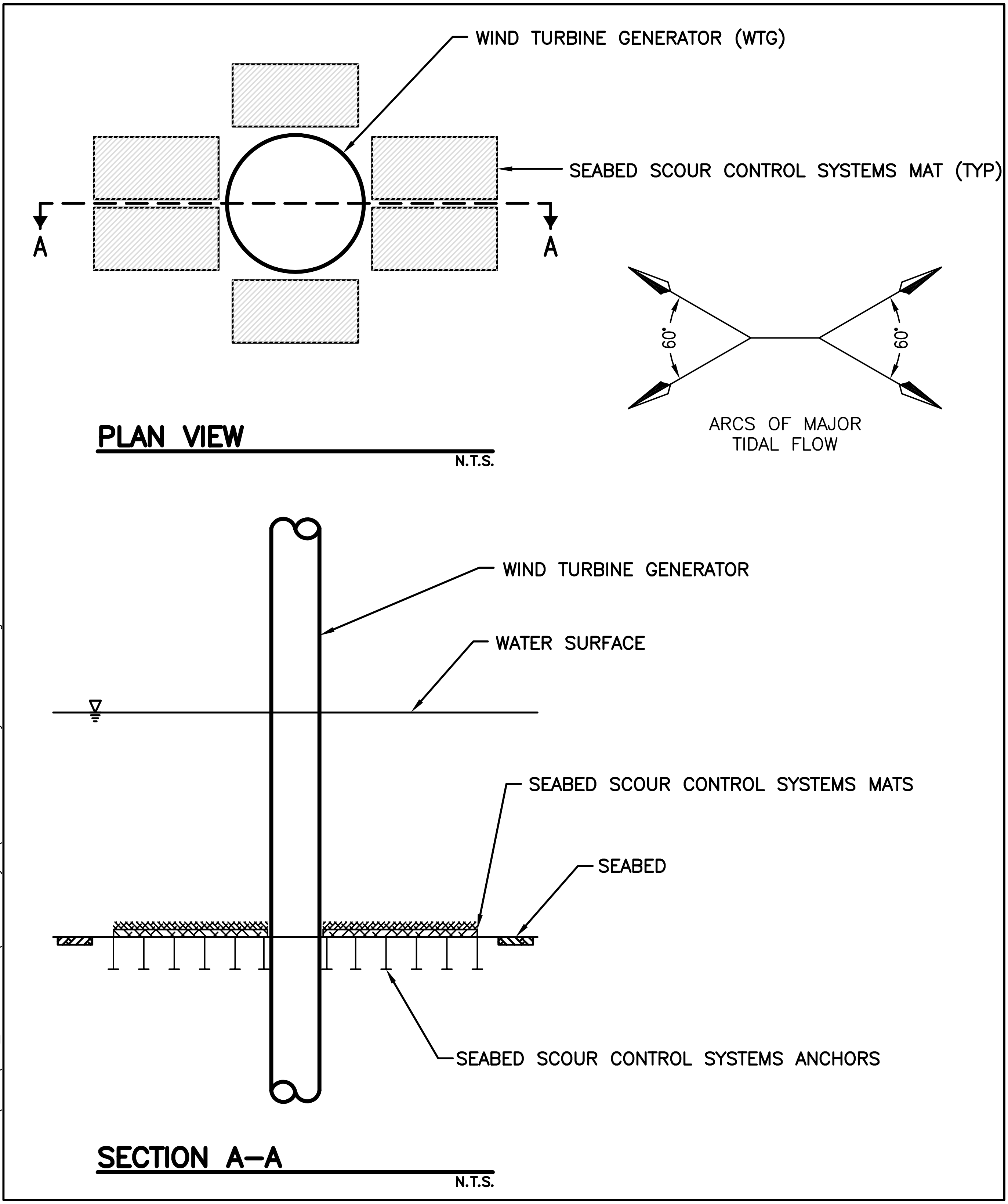


Reference:

U.S. Army Corps of Engineers. May 2001.
Evaluating Scour at Bridges (Hydrologic Engineering Circular No. 18), Figure 3.2

Representation of Scour at Cylindrical Pile

Figure 3



DATE: Apr 05, 2004 – 2:53PM
FILENAME: H:\E159\100_Thru21Oct03\scour-analysis\e159-scour-analysis04-rev2.dwg

Cape Wind Energy for Life.

ESS Group Inc. Engineers Scientists Consultants

Cape Wind Associates, LLC
Cape Wind Project

Proposed Scour Mitigation

Figure 4

ESS GROUP, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 . Fax: (508) 833-9687

Worksheet for Predicting Approximate Scour Depths and Aerial Extent for Cape Wind Turbine Structures

JOB	Cape Wind Scour Analysis
SHEET NO.	1 OF 8
CALCULATED BY	AHH DATE 01/15/03
CHECKED BY	PRW DATE 01/15/03
SCALE	Revised: 03/17/04 PRW

Color key:
- taken from map titled Preliminary Turbine Array
- taken from GeoTesting Express, Inc., data
- known variables
- taken from Woods Hole Group data
- taken from hydrographic data
- calculated values
- taken from Table C-2 (Shore Protection Manual)
- taken from Figure 6-21 (Sumer & Fredsoe, 2002)
- large-pile regime applies if slender-pile regime equation not appropriate
- slender-pile regime equation not appropriate
- live-bed

Notes:
- [a] *CAN NOT EXCEDE 0.9 * d*
- [b] *IF > 0.5 THEN IT IS A DEEP-WATER WAVE*
- [c] *IF < 15 THEN SINUSOIDAL APPLICABLE, IF > 15 THEN CNOIDAL THEORY APPLIES*
- [d] *IF > 0.1 THEN LARGE-PILE REGIME APPLIES*
- [e] *IF < KC THEN EQUATION APPLIES*
- [f] *IF > 0.05 THEN LIVE BED*

Scour depth for specific structures:

Scenario	letter	#	Vibracore No. (nearest)	grain size d_{50} (ft)	specific gravity of sediment grain	pile diameter D (ft)	wave period T_p (sec)	wave height H_s (ft)[a]	tidal current velocity U_t (ft/s)	wind current velocity U_w (ft/s)	water depth d (ft)	gravity g (ft/s²)	deep-water wavelength L_o (ft)	relative depth d/L_o[b]	tanh(kd) (from Shore Protection Manual)	sinh(kd) (from Shore Protection Manual)	cosh(k(z+d))	amplitude of orbital motion of particles at seabed a (ft)	maximum velocity of water particles at seabed U_m (ft/s)	wavelength L (ft)	Ursell Parameter[c]	Keulegan-Carpenter	diffraction parameter D/L[d]
Scenario 1	C	10	VC01-G10	0.0011	2.65	16.75	3.10	2.50	2.00	0.40	20.00	32.20	49.3	0.4059	0.9283	2.4970	1.0000	0.5006	1.0141	45.7	0.6538	0.1877	0.37
Scenario 1	H	8	VC01-G5	0.0012	2.65	18.00	3.10	2.50	2.00	0.40	56.00	32.20	49.3	1.1365	1.0000	267.7000	1.0000	0.0047	0.0095	49.3	0.0346	0.0016	0.37
Scenario 1	D	1	VC01-G13	0.0016	2.65	16.75	3.10	2.50	2.00	0.40	22.00	32.20	49.3	0.4465	0.9885	6.5350	1.0000	0.1913	0.3875	48.7	0.5570	0.0717	0.34
Scenario 1	L	1	VC01-Y6	0.0007	2.65	16.75	3.10	2.50	2.00	0.40	25.00	32.20	49.3	0.5074	0.9980	15.7300	1.0000	0.0795	0.1610	49.2	0.3869	0.0298	0.34
Scenario 1	A	12	VC01-G9	0.0010	2.65	18.00	3.10	2.50	2.00	0.40	30.00	32.20	49.3	0.6088	1.0000	172.5000	1.0000	0.0072	0.0147	49.3	0.2248	0.0025	0.37
Scenario 1	K	16	VC01-G8	0.0010	2.65	16.75	3.10	2.50	2.00	0.40	32.00	32.20	49.3	0.6494	0.9991	23.0800	1.0000	0.0542	0.1097	49.2	0.1849	0.0203	0.34
Scenario 1	Service Platform		VC01-SP1	0.0012	2.65	3.50	3.10	2.50	2.00	0.40	28.00	32.20	49.3	0.5682	0.9991	23.0800	1.0000	0.0542	0.1097	49.2	0.2760	0.0972	0.07
Scenario 2	C	10	VC01-G10	0.0011	2.65	16.75	8.00	4.50	1.80	0.36	20.00	32.20	328.2	0.0609	0.4593	0.5170	1.0000	4.3520	3.4163	150.7	12.7781	1.6317	0.11
Scenario 2	H	8	VC01-G5	0.0012	2.65	18.00	8.00	4.50	1.80	0.36	56.00	32.20	328.2	0.1707	0.8466	1.5910	1.0000	1.4142	1.1102	277.8	1.9777	0.4934	0.06
Scenario 2	D	1	VC01-G13	0.0016	2.65	16.75	8.00	4.50	2.00	0.40	22.00	32.20	328.2	0.0670	0.5872	0.7087	1.0000	3.1748	2.4922	192.7	15.6917	1.1903	0.09
Scenario 2	L	1	VC01-Y6	0.0007	2.65	16.75	8.00	4.50	2.00	0.40	25.00	32.20	328.2	0.0762	0.6558	0.8687	1.0000	2.5901	2.0332	215.2	13.3379	0.9711	0.08
Scenario 2	A	12	VC01-G9	0.0010	2.65	18.00	8.00	4.50	2.00	0.40	30.00	32.20	328.2	0.0914	0.7958	1.3140	1.0000	1.7123	1.3442	261.1	11.3660	0.5974	0.07
Scenario 2	K	16	VC01-G8	0.0010	2.65	16.75	8.00	4.50	2.00	0.40	32.00	32.20	328.2	0.0975	0.6835	0.9364	1.0000	2.4028	1.8862	224.3	6.9086	0.9009	0.07
Scenario 2	Service Platform		VC01-SP1	0.0012	2.65	3.50	8.00	4.50	2.00	0.40	28.00	32.20	328.2	0.0853	0.6835	0.9364	1.0000	2.4028	1.8862	224.3	10.3126	4.3113	0.02
Scenario 3	C	10	VC01-G10	0.0011	2.65	16.75	12.50	10.80	1.80	0.36	20.00	32.20	801.2	0.0250	0.2985	0.3128	1.0000	17.2634	8.6731	239.1	77.2067	6.4725	0.07
Scenario 3	H	8	VC01-G5	0.0012	2.65	18.00	12.50	19.00	1.80	0.36	56.00	32.20	801.2	0.0699	0.6067	0.7633	1.0000	12.4460	6.2528	486.1	25.5605	4.3423	0.04
Scenario 3	D	1	VC01-G13	0.0016	2.65	16.75	12.50	19.00	2.00	0.40	22.00	32.20	801.2	0.0275	0.4287	0.4611	1.0000	20.6029	10.3509	343.5	210.4869	7.7246	0.05
Scenario 3	L	1	VC01-Y6	0.0007	2.65	16.75	12.50	19.00	2.00	0.40	25.00	32.20	801.2	0.0312	0.4443	0.4958	1.0000	19.1610	9.6265	356.0	154.0702	7.1839	0.05
Scenario 3	A	12	VC01-G9	0.0010	2.65	18.00	12.50	19.00	2.00	0.40	30.00	32.20	801.2	0.0374	0.5612	0.6781	1.0000	14.0097	7.0385	449.6	142.2518	4.8878	0.04
Scenario 3	K	16	VC01-G8	0.0010	2.65	16.75	12.50	19.00	2.00	0.40	32.00	32.20	801.2	0.0399	0.4642	0.5241	1.0000	18.1263	9.1067	371.9	80.1948	6.7960	0.05
Scenario 3	Service Platform		VC01-SP1	0.0012	2.65	3.50	12.50	19.00	2.00	0.40	28.00	32.20	801.2	0.0349	0.4642	0.5241	1.0000	18.1263	9.1067	371.9	119.7078	32.5238	0.01

