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PRIORITIZATION OF ICEBERG GROUNDING EVENTS FROM ICE SEASON DOCUMENTATION

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ABSTRACT

Nine icebergs were reported to have grounded on the northeastern Grand Banks during the year 2000 ice season. Documentation of possible groundings provides a basis for planning seabed scour surveys and thus the ability to study the degradation of scours over time, knowing the exact date of scour creation. All available data for the nine reported grounding events were examined and are summarized in this paper. These data include photographs, iceberg principal dimensions, iceberg drift tracks, seabed bathymetry, winds, currents, ice management tow force and direction and comments made by crew and ice observers. The data were then used to prioritize each of the events for the likelihood of finding a scour mark during field surveys. The prioritization was based on five criteria: event duration, local bathymetry, environmental driving forces, crew and observer comments and presence of older, previously measured scours in the area. Modelling of the scour process was conducted in an attempt to estimate scour length and depth for each event. These modelling efforts were completed in an attempt to help validate the scour model, as well as to provide further information on the likelihood of locating reported scours.

INTRODUCTION

With the advent of offshore oil and gas exploration and production in recent years on the Grand Banks of Newfoundland, the study of iceberg scour processes has become considerably important. In order to perform risk studies to determine the feasibility of certain operations and developments, it is necessary to determine aspects of the scour regime, such as scour width, length, depth, density and frequency of occurrence.

During the year 2000 ice season, a total of 78 icebergs were tracked over 5 months. Based on observer logs (PAL, 2000), 9 of these icebergs were reported to have grounded on the seabed.

Details of these icebergs are given in Table 1 and locations of the reported groundings are shown in Figure 1.

In Spring of 2001, C-CORE led a study for the Geological Survey of Canada (GSC) to assess available information collected by operators during the ice season of 2000, in order to provide recommendations for a GSC field program proposed to be carried-out during the Summer of 2001. The intent of the GSC field program was to locate as many of the 9 potential iceberg scours made during the 2000 iceberg season. The thrust of the surveys was to collect detailed information about these features, knowing specifics of the icebergs that created them, metocean conditions and an estimate of the length of time possibly scouring. Knowledge of when a scour was created helps identify the frequency with which scours are made and, with repetitive surveys, how they degrade over time.

This paper explains how available data were used to assess the reported year 2000 groundings for the likelihood of finding an iceberg scour at the reported locations. Results of the study along with the outcome of scour modelling and available results from the GSC field program are also given.

AVAILABLE DATA

In order to provide recommendations on which of the 9 reported scours would likely be found in a field program, it was necessary to first compile the following information:

- observer logs;
- iceberg principal dimensions;
- iceberg tracks for dates and times;
- bathymetry along iceberg drift tracks;
- amount of time reported grounded;
- wind and current magnitude and direction for the date and location of the groundings;
- iceberg velocity during reported groundings;
- total distance traveled during reported groundings; and
- locations of older scours in the area.

The sources of these data include PAL Environmental Services Ltd. and AMEC Earth and Environmental Ltd. for ice observer logs, Canadian Meteorological Centre for modelled daily surface winds and the Canadian Ice Service (CIS) for predicted daily mean currents in 10m depth bins from the water surface to the seabed. Iceberg track positions were recorded using either visual observations, radar from platforms and ships in the area and aerial surveillance. Available RADARSAT imagery for the region on dates close to groundings were examined and found to provide close confirmation of the iceberg positions reported by observer logs.

Bathymetry data for the northeastern Grand Banks were developed by C-CORE through past studies involving detailed analysis of commercially available field sheet data and nautical charts. The variability of water depth along each iceberg track was based on an interpolation of water depth at each track point. Iceberg drift velocity and travel distance were computed from positional and temporal data given in the observer log database. The Grand Banks Scour Catalog (GBSC) was consulted for details of older scours in the study region.

Example Case Study from Year 2000 Data

Case studies for each potentially grounded iceberg were developed to concisely summarize the data available. An example case study is presented in Figure 2 to Figure 4 for Iceberg 00-065.

Table 1. Iceberg particulars for reported year 2000 groundings (dimensions in m).

