ENVIRONMENTAL IMPACT STATEMENT FOR

OFFSHORE DRILLING

LICENCES PL023 & PL024

THE FALKLAND ISLANDS

ON BEHALF OF

ROCKHOPPER EXPLORATION PLC

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NON TECHNICAL SUMMARY

Background

Rockhopper Exploration PLC (Rockhopper) is a UK company set up in 2004 to explore for oil and gas in the Falkland Islands. Rockhopper hold four Licences in the North Falkland Basin; PL023, PL024, PL032 and PL033, together with a smaller interest in two other licence areas.

Licences PL023 and PL024 lie in shallow water (all less than 200 m), situated to the north of the Falkland Islands. The licence blocks were awarded to Rockhopper in November 2004.

This Environmental Impact Statement (EIS) provides an assessment of the potential environmental impacts associated with the proposed drilling in Licences PL023 and PL024, together with mitigation and management measures and a description of any residual impacts to the environment. The assessment utilises a study of the baseline environment, together with a description of the proposed operations, in order to assess the risk of impacts occurring.

Rockhopper intend to drill one or two wells in their licence area. A semi-submersible rig is most likely to be used for these operations. Semi-submersibles float in deep water and provide a stable platform to allow drilling of the sea floor. A typical deep sea semi-submersible drilling rig has dimensions of approximately 90 m by 80 m with a draught of about 30 m. A conventional rotary drilling system via top drive will be used to drill the wells.

All chemicals to be used during the drilling have been selected to minimise the potential environmental impacts as much as possible. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme (HOCNS) category of ‘E’ (which are of low aqua toxicity, readily biodegradable and non-bioaccumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable.

The well will be drilled vertically in sections (with the diameter of each section decreasing with increasing depth) to a maximum total depth (TD) of around 2500 m with wireline logging programmes conducted in order to evaluate the geological formations. In the event that hydrocarbons are identified in any of the targeted sandstones, cores will also be taken. It is not likely that any well testing will be undertaken, however inclusions for possible well testing have been included in this report. Upon completion of the TD data acquisition programme the well(s) will most likely be permanently abandoned.

Existing Environment

The Patagonian Shelf, on which the Falkland Islands sit, is of regional and global significance for marine resources. It comprises rich assemblages of seabirds, marine mammals, fish, squid and plankton populations.

There has previously been little information available on the benthic environment of this area and environmental surveys were carried out in August 2008 to provide habitat mapping, sediment analysis and identification of benthic species.

Benthic sampling undertaken in August 2008 confirms and supports earlier surveys, which indicated naturally uncontaminated sediments with typical or low background concentrations of metals and hydrocarbons. The macrofauna data recorded were as expected, being homogenous in terms of the number of species. The benthic environment was also considered to be relatively homogenous.

The main fisheries resources in the Falkland Islands are the squid species, *Illex argentinus* and *Loligo gahi*. The existing finfish fishery targets predominantly hake, hoki, red cod and blue whiting. A specialised small ray fishery exists, and a small longline fishery operates targeting Patagonian toothfish. The FIG annual Fisheries Statistics volume 11 (1997–2006) show that the Rockhopper licence area to the north of the Falkland Islands demonstrates a moderate to high level of catch for the *Illex argentinus* in the first season (January to June), and low levels of catches of the *Loligo gahi* in the second season (July to December) and the southern blue whiting throughout the year. There are no significant fisheries interests on the landward side of the licence area, which would indicate that there is also low vulnerability to disturbance from vessel movements to and from the licence area.

Shellfish are not an important component of the commercial fishery although this may be developed in future.

A wide range of marine mammals occur in the waters around the Falkland Islands. Based on survey results between 1998 and 2001, the following species of cetacean were recorded within or adjacent to the licence area; minke whale, hourglass dolphin and Peale's dolphin. Due to the migratory nature of cetaceans, it is probable that other cetacean species present may move through the licence areas, however overall the area is not considered to be of high sensitivity for cetaceans.

Based on seal observations over the same period, only the South American fur seal and the South American sea lion are likely to be spotted in the vicinity of the licence area.

The Falkland Islands are an area of global importance for birdlife, particularly seabird species. The avifauna of the region is well studied and documented, and seabird distribution, breeding and foraging patterns have been studied extensively. The IUCN Red List classifies 24 species as threatened with seven species as 'Endangered' – the highest level of conservation status. Species recorded within the licence area are the King penguin (May to November), Gentoo penguin (April to November), Rockhopper penguin (October to March), Magellanic penguin (November to February) and various species of albatross, petrel, fulmar, prion and shearwater. Other seabirds including shags, ducks, skuas, gulls and terns occur in the nearshore areas outside of the licence blocks.

Based on recorded distributions, the licence area to the north of the Falkland Islands is not of major significance for any of the recorded seabird species. Due to the vulnerable nature of many of these species, however, any impacts to food or habitats may prove significant for population numbers and near-shore areas to the landward side of the licence area are considered particularly vulnerable.

Impacts and Management Measures

Significant environmental sensitivities identified in the licence areas are the highly important seabird populations, presence of marine mammals and fisheries interests. The benthic (seafloor) habitat is considered to be a relatively homogenous environment with no habitats of conservation significance found during the survey in August 2008 of the licence blocks.

Outside of the licence areas, the near shore and coastal environments are considered to be sensitive to any forms of pollution.

The results of the environmental impact assessment of the drilling programme indicate that there are potential impacts which relate to waste management. Minimising the potential impact caused by waste issues can be achieved by implementing policies such as reuse, segregation and storage. Negative impacts will arise from onshore disposal, especially should this be at the Falklands where the capacity will be limited. Economic flow ons from the project will have positive impacts.

The sources of potential impacts include drill cuttings disposal, the risk of large offshore and near-shore oilspills, international transfer of solid and hazardous wastes and use of resources (i.e. fuel and potable water) should they be sourced from the Falklands. All other sources of potential impacts were deemed to be of low significance.

The potential impacts of these operations will be mitigated in a number of ways, including:

- Maintaining a spirit of openness and ongoing consultation with the Falkland Islands Government (FIG), the public and key stakeholders.
- Applying international best practice and established UK standards to operations, particularly in offshore chemical use and emissions reporting.
- Using only water based drilling muds and low toxicity chemicals approved under the UK Offshore Chemical Notification Scheme.
- Implementing a high level of environmental management offshore and applying environmental procedures for potentially impacting operations (chemical storage, bunkering, waste handling, maintenance programmes, seafloor surveys etc).
- Monitoring and reporting consumption and emission figures in accordance with the UK Environmental Emissions Monitoring System (EEMS).
- Establishing and implementing a project specific Oil Spill Response Plan and carrying out training of key personnel in spill response. Employing an oil spill response contractor to provide outside assistance in the case of a major spill.
- Implementing a detailed waste management plan to minimise the quantity of waste going to landfill, prevent unsuitable disposal of waste, maximise the re-use of materials and establish the Best Practicable Environmental Option (BPEO) for storage, treatment, transfer and disposal of waste materials.
- Collecting and sharing environmental data wherever possible, for example in offshore sightings, seabed surveys and metocean conditions.

A more detailed description of recommended mitigation measures and environmental management is provided in Sections 8 and 9 of this report.

TABLE OF CONTENTS

GLOSSARY 1

1. INTRODUCTION 1

1.1. PURPOSE OF THIS DOCUMENT 1
1.2. PROJECT PROPONENT 1
1.3. PROJECT BACKGROUND 1
1.3.1. Overview 1
1.3.2. Location 4
1.3.3. Exploration History 5
1.4. SCOPE 6
1.5. DOCUMENT OVERVIEW AND STRUCTURE 6

2. LEGISLATIVE FRAMEWORK 9

2.1. INTERNATIONAL CONVENTIONS AND AGREEMENTS 9
2.2. NATIONAL LEGISLATION 11
2.2.1. Environmental Impact Assessment 13
2.3. PETROLEUM INDUSTRY STANDARDS AND GUIDELINES 15
2.3.1. E&P Forum 15
2.3.2. E&P Forum / United Nations Environment Programme 15
2.3.3. IPIECA 15

3. STAKEHOLDER ENGAGEMENT 16

4. ALTERNATIVES TO PROPOSED DRILLING PROGRAMME 17

5. PROJECT DESCRIPTION 18

5.1. DRILLING RIG OVERVIEW 18
5.2. PRE-DRILLING SURVEY 20
5.3. DRILLING TECHNIQUE 20
5.4. WELL CONSTRUCTION 20
5.5. WELL DESIGN 21
5.6. CASING 26
5.7. ABANDONMENT 27
5.8. DRILLING FLUIDS 27
5.8.1. Drilling Muds 27
5.8.2. Cement 29
5.9. WELL CONTROL AND BLOW-OUT PREVENTION 29
5.10. WELL TESTING 30
5.11. SUPPORT OPERATIONS 30

6. OPERATIONAL ASPECTS 32

6.1. EMISSIONS TO AIR 32
6.2. EMISSIONS TO WATER 34
6.2.1. Controlled 34
6.2.2. Uncontrolled 36
6.3. WASTE MANAGEMENT 38
6.4. PHYSICAL PRESENCE 39
6.5. RESOURCE USE 39

7. EXISTING ENVIRONMENT 42

7.1. PHYSICAL ENVIRONMENT 42
7.1.1. Meteorology 42

7.1.2. Oceanography 45
7.1.3. Bathymetry 52
7.1.4. Geology 52
7.2. BIOLOGICAL ENVIRONMENT 54
7.2.1. Marine and Inter-tidal Vegetation 54
7.2.2. Plankton 54
7.2.3. Benthic Fauna 57
7.2.4. Fish, Squid and Shellfish 58
7.2.5. Cephalopod 59
7.2.6. Finfish 60
7.2.7. Shellfish 61
7.2.8. Marine Mammals 62
7.2.9. Seabirds 73
7.2.10. Seabird Vulnerability 84
7.2.11. Threatened Species 90
7.2.12. Protected Habitats and Areas 91
7.3. SOCIAL AND ECONOMIC ENVIRONMENT 93
7.3.1. Economy 93
7.3.2. Marine Archaeology 99
7.3.3. Communications 102
7.3.4. Military 102
7.3.5. Navigation and Maritime Transport 103
7.3.6. Oil Industry Infrastructure 103
8. IMPACT ASSESSMENT AND MITIGATION 104
8.1. QUALITATIVE IMPACT ASSESSMENT 104
8.2. EMISSIONS TO AIR 105
8.3. EMISSIONS TO WATER 106
8.3.1. Controlled Discharges 106
8.3.2. Non-routine Discharges 110
8.4. WASTE MATERIALS 118
8.4.1. Offshore Waste Management 118
8.4.2. Onshore Waste Management 119
8.5. PHYSICAL PRESENCE 120
8.6. USE OF RESOURCES 121
8.7. SOCIO-ECONOMIC 122
8.8. CUMULATIVE IMPACTS 123
9. MANAGEMENT FRAMEWORK 129
9.1. INTRODUCTION 129
9.2. RESPONSIBILITIES 130
9.3. ENVIRONMENTAL MANAGAMENT PROCESS 130
9.3.1. Identify Potential Environmental Impacts 130
9.3.2. Assess Significance of Impacts 130
9.3.3. Select Control Measures 130
9.3.4. Develop Environmental Management Plan 130
9.3.5. Monitor Performance 130
9.3.6. Review and Improve 131
9.4. PROJECT ENVIRONMENTAL MANAGEMENT FRAMEWORK 131
9.4.1. Rockhopper Petroleum Environmental Management System 131
9.4.2. Operational Controls and Procedures 132
9.4.3. Reporting 132
9.4.4. Oil Spill Contingency Plan 134
10. CONCLUSIONS 135

11. ACKNOWLEDGEMENTS 136

12. REFERENCES 137

APPENDIX I IUCN SPECIES UNDER THREAT AND STATUS 140

APPENDIX II MODELLING RESULTS 142

APPENDIX III BENTHIC ENVIRONMENTAL SURVEY 143

APPENDIX IV ROCKHOPPER EXPLORATION HSE POLICY STATEMENT144

INDEX OF FIGURES

Figure 1-1 Locality Map 2
Figure 1-2 Allocated licence areas PL023 and PL024 3
Figure 1-3 Proposed well location(s) 5
Figure 1-4 Previous exploration drilling in Falkland Islands waters 6
Figure 1-5 Structure of this EIS 8
Figure 2-1 Falkland Islands Government organogram 14
Figure 5-1 Typical semi-submersible rig layout 19
Figure 5-2 Typical drill ship 20
Figure 5-3 Rotary drilling technique 22
Figure 5-4 Conceptual Well Design for Ernest 24
Figure 5-5 Conceptual Well Design for Weddell 25
Figure 5-6 Casing setting diagram for Ernest 26
Figure 5-7 Casing setting diagram for Weddell 26
Figure 5-8 A Schaffer blow out preventer stack 30
Figure 6-1 Flow diagram of rig controlled drainage 35
Figure 7-1 Climate Averages for Stanley Harbour 43
Figure 7-2 Seasonal wind speed versus direction 44
Figure 7-3 Graph of Falkland Islands' annual wind speed 45
Figure 7-4 Falkland Islands conservation zones (inner and outer) plus major currents and water depths 46
Figure 7-5 Sample locations for the FUGRO metocean survey 47
Figure 7-6 Annual wave exceedance for PL023 and PL024 48
Figure 7-7 Annual wave direction for PL023 and PL024 48
Figure 7-8 Graph of seasonal thermocline (Fugro 1999) 49
Figure 7-9 Sea surface temperatures (Jan 1997) 49
Figure 7-10 Extent of hydrodynamic model and selection of calibration locations 51
Figure 7-11 Petroleum basins of the Falkland Plateau 53
Figure 7-12 Phytoplankton bloom (areas of light blue / green) near the Falkland Islands 56
Figure 7-13 Lobster krill (*Munida gregaria*) 57
Figure 7-14 Cetacean Species Distribution in the North Falkland Basin (1998–2001) 67
Figure 7-15 Cetacean Numbers Recorded per Month (JNCC 2002) 69
Figure 7-16 Pinniped Distribution 72
Figure 7-17 Penguin Numbers Recorded per Month (JNCC 2002) 76
Figure 7-18 Albatross Numbers Recorded per Month (JNCC 2002) 79
Figure 7-19 Monthly vulnerability of seabird concentrations to surface pollution January to June (based on surveys from February 1998 to January 2000) 90
Figure 7-20 Total catch by percentage and fishery type in the Falkland Islands for 2006 95
Figure 7-21 *Illex argentinus* catches (tonnes) by grid square for Season 1 (Jan–Jun 2006) 96
Figure 7-22 *Illex argentinus* catches (tonnes) by grid square for Season 2 (Jul–Dec 2006) 96
Figure 7-23 Loligo gahi catches (tonnes) by grid square for Season 1 (Jan–Jun 2006) 97
Figure 7-24 *Loligo gahi* catches (tonnes) by grid square for Season 2 (Jul–Dec 2006) 97
Figure 7-25 *Micromesistius australis* catches (tonnes) for Season 1 (Jan–Jun 2006) 98
Figure 7-26 *Micromesistius australis* catches (tonnes) for Season 2 (Jul–Dec 2006) 98
Figure 7-27 Known shipwrecks in the Falklands region 100
Figure 7-28 Identified ecologically sensitive areas to impacts from aircraft and helicopter activity 101
Figure 8-1 Drill cuttings sedimentation pattern after 21 days at Ernest well site 108
Figure 8-2 Drill cuttings sedimentation pattern after 21 days at Weddell well site 109
Figure 8-3 Simulation results showing exposure to oil following a major spill from the proposed Ernest well location with wind 10 m/s from 15° after 8 days 113
Figure 8-4 Simulation results showing exposure to oil following a major spill from the proposed Ernest well location with wind 10 m/s from N after 8 days 114

Figure 8-5 Simulation results showing exposure to oil following a major spill from the proposed Ernest well location with wind 10 m/s from 345° after 8 days 115
Figure 8-6 Simulation results showing exposure to oil following a major spill from the Weddell site with wind 10 m/s from 0° after 8 days. 116
Figure 9-1 Environmental management process 129
Figure 9-2 Emissions Estimation Approaches 133

INDEX OF TABLES

Table 1-1 PL023 and PL024 boundary coordinates (original licence areas) 4
Table 1-2 Proposed drilling location coordinates 4
Table 2-1 International agreements of the Falkland Islands applicable to this proposed drilling programme 9
Table 2-2 Falkland Islands' legislation relevant to offshore drilling and the environment 11
Table 5-1 Basis of Design for Ernest 23
Table 5-2 Basis of Design for Weddell 23
Table 6-1 Potential CO_2 emissions from fuel consumption (semi-submersible) 33
Table 6-2 Estimated daily quantities of grey and black water discharge 34
Table 6-3 Expected volumes of drill cuttings discharge 35
Table 6-4 Summary of expected weight of drill cuttings discharge 36
Table 6-5 Oil spill volumes from offshore installation in UK waters 37
Table 6-6 Waste materials likely to be generated from drillings operations 38
Table 6-7 Expected resource consumption 40
Table 7-1 Zooplankton Species in Falkland Island waters 56
Table 7-2 Protected Areas 91
Table 7-3 Marine Wreck Locations 99
Table 8-1 Summary of the impact assessment process 105
Table 8-2 Environmental risk matrix 105
Table 8-3 Drill cuttings residue particle size 107
Table 8-4 Simulation 1 (worst case) total oil beached after 6 days (m^3) 116
Table 9-1 EEMS Data Submission Matrix 134

GLOSSARY

(H)OCNS	(Harmonised) Offshore Chemical Notification Scheme
2D	Two Dimensional
3D	Three Dimensional
ACAP	Agreement on the Conservation of Albatross and Petrels
ACC	Antarctic Circumpolar Current
ACDP	Acoustic Doppler Current Profiler
APF	Antarctic Polar Front
API	American Petroleum Institute
BOP	Blowout Preventer
BPEO	Best Practicable Environmental Option
CBD	Convention on Biological Diversity
CCAMLR	Convention on International Trade in Endangered Species
CH_4	Methane
CITES	Convention on the International Trade of Endangered Species
Cl	Chlorine
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DMR	Department of Mineral Resources
DP	Dynamic Positioning
E&P Forum	The International Exploration and Production Forum (now OGP)
EEMS	Environmental Emissions Monitoring System
EEZ	Exclusive Economic Zone
EIA / EIS	Environmental Impact Assessment / Statement
EMP	Environmental Management Plan
EMS	Environmental Management System
EU	European Union
FICZ	Falklands Interim Conservation and Management Zone
FIFD	Falkland Islands Fisheries Department
FIG	Falkland Islands Government
FIPASS	Floating Interim Port and Storage System
FOCZ	Falklands Outer Conservation and Management Zone
FOSA	Falklands Operations Sharing Agreement
GHG	Greenhouse Gases
HSE	Health, Safety & Environment
IAGC	International Association of Geophysical Contractors
IBA	Important Bird Area(s)
IMO	International Maritime Organisation
ISO	International Organisation for Standardisation
IUCN	International Union for the Conservation of Nature
JNCC	Joint Nature Conservation Committee
KCl	Potassium Chloride

LOT	Leak-off test
LTOBM	Low Toxicity Oil Based Mud
MARPOL	International Convention for the Prevention of Pollution by Ships
MOD	Ministry of Defence
N_2O	Nitrous Oxide
NaCl	Sodium Chloride
NGO	Non-governmental Organisation
NO_X	Nitrogen Oxides
OECD	Organisation for Economic Cooperation and Development
OGP	International Association of Oil and Gas Producers (prev. E&P Forum)
OSCP	Oil Spill Contingency Plan
PHPA	Partially-Hydrolyzed Polyacrylamide
PON	Petroleum Operations Notices
PSA / PSC	Production Sharing Agreement / Production Sharing Contract
ROV	Remotely Operated Vehicle
SMRU	Sea Mammals Research Unit
SO_2	Sulphur Dioxide
TD	Total Depth
UK	United Kingdom
UKOOA	United Kingdom Offshore Operators Association
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compound
WBM	Water Based Mud

1. INTRODUCTION

1.1. PURPOSE OF THIS DOCUMENT

This document constitutes an Environmental Impact Statement (EIS) as specified under the Offshore Minerals Ordinance 1994 Part VI. It has been compiled by RPS Energy at the request of Rockhopper Exploration plc. This Statement provides an assessment of the potential impacts from proposed exploratory drilling within production licence areas 23 and 24 (PL023 and PL024) of the North Falkland Basin.

Undertaking an EIS ensures that potential environmental impacts associated with the proposed project, for both routine and non-routine operations, are correctly identified and assessed. In doing so, relevant preventative and management measures can be developed and implemented to mitigate adverse environmental impacts appropriately.

This document meets the requirements outlined in the Falkland Islands' legislation pertaining to offshore exploration and production activities – The Offshore Minerals Ordinance 1994; Amended 1997.