Scenario	letter	f_w (slender-pile regime (D/L < 0.1), combined wave and current)	U_c (ft/s)	U_{cw}	A	B[e]	delta	S (ft)	S/D (large-pile regime (D/L > 0.1), wave only)	S (ft)	Shields Parameter[f]	angle of internal friction for soil $Φ_s$	outward distance from edge of pile (ft) x_s (ft)	assumed angle for wake vortex shedding $Φ_w$	scour shadow from wake vortex x_w (ft)	greatest scour distance S_d (ft)
Scenario 1	C	0.004	2.40	0.703	0.330	0.220	-0.033	**N/A**	0.100	**1.68**	0.0352	27	13.34	15	6.25	19.59
Scenario 1	H	0.004	2.40	0.996	0.772	0.056	-0.054	**N/A**	0.001	**0.02**	0.0000	27	10.84	15	0.07	10.90
Scenario 1	D	0.004	2.40	0.861	0.538	0.105	-0.033	**N/A**	0.001	**0.02**	0.0036	27	10.08	15	0.06	10.15
Scenario 1	L	0.004	2.40	0.937	0.664	0.073	-0.044	**N/A**	0.001	**0.02**	0.0013	27	10.08	15	0.06	10.15
Scenario 1	A	0.004	2.40	0.994	0.768	0.056	-0.054	**N/A**	0.001	**0.02**	0.0000	27	10.84	15	0.07	10.90
Scenario 1	K	0.004	2.40	0.956	0.698	0.067	-0.047	**N/A**	0.001	**0.02**	0.0005	27	10.08	15	0.06	10.15
Scenario 1	Service Platform	0.004	2.40	0.956	0.698	0.067	0.030	**N/A**	0.001	**0.004**	0.0004	27	2.11	15	0.01	2.12
Scenario 2	C	0.004	2.16	0.387	0.094	0.972	0.660	**2.71**		**0.00**	0.3994	27	15.37	15	10.12	25.50
Scenario 2	H	0.004	2.16	0.661	0.285	0.269	0.224	**3.01**		**0.00**	0.0371	27	16.71	15	11.24	27.95
Scenario 2	D	0.004	2.40	0.491	0.148	0.598	0.592	**3.79**		**0.00**	0.1498	27	17.49	15	14.14	31.62
Scenario 2	L	0.004	2.40	0.541	0.182	0.471	0.500	**3.94**		**0.00**	0.2120	27	17.77	15	14.69	32.46
Scenario 2	A	0.004	2.40	0.641	0.266	0.295	0.302	**3.76**		**0.00**	0.0712	27	18.17	15	14.02	32.19
Scenario 2	K	0.004	2.40	0.560	0.196	0.432	0.469	**3.97**		**0.00**	0.1401	27	17.85	15	14.83	32.68
Scenario 2	Service Platform	0.004	2.40	0.560	0.196	0.432	3.880	**5.03**		**0.00**	0.1127	27	11.98	15	18.78	30.76
Scenario 3	C	0.004	2.16	0.199	0.041	2.351	4.122	**7.08**		**0.00**	2.5743	27	23.95	15	26.44	50.39
Scenario 3	H	0.004	2.16	0.257	0.052	1.795	2.547	**6.01**		**0.00**	1.1784	27	22.60	15	22.45	45.05
Scenario 3	D	0.004	2.40	0.188	0.040	2.477	5.247	**8.52**		**0.00**	2.5837	27	26.76	15	31.78	58.54
Scenario 3	L	0.004	2.40	0.200	0.041	2.349	4.835	**8.20**		**0.00**	4.7526	27	26.14	15	30.59	56.73
Scenario 3	A	0.004	2.40	0.254	0.051	1.816	3.072	**7.09**		**0.00**	1.9527	27	24.71	15	26.46	51.17
Scenario 3	K	0.004	2.40	0.209	0.043	2.251	4.545	**7.98**		**0.00**	3.2655	27	25.72	15	29.80	55.52
Scenario 3	Service Platform	0.004	2.40	0.209	0.043	2.251	30.273	**6.86**		**0.00**	2.6278	27	15.56	15	25.60	41.16

ENVIRONMENTAL SCIENCE SERVICES, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 • Fax: (508) 833-9687

SAMPLE CALCULATION:

SITE: LETTER L
\# 1

NEAREST VIBRACORE: VC01-Y6

$d_{50} = 0.0007$ ft (known)

SPECIFIC GRAVITY = 2.65 (known)

STRUCTURE DIAMETER (D) = 16 ft (known)

WAVE CHARACTERISTICS: USE SCENARIO 2 FROM REPORT

$T_p = 8$ sec (known)

$H_s = 4.5$ ft (known)

CURRENT: TIDAL (U_t) = 1.8 ft/sec (known)

WIND (U_w) = 0.36 ft/sec (known)

WATER DEPTH (d) = 25 ft (known)

GRAVITY (g) = 32.2 ft/sec (known)

* SEE ATTACHED SPREADSHEET TO DETERMINE SPECIFIC DATA SOURCES

① CALCULATE DEEP-WATER WAVELENGTH (Sorensen, 2.17)

$$L_0 = \frac{g T_w^2}{2\pi} = \frac{32.2\,(8^2)}{2(3.14)} = 328.15 \text{ ft}$$

② CALCULATE RELATIVE DEPTH (SPM, Table C-2)

$$\frac{d}{L_0} = \frac{25}{328.15} = 0.0762$$

ENVIRONMENTAL SCIENCE SERVICES, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 • Fax: (508) 833-9687

③ USING d/L_o AND TABLE C-2 OF SPM VOL. 2:

$\tanh(kd) = 0.6375$

$\sinh(kd) = 0.8275$

(VALUES TAKEN FROM NEAREST TABULAR VALUE, NOT INTERPOLATED)

④ CALCULATE AMPLITUDE OF ORBITAL MOTION AT SEABED:

$$a = \frac{H_w}{2} \frac{\cosh(k(z+d))}{\sinh(kz)} \quad \text{(SBF, A.14)}$$

for $z = -d$, $\cosh(k(-d+d)) = 1$

$$a = \frac{H_w}{2\sinh(kz)} = \frac{4.5}{2(0.8275)} = 2.719 \text{ ft}$$

⑤ CALCULATE MAXIMUM VELOCITY OF PARTICLE AT SEABED FROM WAVE ACTION

$$U_m = \frac{\pi H}{T_w} \frac{\cosh(k(z+d))}{\sinh(kd)} \quad \text{(SBF, A.10)}$$

for $z = -d$ $\cosh(k(-d+d)) = 1$

$$U_m = \frac{\pi H}{T_w \sinh(kd)} = \frac{3.14(4.5)}{8(0.8275)} = 2.134 \text{ ft/sec}$$

⑥ CALCULATE WAVELENGTH

$$L = L_o \tan(kd) \quad \text{(Sorensen, 2.14)}$$

$$L = 328.15(0.6375) = 209.2 \text{ ft}$$

⑦ CALCULATE URSELL PARAMETER TO CONFIRM SINUSOIDAL THEORY APPLIES

$$U = \frac{HL^2}{d^3} = \frac{4.5(209.2)^2}{25^3} = 12.6 \quad \text{(Sorensen, p. 61)}$$

IF U>15, USE CNOIDAL THEORY TO CALCULATE L.
SEE Sorensen, p. 63 FOR EXAMPLE

ENVIRONMENTAL SCIENCE SERVICES, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 • Fax: (508) 833-9687

⑧ CALCULATE THE KEULEGAN-CARPENTER NUMBER
(GOVERNS FORMATION AND EXTENSION OF WAKE PATTERNS IN OSCILLATORY MOTION)

$$KC = \frac{2\pi a}{D} \quad (S\&F, 2.10)$$

$$KC = \frac{2(3.14)(2.719)}{16} = 1.07$$

⑨ CALCULATE DIFFRACTION PARAMETER

$$\frac{D}{L} = \frac{16}{209.2} = 0.076 \quad (S\&F, p.150)$$

<0.1 ∴ SLENDER-PILE REGIME

⑩ USE KC AND (D/L) TO DETERMINE APPROPRIATE EQUATION OR GRAPHICAL METHOD:

KC: $10^{-1} - 2$ = STEADY-STREAMING
$2 - 6$ = TRANSITION
$6 - 10^4$ = HORSESHOE AND VORTEX SHEDDING

ADDITIONALLY, FOR $(D/L) < 0.1$, FOR $KC < 6$, S&F 3.21 DOES NOT APPLY. ASSUME SLENDER-PILE REGIME TO CALCULATE EMPIRICAL VALUES A AND B.
FOR COMBINED WAVE AND CURRENT ACTION, IF $KC \geq B$, THEN S&F 3.30 APPLIES. IF 3.30 AND 3.31 DO NOT APPLY, ASSUME LARGE PILE REGIME AND APPROXIMATE PREDICTED SCOUR DEPTH FROM S&F FIG. 6.21.

⑪ CALCULATE COMBINED TIDAL AND WIND CURRENT VELOCITY

$$U_t + U_w = 2.16 \text{ ft/sec} = U_c$$

⑫ CALCULATE COMBINED WAVE AND CURRENT VELOCITY EFFECT

$$U_{cw} = \frac{U_c}{U_c + U_m} \quad (S\&F, 3.29)$$

$$U_{cw} = \frac{2.16}{2.16 + 2.134} = 0.503$$

ENVIRONMENTAL SCIENCE SERVICES, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 • Fax: (508) 833-9687

JOB: CAPE WIND SCOUR ANALYSIS
SHEET NO. 5 OF 8
CALCULATED BY: AHH DATE: 11/22/02
CHECKED BY: DAW DATE: 12/8/02
SCALE:

(13) CALCULATE QUANTITIES A AND B

$A = 0.03 + \frac{3}{4} U_{cw}^{2.6}$ (S&F 3.31)

$A = 0.03 + \frac{3}{4}(0.503)^{2.6} = 0.156$

$B = 6\exp(-4.7 U_{cw})$ (S&F 3.32)

$B = 6\exp(-4.7(0.503)) = 0.564$

KC > B

(14) PREDICT SCOUR DEPTH BASED ON S&F 3.30

$\frac{S}{D} = \frac{S_c}{D}\left[1 - \exp(-A(KC - B))\right]$

SC = SCOUR DEPTH FOR STEADY CURRENT ALONE

$\frac{S}{D} = \frac{S_c}{D}(0.075)$

FROM S&F 3.12: $\frac{S_c}{D} = 1.3 + \sigma_{S/D} = 1.3 + 0.7 = 2.0$

FOR MAX. SCOUR DEPTH FOR DESIGN:
$\frac{S_c}{D} = 1.3 + 2\sigma_{S/D} = 1.3 + 2(0.7) = 2.7$

$S = \frac{S_c}{D}(0.075)(D)$

$S = 2.7(0.075)(16) \approx 3.3$ ft

(15) CALCULATE SHIELDS PARAMETER TO DETERMINE BED SCOUR CONDITIONS:

$\theta = \frac{U_m^2\left(\frac{f_w}{2}\right)}{g(s-1)d_{50}}$ (S&F, 1.3)

$f_w = 0.004$ FOR SLENDER PILE REGIME (S&F, p201)