ID	Size	Shape	Length	Width	Height	Draft (est.)
00-009	Medium	Tabular	70	40	10	58
00-011	Large	Pinnacle	120	82	40	84
00-018	Medium	Pinnacle	70	40	35	58
00-021	Medium	Dome	63	49	18	75
00-032	Large	Pinnacle	138	114	27	124
00-044	Medium	Pinnacle	100	60	30	74
00-065	Large	Pinnacle	242	76	55	135
00-067	Large	Pinnacle	110	76	40	102
00-068	Medium	Dry Dock	80	30	15	64

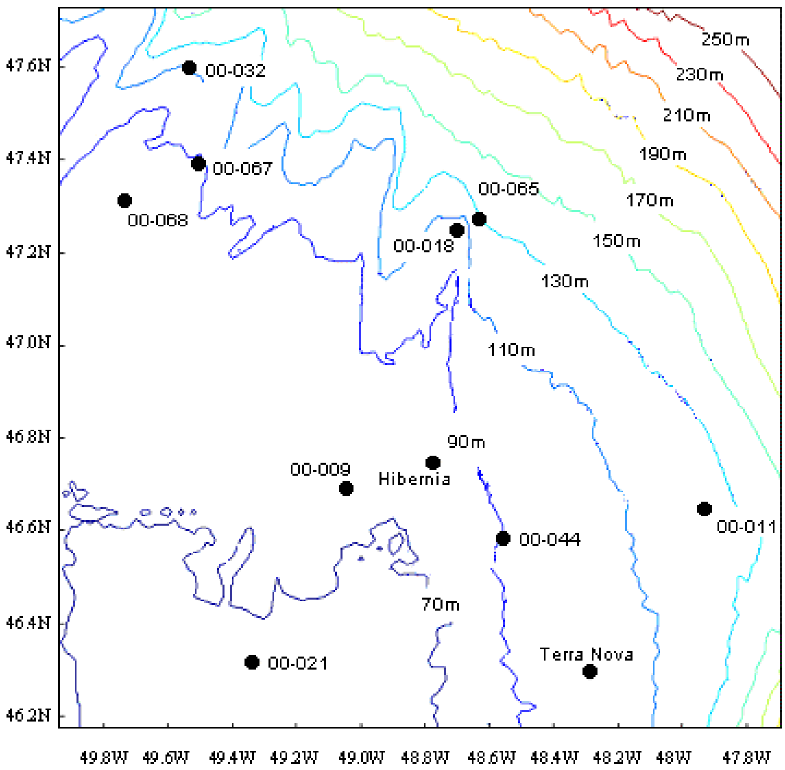

Figure 1. Positions of reported year 2000 iceberg groundings.

<table>
<tr>
<td>Iceberg Particulars</td>
<td>
Size: Large
Length: 242 m
Width: 76 m
Height: 55 m
Estimated Draft: 135 m
Reported Shape: Pinnacle
Approx. Grounded Location:
47º 16.57’ N, 48º 37.84’ W
Water Depth: 127 m</td>
</tr>
<tr>
<td>Anecdotal Information</td>
<td>• Iceberg was tracked from April 28 to June 4, 2000 using radar and visual observation from ships in the area.
• Iceberg was expected to be grounded 10:27, April 28 when tracking first began.
• Total time expected grounded: ~330 hours
• Iceberg was reported as ungrounded by 05:00 on May 12 and was later towed by the Maersk Gabarus for approximately two and a half days.
• No other grounding incidents were reported as the iceberg entered deeper water.</td>
</tr>
<tr>
<td>Environmental Conditions</td>
<td>• Winds generally light-moderate 3-10 m/s from April 28 through May 11, except for strong 15 m/s winds to the NE April 29. A fair degree of fluctuation in wind directions during this period, but generally blowing offshore to the north through SE.
• Currents generally moderate ~30-60 cm/s to the east and NE through this same April 18 to May 11 period of interest.
• Winds and currents also appear to be of moderate magnitude and direction generally to the NW through NE for the 12^{th} through the 19^{th} when the berg drifted up to the NW and N into deeper waters until having towing commence on the 19^{th}.
• Through the period at least from the 28^{th} through 6^{th} the winds and currents appear to have been of sufficient magnitude and direction that they would have otherwise moved the berg further offshore into deeper waters had it not been grounded, particularly the near gale force winds to the NE on the 29^{th}.</td>
</tr>
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Figure 2. Case study of general information for iceberg 00-065.