1.2. PROJECT PROPONENT

The EIS has been prepared by RPS on behalf of the proponent, Rockhopper Exploration plc (Rockhopper). Rockhopper is a UK company listed on the Alternative Investment Market which was set up in 2004 to explore for oil and gas in the Falkland Islands.

Rockhopper holds 100% of four licences in the North Falkland Basin – PL023, PL024, PL032 and PL033 (Figure 1). PL032 and PL033 were previously licensed to Shell. Rockhopper also holds an interest in licences PL03 and PL04, operated by Desire Petroleum plc.

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1.3. PROJECT BACKGROUND

1.3.1. Overview

In November 2004 two new licences covering 16 blocks and a total area of 4,200 km^2 in the southernmost part of the North Falkland Basin were awarded to Rockhopper. The initial term (Phase 1) was for 3 years and under the terms of the licences Rockhopper moved to the second Exploration Term (Phase 2) in November 2007. During Phase 1 Rockhopper fulfilled their licence commitment to collect a minimum of 640 km of two dimensional (2D) seismic data. At the end of Phase 1, 50% of the licence area was relinquished and the company moved to Phase 2, under which additional seismic data has been acquired and Rockhopper are committed to drilling at least one exploration well.

Figure 1-1 Locality Map

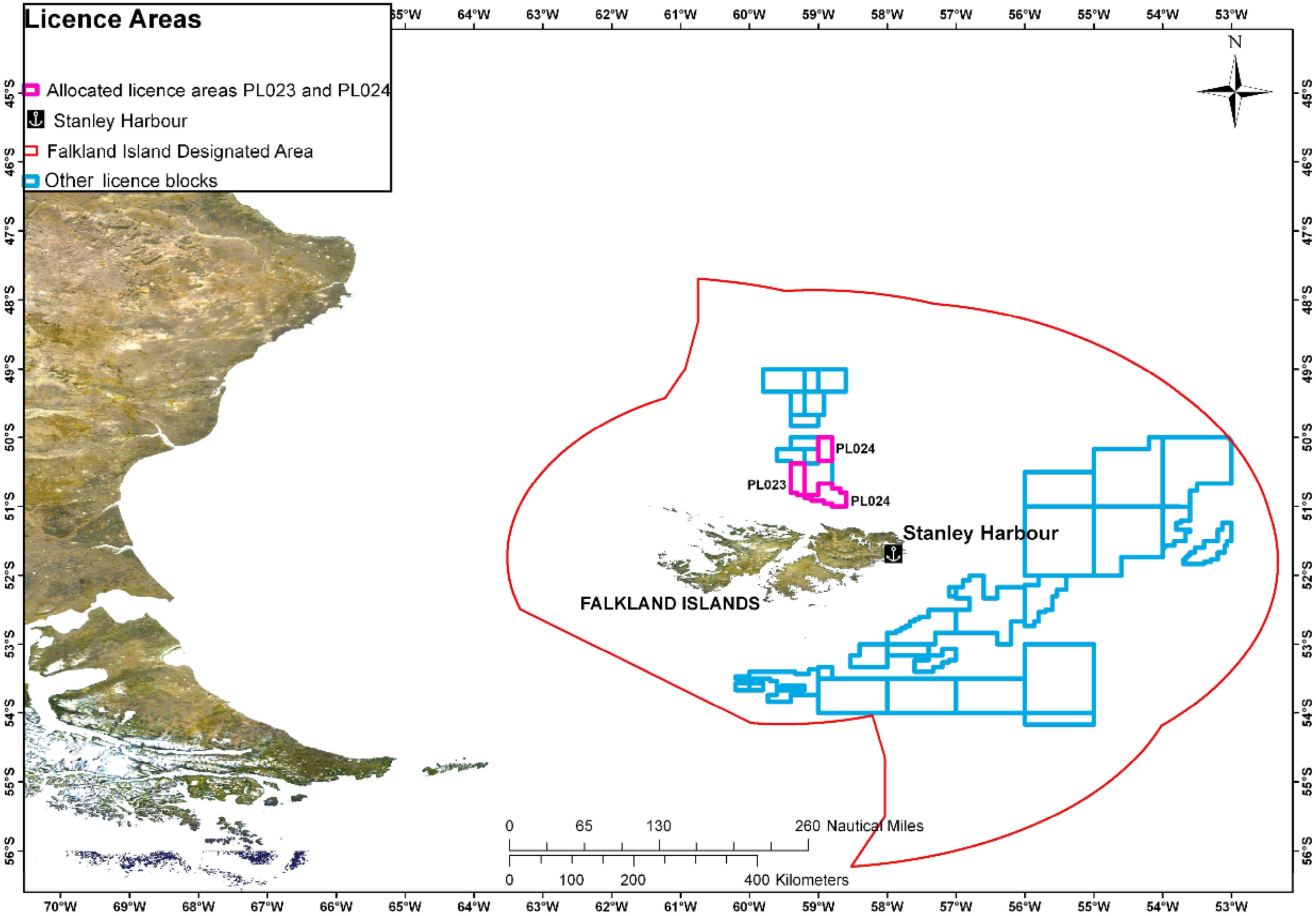


Figure 1-2 Allocated licence areas PL023 and PL024

1.3.2. Location

The Falkland Islands are an archipelago of approximately 700 islands in the South Atlantic, the largest of which are East Falkland and West Falkland (Figure 1-1). Situated some 770 kilometres (480 miles) north-east of Cape Horn and 480 km (300 miles) from the nearest point on the South American mainland, the Falklands have a total land area of 12,173 square kilometres (km^2) (4700 square miles) and a permanent population of 2913 (FCO, 2007).

The designated exploration area for the Falkland Islands covers over 400,000 Km^2 (Figure 1-2), which is approximately 50% bigger than the UK North Sea (FIG website). The area is based on a pre-existing fisheries conservation zone, with the western boundary of the Falkland Islands' Designated Area coinciding with the eastern limits of the Argentine Exclusive Economic Zone (EEZ).

The designated area is subdivided into quadrants based on one degree of latitude by one degree of longitude, each of which is subdivided into thirty Blocks. The numbering system used for Quadrants, Blocks and the wells drilled in them is similar to that in the UK North Sea (FIG website).

Within this designated exploration area lies the North Falkland Basin, immediately to the north of the Falklands, where Rockhopper has been involved in the exploration for hydrocarbons since 2004. PL023 and PL024 are in the southern region of the Basin and have a combined area of 2099.9 km^2. Boundary coordinates are provided in Table 1-1.

Seven licences were originally awarded for the North Falklands Basin during the initial bidding phase, covering 48 blocks. Various changes to the ownership of the blocks have occurred since, and two new blocks were awarded in 2004. Current North Falkland Basin licence holders are Desire, Argos Resources and Rockhopper.

Table 1-1 PL023 and PL024 boundary coordinates (original licence areas)

PL023 coordinates			
NW	50°22'S, 59°24'W	**NE**	50°22'S, 59°12'W
SW	50°47'S, 59°24'W	**SE**	50°49'S, 59°12'W

PL024 coordinates (northern)				PL024 coordinates (southern)			
NW	50°00'S, 59°0'W	**NE**	50°00'S, 58°48'W	**NW**	50°50'S, 59°12'W	**NE**	50°40'S, 58°48'W
SW	50°20'S, 59°00'W	**SE**	50°20'S, 58°48'W	**SW**	51°00'S, 58°48'W	**SE**	51°00'S, 58°36'W

The proposed drilling programme will occur within prospects located in reasonably shallow water, less than 200 metres (m) deep. Proposed drilling location coordinates are presented in Table 1-2 and illustrated in Figure 1-3. Ernest-A is proposed for drilling and Weddell may possibly be drilled but is unlikely.

Table 1-2 Proposed drilling location coordinates

Well Name	Latitude	Longitude
Ernest	50° 18’ 17.305" S	58° 56’ 37.292" W

Weddell	50° 47' 16.49" S	58° 52' 42.31" W

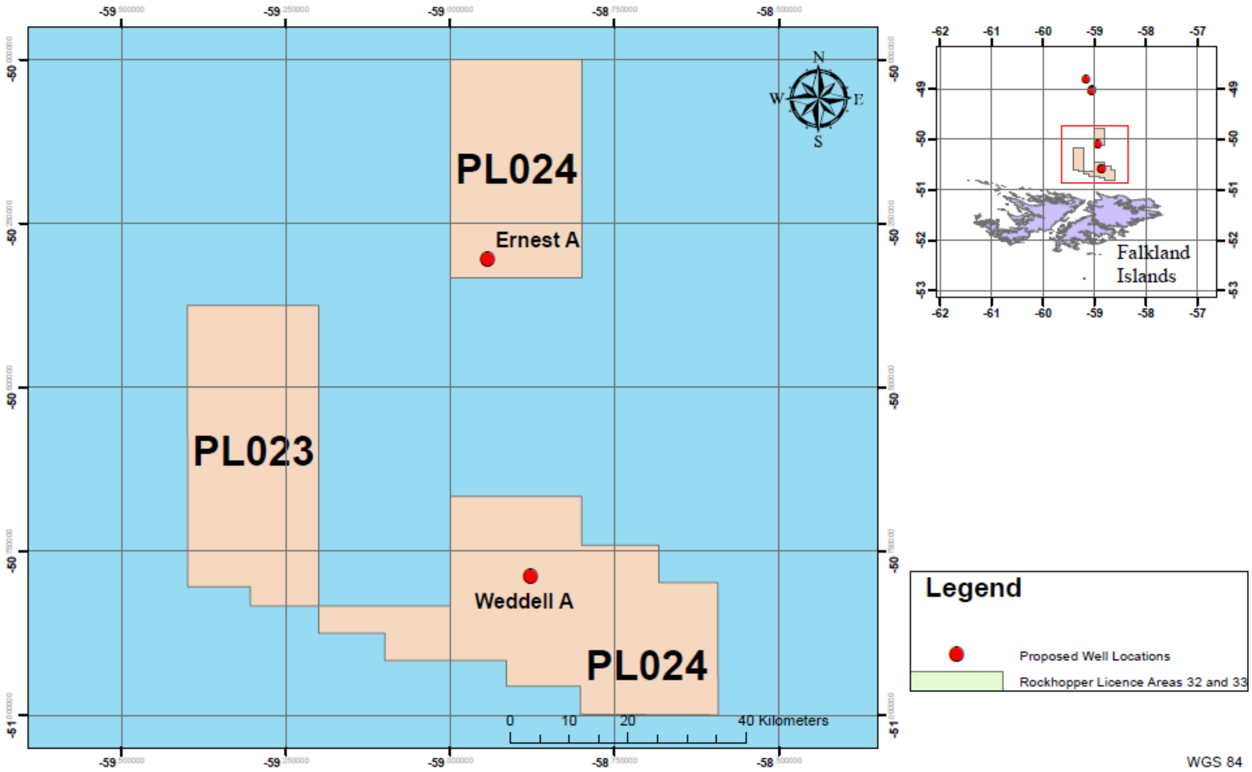


Figure 1-3 Proposed well location(s)

1.3.3. Exploration History

The exploration history of the Falkland Islands is well documented and can be found outlined on the Falkland Islands Government (FIG) Department of Mineral Resources (DMR) website (www.falklands-oil.com). Below is a brief overview, adapted from the Department's website.

1.3.3.1. Seismic Exploration

The first seismic exploration in the region, in the 1950's, had seismic refraction profiles shot across the Falklands area by the Lamont-Doherty Geological Observatory. Seismic data was acquired from 1977–2001 for large areas of the Patagonian shelf by a number of companies.

Rockhopper possesses 2D seismic data across the major prospect in the licence area. In addition, high-resolution shallow-seismic site survey data has been acquired over the Ernest prospect.

1.3.3.2. Drilling

Six exploration wells were drilled within the North Falkland Basin during the 1998 drilling campaign (Figure 1-4). No commercial finds were located, but five of the six wells had oil shows and live oil was recovered at surface. Significant levels of gas were also recorded. There has been no further exploratory drilling in Falkland Island waters' since the 1998 campaign.

In November 2005, Desire submitted an EIS seeking approval to drill up to three wells within Tranches C and D. The EIS has been approved pending submission of the revised operational information and oil spill contingency plan.

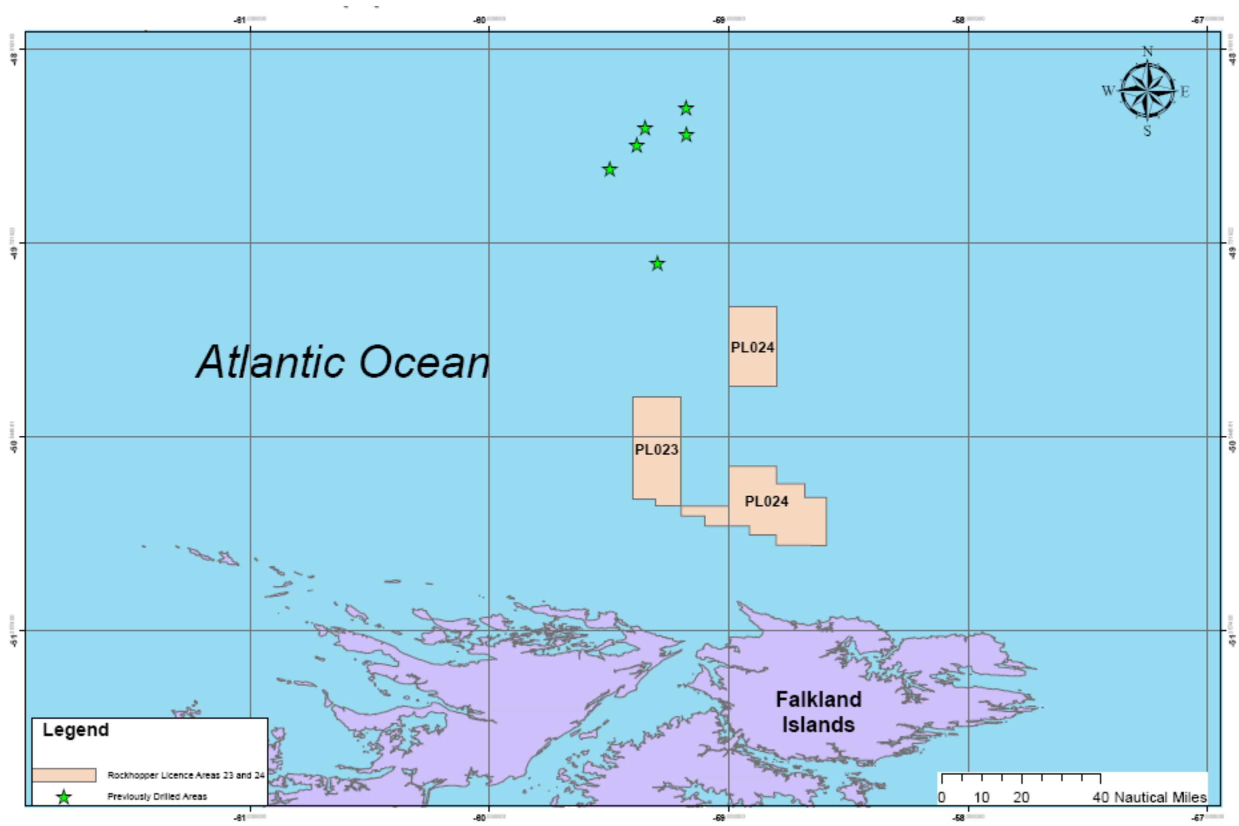


Figure 1-4 Previous exploration drilling in Falkland Islands waters

1.4. SCOPE

The scope of this EIS focuses on the proposed exploratory drilling programme and does not extend to other potential future oil and gas activities in the Falkland Islands.

The Falkland Islands Government commissioned Coopers & Lybrand to study socio-economic impacts of oil and gas development in the Falkland Islands in 1997. As such, the broader impacts of future oil and gas development have already been examined in some detail and FIG require only that the socio-economic impacts of activities directly associated with the proposed drilling programme be considered here.

Health and Safety issues are excluded from this assessment, except where they are considered to have a direct impact on the environment.

Baseline descriptions in this EIS are provided for the offshore area, within PL023 and PL024, of the North Falkland Basin and focus on the most likely drilling location identified in pre-operational planning. The baseline descriptions also encompass relevant coastal and other areas, upon which the proposed operations could potentially impact.

1.5. DOCUMENT OVERVIEW AND STRUCTURE

This document has been completed using publicly available information and data sources, together with specific information provided by the client. The main sources of information utilised include:

- Consultation with relevant FIG departments.
- Basis of Design (BOD) Report prepared for Rockhopper by SPD for the proposed drilling operations.

- Desktop literature review – previous EIA's submitted for the region.
- FIG Fisheries Department 2007, Fishery Statistics, Volume 11 (1997–2006).
- Munro 2004, DRAFT Falkland Islands Baseline Environmental Survey.
- Otley 2005, Patterns of seabird attendance at Patagonian toothfish longliners in the oceanic waters of the Falkland Islands 2001–2004, prepared for the FIG.
- Otley et al. 2006, Origin, age, sex and breeding status of wandering albatrosses (*Diomedea exulans*), northern (*Macronectes halli*) and southern giant petrels (*Macronectes giganteus*) attending demersal longliners in Falkland Islands and Scotia Ridge waters 2001–2005, Polar Biol.
- Otley H, Munro G, Clausen A and Ingham B. 2008. Falkland Islands State of the Environment Report 2008. Falkland Islands Government and Falklands Conservation, Stanley.
- Professor Clayton 2002–2003, Falkland Islands Seaweed Survey, Monash University.
- White et al. 2001, Vulnerable Concentrations of Seabirds in Falkland Islands Waters, prepared for the Joint Nature Conservation Committee.

Full references are provided at the end of this report.

The structure of this report is as depicted in Figure 1-5.

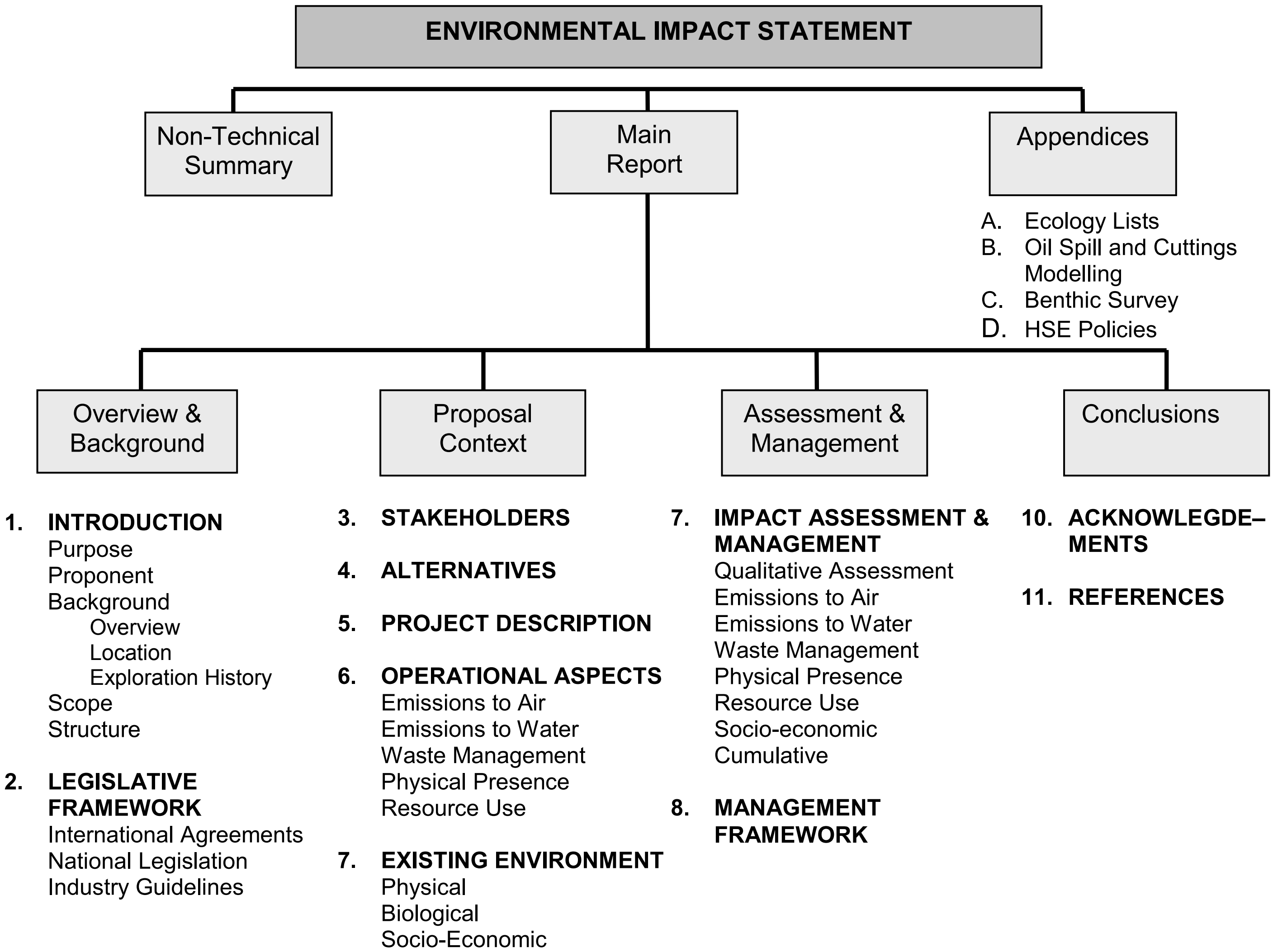


Figure 1-5 Structure of this EIS

2. LEGISLATIVE FRAMEWORK

This section summarises the international and national legal context for the proposed drilling programme. It is not intended to provide a complete analysis of the wider legal framework within the Falkland Islands, but only that relevant to the natural environment and local stakeholders. Legislation specific to health and safety, tax and finance are outside of the scope of this EIS.