$\theta = 0.235$ IF $\theta > 0.05$, THEN LIVE-BED SCOUR

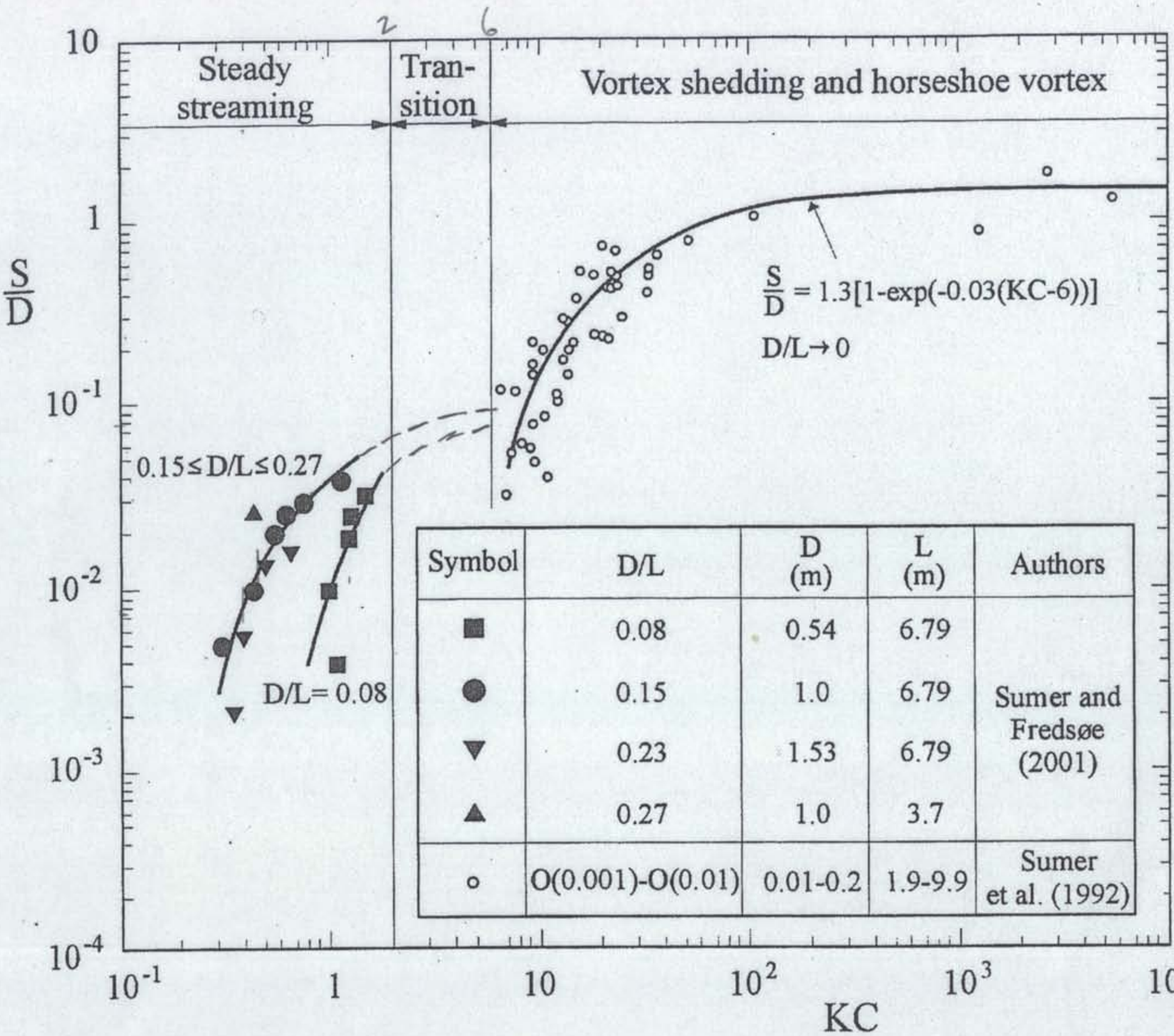


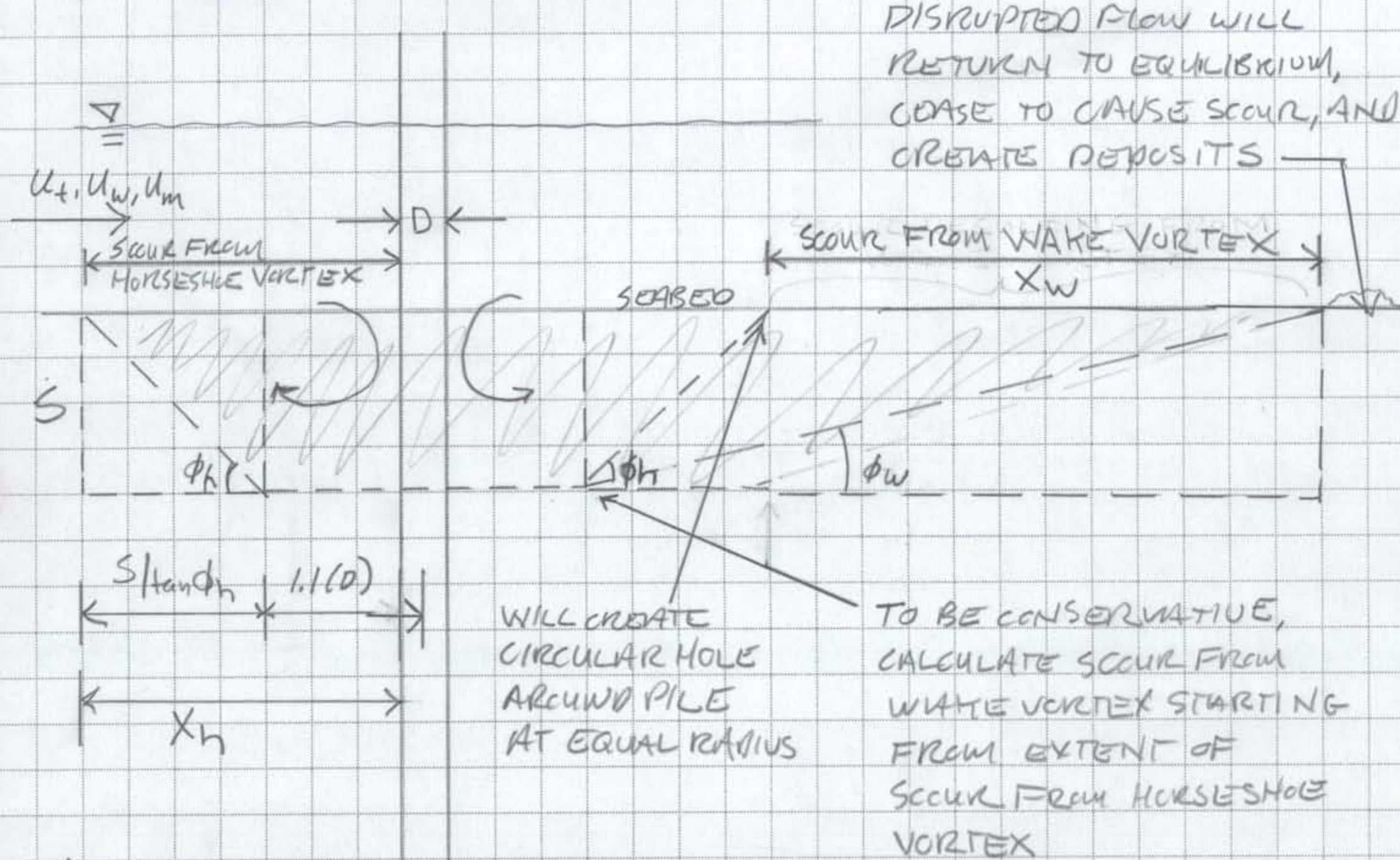
Figure 6.21: Maximum scour depth at the *periphery* of the pile base. Live bed. Sumer and Fredsøe (2001).

ENVIRONMENTAL SCIENCE SERVICES, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 • Fax: (508) 833-9687

JOB: CAPE WIND SCOUR ANALYSIS
SHEET NO. 7 OF 8
CALCULATED BY: AHH DATE: 11/18/02
CHECKED BY: DRW DATE: 12/8/02
SCALE:

PREDICTION OF SCOUR HOLE DIMENSIONS:

S = PREDICTED SCOUR DEPTH



$\phi_h = 27°$ (LOWEST ANGLE OF FRICTION FOR SAND)

$\phi_w = 15°$ (CONSERVATIVE APPROXIMATION)

$$X_h = 1.1(D) - 0.5(D) + S/\tan\phi_h$$

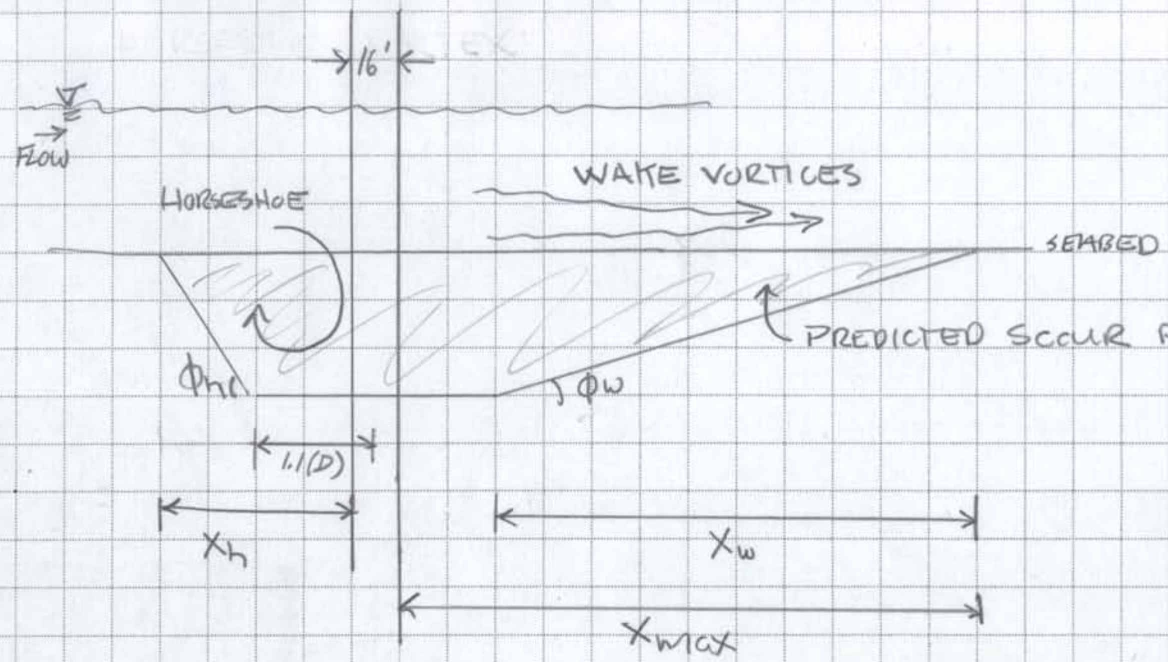
$$X_w = S/\tan\phi_w$$

GREATEST DISTANCE OF SCOUR FROM EDGE OF PILE IS PREDICTED AS: $X_h + X_w = 0.6(D) + S/\tan\phi_h + S/\tan\phi_w$

ENVIRONMENTAL SCIENCE SERVICES, INC.
90 Route 6A, Unit 4B
Sandwich, Massachusetts 02563
Tel: (508) 833-6226 • Fax: (508) 833-9687

JOB CAPE WIND SCOUR ANALYSIS
SHEET NO. 8 OF 8
CALCULATED BY AHH DATE 11/22/02
CHECKED BY DAW DATE 12/9/02
SCALE

(16) PREDICT GEOMETRY OF SCOUR PIT



$X_h = 1.1(D) - 0.5(D) + S/\tan\phi_h = 15.98$ ft

$X_w = S/\tan\phi_w = 12.14$ ft

$X_{max} = 28.12$ ft

* PREDICTION IS BASED ON CONSERVATIVE APPROXIMATE VALUES OF Φ_h AND Φ_w. A DETAILED SENSITIVITY ANALYSIS WOULD LIKELY VERIFY THAT THIS PREDICTED SCOUR DEPTH IS WITHIN A REASONABLE RANGE

Appendix B

Seabed Scour Control Systems Information

1. Introduction

We at SSCS are one of the leading contractors in the field of Seabed Scour Protection. We design and manufacture Scour Protection Systems, carry out Scour Assessment Studies for specific sites and installations and provide Engineering Consultancy and Design Services. Our Systems and Services are used on a world-wide basis.

The hydrodynamic possibilities of using buoyant fronds to arrest scour were appreciated some years ago.

Various trials were carried out in the USA by Dupont, in the Netherlands by Cebo, and both Research Work and Trials by Imperial Chemical Industries (ICI)'s subsidiary company Linear Composites Limited in both Norway and the U.K.

The objective of the development work was to provide erosion protection utilizing high strength industrial fibres to provide a better control than that achieved through conventional methods which, at best, only provide temporary protection.

Initial Research Work by ICI's Linear Composites Ltd and ICI Norge A/S included :

(1). Structure Protective Systems - published trials report from VHL ~ River and Harbour Authority Laboratory, Norwegian Institute of Technology at Trondheim, Norway.

(2). Seabed and Pipeline Protective Systems - unpublished work at the Hydraulics Research Establishment at Wallingford, U.K.

This research was followed by a series of trials and several successful installations. Examples of early successful trials work involved several oil / gas pipelines and also effective trials around the bases of various structures including :

1965- Phillips Petroleum's Arpet 'A' platform on Leman Bank in the S.N.Sea;
1975- Elf Petroleum's Flarestack Base on the Frigg Field; and
- Mobil's Loading Terminal at the Beryl Field.