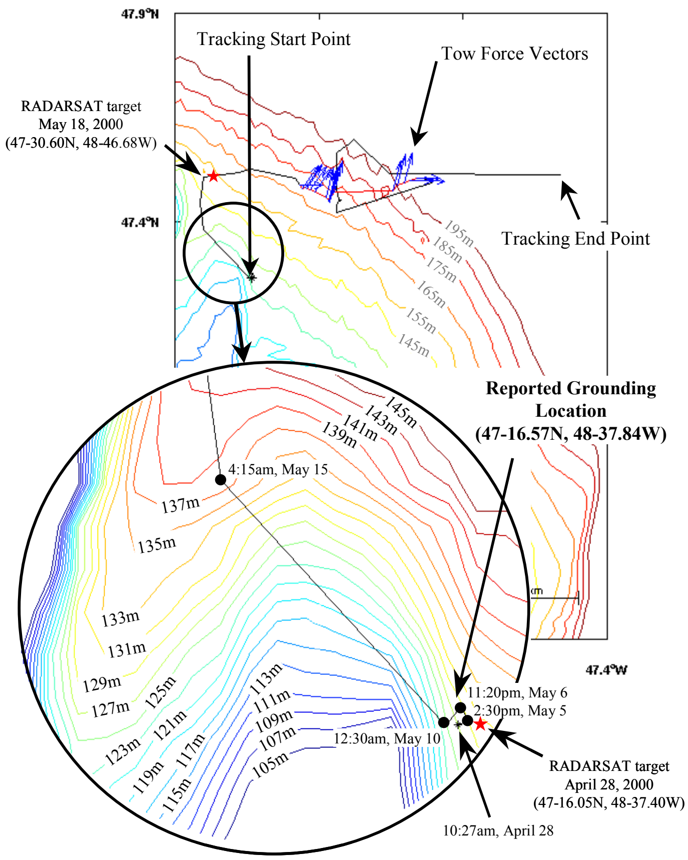

Figure 3. Track, bathymetry and reported location of grounding for iceberg 00-065.

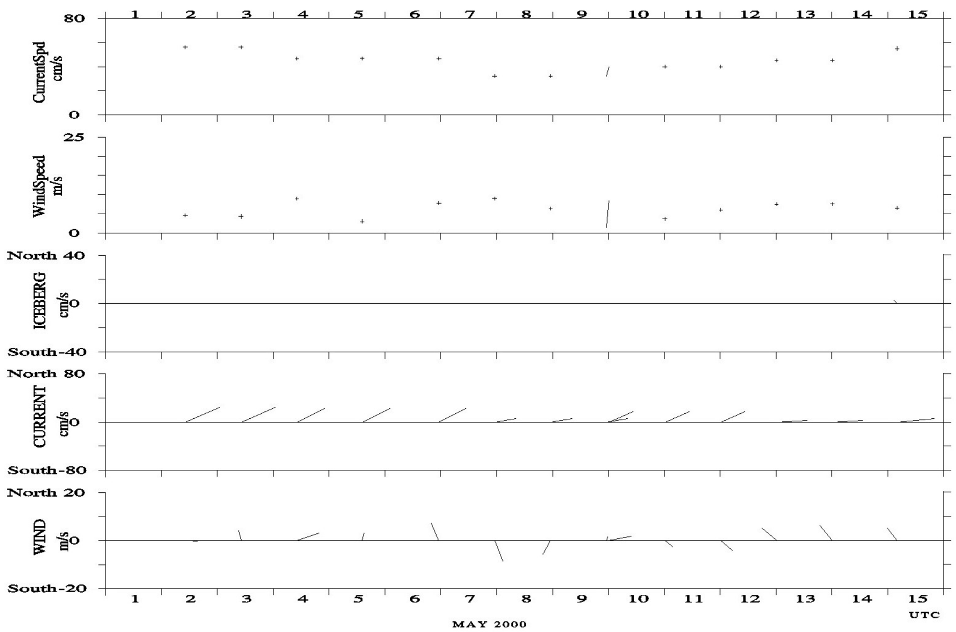

Figure 4. Summary stick plots of metocean conditions during the grounded portion of iceberg 00-065's track.