The Falkland Islands are a United Kingdom Overseas Territory, where supreme authority is vested in HM The Queen and exercised by a Governor on her behalf, with the advice and assistance of the Executive and Legislative Councils, and in accordance with the Falkland Islands Constitution (FCO, 2005).

Falkland Islands law governs petroleum exploration and exploitation on the Falkland Islands Continental Shelf. The licensing system for offshore exploration and production activities is applicable to the entire Falkland Islands Designated Area (Figure 1-2). Exploration and Production Licences can be gained in competitive rounds or an open-door system.

2.1. INTERNATIONAL CONVENTIONS AND AGREEMENTS[1]

International conventions and agreements applicable to offshore drilling activities in the Falkland Islands are summarised in Table 2-1.

Table 2-1 International agreements of the Falkland Islands applicable to this proposed drilling programme

Known as	Full Title	Status	Summary
ACAP	Agreement on the Conservation of Albatross and Petrels	Ratified* April 2004	Seeks to conserve albatrosses and petrels by co-ordination of international activity to mitigate known threats. ACAP has been developed under the umbrella of the CMS (see below).
Basel Convention	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal 1992	Under considera-tion	To reduce the trans-boundary movements and amounts of hazardous wastes and non-hazardous wastes to a minimum, and to manage and dispose of these wastes in an environmentally sound manner.
CBD	Convention on Biological Diversity 1992	Not yet ratified, applies through UK extension of overseas territories	Commitment to conserve biological diversity, to use biological resources sustainably and to share equitably the benefits arising from the use of genetic resources.
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources 1982	Ratified	Aims to protect the marine ecosystem south of 60°.
CITES or The Washington convention	Convention on International Trade in Endangered Species	Ratified* October 1976	Ensures that international trade in specimens of wild animals and plants does not threaten their survival.
CMS or The Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals	Ratified* 1985	Seeks to conserve terrestrial, marine and avian migratory species (those that regularly cross international boundaries, including international waters). Concluded under the

[1] Adapted from the FIG 'The Principal Environmental Conventions and Agreements Relevant to the Falkland Islands and Foreign and Commonwealth Office (FCO)' online database.

Known as	Full Title	Status	Summary
			aegis of the United Nations Environment Programme. All cetacean and Southern Hemisphere albatross species are listed in the CMS.
Environment Charter	Environment Charter	Signed 2001	Charter to protect the Falkland Islands' natural environment, with additional support from the British government through funding and expert advice.
Fisheries Agreement	Fisheries Agreement	1990, issued a joint statement	A joint statement between the British and Argentine governments to create the Falklands Outer Conservation Zone and the South Atlantic Fisheries Commission for the protection of fish stocks.
Hydrocarbons Agreement	UK/Argentine Joint Declaration on Hydrocarbons	1995, issued a joint statement	A joint statement between the British and Argentine governments for the cooperation of offshore activities in the south west Atlantic.
IUCN	International Union for the Conservation of Nature	*Not a legal agreement*	The IUCN assess the conservation status of animal and plant species and assign a threat level. Lists of threatened species status (IUCN red lists) are published for different countries. The list of species identified as under threat by IUCN is given in Appendix I.
Kyoto Protocol	Kyoto Protocol to the UN Framework Convention on Climate Change	By Extension March 2007	An amendment to the international treaty on climate change, assigning mandatory emission limitations for the reduction of greenhouse gas emissions to the signatory nations.
London Convention	1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.	Ratified* 1980. The 1996 Protocol does not yet extend to the Falkland Islands.	Aims to prevent pollution of the sea from dumping of waste and other matters liable to create hazards, harm living resources and marine life, damage amenities, or to interfere with other legitimate uses of the sea. The dumping of Annex I materials is prohibited, Annex II materials require a prior special permit and all other wastes require a prior general permit.
MARPOL 73/78	1973 Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978	Most of the subsidiary agreements ratified.	Seeks to prevent pollution by oil, chemicals, harmful substances in packaged form, sewage and garbage from ships.
Montreal Protocol	Montreal Protocol on Substances that Deplete the Ozone layer	Ratified* December 1988	Aims to protect the ozone layer by phasing out ozone depleting substances.
Ramsar Convention	1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat	Ratified* in 1976	Aims to halt the world-wide loss of wetlands and promote the conservation of wetlands through wise use and management. Both Bertha's Beach and Sea Lion Island have been accepted by the Convention of Parties and listed as having Ramsar status (Section 7.2.12). Wetlands can include marine waters up to a depth of 6 m at low tide.
UNCLOS (or Law of the Sea)	The United Nations Convention on the Law of the Sea (1982)	Ratified* July 1997	Legislation of the world's oceans and seas governing all uses of the oceans and their resources.
UNFCCC	United Nations Framework Convention on Climate Change	By Extension March 2007	Aims to reduce greenhouse gas emissions to combat global warming.

Known as	Full Title	Status	Summary
World Heritage Convention	1972 Convention for the Protection of the World Cultural and National Heritage	Ratified* May 1984	Aims to identify, protect and preserve cultural and natural heritage worldwide. No natural and cultural sites of outstanding global value have been designated with the Falkland Islands.
• 1998 Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention) • MARPOL Annex IV.			
* - Ratified by the UK and ratification extended to the Falkland Islands			

The 1992 Convention on Biological Diversity (UNCED, 1992), ratified by the UK but not by the Falkland Islands, includes UK dependencies within the 'UK: Biodiversity Action Plan' (HMSO, 1994). In connection with the UK's goals to encourage implementation of the Convention, partnerships are formalised in Environmental Charters between the UK and various Overseas Territories.

The first Environmental Charter, stating mutual responsibilities of the UK and its Overseas Territories, was signed on 26 September 2001 by Councillor Mike Summers, representing Falkland Islands Government, and Baroness Valerie Amos, Minister of UK Overseas Territories.

2.2. NATIONAL LEGISLATION

This section details the regulatory framework applicable to this EIS and environmental protection of the Falkland Islands (Table 2-2).

The system of Petroleum Operations Notices (PON) are not legally binding but have been approved by the Mineral Resources Committee as best practice.

Table 2-2 Falkland Islands' legislation relevant to offshore drilling and the environment

Legislation	Key requirements / relevance to proposed operations
1) Relevant to offshore operations:	
Environment Protection (Overseas Territories) (Amendment) Order 1997	Enables the provision of the London Dumping Convention to be implemented in the Falkland Island waters.
Merchant Shipping (Oil Pollution) Act 1971	Applied to the Falkland Islands by 1975 Order in Council (SI 1975/2167 as amended by SI 1976/2143 and SI 1981/218). This Act regulates responsibility for oil pollution from ships.
Offshore Minerals (Amendment) Ordinance 1997	Amends the Offshore Minerals Ordinance 1994 to make further provision in relation to the application of the Health and Safety at Work etc. Act 1974.
Offshore Minerals Ordinance 1994	The licensing framework for offshore exploration and production. Regulates offshore installations and pipelines, offshore health and safety, oil pollution, liability for environmental damage, and abandonment. Sets out the requirement for Environmental Impact Assessment and preparation of Environmental Impact statements. Production Licences (PL003 and PL004) are issued under this Ordinance.
Offshore Petroleum (Licensing) (Amendments) Regulations 2004	Enables applications to be made under the Offshore Petroleum (Licensing) Regulations 2000 in respect of areas formerly licensed under the Offshore Petroleum (Licensing) Regulations 1995, but prevents applications which were formerly licensed and being considered within two years of the expiration or sooner determination of that licence.

Offshore Petroleum (Licensing) Regulations 1995	Provides the schedule, model clauses and format for application of exploration or production licences in Falkland Island waters, as well as conditions for record keeping, sampling and drilling.
Offshore Petroleum (Licensing) Regulations 2000	Updates the schedule, model clauses and format for application of exploration or production licences in Falkland Island waters, as well as conditions for record keeping, sampling and drilling.
Offshore Petroleum (licensing) Regulations 2000 – Invitation to apply for open door licences	Invites applications for production licences in respect of blocks specified within Schedules 1 and 2. Specifies exploration terms, conditions, financial terms and application criteria.
Petroleum Operations Notice No.1	Specifies the record and sample requirements for surveys and wells, including reporting requirements and sampling details.
Petroleum Operations Notice No.2	Specifies reporting procedures including monthly and daily reports, drilling reports and changes to the work programme.
Petroleum Operations Notice No.3	Provides guidance on the procedure to follow for notification prior to carrying out a geophysical survey.
Petroleum Operations Notice No.4	Comprises the pro-forma and accompanying guidance notes to use for an application for consent to drill exploration, appraisal and development wells.
Petroleum Operations Notice No.5	Comprises the pro-forma and accompanying guidance notes to use for an application to abandon or temporarily abandon a well.
Petroleum Operations Notice No.6	Comprises the pro-forma and accompanying guidance notes to use for an application to complete and/or workover a well.
Petroleum Operations Notice No.7	Specifies the definition of a well and the system to be used for numbering a well.
Petroleum Operations Notice No.8	Specifies reporting requirements in the event of an oil spill, guidance on the use of dispersants and provides contact numbers and reporting forms to use in case of oil pollution.
Petroleum Survey Licences (Model Clauses) Regulations 1992	The regulatory framework governing offshore exploration activity, including; field observations, geological and geophysical investigations, the use of remote sensing techniques, and sea floor sampling.
2) Relevant to environmental protection:	
Conservation of Wildlife and Nature Ordinance 1999	Replaces the Wild Animals and Birds Protection Ordinance of 1964. Protects wild birds, wild animals and wild plants, egg collection, prohibits the introduction of new species and designates conservation areas (National Nature Reserves). Fauna specified so far for protection are two species of trout and all species of butterflies. Protection of wild plants extends to 29 listed species, including those listed as threatened on the Falklands Red List (Broughton, 2002). National Nature Reserves can be designated to area of Crown land, marine area or privately owned land with the agreement of the owner. Marine areas may be designated in Falkland Islands territorial waters (12 nautical miles) or 3 nautical miles beyond, but no marine areas have been designated yet.
Control of Kelp Ordinance 1970	Makes provision for the licensing of seaweed harvesting and export.
Endangered Species Ordinance 2003	Upholds the CITES, and controls the import and export of species listed in the CITES.
Marine Environment Protection Ordinance 1995	Implements the conditions of the London Dumping Convention 1972 and prohibits, other than under license, the deposition or incineration of materials in Falkland Island waters. Is a system of licensing and licence offences with strict liability for certain loss or damage in relation to polluting incidents.

	The Deposits in the Sea (Exemptions) Order 1995, as approved under the Marine Environment Protection Ordinance, specifies categories of material exempt from requiring a licence for deposition. Includes sewage or domestic waste discharge from a vessel or platform, drill cuttings or muds under specific circumstances and the incineration of hydrocarbons.
Marine Mammals Protection Ordinance 1992	Prohibits the killing or taking of marine mammals (or to use explosives within the FOCZ where this is likely to cause harm to any marine mammal) on land or in internal waters, territorial sea or fishery waters of the Falkland Islands. It is unlawful to import or export marine mammals without a licence.
National Parks Ordinance 1998	Establishes the system for designation of National Parks, based on natural beauty and recreation value. No marine areas are being considered under this ordinance.
Waste Management Framework	Apart from siting of disposal sites under the 1991 Planning Ordinance, there is no regulatory framework specifically for waste management and disposal.

Other relevant environmental studies and strategies produced or currently in production by, or on behalf of, the FIG and Falklands Conservation include:

- Falkland Islands Environmental Baseline Survey Desk Study Report, Brown & Root Environmental 1997.
- Socio-Economic Study of the Falkland Islands, Coopers & Lybrand 1997.
- Falkland Islands Waste Disposal, Halcrow 1998;
- Falkland Islands Sustaining a Secure Future, FIG 2002;
- Falkland Islands Structure Plan 2001–2016, FIG 2004;
- Falkland Islands Biodiversity Strategy 2008–2018, FIG 2008;
- Falklands Islands State of the Environment Report, FIG 2008;
- Islands Plan 2008/011, FIG 2008.

2.2.1. Environmental Impact Assessment

The Offshore Minerals Ordinance 1994 PART VI 'Miscellaneous and General' provides the regulatory framework for requiring and undertaking an Environmental Impact Assessment (EIA) or Environmental Impact Statements (EIS) in the Falkland Islands. An EIA or EIS may be required if it is considered by the Governor that the environment might be substantially affected by the activity in question.

An EIA is an assessment commissioned by the Governor and carried out on his behalf. An EIS is a statement prepared by, or on behalf of, the applicant. The scope and content of an EIA and EIS are specified within Schedule 4 of the Offshore Minerals Ordinance 1994 and are essentially the same. An EIA commissioned by the Governor, however, does not have to go through a public review period, whereas an EIS submitted by an applicant will generally be required to go through a 42 day public consultation period.

Schedule 4 of the Ordinance specifies that the following information may be required within an EIA or EIS:

- description of the proposed development such as the location, and/or the design and size or scale of the development;
- identification and assessment of the likely impacts of the development on the surrounding environment;

- description of likely significant impacts, direct and indirect, on the surrounding environment; such as human beings, flora, fauna, seabed and subsoil, soil, water, atmosphere and air quality, climate, seascape or landscape, inter-action between any of the foregoing, material assets, and cultural heritage;
- description of management measures to avoid, reduce or remedy significant impacts; and
- non-technical summary of the information specified above.

Where public review is required, the statement is published in the Falkland Islands Gazette for a period of 42 days following government submission. Opportunities for public discussion, dissemination of information, and feedback from stakeholders will be available. In addition, the document is also presented to the Executive Council (ExCo) (**Figure 2-1**).

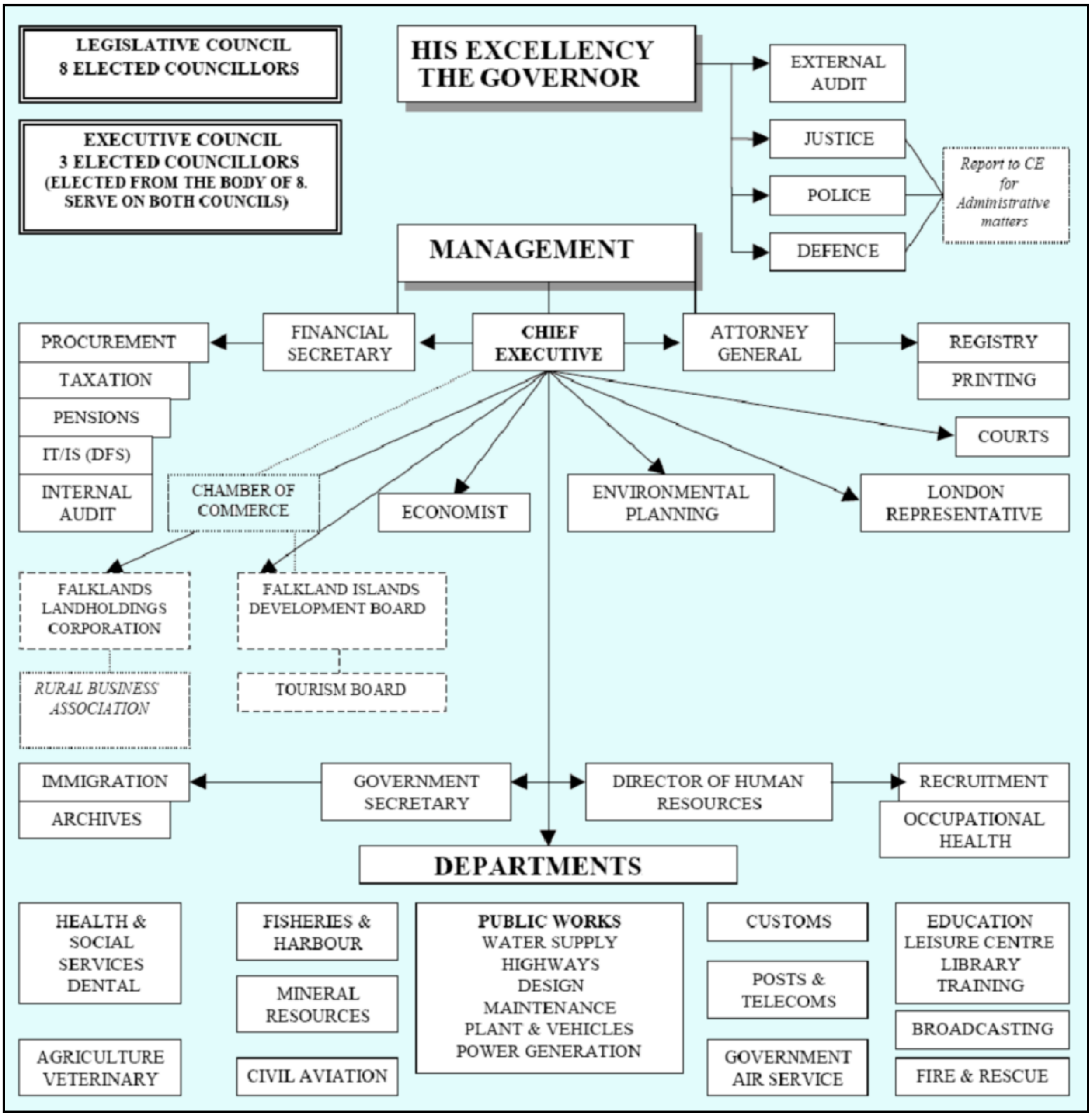


Figure 2-1 Falkland Islands Government organogram

(Adapted from diagram provided by FIG)

2.3. PETROLEUM INDUSTRY STANDARDS AND GUIDELINES

The following standards and guidelines, produced by the Exploration and Production (E&P) sector, are available either publicly (online) or just to members. Elements of the best practice guidelines will be utilised in developing the drilling operations specific EMP.

2.3.1. E&P Forum

Exploration and Production (E&P) Waste Management Guidelines (Report No. 2.58/196, Sept 1993)

Guidance on area-specific waste management planning, and handling and treatment methods of drilling and production waste streams.

2.3.2. E&P Forum / United Nations Environment Programme

Joint Technical Publication; Environmental Management in Oil and Gas exploration and Production 1997

An overview of environmental issues and technical and management approaches to achieve high environmental performance in oil and gas exploration and production.

2.3.3. IPIECA (International Petroleum Industry Environmental Conservation Association

The Oil and Gas Industry: Operating in Sensitive Environments

An oil industry association publication with the objectives of; demonstrating that minimal impact operations are achievable in a diverse range of environmental and social settings; actively encouraging exchange of company experiences and best practices; and providing a basis for discussion with groups outside the industry with a view to promoting ongoing improvements in industry performance.

3. STAKEHOLDER ENGAGEMENT

This EIS provides stakeholders with an understanding of the proposed drilling programme, rationale for drilling, the existing environment, the potential impacts from drilling, and the proposed mitigation and management measures. It also provides a means to gain feedback following the public review period.

The following stakeholders have been consulted through targeted meetings, correspondence, phone conversations, and presentations:

- Falkland Islands Government representatives
    - Environmental Planning Officer
    - Environmental Officer
    - Deputy Financial Secretary
    - 1st Sec Government House
    - General Manager FIDC
    - Chief Executive
    - Acting Attorney General
    - Director of Public Works
    - Director of Fisheries
    - Director of Minerals and Agriculture
- Other operators – Desire, Argos, Borders, FOGL/BHP
- Ministry of Defence (MoD)
- British Geological Survey (BGS)
- British Antarctic Survey (BAS)
- Falklands Conservation
- Local community

Meetings to address stakeholder concerns and provide information updates have been held in the Falkland Islands on three separate occasions in September 2005, February 2006 and September 2007. The agenda for the 2007 stakeholder trip included meetings with Government representatives, environmental organisations, the military, Councillors, Chamber of Commerce representatives, members of the public and local schools.

Issues of concern for this proposed drilling campaign include potential impacts on threatened species and restriction to access areas of high value for commercial fisheries. Potential impacts from this drilling programme are identified and assessed in the following chapters, together with proposed measures to manage the potential impacts.

Public consultation will also be undertaken, as per legislative requirements, for 42 days after the submission of this EIS.