At the beginning of the 1980's Seabed Scour Control Systems Limited (SSCS) was established and using information and trials data made available by ICI and the River & Harbour, Trondheim, and also by Royal Dutch Shell Chemicals began a period of extensive research and development trials in conjunction with Shell Oil, and later Amoco, in the S. N. Sea which culminated in multiple field trials successes; and in 1984 SSCS commenced full production of their Scour Control Systems. Within a year the SSCS frond systems had gained the full support of Britain's National Federation of Fishermen's Organisations. A much abbreviated report containing extracts from the original SINTEF Report – "Viscous Drag Fronds – Flume Tank Trials" (ICI Linear Composites ~ SSCS) issued by River & Harbour Laboratory, Norwegian Institute of Technology, Trondheim is attached (SCI_DEV.doc).

1. Introduction

We at SSCS are one of the leading contractors in the field of Seabed Scour Protection. We design and manufacture Scour Protection Systems, carry out Scour Assessment Studies for specific sites and installations and provide Engineering Consultancy and Design Services. Our Systems and Services are used on a world-wide basis.

The hydrodynamic possibilities of using buoyant fronds to arrest scour were appreciated some years ago.

Various trials were carried out in the USA by Dupont, in the Netherlands by Cebo, and both Research Work and Trials by Imperial Chemical Industries (ICI)'s subsidiary company Linear Composites Limited in both Norway and the U.K.

The objective of the development work was to provide erosion protection utilizing high strength industrial fibres to provide a better control than that achieved through conventional methods which, at best, only provide temporary protection.

Initial Research Work by ICI's Linear Composites Ltd and ICI Norge A/S included :

(1). Structure Protective Systems - published trials report from VHL ~ River and Harbour Authority Laboratory, Norwegian Institute of Technology at Trondheim, Norway.

(2). Seabed and Pipeline Protective Systems - unpublished work at the Hydraulics Research Establishment at Wallingford, U.K.

This research was followed by a series of trials and several successful installations. Examples of early successful trials work involved several oil / gas pipelines and also effective trials around the bases of various structures including :

1965- Phillips Petroleum's Arpet 'A' platform on Leman Bank in the S.N.Sea;
1975- Elf Petroleum's Flarestack Base on the Frigg Field; and
- Mobil's Loading Terminal at the Beryl Field.

At the beginning of the 1980's Seabed Scour Control Systems Limited (SSCS) was established and using information and trials data made available by ICI and the River & Harbour, Trondheim, and also by Royal Dutch Shell Chemicals began a period of extensive research and development trials in conjunction with Shell Oil, and later Amoco, in the S. N. Sea which culminated in multiple field trials successes; and in 1984 SSCS commenced full production of their Scour Control Systems. Within a year the SSCS frond systems had gained the full support of Britain's National Federation of Fishermen's Organisations. A much abbreviated report containing extracts from the original SINTEF Report – "Viscous Drag Fronds – Flume Tank Trials" (ICI Linear Composites ~ SSCS) issued by River & Harbour Laboratory, Norwegian Institute of Technology, Trondheim is attached (SCI_DEV.doc).

A Report issued by British Maritime Technology in 1987 for the UK Department of Energy - Trials Report on Wave Force Coefficients for Horizontal and Vertical Cylinders with Kelp Fouling provided confirmatory Coefficient of Drag Cd data for Kelp Seaweed and for Fronds (Artificial Seaweed).

The SSCS Frond Systems remain the only field proven scour control product that reduces current velocity by providing a strong and unbroken viscous drag barrier. SSCS also solved the very real diver safety and the substantial anchoring or hold down requirements that had been demonstrated as vital in both the Norwegian and in other trials.

2. SSCS' Scour Control Systems

The use of **SSCS** Scour Control Systems will provide a permanent maintenance free solution for the stabilisation of the seabed whilst avoiding ANY interference with marine life or other environmental issues or creating secondary scour or possible damage to a subsea structure, cable or pipeline, which can and does occur with other alternatives. Unlike Rock Dumping, or the use of gabions or of concrete blocks, edge scour and settlement is NOT an issue with SSCS products and after 25 to 35 days the sediment bank built up over the fronded area ensures that there is no problem with fishermen for fishing or trawling in the area, and to a degree the small quantity of short exposed fronds appear to provide a natural habitat for marine life.

Today **SSCS** are the only manufacturer of a field proven scour control product that uses the concept of a continuous viscous drag barrier of overlapping continuous lines of high tensile strength polypropylene fronds to reduce current velocity thereby using those mechanisms which create scour to correct and prevent further scour occurring.

During the past 18 years **SSCS** has been a regular supplier to all major oil companies for scour correction and protection of pipelines, structures, cables and sub-sea installations initially in the Southern North Sea including Shell, BP Amoco, Arco British, Conoco, Exxon (Esso) and Phillips Petroleum amongst others. Today some 9,000 SSCS mattresses and mats have been installed throughout the world, not only in the North Sea and in the UK but from the Gulf of Mexico, through Labrador, Nigeria, Ghana, India, China, Malaysia and from Thailand to Australia.

We consider Scour Protection to be an important aspect of many offshore, coastal and riverine developments and believe that our systems and consultancy services could be of interest to you.

3. Environment. SSCS's Frond Systems were judged in 1996 to be:

"Environmentally acceptable - the sandbank contours follow and blend into the river or seabed, and does not affect marine life or vegetable growth or fishing"

~ ***Dr Krystian W. Pilarczyk, Road and Hydraulic Engineering Division, Rijkswaterstaat, Delft & Dr Ryszard B. Zeidler, Institute of Hydro-Engineering, Polish Academy of Sciences.***

SSCS has received approvals for the use and deployment of its Scour Control products from:

~ UK Ministry of Agriculture and Fisheries;
~ UK Department of Transport (Marine Directorate);
~ US Corps of Engineers;
~ The British National Federation of Fishermen's Organisations;
~ UK National Rivers Authority (now The Environment Agency);
~ hydraulic Engineering Division, Rijkswaterstaat, Netherlands;
~ The Inst. of Hydro-Engineering, Polish Academy of Sciences; and from
~ Many Oil Companies (including Amoco, Exxon Mobil, Arco, BHP, Conoco, Lasmo, Maersk, NAM, Phillips and Shell).

The Scour Control Products designed and supplied by Seabed Scour Control Systems Limited have been approved as environmentally acceptable. In the recent past we were awarded a major contract for the protection of a major Power Supply Cable to be installed between England and the Isle of Man because the local fishing community would not accept any of the alternative proposals made by Pirelli (the cable supplier and Installer). We had not even been aware of this potential task until the fishermen told Pirelli that we must be consulted.

We would also refer you to our website: www.scourcontrol.co.uk

4. Additional Document attached. We have attached the following documents which we trust will give you more information that you may require:

a). British Fishing Industry Support for SSCS Systems (examples):
- National Federation of Fishermen's Organisations (British) - letter dated 31 May, 1988;
- Fleetwood Fishermen's Producers Organisation - letter dated: 04 July, 2001; and
- Fleetwood Fishermen's Producers Organisation - letter dated: 05 July, 2001.

c). Authorised Excerpts from "Offshore Breakwaters and Shore Evolution Control", by KRYSTIAN W. PILARCZYK, *Road and Hydraulic Engineering Division, Rijkswaterstaat, Delft &* RYSZARD B. ZEIDLER, *Institute of Hydro-Engineering, Polish Academy of Sciences (IBW PAN):* ISBN 90 5410627 1; © 1996 A. A. Balkema, Rotterdam.

d). - Shell U.K. - Letter of Approval (13th December, 1985);

- "Natural Protection" SSCS Leaflet (2 pages); and
- SSCS Work Experience Summary (1984 to 2001).

5. Fisheries Enhancement.

Electrical Power generation from Renewable Natural Resources is we believe of paramount importance at this time due to the environmental damage being done by the combustion of fossil fuels. This has created tremendous support for Offshore Wind Farm Projects.

The present SSCS Scour Protection Systems are not only "environmentally friendly" but they have a positive, albeit minor, effect on fisheries enhancement. In the presence of heavy fishing effort (such as in the North Sea), where trawling of near-shore nursery areas results in high mortalities, our Frond Systems provide food, shelter from predators, spawning habitat and nursery ground for a whole range of commercially important species.

The fact that at an offshore wind farm site several wind generating units will be sited in a relatively close lattice format adds to the high potential for stock recruitment due to the synergism involved.

Fisheries enhancement is an area with which we have also become involved and we would be pleased to discuss our seabed mats which are specifically designed for fisheries enhancement, the Enviro-Mats, which we are developing and which could be used between Offshore Wind Farm Monopile structures to very significantly enhance natural aquaculture: however, we must advise you that our trials of these Mats have not been fully completed and that our Enviro-Mats do NOT provide scour protection.

Enviro-Mat trials to date have been successful in S.E Asia and in Ghana, but the Enviro-Mats are not yet sufficiently proven for bulk production.

We trust that this information will prove to be of interest and look forward to receiving any comments or enquiries you may have
Please let us know if you need any further information.

David Partridge,
Technical Director & General Manager,
Seabed Scour Control Systems Limited
Harfreys Road, Harfreys Industrial Estate,
Great Yarmouth, Norfolk NR31 0LS. U.K.
Tel: + 44 (0)1493 443380 Fax: + 44 (0)1493 443390
E-Mail: info@sscsystems.com ** Web Site: www.scourcontrol.co.uk

"Natural" PROTECTION against Seabed Scour and Erosion ~ Combining the Forces of Nature for a permanent solution

- When conditions that create scour exist underwater the problems associated with such scour can impact on subsea facilities immediately they are installed. That impact can become severe if it is not remedied. Scour can be physically damaging and can impose often unacceptable operating conditions as well as being environmentally detrimental.
- Following intensive Research and Development, Seabed Scour Control Systems Ltd (**SSCS**) created a method of harnessing nature to produce an economic, effective and permanent end to scour and **SSCS** has been providing solutions to the problems associated with scour in the offshore oil and gas industry since 1984.
- The **SSCS** Buoyant Frond Protection Systems have been used to protect all types of subsea installations by all of the major operating companies within the oil and gas sector. Installed both to provide immediate protection for new facilities and for post installation scour rectification works they provide long term maintenance-free protection.
- High Tensile Strength Buoyant Polypropylene Fronds set in parallel lines create Viscous Drag and so reduce the velocity of the current and STOP Scour. This Velocity Reduction leads to particles in suspension being deposited into the fronded area to form a permanent natural and dense sandbank which is also a natural habitat for marine life.

1. Initial sediment build-up covering mattress and the foot of the fronds.

2. Further build-up "mounding" in centre and sloping to mattress edge.

3. Reinforced sediment bank near full development with a few short lengths of fronds still exposed.

4. Diver inspecting sediment bank in fully developed stage with short random fronds showing typical "ripple" pattern appearing on surface

5. One year after installation on a scoured pipeline. Marine life colonies on the final sediment bank which is sustained by natural ebb and flow of currents.

- The **SSCS** Systems and their applications have been approved by:-

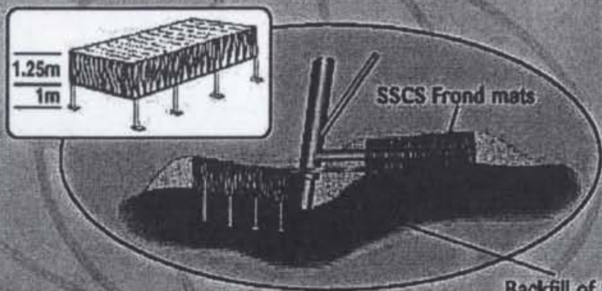
UK Ministry of Agriculture and Fisheries;
UK Department of Transport (Marine Directorate);
US Corps of Engineers;
UK National Rivers Authority (now Environment Agency);
British National Federation of Fisherman's Organisations;
Institute of Hydro-Engineering, Polish Academy of Sciences;
& Hydraulic Engineering Division, Rijkswaterstaat, Netherlands.

SSCS Products are approved as being an environmentally acceptable solution to scour.

- While the application of the **SSCS** Frond Systems has been acknowledged within the offshore industry they are now also being recognised for their efficacy and already proven use with Submarine Cables (Power and Telecommunications) and also with Offshore Wind Farms.