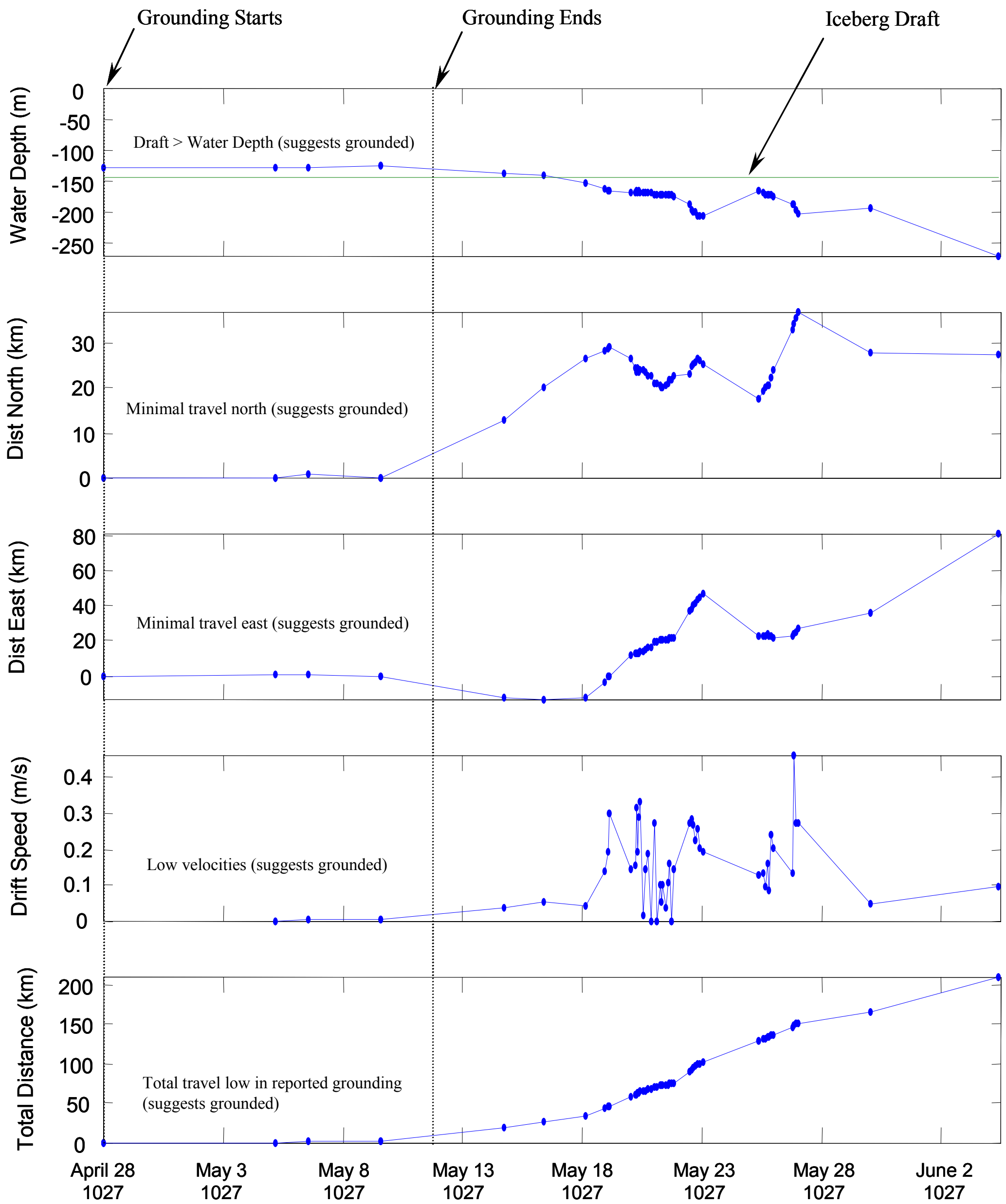

Figure 5. Summary plots of drift and bathymetric conditions for iceberg 00-065.

CRITERIA FOR PRIORITIZATION

The criteria listed in Table 2 were used to prioritize the reported groundings in order of likelihood of being located during subsequent seabed surveys. The weights given indicate the relative importance of each criterion (higher weight indicates greater importance).

Results of the prioritization are given in Table 3. Analysis of these results indicated that icebergs 00-011 and 00-018 rank poorly with ranking scores much lower than the other 7 icebergs. These scores indicated that the possibility of locating scours during field work would be low and, therefore, it was recommended that these potential scours be searched for last, if time was available.