Stakeholders have been, and will continue to be, consulted regularly throughout the proposed drilling programme.

4. ALTERNATIVES TO PROPOSED DRILLING PROGRAMME

A necessary part of the impact assessment process is the consideration of alternatives to the proposed activity. Many complex factors control the situation of oil wells (geology, topography, communications, and engineering technology), meaning only a few viable alternatives can be considered environmentally. Two simple alternatives may be to drill or not drill at all.

Processed and interpreted seismic data are used to indicate areas where hydrocarbons may be trapped in oil or gas-filled geological structures. Without exploratory drilling, seismic data is unable to confirm whether oil and gas are present, the volume of the reservoir, whether the hydrocarbons can be commercially extracted, or even the actual rock types. Hence, exploratory drilling is a necessary step in the development of commercial hydrocarbons and is a requirement under the terms of the production licence awarded to Rockhopper. The potential impacts from these activities and recommended mitigation measures are discussed in subsequent chapters.

Direct benefits to the region and country from the extraction of natural resources could include increased financial income and local business opportunities. Secondary or indirect benefits could be an increased standard of living, and better education, social services and amenities (for example, improved waste disposal). These benefits could also potentially raise awareness of environmental protection in the area.

The implications of not proceeding mean that the potential environmental and social impacts (positive and negative) from the drilling operations will not occur. The environment will not necessarily maintain its current baseline condition however, as impacts from fishing and vessel activity such as waste water discharge, sedimentation, fall-out of atmospheric pollutants, and ballast water discharge will still take place.

Should the drilling programme not proceed, the potential financial and social benefits of oil and gas production cannot be realised. Ultimately, no drilling would preclude development of offshore hydrocarbon resources with missed opportunities in business and economic investment.

Alternative drilling methods and types of drill unit exist and each have their own environmental impacts. The use of a dynamically positioned (DP) drill ship or semi-submersible drilling rig would minimise seafloor disturbance as anchoring would not be required (as in a traditional semi-submersible). Such a unit would however require continual positioning using thrusters and both fuel consumption and underwater noise would therefore be considerably higher than for an anchored unit. DP drill units are generally larger and more expensive than anchored units.

Directional drilling is also possible where the well cannot be positioned over the target reservoir, for example where the drilling target lies under an inaccessible or highly sensitive area. Directional drilling requires additional resources and time, is more complicated and more expensive than vertical drilling. It would only be considered where there is an exceptional reason why the well cannot be positioned over the target reservoir, which, taking full account of the baseline environmental and benthic data, is not considered to be the case in this instance.

Cuttings from the wells for this drilling campaign will be treated and disposed of to sea through the cuttings caisson (as water based muds will be used) in line with standard industry practice. Downhole injection of cuttings is not possible, as no suitable geological formation or old well exist to store the cuttings discharge.

For this project, a slim hole design is being utilised to minimise the generation of cuttings. In addition the use of water based muds, low toxicity chemicals and a solids control package on the rig will all mitigate the potential polluting impacts from cuttings disposal to sea.

5. PROJECT DESCRIPTION

Rockhopper proposes to drill one or two exploration wells within the licence area.

5.1. DRILLING RIG OVERVIEW

To establish whether hydrocarbons are present it is necessary to drill a well. Offshore wells are typically drilled by mobile drilling units of which there are three broad designs currently in use: drill ship, semi-submersible and jack up.

A semi-submersible drilling rig (Figure 5-1) is one of the commonly used designs of mobile drilling rigs worldwide and will be used to drill the well. Semi-submersibles float in deep water and provide a stable platform to allow drilling of the sea floor. Semi-submersibles reduce ‘heave’—the vertical motion of a vessel in response to the action of waves—by reducing the area of hull in contact with the water to a minimum. Vertical circular sectioned columns are fitted beneath the deck at each side, terminating in underwater pontoons hulls containing large tanks for ballast, fuel and fresh water. The columns and pontoon provide the buoyancy to keep the vessel afloat and some of the tanks can be flooded to lower the vessel to a sufficient depth in the water to maximise stability and minimise wave movements whilst drilling.

A typical semi-submersible drilling rig has dimensions of approximately 90 m by 80 m with a draught of about 30 m. Semi-submersible rigs are capable of operating in water depths well in excess of that to be encountered at the potential drilling location and can drill to depths in excess of 7500 m.

They carry a crew of up to 100 personnel and include offices, crew cabins, mess halls, recreation area, sickbay and control room.

To support the drilling operation bulk storage is provided for:

- Cement
- Fuel oil
- Liquid mud
- Bulk mud chemicals
- Drill water
- Potable water.

Although unlikely, it is possible that a drill ship may be used for the drilling operations (Figure 5-2). Drill ships are oceangoing vessels with a derrick mounted in the middle, over an opening for the drilling operation. They maintain station over the well bore or seabed location by means of an advanced dynamic positioning computer system which operates the ship’s propulsion system. It is also possible that anchors may be used to stabilise the drill ship.

Like the semi-submersible, the drill ship will carry a crew of up to 100 personnel and will have similar facilities available on board.

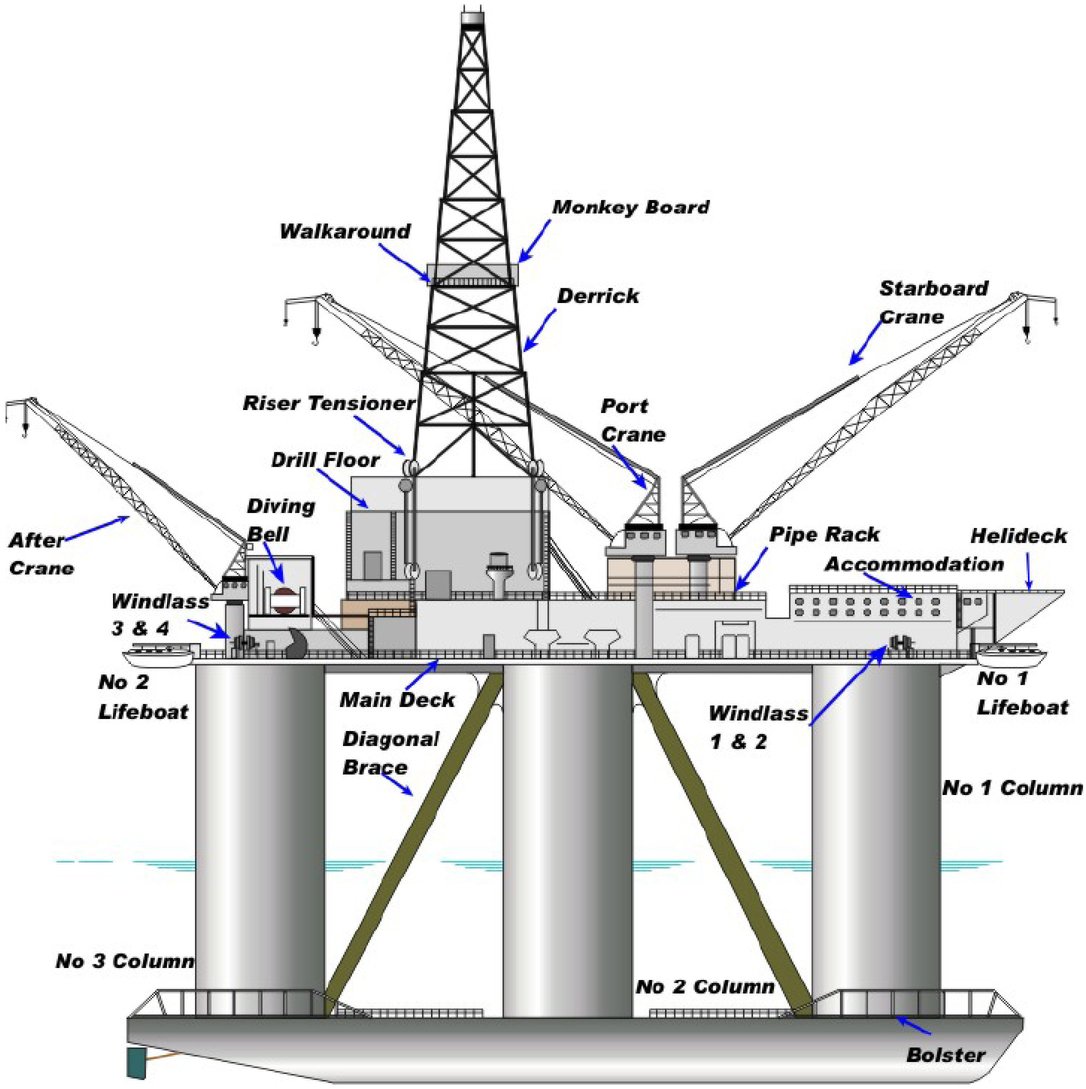


Figure 5-1 Typical semi-submersible rig layout

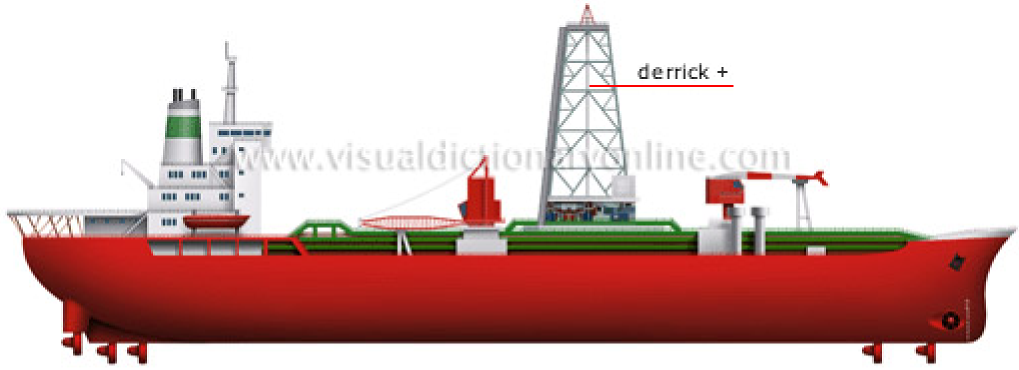


Figure 5-2 Typical drill ship

Source: www.visualdictionaryonline.com

5.2. PRE-DRILLING SURVEY

Site survey data analysis will provide information on:

- Bathymetry (water depths);
- Any obstructions that may be present on the seabed;
- Information on the seabed geological structure to help design and plan for the anchoring of the rig;
- The nature of shallow sediments to aid in anchoring;
- The potential for shallow gas deposits at the location which can be hazardous to drilling.

5.3. DRILLING TECHNIQUE

A conventional rotary drilling system will be used to drill the wells (Figure 5-3). This comprises a gantry like structure (the derrick) mounted on the drill floor. A hoisting drum or draw works is also mounted on the drill floor at the base of the derrick. A drilling line (made up of wire rope) passes from the draw works to the top of the derrick through a system of pulleys known as the 'crown block', and is finally attached via another series of pulleys (the travelling block) to the hook. The system operates like a crane and can be raised and lowered within the derrick.

Suspended from the hook is a top drive on to which the drill string is attached. The drill string is made up of uniform lengths of hollow steel pipe, screwed together. When the drilling starts, a rotary drilling bit is attached to the lower end of the drill pipe and lowered by the draw works through a rotary table mounted on the drill floor. The top drive provides the rotary motion for the drill bit.

5.4. WELL CONSTRUCTION

Wells are drilled in sections, with the diameter of each section decreasing with increasing depth. During the drilling of the upper well sections the drill string (also called drill pipe) and drill bit are typically left open to the seawater. However, before drilling lower sections of the well a hollow tube known as a 'marine riser' is run between the rig and the seabed with the drill string passing down the centre of the riser. Once a marine riser has been run the drilling mud can be returned to the rig, in the space (or annulus) between the drill string and the riser casing / open hole. The lengths and diameters of each section of the well are determined prior to drilling and are dependent on the geological conditions through which the well is to be drilled. Once each section of the well is completed, the drill string is lifted and protective steel pipe or casing lowered into the well and cemented into place. The cement requires several additives to ensure that the casing is safely adhered to the well bore. The casing helps to maintain the stability of the hole and also eliminates mud losses from the well bore into surrounding rock formations.

5.5. WELL DESIGN

As part of the well planning process, Rockhopper Exploration plc has retained SPD Ltd to provide a general well engineering basis of design (BOD) document. The conceptual well designs are shown in Figure 5-4 and Figure 5-5, with a diagram of the proposed casing setting provided in Figure 5-6 and Figure 5-7. For the purposes of the basis of design, it has been assumed that:

- The well will be drilled vertically to total depth (TD).
- Wireline logging programmes will be conducted for formation evaluation purposes in the hole sections below the surface casing shoe.
- In the event that hydrocarbons are identified in any of the targeted sandstones, core will be cut.
- No drill stem testing is currently planned.
- Upon completion of the TD data acquisition programme, the well will be permanently abandoned.

Although it has been assumed that no drill stem testing will be carried out, a brief description of how this operation would be undertaken, the potential impacts on the environment and any mitigation measures has been included here in case this situation changes. Drill stem testing is therefore included within this EIS as a contingency (see Section 5.10 for details on well testing).

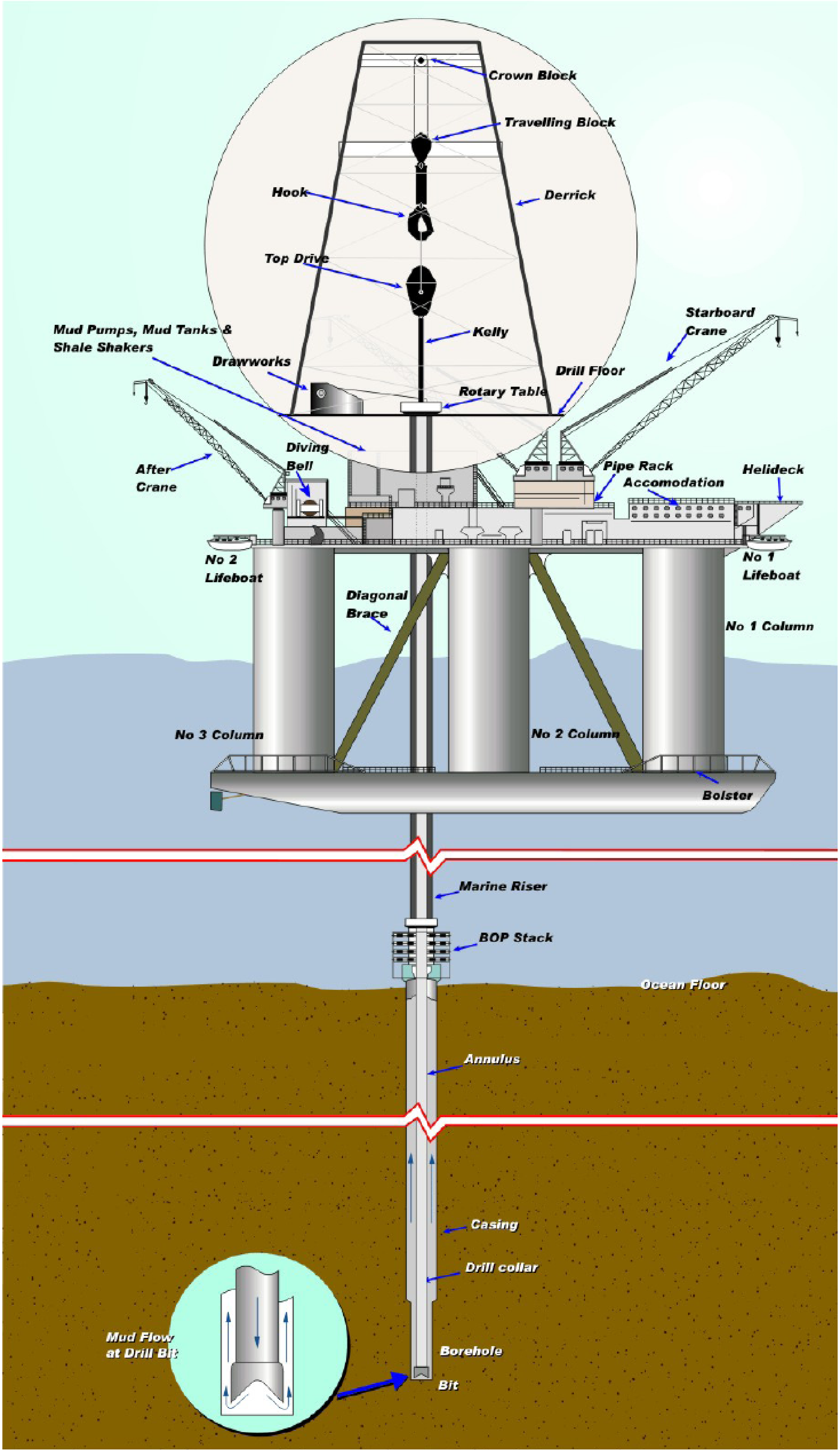


Figure 5-3 Rotary drilling technique

The recommended well design is as follows:

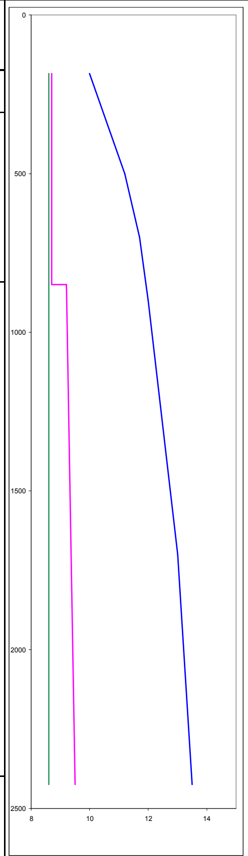
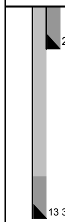
Table 5-1 Basis of Design for Ernest

Hole Size	Casing	Setting Depth (MDBRT)	Weight & Grade
Ernest			
36”	30” x 20”	185-270 m	Conductor pipe
17½”	20” x 13³/₈”	185-800 m	20”, 169 ppf, X-56, ALT-2 13 3/8”, 68 ppf, L-80, Dino Vam
12¼”	nil	TD	

Table 5-2 Basis of Design for Weddell

Hole Size	Casing	Setting Depth (MDBRT)	Weight & Grade
Ernest			
36”	30” x 20”	175-270 m	Conductor pipe
17½”	20” x 13³/₈”	175-340 m	20”, 169 ppf, X-56, ALT-2 13 3/8”, 68 ppf, L-80, Dino Vam
12¼”	nil	TD	

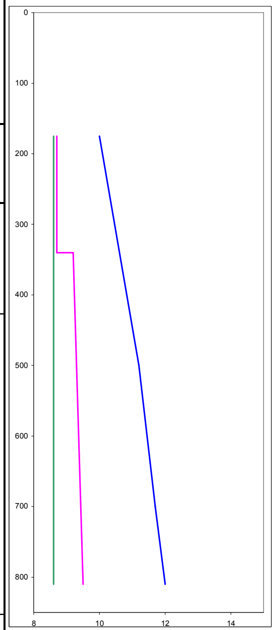
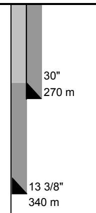
RIG	ELEVATIONS	SURFACE LOCATION	TARGET LOCATION	WELL TYPE	TOTAL DEPTH	WELLHEAD
TBA	RTE: ± 25 m (MSL) WD ± 160 m (MSL)	TBA	TBA	VERTICAL EXPLORATION WELL	2,425 m TVDBRT	TBA

m TVDBRT	AGE	FORMATION	Formation Tops (m TVDBRT)	Objectives & Coring	ROP	POTENTIAL DRILLING HAZARDS	PORE PRESSURE & FRACTURE GRADIENT (m TVDBRT)	CASING & CEMENT (m MDBRT)	Inclination	Hole Size	CASING & WELLHEAD	CEMENT	MUD	DATA ACQUISITION & SURVEY PROGRAMME
0														
	Tertiary	Tertiary	185		8.0	Losses with high density cement slurry		30" 270 m	0°	36"	30" x 20" conductor	Single Lite Slurry 12.5 ppg to mudline	Seawater + visc sweeps Displace to 10.0 ppg at TD	Survey: MWD LWD: Nil Wireline: Nil
500					20.0 20.0	Wash-outs in unconsolidated sands Flowing sands - Shake blinding and losses		13 3/8" 800 m	0°	17½"	20" x 13 3/8" Casing	Lead Slurry 12.5 ppg TOC: Mudline Tail Slurry 16.0 ppg 200m above shoe	Seawater + visc sweeps Displace to 10.0 ppg at TD	Survey: MWD LWD: GR Wireline: Nil
1,000 1,500	Cretaceous	Claystones and Sandstones	545		20.0 10.0	Flowing sands - Shake blinding and losses Tight hole / reactive clays Angle build due to formation dip			0°	12¼"	Leak-off test 11.0 ppge expected		KCI / Polymer WBM 9.2 ppg	Survey: MWD LWD: GR, Res Coring: If hydro-carbons present
2,000	Jurassic	Tuffaceous Claystones and Sandstones	1,975		10.0	Abrasive sands Ledging in interbedded formations							9.5 ppg	Wireline: 1. GR, res, neut, dens, sonic 2. MDT 3. Dipmeter 4. VSP 5. SWC
		Basement	2,365											
2,500		TD	2,425											