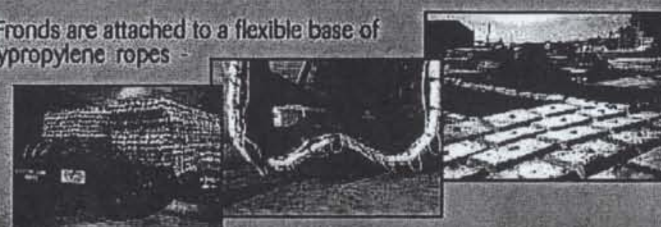
TIME AND TIDE STOPS FOR NOTHING - BUT SSCS SCOUR CONTROL SYSTEMS ARE FOREVER

- **SSCS Buoyant Frond Lines** ~ In all **SSCS** systems the Buoyant Fronds are set in continuous overlapping parallel lines, individual Fronds are 40mm wide UV Stabilised Polypropylene with a High Tensile Strength per strip: 681 to 1181N ~ Adequate Tensile Strength is essential for Viscous Drag systems. Standard Frond length: 1.25 metres. All Fronds are "Fibrillated" in film profile, sewn into base 6 tonne and 1.4 tonne MBS polyester webbing.



- **SSCS Frond Mats** ~ Mats are rolled out on the seabed and have a flexible anchoring system for diver installation - **SSCS** Anchors have a Lloyds and ABS certified retention of 1tonne per anchor. Standard Sizes ~ Type 12: 2.5m x 5.0m; Type 25: 5.0m x 5.0m and Type 30: 7.5m x 5.0m. All with high tensile strength buoyant fronds 1.25m in height.

- **SSCS Fronded Concrete Mattresses** ~ The **SSCS** Fronds are attached to a flexible base of concrete blocks inter-linked by a network of polypropylene ropes - for diver or work class ROV installation. Standard base block heights ~ 150mm,300mm, and 450mm. Block density 2.4t/m³ - density options are available up to 3.6t/m³. Sizes: Moulds are 10m x 3m in plan area. Tapered edge blocks are available for harsh or severe environments.



- **SSCS Anchors** ~ These are increasingly used for seabed retention purposes ranging from anchoring data recorders, GRP gratings, SSIV packages, fastening power and telecomms cables to the seabed and to provide temporary anchor points for subsea installation works, and are widely used by clients for projects where underwater anchoring and retention functions are required. The **SSCS** anchor driven in sand creates a LRQA and ABS certificated retaining force of 1tonne.

- **Consultancy ~ Scour Protection Assessment & Layout Design** - **SSCS** will execute for any site a full technical assessment and assess scour potential (given site specific environmental data) and, where necessary, provide an efficient, cost effective, permanent and maintenance free scour protection Design for installation.

- **Benefits** ~ "The key benefits in stabilizing and protecting submerged structures and pipelines with **SSCS** are: *Lower cost compared to currently used systems; "One-Off" only Cost - a Permanent Engineering Solution to Scour; Stops Scour immediately on installation; Build up of Permanent Mass Fibre Reinforced Sandbanks; Environmentally Acceptable; Effective in Deep and Shallow Water; Impact Damage Protection from Energy-Absorbing Sand; Load Bearing Solution - Natural agitation of Fronds creates Sand Compaction."*

Hydraulic Eng. Division, Rijkwaterstaat, Netherlands.

- **SSCS Services and Applications** ~
  - *Base Protection of Subsea Structures*
  - *Protection of Cable / Pipeline Crossings*
  - *Subsea Cables (Power and Telecomms) Scour Protection*
  - *Scour Prevention at Offshore Wind Farms*
  - *Site Assessment & Design Service*
  - *Pipeline Scour Correction and Prevention*
  - *Outfall Scour Protection.*

- **SSCS "Specials"** ~
Designed and built as required.

Mat "Special" for a Subsea Power Cable

Fronded Concrete Mattress "Special" for a Telecomms Cable Crossing a gas Pipeline

Seabed Scour Control Systems Ltd

Harfreys Road, Harfreys Ind. Estate, Great Yarmouth, Norfolk NR31 0LS, UK.

Tel: 44 +(0)1493 443380 --- Fax: 44 (0)1493 443390

Email: info@sscsystems.com --- Website: www.scourcontrol.co.uk

Registered in England No. 2459166

Seabed Scour Control Systems Limited

WORK EXPERIENCE SUMMARY (1984 to 2001)

Our Work Experience Record below summarises contracts awarded by Customers (many of whom have become multiple users). **SSCS** also carry out scour potential assessment studies for individual projects and design and supply for contracts; the installation in virtually all cases is by competent underwater engineering contractors.

1). CLIENTELE

OPERATORS / OWNERS

Amoco
Arco British
BP
British Aerospace
British Gas
British Marine Technology
British Telecomms
Burlington Resources
Cabot
Cairn Energy India
China National Offshore Oil Corp'n (CNOOC).
Conoco
Elf Petroleum
Elsamprojekt
Exxon
Hamilton Brothers
Kier
Lasmo
Maersk Oil & Gas
Marmara Misr, Egypt
Manx Cable Company
Marenco Engineering
Ministry of Defence (U. K.)
Mobil
Monsanto
NAM
Norsea Com A/S
Nuclear Electric
Odeco
Pennzoil
Phillips Petroleum
Premier Oil
Ranger Oil
Sable Energy
Shell
Transco
Woodside Energy

DESIGN & ENGINEERING CONSULTANTS

Amec Services
Andrew Palmer & Assocs.
Brown & Root Eng. Services
Clough Engineering
Genesis Consultants
J P Kenny, Staines
J P Kenny, Aberdeen
J P Kenny, Kuala Lumpur
J P Kenny, Perth
Kvearner Oil & Gas
Marenco
McDermott
Mentor Project Engineering
Ocean Resources
Offshore Data Limited
Suction Pile Technology
Worley Engineering

UNDERWATER ENGINEERING CONTRACTORS

2W
Allseas
British Underwater Engineering
Covus Corporation
DeGrout
DSND Subsea
Dutch Diving & Salvage
Coflexip Stena Offshore
ETPM
European Marine Contractors
Global Industries
Halliburton Subsea
McDermott
Northern Divers Engineering
Oceaneering
Oceantech
Odebrecht Oil & Gas
Odeco
Rockwater
Saipem
Seaway
Smit International
Stolt Offshore
Suction Pile Technology
Underwater Marine Contractors

2). COUNTRIES / LOCATIONS

Australia; Canada; China; Gabon; Gulf of Mexico; Hong Kong; Isle of Man; Isle of Skye; India; Irish Sea; Italy; Malaysia; Mediterranean; Menai Straits; Morecombe Bay; Myanmar (Burma); Nigeria; North Sea (UK, Denmark, Netherlands & Norway); Nova Scotia; River Severn; Scottish Highlands; Timor Sea; Trinidad; and Wales (both North & South).

Seabed Scour Control Systems Limited
Harfreys Road, Harfreys Industrial Estate, Great Yarmouth,
Norfolk, NR31 0LS, U. K.
Tel: +44 (0)1493 443380 * * * Fax: +44 (0)1493 443390
E-mail: info@sscsystems.com
Web Site: www.scourcontrol.co.uk or www.erosioncontrol.co.uk

WORK EXPERIENCE SUMMARY (continued)
(1984 to 2001)

3). SERVICES PROVIDED

CONSULTANCY

- Scour Assessment Studies by Site
- Engineering Consultancy and Design Services

PRODUCTS

- Design and Manufacture of Scour Control Mats, Fronded Concrete Mattresses & Safe Anchors
- System Pre-installation Engineering & Installation Supervision

4). SYSTEM APPLICATIONS

Scour Protection and Stabilisation of:

Pipelines
Control Umbilicals and Cables
Risers and Spool pieces
Subsea Structures and Substructures
Jack-up Drill Rig Spud Cans
Telecommunications and Power Cables
Outfalls
Bridge Piers
Offshore Wind Turbine Monopile Structures

Protection against Coastal Erosion

Aquaculture and Fisheries Enhancement

Seabed Scour Control Systems Limited
Harfreys Road, Harfreys Industrial Estate, Great Yarmouth,
Norfolk, NR31 0LS, U. K.
Tel: +44 (0)1493 443380 * * * Fax: +44 (0)1493 443390
E-mail: info@sscsystems.com
Web Site: www.scourcontrol.co.uk or www.erosioncontrol.co.uk

OFFSHORE BREAKWATERS

AND SHORE

EVOLUTION CONTROL

KRYSTIAN W. PILARCZYK
Road and Hydraulic Engineering Division, Rijkswaterstaat, Delft

RYSZARD B. ZEIDLER
Institute of Hydro-Engineering, Polish Academy of Sciences (IBW PAN)

Excerpts from CHAPTER 6

Structural Design

Published By:~

A.A.BALKEMA/ROTTERDAM/BROOKFIELD/1996
A.A.Balkema Publishers, Old Post Road, Brookfield, VT05036, USA.

ISBN 90 5410627 1

Printed in the Nederlands.

OFFSHORE BREAKWATERS AND SHORE EVOLUTION CONTROL

Excerpts from: CHAPTER 6

Structural Design

6.4 COMPOSITE SYSTEMS USING GEOTEXTILES

6.4.6 *Artificial Seaweed for erosion control and scour prevention*

1. Seaweed in historical perspective

Field observations show that in some coastal areas natural seaweed plays an important role in retaining sand along the coastlines due to the reduction of the shear stresses exerted by current and wave on the seabed. This fact has led to the concept of producing and applying artificial seaweed for erosion control. The first users of artificial fibres for erosion control and scour prevention date back to the sixties (England, Denmark, the Netherlands). Artificial seaweed was produced from polypropylene tape having a specific gravity of less than one, 3 to 10 mm wide, connected edge to edge to form a continuous serrated sheet. In some cases dozens of tapes were bundled together to form tufts of seaweed. Fronds varied from 1 to 2m in length. One of the main engineering problems was the anchorage of the seaweed on the bottom. Unproper anchorage was also main reason of the failures encountered with this system (Roger , 1987).

In the Netherlands, research on artificial seaweed has been conducted in Cupertino with the Shell Plastics Laboratory, Nicolon Geotextiles Company and the Rijkswaterstaat (Dutch Public Works Dept.), cf. Bakker et al. (1972). Research has concentrated on the use of seaweed as a low-cost alternative to rock mattresses to control tidal scour and/or to prevent scour around man-made offshore structures. Some less successful attempts have been made to apply artificial seaweed for control of beach erosion. In 1964, Shell developed a gas injected polypropylene material that has much greater buoyancy. Polypropylene normally has a specific gravity of 0.9. Gas injection reduces the specific gravity to 0.2, substantially increasing the buoyancy. The added buoyancy was found to reduce sinking when the material fouled with marine organisms or debris. In scope of that joint project, Shell provided the polypropylene, Nicolon manufactured the seaweed (Nicolon 1985) and the Rijkswaterstaat installed and monitored the tests.

In parallel with the prototype testing, some model investigations at the Delft Hydraulics were conducted with purpose of better understanding the physical mechanisms of erosion control by an artificial seaweed (Delft Hydraulics 1973).

The flume studies for Nicolon indicated that continuous screens of seaweed, perpendicular to the current were more effective than tufts of seaweed at intervals. It was hypothesised that the seaweed reduced sediment transport by absorbing part of turbulent shear stress with fronds. The reduced shear stress transferred to the bottom sediment resulted in reduced bed load. A similar reduction in turbulent vertical mixing within the boundary layer established by the seaweed reduced suspended sediment transport as well.

Tufts were found to have less effective on the current velocity because of the increased turbulence generated between them.

Several methods of installation were developed depending on the water depth, current velocity and wave climate. The material was placed in tidal channels, perpendicular to the direction of flow, in the hope of trapping enough sand to for a dam across the channel. Water depths most frequently ranged from 3 to 15 metres. Several were placed in inter tidal locations at low tide. (Summary of Trials and frond Anchorage Systems are omitted as this bears no relevance to SSCS). **Large prototype tests were evaluated by Bakker et al. (1972) and ten Hoopen (1976).**

The experience from the US and European projects around that artificial seaweed can be successfully applied for scour prevention around the legs of offshore platforms and around offshore pipelines when the anchorage is designed properly (i.a. Linear Composites 1986).

Some additional information on experience with artificial seaweed and alternative solutions with geotextile curtains hanging on beams of the legs of offshore platforms can be found in SUT Seminar (1980) and River and Harbour Laboratory (1976 @ *Trondheim*).