Table 2. Criteria for prioritization of iceberg grounding events.

Criteria	Description	Weight
Event Duration	For short duration events, the likelihood of measuring a scour mark during seabed surveys is lower than what would be expected for longer duration events since these would be more likely to leave greater area marks at the grounding location. This criterion is a general assumption that does not consider the type and force of iceberg/seabed interaction.	5
Bathymetry vs. Draft	If the reported iceberg draft exceeds water depth at a given location, it is likely a scouring event has occurred. The main difficulty with this criterion lies in the accurate assessment of iceberg draft. Iceberg draft can be measured by sidescan sonar equipment or estimated using derived relationships.	3
Environmental Driving Forces	Since environmental driving forces are the prime movers of drifting icebergs, these data can be examined to determine if an iceberg was being forced aground in the locations reported and whether a change in conditions would have been expected to initiate refloating.	4
Observer and Crew Comments	The databases supplied by PAL (2000) and AMEC (2000) contain comments made by crew and observers in the field. These were assessed, where available, to help determine the conditions of reported grounding events.	3
Older Scours in the Region	If an iceberg has grounded in a region where the seabed has already been disturbed by scour marks, the possibility of distinguishing the new scour from older features is likely to be lower if the region has not been previously surveyed. The GBSC was queried for all previously measured scours in the region of the reported groundings.	2

Table 3. Grounding events prioritized according to most likely measurable scours.

ID	Water Depth (m)	Ranking Score (higher=better)	Ranking (1=best 9=least)
00-009	75	67	1
00-011	120	22	9
00-018	102	29	8
00-021	68	55	5
00-032	112	63	3
00-044	91	47	6
00-065	127	67	2
00-067	90	61	4
00-068	75	45	7

MODELLING TECHNIQUES TO ESTIMATE SCOUR LENGTH AND DEPTH

Using a numerical model developed at C-CORE (McKenna et al., 1999 and KRCA, 2000), the scour process was simulated in order to estimate scour length and depth for each of the 7 most likely year 2000 reported groundings. The model combines environmental driving forces, soil type, iceberg characterization and iceberg hydrostatics to simulate the scour process up a seabed slope. The model does not perform predictions for creation of pits. Characteristics of monitored iceberg behaviour were used to estimate input conditions where data were not available. Modelled scours are assumed to be linear in shape and that the keel does not encounter obstacles or irregularities on the seabed. As well, the environmental driving forces acting on the iceberg are assumed to be constant over the length of the scour, and in the same direction as free drift values.

Input Parameters and Assumptions

Parameters required for input to the model can be divided into three main groups: iceberg characteristics and hydrostatics, seabed characteristics and environmental driving forces.

Iceberg characteristics included length, width, draft, sail height, keel offset and rake angle. Where possible, these values were taken directly from the PAL (2000) database. In cases where data were unavailable directly, relationships developed from existing data were used. Iceberg hydrostatics were based on pitch and heave stiffness. These values were calculated based on relationships developed using the iceberg profile data contained in Mobil Hibernia Development Studies (1984).

Seabed characteristics included soil type and strength, seabed slope and the distribution of scour widths in the study region. Since soil strength and type may vary between the different iceberg grounding locations, it was difficult to estimate these properties for each site. An assumption was made that the soil is the same at all reported grounding locations. Seabed slope was calculated using bathymetric data directly along the path of the drifting icebergs just before the grounding was reported. Since scour width for each reported event was unknown, it was assumed equal to the mean for the northeastern Grand Banks.

Environmental driving forces included forces from wind, waves and currents. Wind and current forces were calculated using velocity and direction for the period of up to a day before the grounding was reported. Wave forces were calculated directly using the wind force.

Modelling Results

Modelling results are summarized in Table 4. Modelled free drift velocities for icebergs 00-044 and 00-068 compare favourably with those estimated from the database, while modelled velocities for icebergs 00-009, 00-032 and 00-067 do not compare well with actual velocities. There appears to be a slight positive correlation between free drift velocity and modelled scour length and depth.