Objectives:	Cretaceous Sands	TD Criteria: TBA	**REMARKS:**
Target Tolerance:	TBA	Final Well Status : Plugged and abandoned.	1. The 13 3/8" casing setting depth has been selected to case off the flowing sands, and to provide sufficient formation strength to drill to TD.
Expected Hydrocarbons:	Oil	BOP Requirements: 18 3/4", 10,000psi subsea	
BHST Degrees C	± 105°C		
Temperature gradient:	4.5°C / 100m		
H_2S nil	CO_2 Unknown		

Figure 5-4 Conceptual Well Design for Ernest

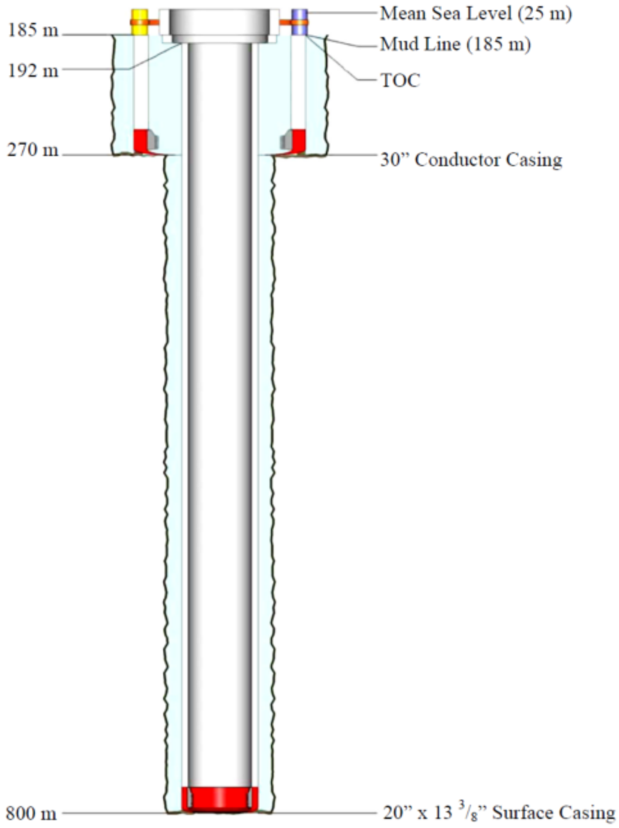
RIG	ELEVATIONS	SURFACE LOCATION	TARGET LOCATION		WELL TYPE	TOTAL DEPTH	WELLHEAD
TBA	RTE: ± 25 m (MSL) WD ± 150 m (MSL)	TBA	TBA		VERTICAL EXPLORATION WELL	835 m TVDBRT	TBA

m TVDBRT	AGE	FORMATION	Formation Tops (mTVDBRT)	Objectives & Coring	ROP	*POTENTIAL DRILLING HAZARDS*	PORE PRESSURE & FRACTURE GRADIENT (m TVDBRT)	CASING & CEMENT (m MDBRT)	Inclination	Hole Size	CASING & WELLHEAD	CEMENT	MUD	DATA ACQUISITION & SURVEY PROGRAMME
0														
250	Tertiary	Claystones, Sandstones and Thin Limestones	175		8.0	Losses with high density cement slurry			0°	36"	30" x 20" conductor	Single Lite Slurry 12.5 ppg to mudline	Seawater + visc sweeps Displace to 10.0 ppg at TD	Survey: MWD LWD: Nil Wireline: Nil
	Cretaceous	Claystones and Sandstones	270		20.0	Wash-outs in unconsilidated sands Flowing sands - Shakers blinding and losses			0°	17½"	20" x 13 3/8" Casing	Lead Slurry 12.5 ppg TOC: Mudline Tail Slurry 16.0 ppg 100m above shoe	Seawater + visc sweeps Displace to 10.0 ppg at TD	Survey: MWD LWD: GR Wireline: Nil
500 750	Jurassic	Tuffaceous Claystones and Sandstones	340		20.0	Tight hole / reactive clays Angle build due to formation dip Abrasive sands Ledging in interbedded formations			0°	12¼"	Leak-off test 11.0 ppge expected		KCl / Polymer WBM 9.2 ppg	Survey: MWD LWD: GR, Res Coring: If hydro-carbons present Wireline: 1. GR, res, neut, dens, sonic 2. MDT 3. Dipmeter 4. VSP 5. SWC
	Basement		800											
810	TD		835		10.0									

Objectives:	Cretaceous Sands	TD Criteria: TBA	**REMARKS:**
Target Tolerance:	TBA	Final Well Status : Plugged and abandoned.	1. The 13 3/8" casing setting depth has been selected to case off the flowing sands, and to provide sufficient formation strength to drill to TD.
Expected Hydrocarbons:	Oil	BOP Requirements: 18 3/4", 10,000psi subsea	
BHST Degrees C	± 34°C		
Temperature gradient:	4.5°C / 100m		
H_2S nil	CO_2 Unknown		

Figure 5-5 Conceptual Well Design for Weddell

5.6. CASING



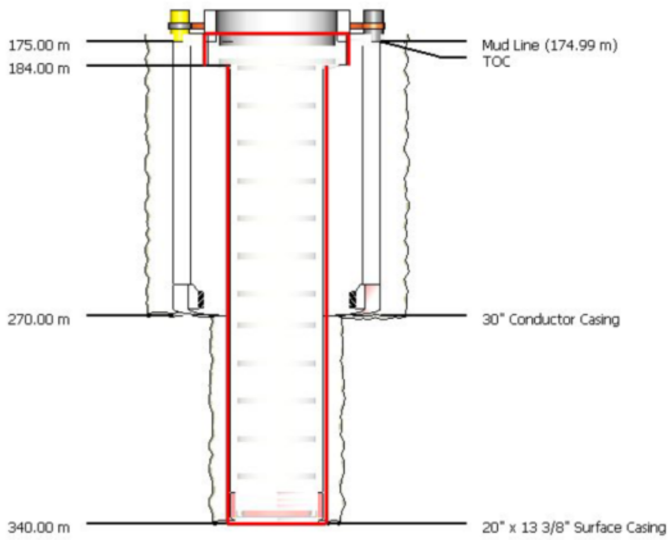


Figure 5-6 Casing setting diagram for Ernest

Figure 5-7 Casing setting diagram for Weddell

The casing seats have been selected for the following reasons:

<u>36" Hole and 30" x 20" Conductor Setting Depth</u>

A 36" hole will be drilled to allow a 30" x 20" conductor to be run and cemented. A 30" x 20" conductor is required for well loading and stability purposes.

The conductor setting depth has been selected as 85 m below the mudline for the following reasons:

- Conductors have been successfully set below this depth regionally. As such it can be concluded that drilling a 36" hole to this depth with seawater and viscous sweeps is a low-risk activity.
- The formation strength at this depth should be sufficient to hold a mud weight of 10 ppg (recommended spud mud weight), and allow returns to be taken to the seabed.

<u>17½" Hole and 20" x 13⅜" Casing Setting Depth</u>

The surface casing size has been selected as 20" x $13^3/_8$" in order to allow a contingency $9^5/_8$" casing string to run deeper in the well if required. This casing scheme allows the well sizes to be slimmed down (that is, a separate 20" casing string is not being used) while also preserving a minimum hole size of $8^1/_2$" through the reservoir.

The surface casing setting depth has been selected as approximately 700 m below seabed for the following reasons:

- **Formation Strength:** The casing seat should provide sufficient formation strength to allow the well to be drilled to TD in 12¼" hole section.
- **Flowing Sands:** The offset wells encountered significant surface mud losses when unconsolidated shallow sand returns led to shaker blinding. In order to avoid this problem in future, and to deliver the required formation strength as stated above, it is planned to set surface casing below these sand units.
- **Suitability:** The offset wells used seawater down to a depth of approximately 1500 m, (after surface casing was set) without encountering any major drilling problems. As such, it is concluded that the formations down to 800 m for Ernest, can be successfully drilled with seawater. Therefore, there are no drilling issues foreseen by extending the depth of the surface hole section from previous regional wells.

12¼" Hole and 9⅝" Casing Setting Depth

The $9^5/_8$" casing may be required for kick tolerance purposes, and this size has been selected to allow an $8^1/_2$" hole to be drilled to TD, if the $9^5/_8$" casing is run. The $8^1/_2$" hole size is considered optimal from a data acquisition perspective.

The 12¼" hole section will be drilled to TD unless the formation strength at the $13^3/_8$" casing shoe is lower than anticipated, and a $9^5/_8$" casing string is required for reasons of kick tolerance. Therefore, the actual setting depth and subsequent casing and hole sizes will be dependent upon formation strength obtained, and final anticipated reservoir target depths.

5.7. ABANDONMENT

After TD logging, the well will most likely be plugged and abandoned. Although it is very unlikely, the well may be suspended for re-entry.

The plugging and abandonment will be achieved by setting cement plugs across all open hole permeable formations, and then setting an additional cement plug inside the $13^3/_8$" casing. This design complies with the UKOOA Guidelines for the Abandonment and Suspension of Wells, and ensures that two independent cemented barriers are provided against all permeable and over-pressured formations.

Prior to leaving the location, the wellhead will be cut approximately 3 m below the seabed, and recovered to surface. An ROV seabed clearance survey will then be conducted, to confirm that the seabed is clear of debris.

5.8. DRILLING FLUIDS

5.8.1. Drilling Muds

During the drilling operations, a fluid known as drilling mud is pumped through the drill string down to the drilling bit.

Drilling mud is essential to the operation. It performs the following functions:

- The hydrostatic pressure generated by the mud's weight controls the down-hole pressure and prevents formation fluids from entering the 'well bore'.
- It removes the rock cuttings from the bottom of the hole and carries them to the surface

and when circulation is interrupted it suspends the drill cuttings in the hole.

- It lubricates and cools the drill bit and string.
- It deposits an impermeable cake on the wall of the 'well bore' effectively sealing and stabilising the formations being drilled.

The mud is recycled and maintained in good condition throughout the operation. The mud and suspended cuttings are processed on the platform through screens called 'shale shakers' to maximise recovery of the mud. A variety of chemicals may be added to the mud to serve the following functions:

- Fluid loss control. The layer of mud (wall cake) on the wall of the 'well bore' retards the passage of liquid into the surrounding rock formation. In water-based muds, bentonite is the principal material for fluid loss control although additional additives such as starch and cellulose, all naturally occurring substances, are also used.
- Lubricity. Normally drilling mud alone is sufficient to adequately lubricate and cool the bit. However, under extreme loading, other lubricants are added to prevent the drill string from becoming stuck.
- pH control. Caustic and lime are used to control the alkalinity of the mud to a pH of 9 to 10. This ensures the optimum performance of the polymers in the mud and controls bacterial activity.
- Pressure control. Barite (barium sulphate) is generally used as a weighting agent to control downhole pressure.
- Lost circulation. When drilling through some formations mud can be lost through fissures in the surrounding rock reducing the volume of mud returning to the rig to be cleaned and reused. Naturally occurring fibrous, filamentous, granular or flake materials are used to stop lost circulation when the drill bit enters a porous or fractured formation. Typical materials include ground nut shells and mica.

Two major types of mud are now typically used in offshore drilling:

- Water based mud (WBM) – water forms the continuous phase of the mud (up to 90% by volume);
- Low Toxicity Oil based mud (LTOBM) – base oils refined from crude oil form the continuous phase of the mud. This type of mud system is not considered suitable for use in this drilling campaign.

All chemical additives have been selected to minimise the potential environmental impacts as much as possible. The vast majority (by volume) of planned chemicals have a Harmonised Offshore Chemical Notification Scheme (HOCNS) category of 'E' (which are of low aqua toxicity, readily biodegradable and non-bioaccumulative) and are naturally occurring products (e.g. barite) that are either biologically inert or readily dispersible or biodegradable. Drilling muds for each hole section for the proposed Ernest well will be as described below. A similar system will be used for Weddell should it be drilled.

36" Hole Section

This hole section will be drilled with seawater and bentonite viscous sweeps, taking returns to the seabed. Bentonite is the preferred viscous sweep material due to its wellbore 'plastering' properties, which reduce the risk of large washouts.

At section TD, the hole should be displaced to 10 ppg mud, to maintain wellbore stability prior to running the conductor.

17½" Hole Section

The 17½" hole section will be drilled with seawater and bentonite viscous sweeps, taking returns to the seabed. Bentonite is the preferred viscous sweep material due to it's wellbore 'plastering' properties, which reduce the risk of large washouts.

At section TD, the hole should be displaced to 10 ppg mud, to maintain wellbore stability prior to running the $13^{3}/_{8}$" surface casing.

12¼" and Contingency 8½"Hole Sections

For environmental and logistical reasons, water based drilling fluid systems are most suited to remote locations such as the North Falklands Basin. These drilling fluids and associated solids may be discharged to sea under permit, and additional volume can also be built on the rig. The drilling fluid system used in previous wells was a water / glycol based polymer mud system, and these fluids provided an acceptable level of chemical inhibition for the formations encountered.

Having selected water based mud as the preferred fluid type, consideration must be given to which type of water based mud is the optimal solution. As there are no halites present, salt saturated muds are not required, and the level of inhibition required to maintain satisfactory wellbore conditions suggests that enhanced systems such as silicate based muds are not necessary. However, some tight hole and poor hole cleaning conditions did occur, therefore, it is recommended that a water based mud based on the following generic components is selected:

- KCl based fluid for chemical inhibition
- Polymer addition (such as PHPA) for clay cuttings encapsulation
- Glycol for hydrate suppression and fluid lubricity
- Lime, for H_2S neutralisation, should it be present (not expected).

5.8.2. Cement

Cementing chemicals are used to seal the well casing in place and provide cement design support by:

- Obtaining a strong casing shoe, and isolating all weaker formations drilled in the previous hole section;
- Providing structural support;
- Providing annular isolation of permeable formations (where allowed by trapped pressure considerations);
- Minimising abandonment costs.

5.9. WELL CONTROL AND BLOW-OUT PREVENTION

In addition to careful monitoring and control of the fluid system and installation of casing in each section of the well, a blow-out preventer stack (or BOP) consisting of a series of individual preventers will be installed on the wellhead at the seabed after the top hole sections have been drilled.

The function of the BOP is to prevent uncontrolled flow from the well by positively closing in the well-bore, if flow from the well-bore is detected. The BOP is made up of a series of hydraulically operated rams and can be operated in an emergency from the drill rig.

The well is not anticipated to encounter any zones of abnormal pressure and the BOP will be rated for pressures well in excess of those expected to be encountered in the wells.

During drilling operations small amounts of BOP fluid are typically discharged every two weeks, during testing of the BOP.

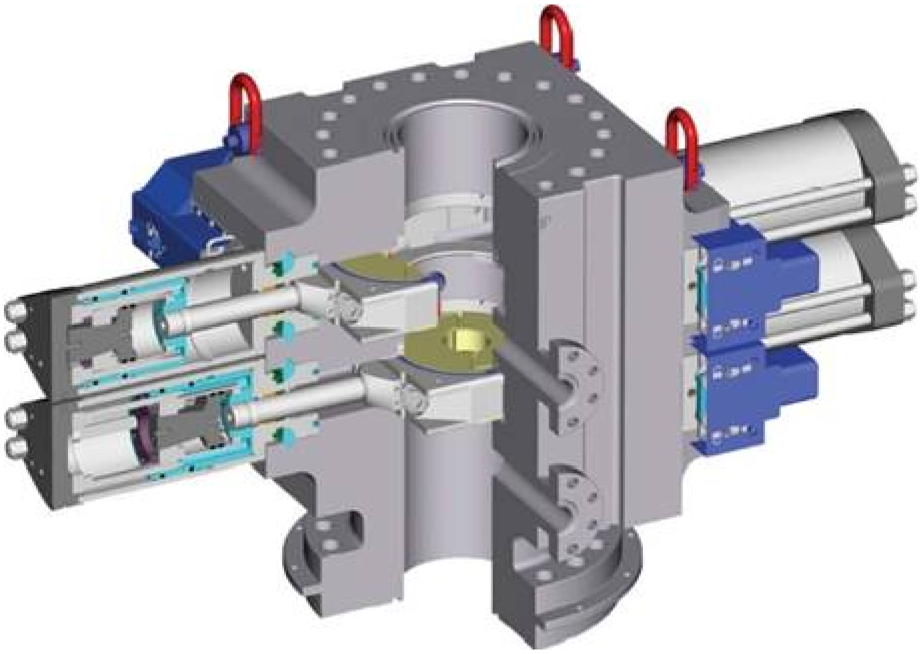


Figure 5-8 A Schaffer blow out preventer stack

5.10. WELL TESTING

If the results of logging indicate a potential for hydrocarbon bearing formations, the well may be tested. As it is currently unknown whether well tests will be undertaken, the potential impacts from this aspect have been included as a precautionary measure. Well testing is carried out in accordance with a Testing Programme and subject to the same approvals as the Drilling Programme.

Technical management of the programme is undertaken by the testing engineer to safely meet the programme objectives.

During well tests, formation fluids are brought to the surface where pressure, temperature and flow rate measurements are made to evaluate the characteristics of well performance. Following testing, hydrocarbons will be sent to the burner boom for disposal by flaring as this is the only practical handling option for the hydrocarbons. Flaring may be initiated using diesel or similar fuel to ignite the mixture. It is intended to use a high efficiency burner to flare the oil during well testing and minimise, as far as practically possible, the release of unburnt hydrocarbons. This will minimise any oil drop-out to sea. Should a visible surface sheen result from hydrocarbon drop-out during flaring, this will be reported through the PON / EEMS systems to FIG.

Should well testing take place it is estimated that the total testing period would be +/- 9 days per well. During this period it is likely that the burning of hydrocarbons would occur for a maximum of a few days per well.

5.11. SUPPORT OPERATIONS

The drilling rig will be supported by two supply vessels operating out of a supply base, anticipated to be in Stanley, which will keep the rig stocked with the items needed to carry out its operations.

In addition, a safety standby vessel will be stationed in the vicinity of the rig for the duration of the drilling programme. A safety standby vessel must be able to accommodate the entire complement of the rig and, if required, will come alongside the rig to assist.

A helicopter will be used for routine maintenance and crew change transfers, and/or any emergencies that require air-lifts.

6. OPERATIONAL ASPECTS

This section describes the operational aspects of the proposed drilling programme based on the operational description given in the preceding chapter.

Aspects of the proposed operations likely to interact with the environment can be categorised as those likely to result in:

- Emissions to air
- Releases to water
- Waste production
- Physical presence
- Resource use

A detailed assessment of the environmental impacts (positive and negative, direct and indirect) likely to result from these aspects is provided in Section 8.

6.1. EMISSIONS TO AIR

Emissions to air from the drilling operations will arise from both primary (direct) and secondary (indirect) emission sources. Primary emissions can be further divided into controlled and uncontrolled emissions:

Controlled Primary Emissions:

- Exhaust emissions (engines, compressors and generators)

Uncontrolled Primary Emissions:

- Flaring
- Noise emissions

Secondary Emission Sources:

- Onshore support services
- Transport emissions (crew changes)

The most significant emission stream will be exhaust gases from combustion. Emissions to air from the combustion of fuel in engines, compressors and generators include:

- Carbon dioxide (CO_2)
- Nitrogen oxides (NO_x, N_2O)
- Sulphur oxides (SO_x)
- Methane (CH_4)
- Volatile organic compounds (VOC)
- Carbon monoxide (CO)
- Particulate material

CO_2 and CH_4 are the two principal greenhouse gasses (GHGs).

Power requirements on the rig will be supplied by diesel generators. In addition to the main power generators an emergency back-up generator will be on-board. Smaller generators may also serve specific purposes, for example to provide power for cementing operations. Estimated fuel use for each stage of the drilling programme is given in Section 6.4; Resource Use.

Based on estimated fuel consumption, emissions of CO_2 can be calculated using 'Tier C Methodology'. This methodology uses emissions models to predict potential emissions based on fuel use. While it is the least accurate tier of emissions modelling, it does not depend on equipment specifications, fuel analysis or monitoring (none of which are available at this time) to run the model.

Guidance on emission factors is published by the offshore industry in 'Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions'. This guidance, produced on behalf of the International Petroleum Industry Environmental Conservation Association, the International Association of Oil and Gas Producers, and the American Petroleum Institute, takes emission factors from 'The Compendium of Greenhouse Gas Emissions Methodologies for The Oil and Gas Industry' (API, 2004).

Table 6-1 is based on the CO_2 emissions from fuel consumption estimates potential carbon dioxide emissions from expected fuel consumption based on drilling two wells using a semi-submersible. CO_2 emissions to the atmosphere are likely to increase if a drill ship is used as they consume more fuel than semi-submersibles.