2. Artificial seagrass (Seabed Scour Control Systems Limited)

The past experience with artificial seaweed indicates that the most promising application for this product is the prevention of localized scour at offshore structures (platforms, pipelines etc.).

The product which actually successfully operates in the market for offshore applications has the form of an underwater artificial seagrass field/mats (developed in 80-ies), and is known as Seabed Scour Control Systems (SSCS 1995). Based on the artificial seaweed concept of 'arrested sedimentation', SSCS system (mat) suffers none of the drawbacks of similar previous systems. It has superb positional stability, it is not prone to phytoplankton colonisation, it requires no special tools or skills for installation and it actually serves to enhance its own effectiveness and that of other conventional sea defence forms. The functioning principles are straight-forward; buoyant fronds floating upright from the seabed act to reduce seabed and near-seabed current velocities, encouraging the deposition of transported (eroded) seabed material. In conjunction with this action, at relatively shallow water the fronds also interfere with wave-induced orbital forces, effectively causing waves to break early and thus reducing the impact on threatened shorelines, breakwaters, etc.

This technique employs chemically inert materials to create a flexible barrier to retard the flow of water. The SSCS scour control mats are retained on the seabed by anchors hydraulically driven to a depth of 1 m. The system has been designed and tested for stability in current velocities in excess 10 knots (> 0.5 m/s). The flexible fronds (mat) can also be incorporated into flexible concrete block mats to provide added effectiveness in stability and in wave dissipation. The main applications are in protecting fixed offshore platforms, mobile rigs and pipelines from the effects of scour.

The KEY BENEFITS in stabilizing and protecting submerged structures and pipelines with SSCS - mats are: ~

a) Lower installed cost compared with currently used systems;

b) 'One-off' only cost - providing a permanent engineering solution to scour that does mostly not require follow-up maintenance;

c) Stops scour immediately upon installation;

d) Progressive build up of permanent mass fibre reinforced sandbank;

e) Environmentally acceptable - the sandbank contours follow and blend into the river or seabed, and does not affect marine life or vegetable growth or fishing;

f) Effective in deep water or shallow water;

g) Impact damage protection by cushioning structures with energy-absorbing sand;

h) Load Bearing solution - natural agitation of fronds creates a high degree of sand compaction.

A typical mat of 5 x 5 metres comprises approximately 1.5 million thread filaments in the 25 square metres. Buoyant frond material is made of UV stabilised polypropylene, fully tested as `chemically resistant'. Specific gravity is about 0.92. Material is fully fibrillated and with profiled film. Buoyant fronds are attached to grid of polyester cross- and anchor- straps in successive continuous rows providing substantial and unbroken overlap of fronds to those in the neighbouring rows. Frond length (height when deployed) of the lines of buoyant frond material is 1250 mm. In riverine (and other special situations) lesser frond heights allied to a proportionate increase in frond density (spacing) in the frond rows may be used. Mats are available ex-stock in the following sizes:

Type 12, 5.0x2.5 m, having 8 anchors;
Type 25, 5.0x5.0, having 16 anchors;
Type 30, 5.0x7.5m, having 24 anchors.

A rolled-up mat is lowered from a vessel using a down line. The exact positioning of the mat under water is executed by two divers. A special anchor developed and patented by SSCS is driven into the seabed by a hydraulic hammer gun. (Further summary of SSCS Installation Procedures omitted).

In case of heavier hydraulic conditions (i.e. velocities higher than 1 m/s, specific angle of current attack), especially in case of protection of offshore pipelines in shallow water where the effect of shoaling waves should be taken into account, the protection often needs a more rigid structure. For this purpose a new mat called 'Frond Flexiform Mattress' has been developed, which combines the buoyant frond mat and flexible concrete mattress. It embodies all the best features of both products in one, and in particular offers both instant protection and the build-up of long-term fibre reinforced consolidated cover.

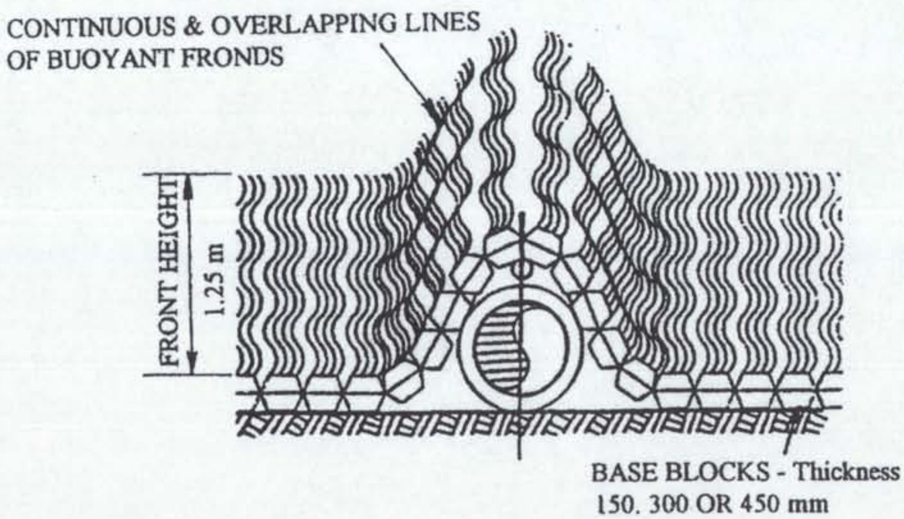


Figure 6.62. Frond Flexiform mattress.

The flexible concrete mattress base consists of high strength concrete segments linked together with a network of high-strength polypropylene ropes to form a continuous flexible concrete barrier. The frond lines are then attached to this base mattress (FIG 6.62).

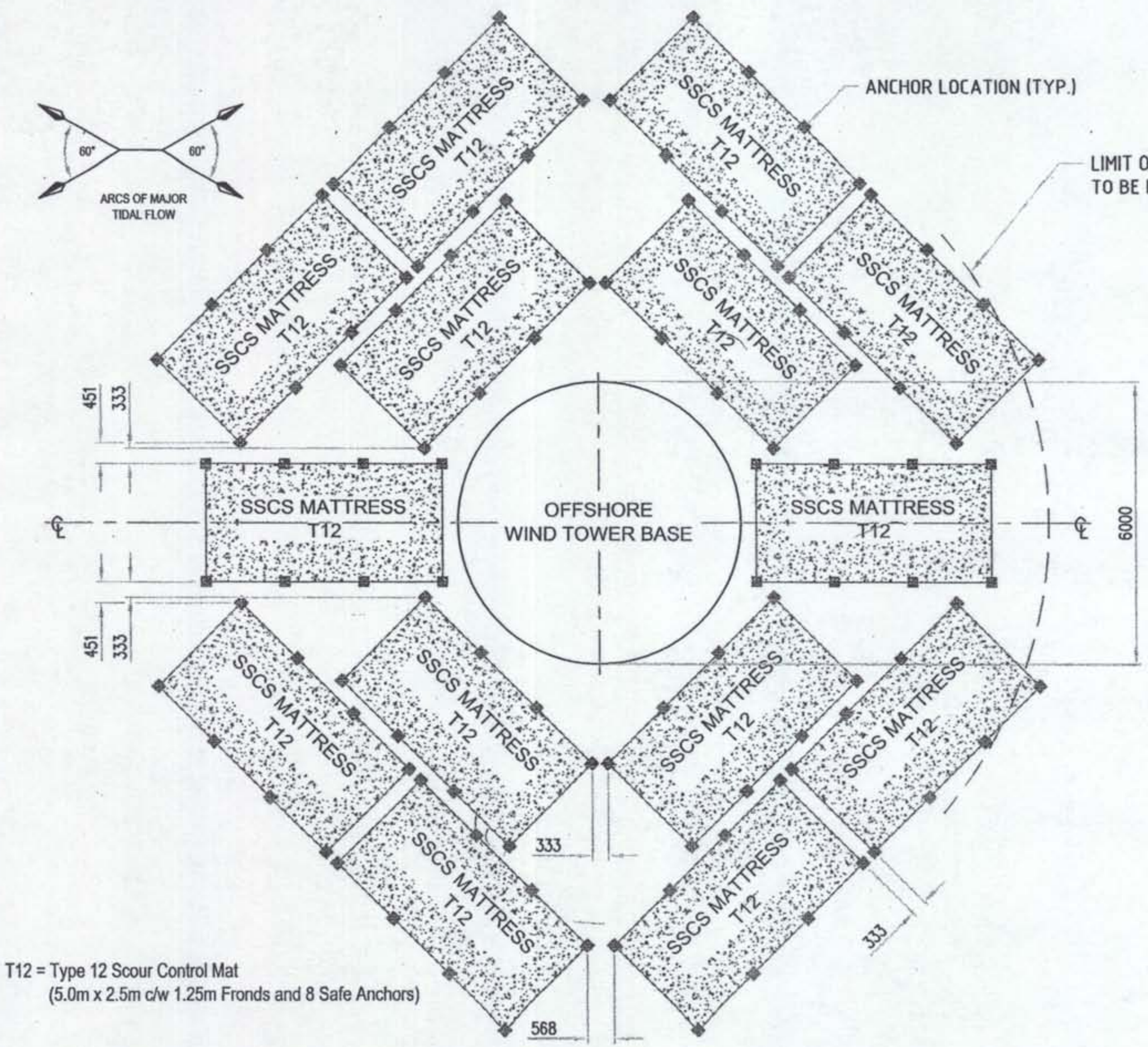
The individually profiled concrete segments provide a high degree of flexibility in two planes and allow for complete protection of subsea structures with the fronds preventing edge scour and internecine block scour by providing a consolidate sand bank build-up over the mattress. The `Frond Flexiform' mattress is suitable for most applications, such as pipeline cover, pipeline hold down, riser elbow protection, and for the long-term protection of structures and bridges.

The initial submerged weight will increase in time due to material bank formed by the fronds giving a total submerged hold down of 1t/sq m or more. Standard mould sizes are 10 x 3 m in plan view. Mattresses may be manufactured in any size within mould dimensions subject to standard block sizes. For lifting and overside the integral lifting loops connected to re-useable quick release frame are applied. Additional 1 tonne SSCS ground anchors may be attached at corners or edges to provide the additional edge hold down to increase protection capability (e.g. against trawling).

Authors: ~

Krystian W. Pilarczyk &
Directoraat-General Rijkswaterstaat,
(Directorate-General for Public Works
and Water Management)
Postbus 5044,
2600 GA Delft,
The Netherlands.

Rysard B. Zeidler
Institute of Hydro-Engineering,
Polish Academy of Sciences
(IBW PAN),
Koscierska 7,
Gdansk-Oliwa,
Poland.



T12 = Type 12 Scour Control Mat
(5.0m x 2.5m c/w 1.25m Fronds and 8 Safe Anchors)

NOTES: - OFFSHORE WIND ENERGY TOWER

1. MATS for SCOUR PROTECTION as indicated on this DRAWING to be by SEABED SCOUR CONTROL SYSTEMS Ltd.

SAMPLE REQUIREMENT per Wind Tower:
6 No. SSCS Type 12 SCOUR CONTROL MATS 5.0m x 2.5m, BUOYANT FROND HEIGHT 1.25m, with 8 in No. Safe Anchors. Weight in Air: 100kg, Weight Submerged: 45kg. FROND Tensile Strength >681N and up to 1181N. Mat Layout to face into MAXIMUM tidal flow directions.

It is IMPORTANT that these Scour Control Mats be Installed a.s.a.p. Tower Installation.

2. MATS to be positioned and anchored by two (2) competent DIVERS. Mats are crane deployed by 2 leg wire rope slings (Slings can be supplied by SSCS). Detailed Installation Instruction are supplied with the Mats.

3. NOMINAL MINIMUM CLEAR DISTANCE between Tower Base and Scour Control Mats to be >9" (>228mm), Normal/Standard: 12" to 15" (305 to 380mm).

4. INSTALLATION SEQUENCE as required by Dive Team. During Installation the SAFE NETS must NOT BE REMOVED UNTIL ALL ADJACENT MATS HAVE BEEN FULLY INSTALLED to prevent Diver or ROV entanglement.

5. MATS should **NOT** be installed at Entry/ Attachment Points intended for Cables. Such Scour Control Mats can be installed immediately AFTER any subsequent connections to the Tower Base have been completed and BEFORE Winter Storms, and Mats should be continued out to the inner end of any cable trenching.