Modelled scour lengths all fall below 2 km and more than half are under 500 m. There appears to be a strong positive correlation between seabed slope and modelled scour depth. This implies that at grounding locations where seabed slope is greater, the scour depth is expected to be deeper and possibly easier to detect in seabed surveys.

Table 4 Results from modelling of the 7 highest ranked year 2000 grounding events.

Iceberg ID	Database	Modelled			
	Free Drift Velocity (m/s)	Free Drift Velocity (m/s)	Scour Depth (m)	Scour Length (m)	Rise-up (m)
00-009	0.38	0.84	0.24	1280	0.26
00-021	0.43	0.73	0.22	1180	0.24
00-032	0.13	0.90	1.23	200	1.40
00-044	0.19	0.34	0.14	260	0.16
00-065	N/A	0.24	0.51	280	0.56
00-067	0.05	0.39	0.19	760	0.30
00-068	0.33	0.20	0.11	220	0.11

FIELD PROGRAM RESULTS

Incomplete results from a field program conducted during the summer of 2001 by the GSC are summarized in Table 5. These results show that 5 of the 7 recommended possible groundings from 2000 were found and surveyed. Results of the field program indicate that most groundings resulted in pits rather than linear scour features. Where scour lengths were measured, they were found to be larger than those predicted by the modelling process, in one case 7 times longer than predicted. Scour depths for the two measured linear features were well predicted by the scour model. A sidescan sonar plot of the scour created by iceberg 00-065 is shown in Figure 6.

Table 5. GSC Summer 2001 field program results.

Iceberg ID	Findings
00-009	• 2000 m maximum length (discontinuous) • No measurable depth (<0.30 m) • Rise-up =1 m • Scour located in 75-76 m water depth
00-021	• 2 small adjacent pits were found (15 m x 10 m & 20 m x 12 m) • Scour located in 70 m water depth
00-032	• 2 adjacent pits were found • Largest pit depth was 3 m • No appreciable rise-up
00-044	Not found
00-065	• 1400 m length • Maximum depth = 1.1 m, average = 0.5 m • Rise-up = 3 m • Scour ended with terminal pit 2.5 m deep
00-067	• Single pit 4 m deep located in 89 m water depth
00-068	Not found

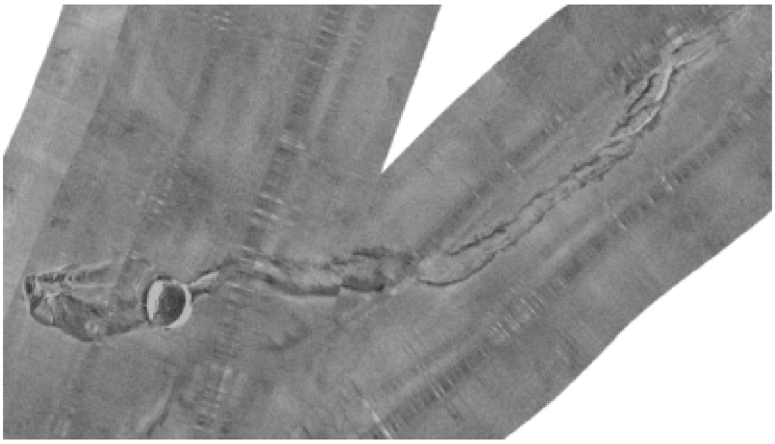

Figure 6. Sidescan sonar plot of the scour created by iceberg 00-065.

CONCLUSIONS

Using photographs, principal iceberg dimensions, iceberg drift tracks, seabed bathymetry, winds, currents, ice management tow force and direction, and comments made by crew and ice observers, case studies for 9 reported groundings from year 2000 ice operations of the Grand Banks were compiled.

The nine reported groundings were prioritized based on six criteria, indicating that seven of the nine events were likely to have produced scours or pits that could be measured during GSC field work in the Summer of 2001.

A scour prediction model developed at C-CORE was modified to estimate expected scour depth and length for the seven most likely measurable reported groundings. Modelled scour depths ranged from 0.11 m to 1.23 m, while modelled scour lengths ranged from 200 m to 1280 m.

Results from the GSC field program conducted during the summer of 2001 showed that five of the seven highest ranking grounding events were located and measured successfully. A comparison between field and modelled results indicates that the scour model produced good predictions of scour depth, however scour lengths were under predicated. It is expected that modelling results would improve with the completeness and quality of input data.

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