Table 6-1 Potential CO_2 emissions from fuel consumption (semi-submersible)

Area of use:	Fuel	Fuel consumption		Carbon emission factor from original source document*		Estimated CO_2 emission (tonnes)
		M3	TJ	Emission Factors	Source	
Drilling Rig	Diesel / Gas Oil	1200	45.84	70.4 tonnes CO_2/TJ	IPCC 1996	3227.13
Vessels		4131	157.79			11,108.51

Based on 100% oxidisation of carbon content, with a Higher Heating Value (HHV) for diesel of 3.82×10^{10} J/m^3[2] and a combustion emission factor of 70.4 tonnes/TJ (HHV) for diesel

Flaring emissions from possible well testing are likely to produce the greatest levels of non-methane VOCs, and low levels of CH_4, SO_X, NO_X and CO. Hydrocarbons burned during well tests may significantly add to operational atmospheric emissions, although each well test event would be relatively short-lived. Further details on well test emissions cannot be provided without information on flare tip design and fuel type.

Fugitive emissions may arise from loading and unloading of materials, chemical use, possible chemical or oil spills, leaks from seals and flanges, poor housekeeping practices (for example containers left unsealed) and from small-scale engineering and maintenance operations such as welding.

These small scale emissions cannot be accurately quantified, but can be minimised by good maintenance and housekeeping practices and by following operational controls for loading and unloading.

Airborne noise will be generated by all phases of the programme including drilling and power generation, vessel movements and helicopter use. The main potential impact of airborne noise will be disturbance to wildlife from helicopter transfers. There are a number of wildlife avoidance areas around the Falklands which are shown in Figure 7-28, adapted from information provided by the Defence Geographic Centre (part of the UK MoD).

Wildlife avoidance areas currently apply primarily to military flights and use of helicopters, although they will be equally applicable to helicopter movements to and from any vessels or drill

[2] Refer to the GHG Emissions Compendium for a full description of calculation methodologies, factors and assumptions (API 2004)

units operating offshore the Falkland Islands. These areas are shown in full on map GSGS 5563, Falkland Islands range and avoidance areas, Edition 4, as produced by the UK MoD (classified). Impacts to seabird and marine mammal colonies from helicopter transfers can be mitigated through pre-selecting routes to avoid sensitive areas and important times of year for those species.

Secondary emissions from support services, transport and manufacturing are referenced here, but not quantified. Extensive pre-planning has been undertaken to ensure that the required equipment, materials and personnel are available at the right location and time. A drilling management company will be used to ensure sufficient materials are available and unnecessary waste is minimised through detailed resource planning. Accurate planning and project implementation help to minimise unnecessary emissions from secondary sources.

Rig crews will be transferred to and from the rig by helicopter. Typically around three scheduled flights will be made to the rig every two weeks from Stanley, with additional flights as required for rapid transport of personnel or equipment to or from the rig.

6.2. EMISSIONS TO WATER

Aspects of the drilling programme that are likely to discharge into the marine environment can be divided into controlled and uncontrolled emissions. Uncontrolled emissions to water encompass those from both routine operations and abnormal/emergency situations. Controlled emissions include:

- Domestic (grey) water discharge (from showers, basins, laundry)
- Sewage (black water) discharge
- Discharge from bilges and machinery spaces via the oily water separator
- Macerated food waste
- Discharges from the solids control system

Uncontrolled releases include routine discharges from deck run-off and vessel wash waters together with abnormal releases such as potential flare drop-out during well testing, release of fire-suppressing foam, oil spills, chemical leaks and accidental solid waste discharges.

6.2.1. Controlled

Sources of controlled discharges from the rig drainage system are illustrated in Figure 6-1.

Sanitary wastes such as black (sewerage) and grey water (showers and washing facilities) will contain detergents and cleaning agents from toilets and showers, together with human waste. All black water is routed via sewage treatment systems before being discharged to sea. Sewage treatment includes both maceration and chlorination prior to discharge.

An estimated 0.22 m^3/day of grey water and 0.10 m^3/day of black water will be generated by each person on board the rig and vessels (based on previous modelling and assumptions for offshore drilling operations (BP, 2002)). Estimated discharge levels for grey and black water from the drill rig are presented in Table 6-2.

Table 6-2 Estimated daily quantities of grey and black water discharge

	Well 1
Ave. No. rig based personnel	100
Grey water produced (m^3)	**22**
Black water produced (m^3)	**10**

Bilge water and drainage from machining and engineering areas are likely to be contaminated with hydrocarbons and/or chemicals. Waste water from these areas will be separated from clean water drainage and routed to the oily water treatment system onboard.

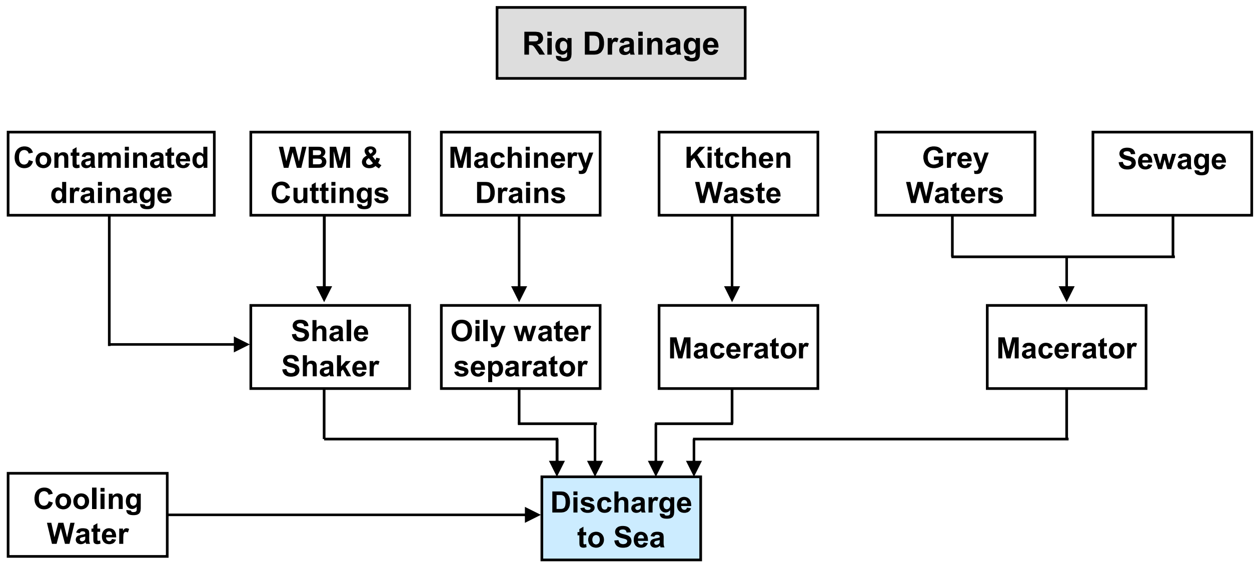


Figure 6-1 Flow diagram of rig controlled drainage

6.2.1.1. Cuttings

The 36" and $17^1/_2$" surface hole will be drilled using seawater with cuttings discharged to the seabed. Subsequent sections of the well will be drilled using a marine riser system to allow cuttings to be returned to the rig for treatment prior to discharge through the cuttings caisson.

Discharged cuttings will contain trace amounts of (water based) drilling muds and chemical additives used in the drilling process.

Approximate volumes of drill cuttings discharge that may be generated by the proposed drilling programme, based on the targeted hydrocarbon play and target depth are presented in Table 6-3 and Table 6-4.

Table 6-3 Expected volumes of drill cuttings discharge

	Ernest		
Hole Size (in)	**36"**	**17½"**	**12¼"**
Depth from (m)	185	270	800
Depth to (m)	270	800	2425
Footage (m)	85	530	1625
Cuttings Volume (m^3)	55.82	82.24	123.56
Excess (%)	50	25	25
Total Volume Discharged (m^3)	**83.73**	**102.81**	**154.45**
Cuttings Density (MT/m^3)	2.6	2.6	2.6
Total Weight Discharged (MT)	**217.69**	**267.30**	**401.57**
Discharged:	To seabed	To seabed	To sea

Weddell			
Hole Size (in)	**36"**	**17½"**	**12¼"**
Depth from (m)	150	235	340
Depth to (m)	235	340	810
Footage (m)	85	105	470
Cuttings Volume (m^3)	55.82	16.29	35.74
Excess (%)	50	25	25
Total Volume Discharged (m^3)	**83.73**	**20.37**	**44.67**
Cuttings Density (MT/m^3)	2.6	2.6	2.6
Total Weight Discharged (MT)	**217.69**	**52.95**	**116.15**
Discharged:	To seabed	To seabed	To sea

Table 6-4 Summary of expected weight of drill cuttings discharge

Well	*36" Hole*	*17 1/2" Hole*	*12 1/4" Hole*
Ernest	217.69	267.30	401.57
Weddell	217.69	52.92	116.15
Total	**435.38**	**320.22**	**517.72**

Drill cutting modelling has been undertaken based on the hydrodynamic model produced for the North Falkland Basin. Full results of the modelling are provided in Appendix II. A summary of the results of the cuttings plume and potential build-up of a cuttings pile are provided in Section 8.3.1.2.

6.2.2. Uncontrolled

Uncontrolled discharges include oil and chemicals spills (either direct to water or within deck wash-down water), release of fire suppressing foam during emergencies or simulations and flare drop-out from well tests. At this time no well testing is planned, although the potential impacts have been considered to account for any variation in operational planning.

6.2.2.1. Major Oil Spills

The risk of a major spill from a blow-out or loss of well control is the greatest environmental threat. Although unlikely to occur, the impact of a major spill on the natural environment could be extremely damaging. Hydrocarbon spills of varying sizes and types could also result from related operations including the bunkering of fuel oil, the storage and handling of oil drums or faults in the oil/water separator and the rig drainage system.

The greatest number of oil spills from offshore oil and gas activity are of small volumes (<1 tonne) and from non-emergency situations. Table 6-5provides a breakdown of the quantities of oil spilled in UK waters from 1994 to 2004.

Table 6-5 Oil spill volumes from offshore installation in UK waters

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total Amount Spilled (tonnes)	174	84(2)	127	866	137	120	524	94	96	113	75
Amt of Spills > 1 tonne	-	-	-	26	14	21	18	17	18	10	13
Amt of Spills < 1 tonne	-	-	-	323	378	-	405	419	463	365	425
Total Number of Oil Spill Reports	147	145	300	349	392	372	423	436	481	375	438

(DTI Oil and Gas Directorate website)

The highest probability, therefore, is for a small operational spill of fuel oils such as diesel. Oil spill trajectory modelling has been carried out based on the hydrodynamic model for the North Falklands Basin. Details of the various oil spill scenarios and trajectory modelling are included in Appendix III. A summary of the results of the modelling exercise are provided in Section 8.3.2.2.

The spill scenario for modelling was based on a continuous release of 1000 m^3 per hour for 12 hours. Two different simulations were run to account for both historic wind data and also a theoretical constant wind speed and direction. The latter provided an indication of the movement of any spill and could incorporate theoretical events such as a continuous 8 day northerly to show potential beaching areas, whereas the former provided an estimation of the frequency of occurrence of similar events.

Detailed modelling carried out for the Ernest and Weddell drilling prospects showed a very low probability of beaching from the proposed well locations.

Based on these findings an Oil Spill Contingency Plan (OSCP) will be developed specifically for the drilling operation. This will focus on treatment at source and offshore remedial action for a major spill from drilling activity, however as the risk of a beaching incident from the drilling location cannot be completely discounted, the need for additional training and shore-based resources will also be incorporated.

Large spills can only occur as a result of a loss of well control or blow out. Historically, the worldwide frequency of blow outs is approximately 0.0063 per well, or 1 in every 159 wells (Holland, 1997). However, in the UK over 3500 exploration, appraisal and development wells have been drilled from 1997 to 2008 (includes mechanical sidetracks, DECC website) with no major blow outs. The probability of a blow out during drilling in the Falklands is therefore very low.

Any large release of oil constitutes a major potential impact and further investigation of the likelihood, potential impacts and recommended mitigation measures to address this aspect is provided in Section 8.3.2.

6.2.2.2. Operational Spills

It is more likely that minor spills of hydrocarbons, chemicals or drilling mud may occur than of a blow-out major spill. Operational spills may arise from bunkering operations (offshore or in port), failure in the solids control system or container and equipment leaks.

Small scale spills from vessel movements and loading / unloading operations in port pose a greater risk to the near shore environment than a major spill in PL023 and PL024. The use of standby vessels with spill response capability (both booms and dispersant spraying equipment) rotating between Stanley and the drilling location ensures that a first tier response will be available at both the well site and port area at all times.

6.3. WASTE MANAGEMENT

Waste streams likely to originate on the rig are summarised in Table 6-6. Expected waste types are based on previous experience, operational planning waste manifests from similar operations in the UK.

Waste from the rig can be broadly divided into the following broad classifications:

- non-hazardous combustible solid waste such as paper, wood and cardboard
- non-hazardous, non-combustible waste such as scrap metal
- hazardous solid waste such as paint cans and empty chemical containers
- hazardous liquid wastes such as oily wastes, paint and solvent residues.

Table 6-6 Waste materials likely to be generated from drillings operations

<table>
<tr><th colspan="2">Likely waste types</th><th>Details</th></tr>
<tr><td colspan="2">Empty Chemical Drums</td><td>May contain residues</td></tr>
<tr><td colspan="2">Fluorescent Tubes</td><td>Special waste in large numbers</td></tr>
<tr><td colspan="2">Oil Contaminated Solids</td><td>Oily rags, filters, soak ups etc</td></tr>
<tr><td colspan="2">Batteries</td><td>Nicad, Lead Acid, Lithium, Household</td></tr>
<tr><td colspan="2">Waste oil</td><td></td></tr>
<tr><td colspan="2">Helifuel</td><td></td></tr>
<tr><td colspan="2">Waste Paint</td><td>Solvent based, Water Based</td></tr>
<tr><td colspan="2">Thinners</td><td></td></tr>
<tr><td colspan="2">Flammable Liquids</td><td></td></tr>
<tr><td colspan="2">Flammable Solids</td><td></td></tr>
<tr><td colspan="2">Chlorinated Solvents</td><td></td></tr>
<tr><td colspan="2">Water Based Mud Slops</td><td></td></tr>
<tr><td colspan="2">Corrosion Inhibitors</td><td></td></tr>
<tr><td colspan="2">Aerosols</td><td></td></tr>
<tr><td colspan="2">Gas Cylinders</td><td></td></tr>
<tr><td colspan="2">Brines</td><td></td></tr>
<tr><td colspan="2">Low Hazard Solids</td><td>Cement, Barites etc</td></tr>
<tr><td rowspan="3">From Well Test Operations
(if undertaken)</td><td>MEG</td><td>(Mono ethylene glycol)</td></tr>
<tr><td>TEG</td><td>(Triethylene glycol)</td></tr>
<tr><td>Mercury</td><td></td></tr>
</table>

The drill rig and associated vessels are likely to generate the following volumes of waste **per well** on average (as per waste manifests from similar UK wells):

- General Waste (timber, old pallets, and dunnage) – estimate 40 metric tonnes (MT)
- Compacted waste (office debris/kitchen waste) – estimate 5 MT
- Empty drums (possibly hazardous) – estimate 10 MT
- Waste oil – estimate 4000 litres

- Scrap Iron / cut casing – varies between operations
- Old slings / shackles / lifting gear – varies between operations
- Hazardous waste (batteries/chemicals) – varies between operations.

It is currently Rockhopper's intention to recycle and/or dispose all solid waste, other than hazardous wastes, in the Falkland Islands. Hazardous waste will be safely contained and appropriately packaged for transportation by a licenced hazardous waste management contractor.

All waste transfers from the rig will be fully documented in line with rig procedures and relevant international regulatory monitoring and reporting procedures. Operational controls will be used to ensure the transfer of waste skips follows best practice (fugitive releases are minimised by covering skips, any necessary health and safety documentation accompanies hazardous wastes, wastes are kept segregated throughout transfer etc).

Rockhopper will ensure that the licenced waste management contractor has obtained all necessary permits and approvals required for transboundary movement of hazardous waste. Any bilateral / regional agreements, the Basel Convention (Table 2-1) and the waste shipment regulations of the destination country will be taken into account and adhered to. Detailed waste management plans will be developed and implemented when a licensed waste management contractor has been selected.

6.4. PHYSICAL PRESENCE

Offshore structures can also act as an obstacle to migrating marine fauna such as whales, while mobile facilities such as support vessels can present a collision hazard. The potential for physical disruption to marine species is limited by the small footprint of the rig and limited duration of the drilling campaign.

Drilling facilities and equipment, such as anchors and the drill bit, will also physically impact the seabed and the existing benthos. However the small footprint and short-lived nature of the operations will mitigate potential impacts to the seafloor.

PL023 lies within the medium catch level of the *Illex argentinus* squid, and may potentially disturb the commercial fishing in this area. However, due to the short duration of the drilling and as the majority of the fishing area for the Illex lies to west of the licence areas it is unlikely that the disturbance will be significant.

Very low levels of shipping in the area mean that there is not likely to be any potential disturbance to on-going shipping operations.

6.5. RESOURCE USE

Based on operational planning of personnel requirements, mobilisation times and drilling schedules, the expected consumption of drilling water, potable water and fuel for drilling the proposed Ernest and Weddell wells is estimated in Table 6-7. The estimates have been based on the drilling campaign using a semi-submersible. More fuel will be consumed should a drill ship be used (estimate 20–40 tonnes / day).

Table 6-7 Expected resource consumption

Resource Use (m^3)		Mobilisation (31 days)*	Ernest (22 days)	Weddell A (18 days)	Demob (31 days)*	TOTAL (m^3)
Rig	**Drillwater**	155	1276	924	140	**2495**
Rig	**Potable Water**	404	551	399	358	**1712**
Rig	**Fuel**	2125	1160	840	1909	**6034**
Supply Vessel #1	**Fuel**	1085	180	147	1085	**2497**
Supply Vessel #1	**Potable Water**	62	30	25	50	**167**
Supply Vessel #2	**Fuel**	372	180	147	372	**1071**
Supply Vessel #2	**Potable Water**	62	30	25	62	**179**
Standby Vessel	**Fuel**	48	45	37	30	**160**
Standby Vessel	**Potable Water**	32	30	25	20	**107**
Total Fuel Burn		**3630**	**1565**	**1171**	**3396**	**9762**
Total Drillwater Requirement		**155**	**1276**	**924**	**140**	**2495**
Total Potable Water Requirement		**560**	**641**	**474**	**490**	**2165**

* - Mobilisation and demobilisation is for the entire Rockhopper drill campaign and includes time and resources for the proposed wells in PL032 and PL033.

Based on the calculations for the proposed drilling campaign, it is estimated that around 988 litres per day of Helifuel will be used (based on an average of three weekly maintenance trips to the rig).

Primary resource consumption during the drilling campaign will comprise:

- food and water for crew
- drilling and cementing materials
- drilling water
- fuel oil and Helifuel
- paints and solvents
- water based muds
- engineering and maintenance consumables (welding rods and rags etc).

Secondary resource consumption is expected to comprise:

- flights / transfers
- helicopter support
- personnel transfer station
- emergency response facilities.

Estimated figures for likely consumption have been provided for water consumption, fuel use, and operational materials. Data on other resource areas cannot be realistically estimated at this stage of planning. Secondary resource consumption and use of food, paints and solvents, contingency chemicals and maintenance consumables have not been detailed here and are expected to be minor.

7. EXISTING ENVIRONMENT

This section describes the key physical, biological and socio-economic values of the marine environment within and adjacent to the proposed drilling locations. Where required, details of coastal, inter-tidal and terrestrial resources relevant to the drilling operations have been included.

Data has been sourced from:

- Desktop literature review – including publicly available material on websites and previous EIA's submitted for the region.
- Falkland Islands Environmental Baseline Surveys, 1997 and 2004.
- State of the Environment Report, 2008.
- Joint Nature Conservation Committee (JNCC) and Falklands Conservation publications.
- Consultation with relevant FIG authorities and stakeholders.
- Benthic Field Survey (August 2008)
- Client data

7.1. PHYSICAL ENVIRONMENT

The proposed drilling locations are in the North Falkland basin approximately 100 km north of the main Falkland Islands in the South Atlantic Ocean.

7.1.1. Meteorology

Meteorological data for offshore Falkland Islands area is sparse, relative to other explored offshore areas, but the following available data has been reviewed:

- UK Meteorological Office data from vessel observations and weather station locations on the Islands;
- Baseline surveys, 1997 (Brown and Root) and 2004 (Falklands Conservation);
- Hydrographer of the Navy pilot information (1993);
- Published article in Aquatic Conservation Journal (Upton and Shaw, 2002).