6. **Additional Stability Post Installation - Frond induced Sedimentation:** EACH Type 12 Mat, 5m x 2.5m, the submerged sediment bank should be in the range:

~ 10.2 tonnes to 12.4 tonnes submerged weight **over each** mat; this hold down is **additional** to the retention provided by the eight (8) Safe Anchors and also excludes gently sloping extension of sediment bank down to seabed in a smooth curve up to 2.2m away from mat edge.

United States Representative

Ocean and Coastal Consultants, Inc.
35 Corporate Drive Trumbull, CT 06611
Tel: (203) 268-5007 Fax: (203) 268-8821

REF	DATE	BY	CH'K'D	DESCRIPTION
0	26/09/02	DBK		FIRST ISSUE

REVISIONS

NOTES

CAD REF No. 354002.DWG

CLIENT : G.E. Wind Energy

TITLE : SAMPLE SCOUR CONTROL MAT LAYOUT FOR 6m DIAMETER TOWER

DRAWN DBK	DATE 5/12/02	
CHECKED	DATE	
APPROVED	DATE	
SCALE 1:100	JOB No	
DO NOT SCALE		

Seabed Scour Control Systems Ltd.
Harfreys Road, Harfreys Ind. Estate, Gt. Yarmouth, Norfolk NR31 OLS
Tel: 44 + (0) 1493 443380 Fax: 44 + (0) 1493 443390

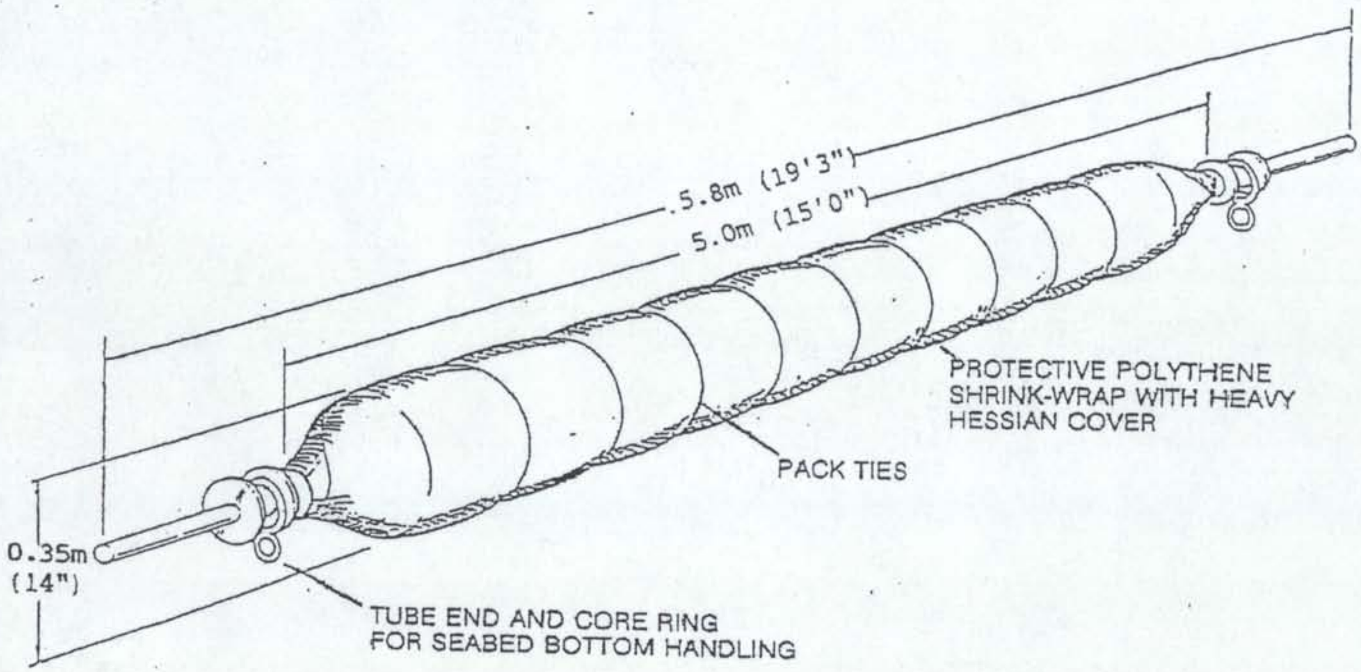
DRG No SSCS 5441.01/OCC 90-1585

REV. 0

CLIENT		SIG	DATE	Seabed Scour Control Systems Limited
PROJECT	DRG'N			
	APPV'D			
	REV.			
DRG TITLE				
				DRG NO.

SEABED SCOUR CONTROL MAT
TYPE 12

PACKED TRAVEL/STORE MODE



SHIPPING DETAIL/GROSS AIR WEIGHT = 100Kg(220lb)
CUBE = LENGTH X DIAMETER

FIGURE 1

REVISIONS

CLIENT		SIG	DATE	**Seabed Scour Control Systems Limited**
PROJECT	DRG'N			
	APPV'D			
	REV.			

DRG TITLE

DRG NO.

SEABED SCOUR CONTROL MAT
TYPE 12

PRE-INSTALLATION: PROTECTIVE HESSIAN WRAP AND BLACK POLYTHENE COVER REMOVED TOPSIDE IMMEDIATELY BEFORE LOWERING TO SEABED

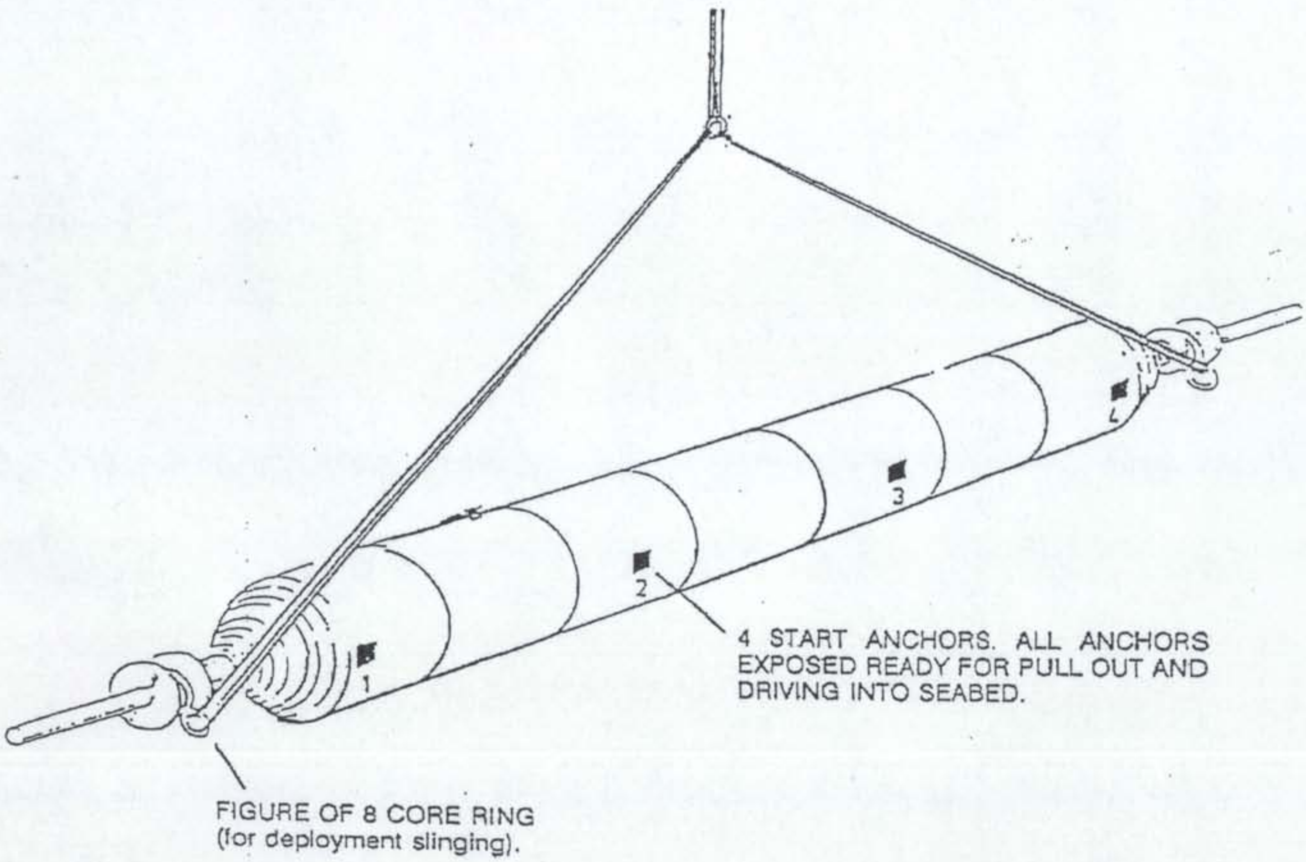


FIGURE 2

REVISIONS

CLIENT		SIG	DATE	Seabed Scour Control Systems Limited
PROJECT	DRG'N			
	APPV'D			
	REV.			
DRG TITLE				
				DRG NO.