Reviews indicate that the Falklands have a cool temperate oceanic climate, dominated by westerly winds. As the Falklands lie to the north of the Antarctic Polar Front (APF) or Antarctic Convergence, where cool surface waters to the south meet warmer surface waters from the north, the climate is moderate preventing prolonged snow and ice cover (Munro 2004). The region is exposed to an almost unbroken series of meteorological depressions and troughs that move across the area (Hydrographer of the Navy, 1993).

7.1.1.1. Temperature

The Falklands have a narrow terrestrial temperature range with mean annual maximum temperatures of approximately 10°C, mean annual minimum temperatures of approximately 3°C, and mean monthly ranges of between –5°C to 20°C (Figure 7-1). Temperatures over the open sea are less variable than on land.

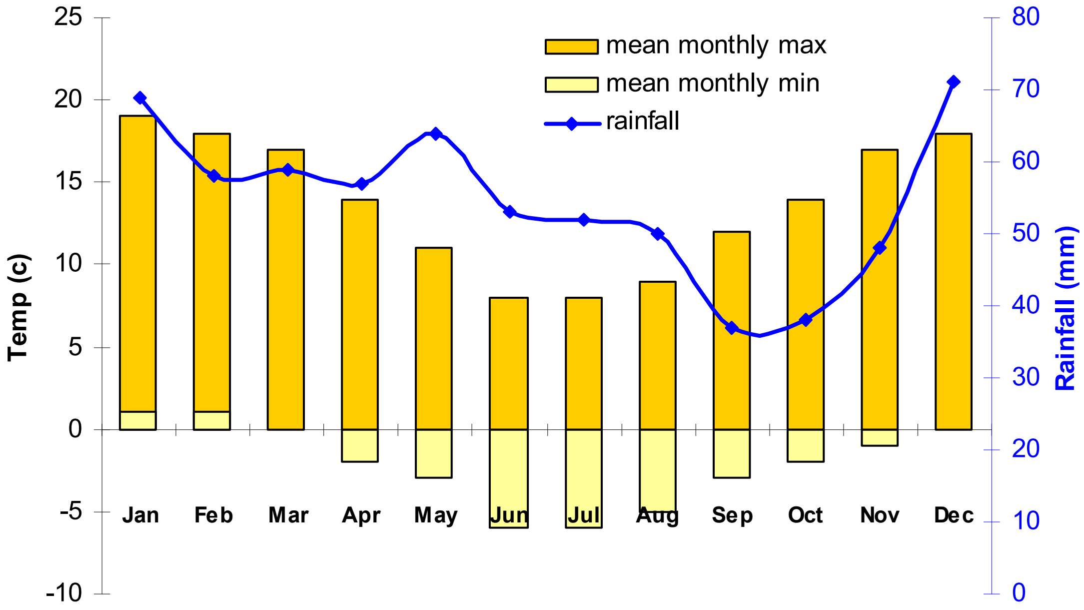


Figure 7-1 Climate Averages for Stanley Harbour

7.1.1.2. Precipitation

Figure 7-1 shows the average monthly rainfall for Stanley Harbour, the proposed supply base. Average annual rainfall for the Falklands is low but consistent, and due to their location in the lee of the South American continent, the ‘rain shadow’ effect of the Andean cordillera is still prevalent (Munro, 2004).

Average annual rainfall at Stanley is around 650 mm and decreases to the north of the Falklands. Less than 650 mm average annual rainfall is expected at the proposed drilling locations.

The Falklands experience approximately 11 days of snow a year, most frequently in August. Weather conditions in the North Falkland Basin are less extreme than further south, with the frequency of both violent storms and squalls increasing south of 50°S (Hydrographer of the Navy, 1993). There is no clear seasonal variation in atmospheric pressure with maximum pressures ranging between 1003 and 1035 millibars (Upton and Shaw, 2001).

7.1.1.3. Winds

The prevailing wind direction is an annual broad arc spanning south-west to north-west constantly (Figure 7-2). Winds predominantly range between 11–21 knots (Beaufort scale 4 to 5) or below (Figure 7-3). Strong gales and storms (Beaufort scale 7+) are rare in the area, but may occur in winter or from a westerly direction.

There is no pack or floating ice as the area is 1365 km (850 miles) north of the Antarctic Circle. There have been rare incidents of ice passing close to the eastern margin of the offshore exploration zones (Richards, 2001), however the risk of icebergs impacting the drilling operations in PL023 and PL024 is considered to be minimal.

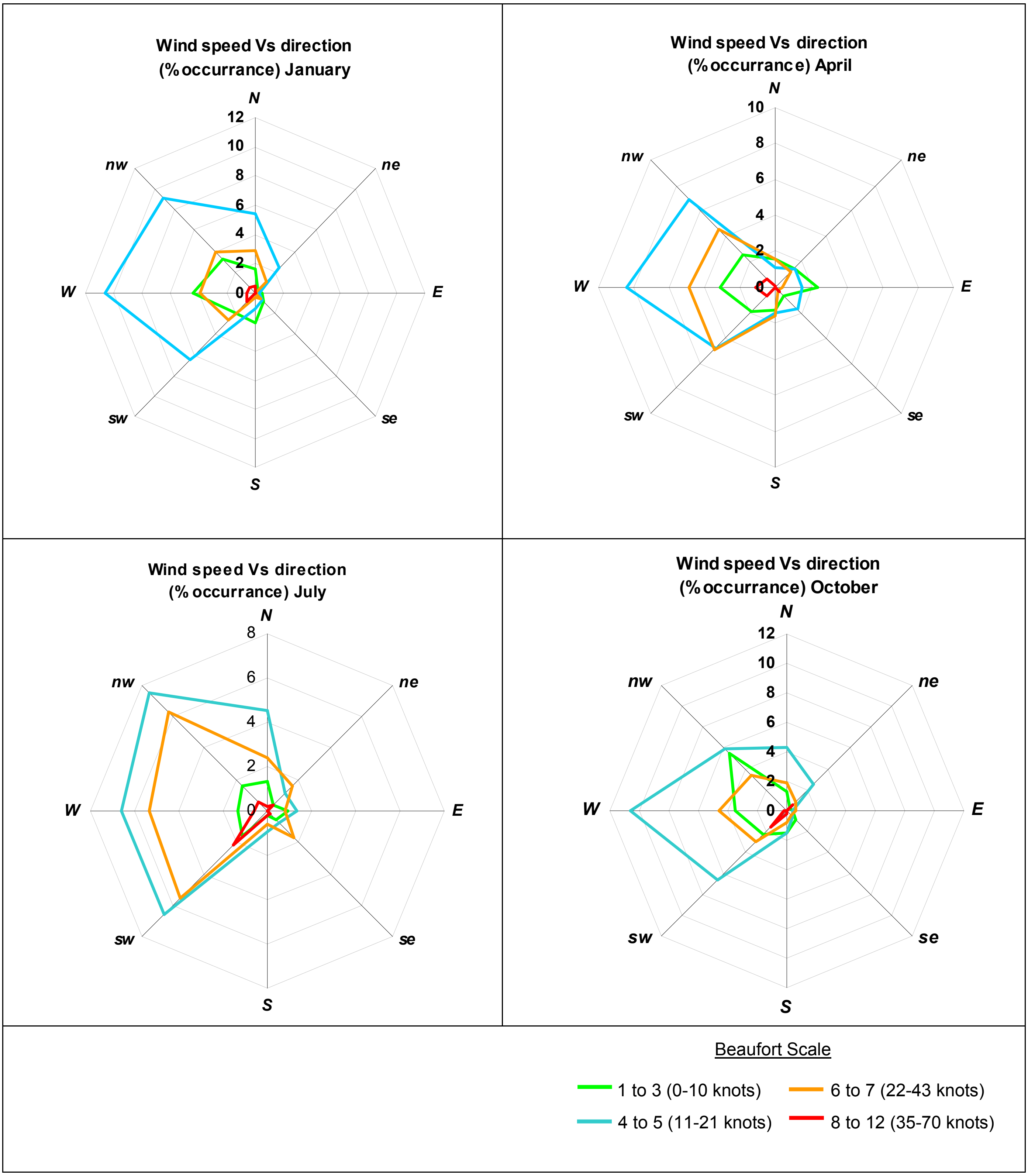


Figure 7-2 Seasonal wind speed versus direction

(Source: Met Office, 2007)

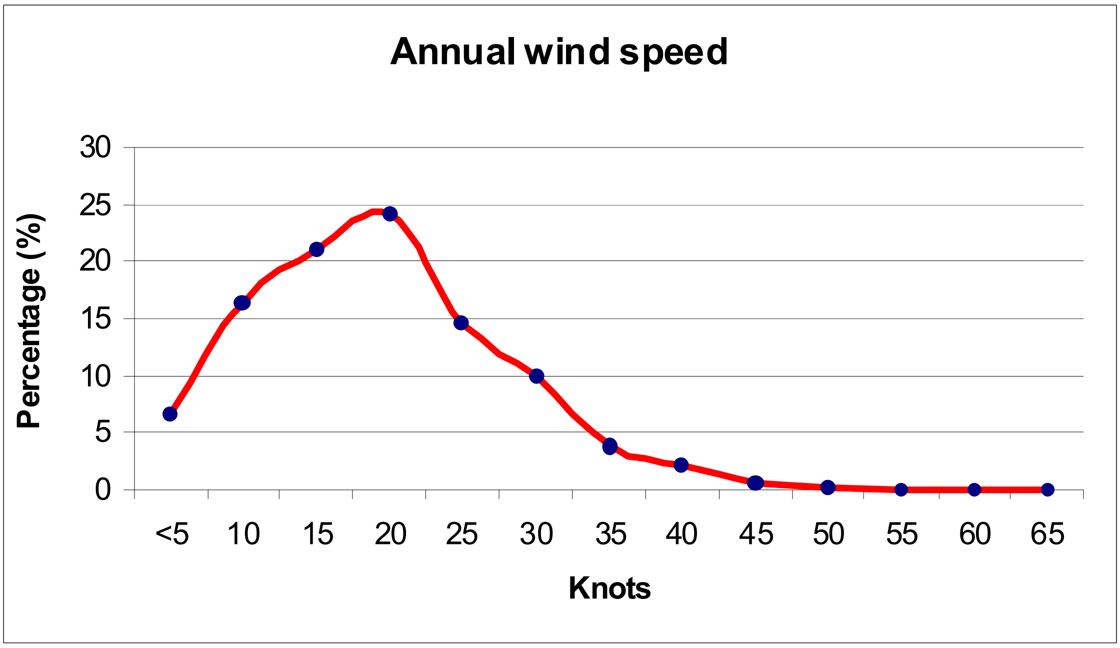


Figure 7-3 Graph of Falkland Islands' annual wind speed

7.1.2. Oceanography

The Falklands lie to the north of the Antarctic Polar Front or Antarctic Convergence, where cool surface waters to the south meet warmer surface waters from the north. The Antarctic Polar Front (APF) is ecologically important (Munro, 2004) and occurs between 50°S and 60°S (Laws, 1984).

The Antarctic Circumpolar Current (ACC) intensifies and deviates northwards as it flows around Cape Horn, and splits to either side of the Falkland Islands. The 'Patagonian' or 'West Falkland Current' flows north on the west side of the Falklands, whereas the stronger East Falkland current runs north, then swings west to re-converge with the 'West Falkland Current', continuing northwards in a 100 km wide band towards the warm south flowing Brazil Current (Munro, 2004; Glorioso & Flather, 1995).

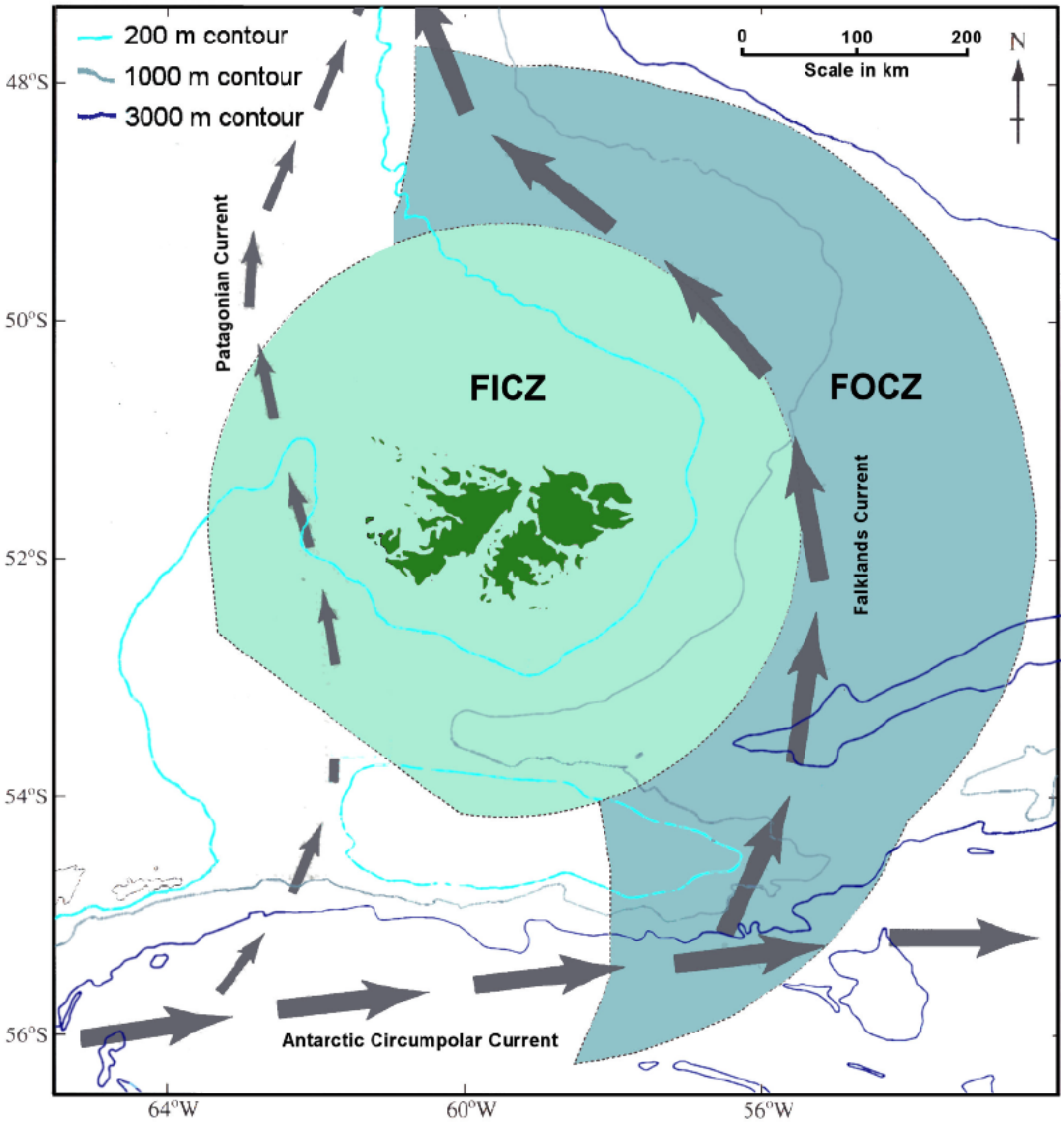


Figure 7-4 Falkland Islands conservation zones (inner and outer) plus major currents and water depths

Average diverging current speeds are less than 25 cm/s (0.5 knots) to the west and 25–50 cm/s (0.5–1 knots) to the east of the Falklands (Hydrographer of the Navy, 1993). Tidal cycles around the Falkland Islands are semi-diurnal (twice daily), with tides ranging from 0.3–3.5 m above local datum (Brown & Root, 1997).

Current patterns and bathymetry influence nutrient circulation and marine productivity levels. The area of upwelling on the continental shelf north of the Falklands has high biological productivity, and therefore high concentrations of birds and marine mammals.

The 1997 Proudman Oceanographic Laboratory currents model for the Patagonian Shelf area showed the Falkland Current at depths below 200 m flowing north, closely following the shape of the Continental Shelf slope. The model also indicated that in the area of the northern licence areas residual flow is 0.1 m/s in a north-west direction off the edge of the Continental Shelf. In the shallower water, closer to the Falklands, residual current flow is negligible and water movement is dominated by tidal flows.

A metocean survey (FUGRO, 1999) was commissioned to undertake oceanographic (and meteorological) measurements of the area to the north of the Falklands (Figure 7-5). The results for locations A and B, which are within and adjacent to licensed areas, are summarised below.

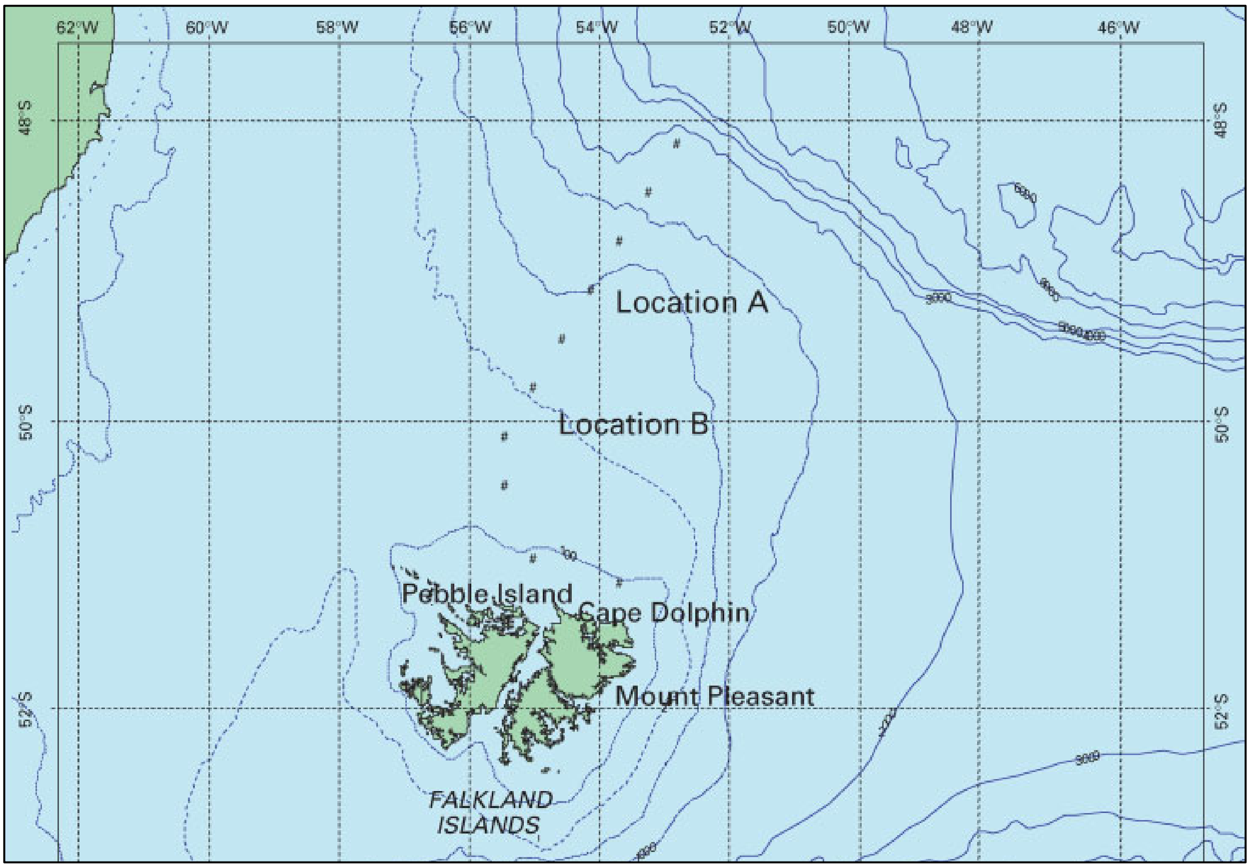


Figure 7-5 Sample locations for the FUGRO metocean survey

(Source: FUGRO, 1999)

The Brazil Current and the Falklands Current meet at a confluence region situated off the Argentine and Uruguayan coasts, extending between 30° and 50°S, and as far out as 45°W (dependent upon annual variability).

All-year current rose plots indicate that flows in the south-west to north-west sector dominate the regime at Location A, although occasional relatively high strength events flowed towards the northerly sector. Dominant current directions at Location B varied little through the year, flowing predominantly along a south-west / north-east axis.

Current speeds were generally higher and more tidally driven further up the slope at Location B than at Location A. Current speeds at both these locations were relatively low, with all year maximum near-surface current speeds not exceeding 0.7m/s at A and 0.8m/s at B.

Current speeds at Location A were highest during spring and summer months, with maximums occurring in the summer months near the surface. Maximum current speeds at Location B were highest in autumn; summer and spring current speeds were similar and winter currents almost 30% lower than in autumn. The tidal current was a more important component of total flow at Location B than Location A.