SEABED SCOUR CONTROL MAT TYPE 12

DEPLOYMENT FROM VESSEL

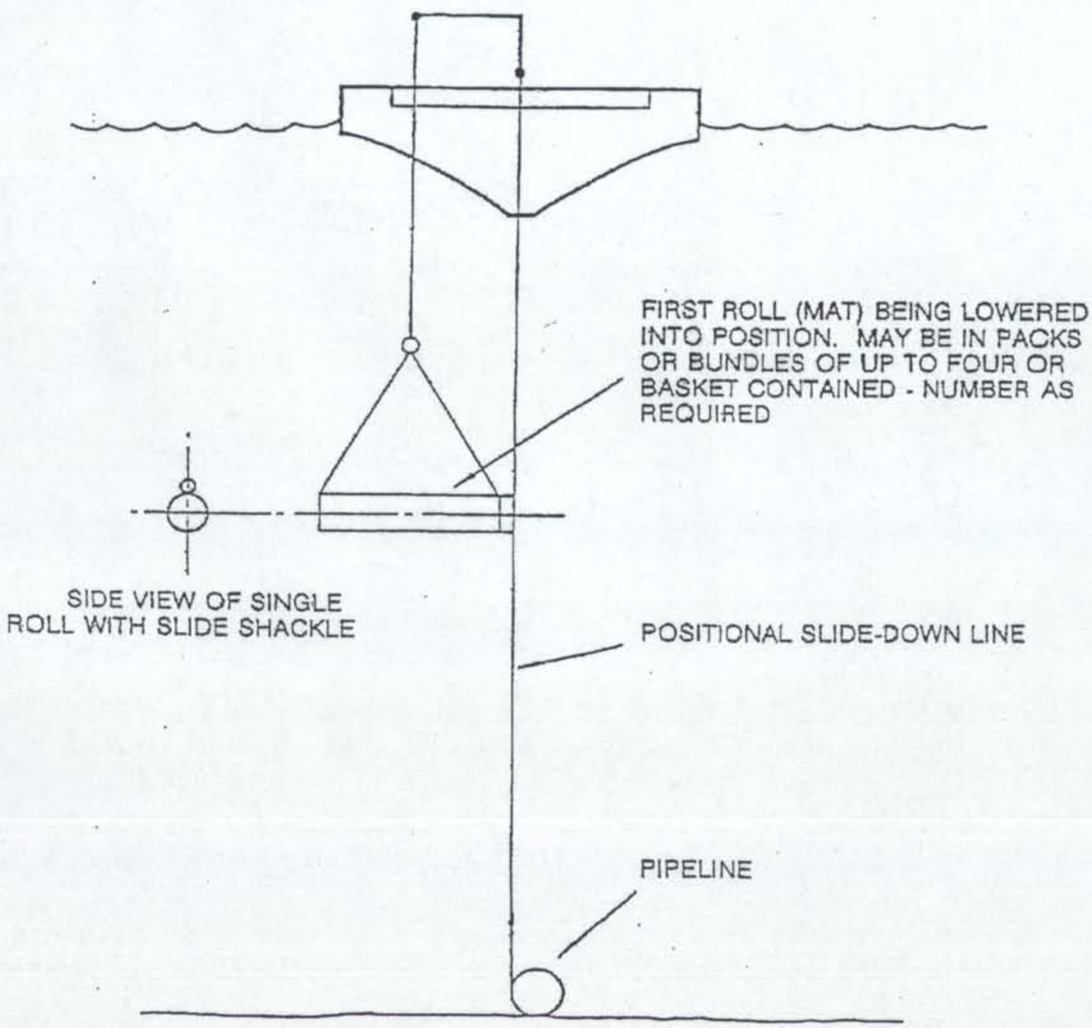


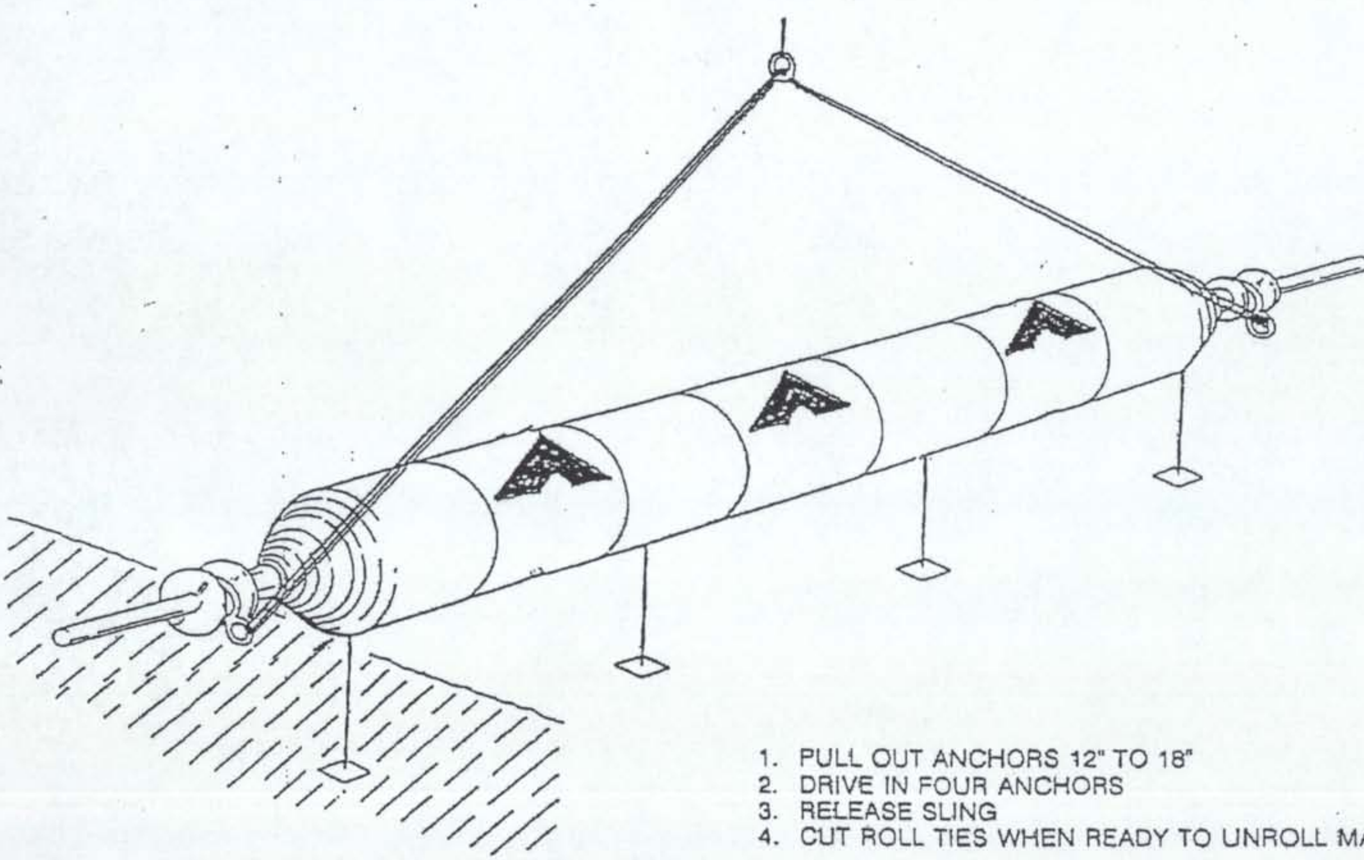
FIGURE 3

REVISIONS

CLIENT		SIG	DATE	Seabed Scour Control Systems Limited
PROJECT	DRG'N			
	APPV'D			
	REV.			
DRG TITLE				DRG NO.

SEABED SCOUR CONTROL MAT
TYPE 12

SEABED START POSITION



1. PULL OUT ANCHORS 12" TO 18"
2. DRIVE IN FOUR ANCHORS
3. RELEASE SLING
4. CUT ROLL TIES WHEN READY TO UNROLL MAT

FIGURE 4

REVISIONS

CLIENT		SIG	DATE	**Seabed Scour Control Systems Limited**
PROJECT	DRG'N			
	APPV'D			
	REV.			

DRG TITLE

DRG NO.

SEABED SCOUR CONTROL MAT
TYPE 12

MAT END ANCHORED READY FOR UNROLLING AND DRIVING IN REMAINING END ANCHORS

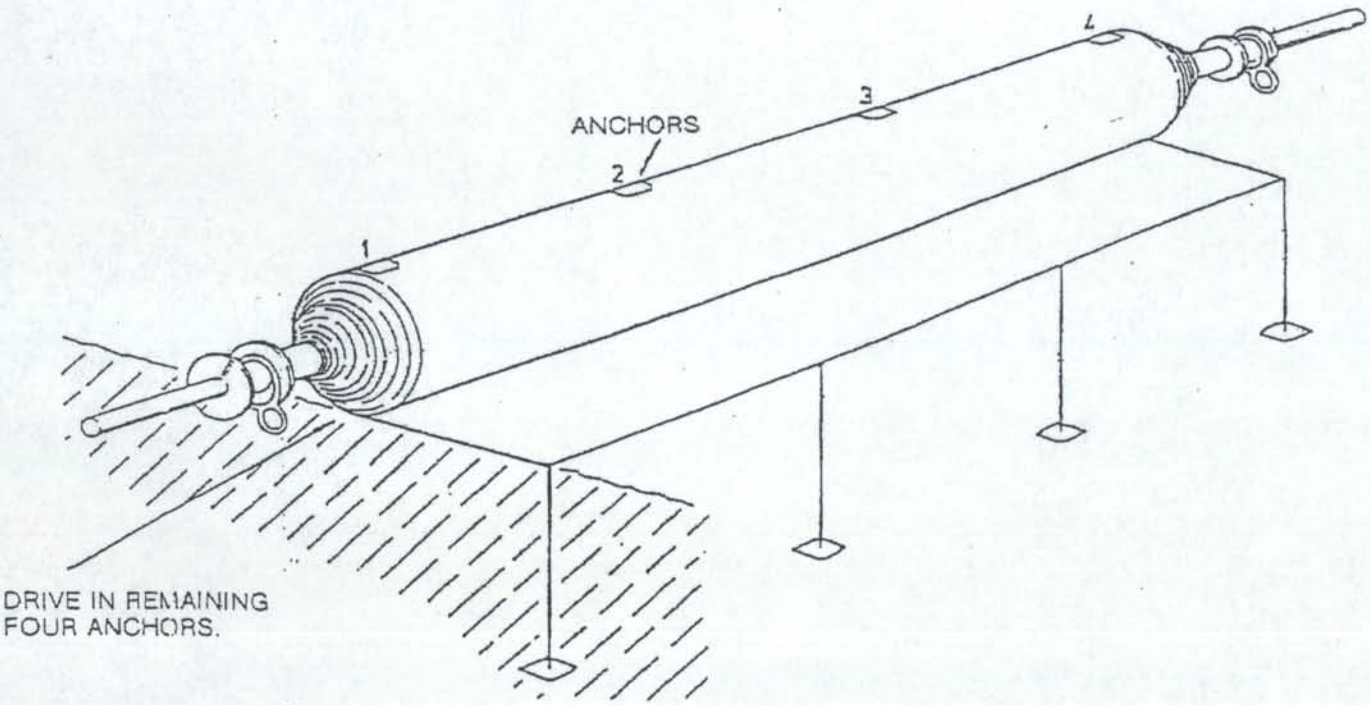


FIGURE 5

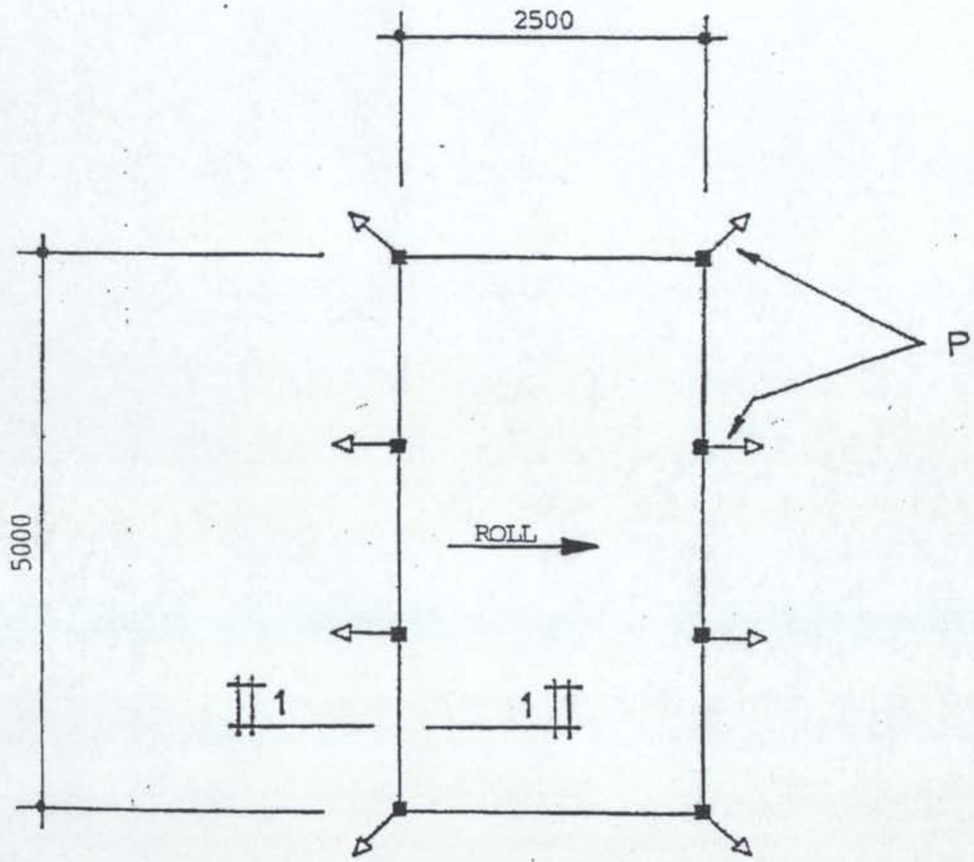
REVISIONS

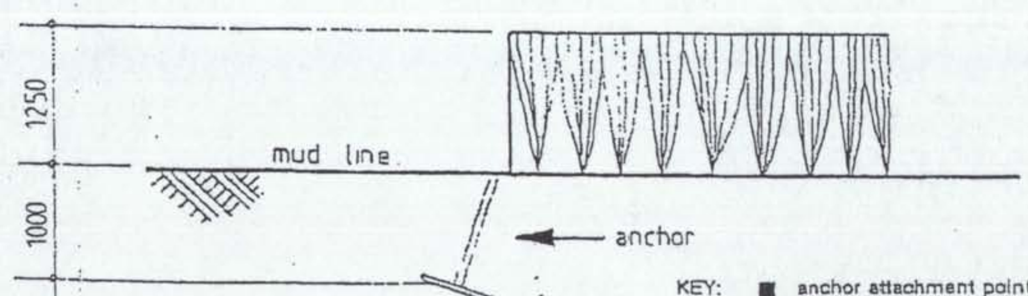
CLIENT		SIG	DATE	Seabed Scour Control Systems Limited
PROJECT	DRG'N	[signature]	15/6/00	
	APPV'D			
	REV.			

DRG TITLE

DRG NO.

SEABED SCOUR CONTROL MAT
TYPE 12





REVISIONS

NOT TO SCALE

KEY:
- ■ anchor attachment point
- ◁ position of driven 1 tonne anchor
- P pull out distance of anchor prior to driving: 305mm (12") to 450mm (17.75")

SECTION 1 - 1

MAT INSTALLATION

FIGURE 6