Wave height exceedance for PL023 and PL024 is shown in Figure 7-6. Seasonality in wave height showed a more energetic wave environment between June and September, corresponding to the Southern Hemisphere winter. At both locations the direction of wave approach was predominantly south-west to north-west, although a number of energetic events from the north and east were recorded, with the longest period swells coming from the north-east (Figure 7-7). Hundred year return height values were 12.6 m and 10.9 m respectively.

A seasonal thermocline, approximately 50 m deep, was most marked during February and still present during October and November (Figure 7-8). A number of seasonal changes exist in the depth of the thermocline and width of the Falklands Current (FUGRO, 1999). Surface water temperatures are illustrated in Figure 7-9.

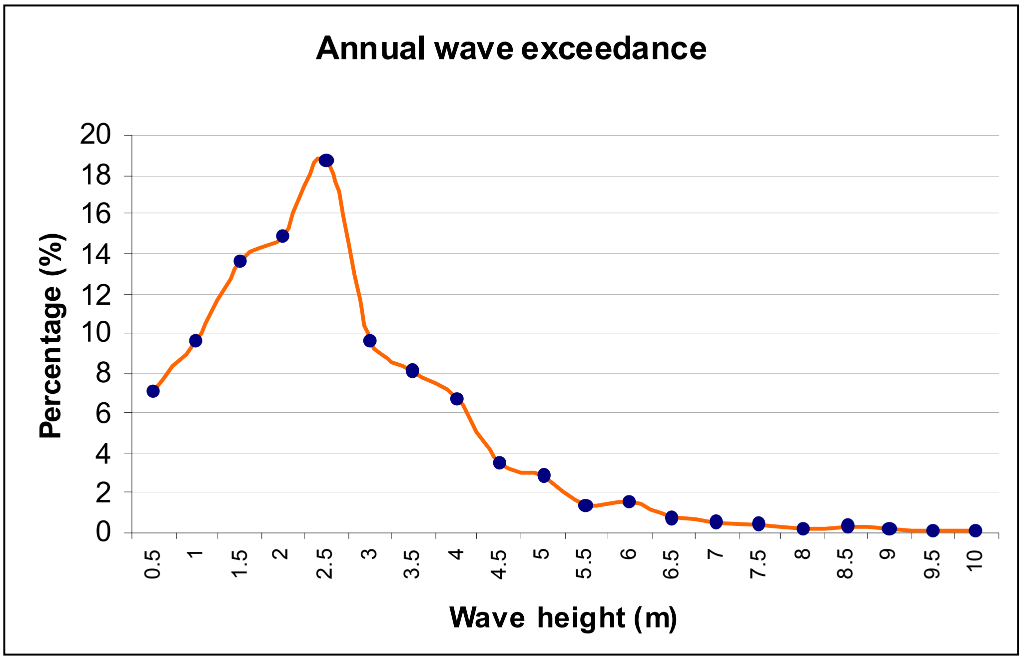


Figure 7-6 Annual wave exceedance for PL023 and PL024

(Source: Met Office, 2007)

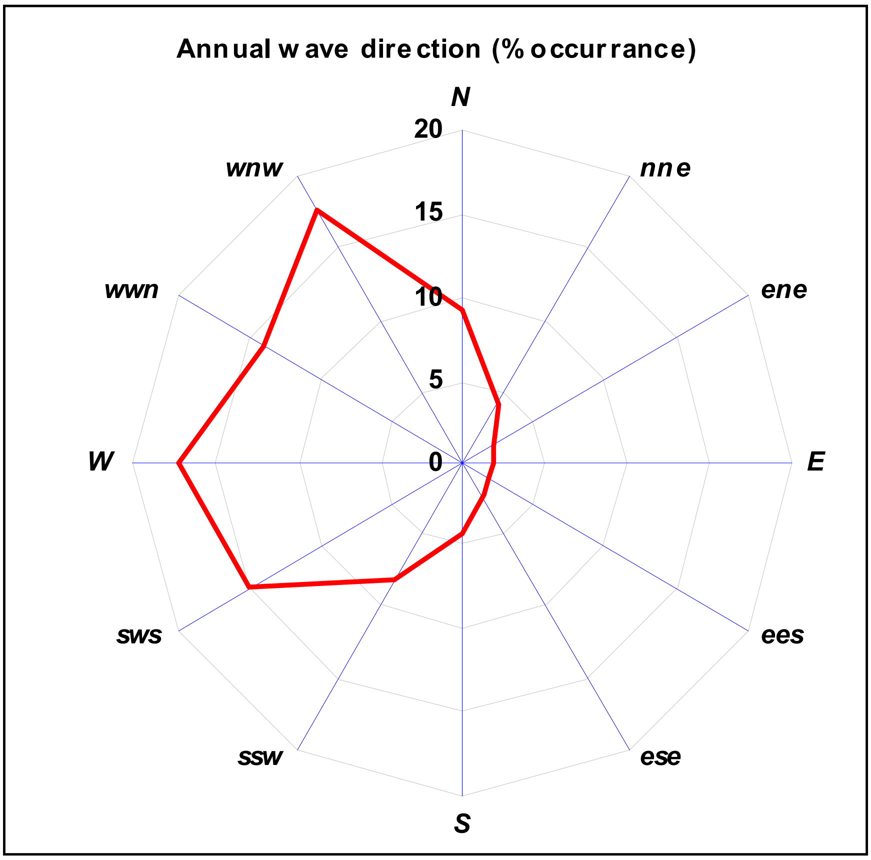


Figure 7-7 Annual wave direction for PL023 and PL024

(Source: Met Office, 2007)

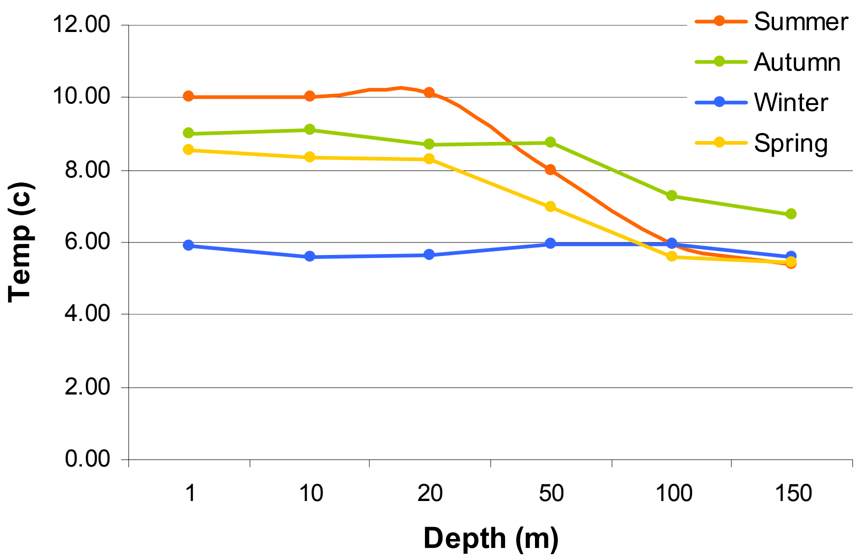


Figure 7-8 Graph of seasonal thermocline (Fugro 1999)

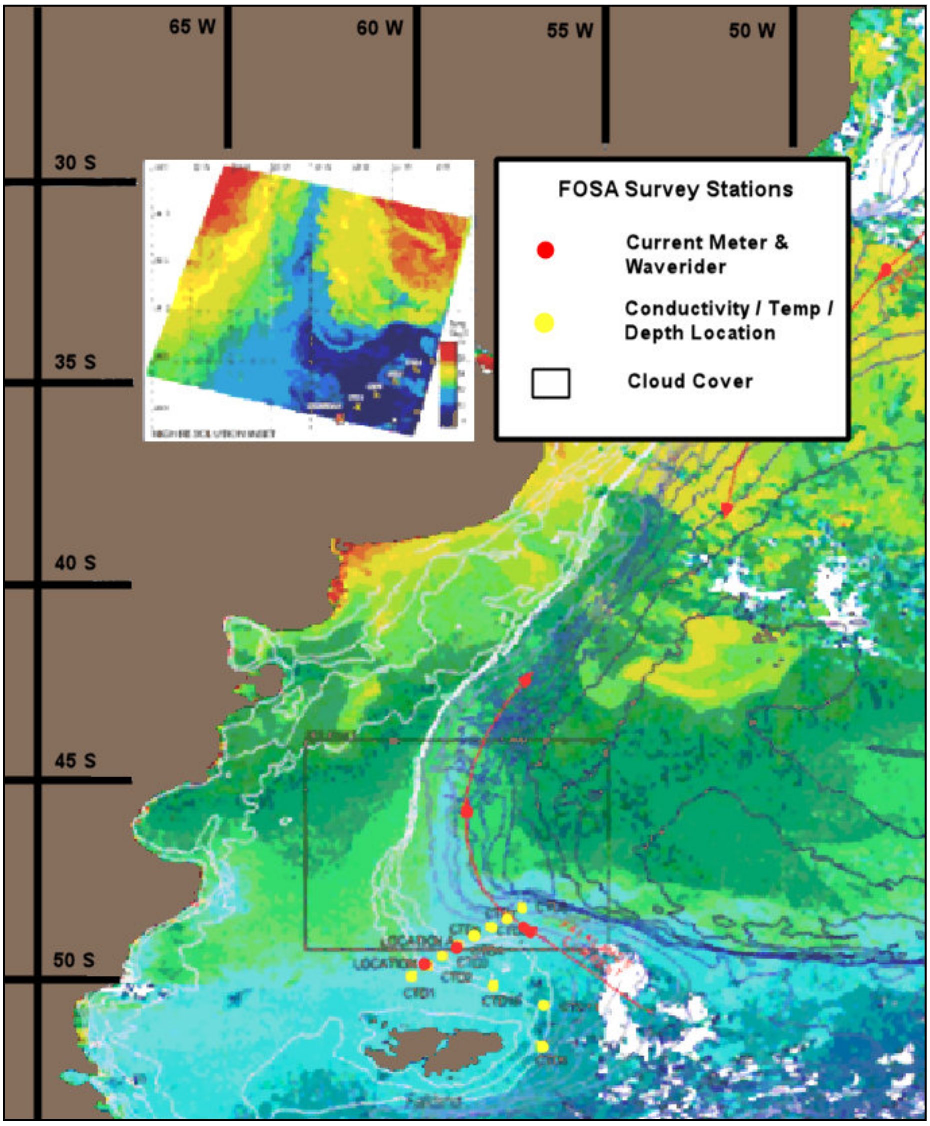


Figure 7-9 Sea surface temperatures (Jan 1997)

Map shows drifter buoy tracks, mooring and CTD locations, with high resolution data shown in insert. (adapted from FUGRO, 1999)

7.1.2.1. Hydrodynamic Model

In order to provide a detailed model of current movements for the purposes of oil spill and drill cutting dispersion modelling, a detailed hydrodynamic model of the North Falkland Basin was developed by RPS Belfast. The model was calibrated using a combination of historic records and ADCP (Acoustic Doppler Current Profiler) current data acquired during seismic surveys.

A summary of the methodology and conclusions of the hydrodynamic modelling is provided below.

The basic hydrodynamic model employed in this study is the MIKE21HDFM, a flexible mesh barotropic finite volume model. The modelling system is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used.

The extent of the model is shown in Figure 7-10. The model covers the eastern coast of South America from the Cabo San Diego (Isla Grande de Tierra del Fuego to the Rio Grande on the coast of Uruguay. From there it extends to 40°W in south easterly direction having an open boundary along the 40th western meridian. This boundary terminates close to the Coronation Islands in the South, where it cuts across to the South Shetland Islands (Antarctic) and crosses the Drake Passage. Both the south Shetland Islands and the Coronation Islands are not included in the model.

The model area encompasses one of the most challenging sea areas worldwide. The area features some of the largest tidal ranges worldwide close to the Magellan Strait, with significant currents along the edge of the continental shelf caused by both astronomic and topographically influence. Density driven currents are reported to be relatively small, however the Falklands Current, part of the ACC, which originates in the Drake passage and travels north forced by the bathymetry of the sea area, dominates the ocean currents in this section.

The model bathymetry was derived from C-Map Chart data sets for the area. Based on this data the mesh was constructed with particular detail to the edges of the continental shelf and the area immediately around the Falkland Islands, where the mesh has an average cell size of 12 km^2 (5 km cell size). In the Atlantic Ocean the cell size is increase and can be up to 60 km. The model bathymetry was corrected for mean sea level to allow for the large tidal ranges on the continental shelf, although for the majority of the model this is irrelevant due to the large water depths.

The boundary conditions were derived from a 0.25 degree global tidal model providing eight harmonics for the generation of surface elevation along the open boundaries. The global tidal model is based on a study as part of the TOPEX/POSEIDON study and details can be found in Andersen (1995). The boundaries derived from the above model were corrected to take into account the influence of the ACC in the Drake Passage.

A number of numerical models have been developed for this area and details can be found in Glorioso & Flather (1995). Data for calibration of the model is relatively scarce with limited tidal elevation and tidal current data available. Two sources for direct comparisons were used, the tidal elevations predicted for a number of ports by C-Map and field data obtained on behalf of the Falklands Operations Sharing Agreement (FOSA) and published by Upton and Shaw (2002). In particular the latter data sets were post processed and tidal elevations at two sites, as well as the depth averaged current velocities and directions were produced for comparison with the model. In this summary three tidal locations are used for comparison, Port Stanley on the eastern side of the Falklands and New Island, located at the most western side of the Falklands Islands Group, as well as Caleta San Pablo, which is on the main land of the Isla Grande de Tierra del Fuego of South America. The locations are indicated in Figure 7-10.

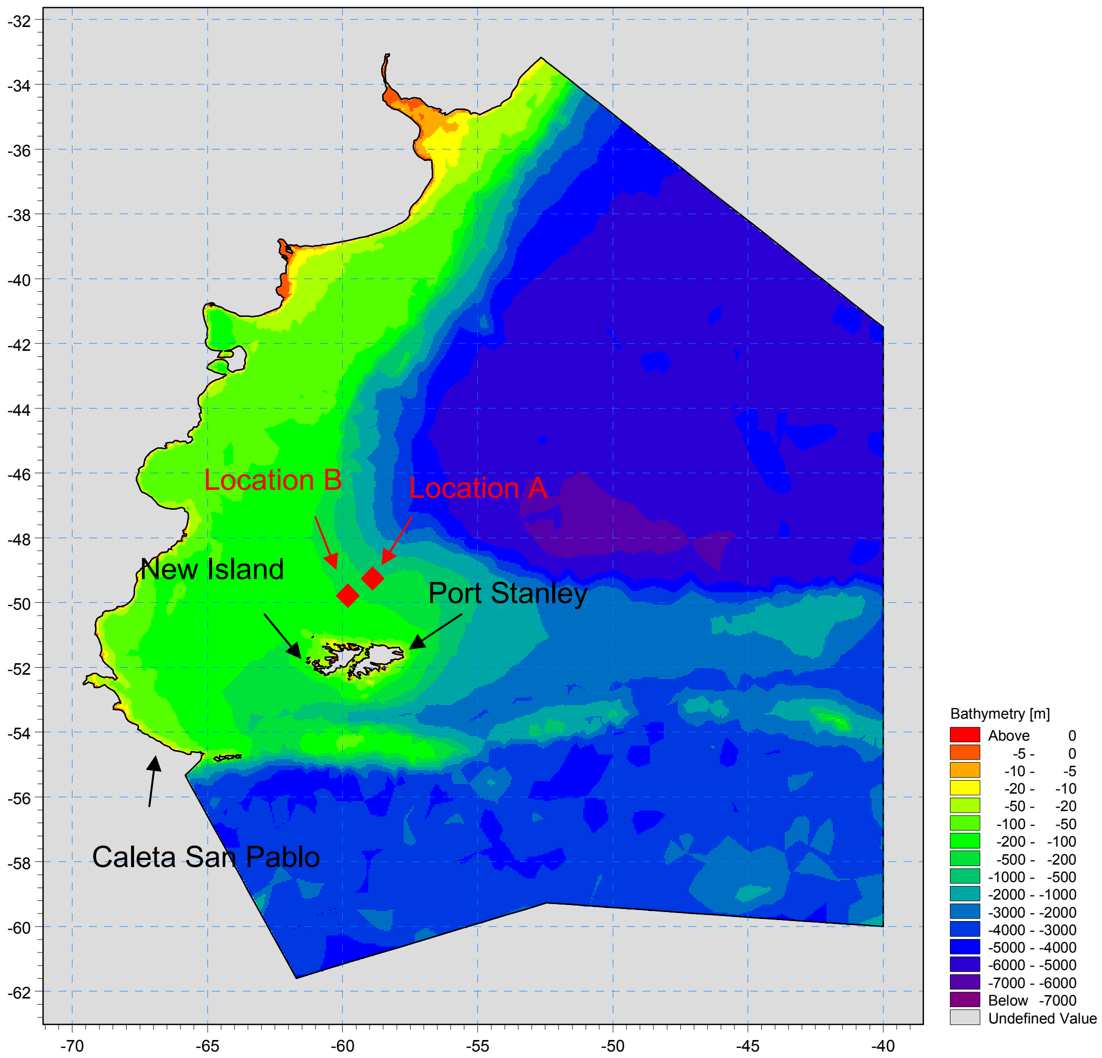


Figure 7-10 Extent of hydrodynamic model and selection of calibration locations

The FOSA data sets were analysed and harmonics for tidal elevation, current speed and direction were derived at two locations, locations A (49.1667°S 58.9167°W) and location B (49.6667°S 59.75°W).

Overall the velocities in the two current meter locations are relatively small, primarily due to the fact that the FM current is found further north and the water depths are relatively large (Location A 490 m, location B 210 m), thus tidal velocities components are expected to be low. In turn these low velocities are rather difficult to measure over a long period and the underlying fluctuations can be of the same magnitude as the average velocities.

Given the low current velocities in this area wind driven currents are of significant importance and can dominate the overall current field in particular in the upper layers. While the three measurements taken at greater depth follow a similar pattern both in terms of direction and velocity, the near surface current differs from these. Over the 48 hour period starting on the 15th December 1997 the surface current direction ranges between 270° and 340° with significant scatter, which coincides with the wave direction. Similarly the current speeds near surface are significantly higher compared to the currents at greater depth.

Analysing the water temperature at different depths over a seven month monitoring period it can be seen that the temperature at depths of 100 m and more is almost constant throughout the year with variation of 5°C near the surface between January and June that year.

Harmonic analysis of the tidal elevations and currents based on the depth averaged current velocities and directions, was undertaken and the predicted currents and elevations for the two locations were derived. These were used to calibrate the hydrodynamic model.

Overall the model show good correlation with the predicted astronomic water levels. At Port Stanley the high water levels are well matched, however the low waters are 0.3 m lower in the hydrodynamic model compared to the observed values. This is due to the model resolution in this area and the approach channel to Port Stanley being too deep in the model. However in terms of the overall model correlation this is acceptable. The two locations obtained from the FOSA field observations show very good correlation in terms of phasing and good correlation with respect to tidal elevation. Again the model is slightly over estimating the tidal range.

In conclusion, the hydrodynamic model developed for the oil spill and drill cuttings simulation shows a good correlation between observed surface elevations and current magnitude and direction in the area of interest and is therefore considered fit for purpose.

7.1.3. Bathymetry

The Falkland Islands are situated on an area known as the Falklands Plateau, separated to the north from the Argentine Basin by the Falklands Escarpment. The general bathymetry of the North Falkland Basin indicates a gently sloping gradient with contours oriented along a north-west south-east direction. The proposed survey area lies on the northern edge of the Falklands Plateau, close to the shallow shelf break dropping into the North Falklands Basin. Whilst the gradient of the seabed is expected to be very gradual within the survey area, localised small scale bathymetric features such as hummocks, channels and low level bedforms might be encountered within the area. Furthermore, area that indicated coarser sediment deposits may also exhibit some minor relief associated with these features.

Observations made during the previous geophysical and environmental surveys to the north of the current area (Tranches A, B, C and F) indicated water depths ranging from 220 m to 500 m. Detailed multibeam acquisition indicated the presence of numerous poorly preserved iceberg keel scars showing homogeneous sediment infill.

Other complex topographic features observed were a series of depressions (generally with a maximum depth of up to 4 m) and an east-west trending trough or channels of unknown origin; commonly up to 1.5 km wide and up to 210 km in length. Furthermore, a number of hard sonar contacts were also identified, although the absence of any notable relief suggested that these were patches of glacial debris, such as glacial gravels and partially buried boulders.

The Falklands Plateau is characterised by a layer of fine to medium sand, which may be up to 2 m thick (Bastida et al, 1992). Some areas are known to have a high percentage of gravel comprising either small pebbles or bioclasts with both gravels and sedimentary concretions recorded in the earlier baseline surveys in the North Falklands Basin (Gardline, 1998). The prevalence of hard-bottom areas is not accurately known due to the difficulties in sampling. Although originally reported to be scarce, it is believed these areas may have been under reported (Bastida et al, 1992 and Munro, 2004).

7.1.4. Geology

The Falkland Islands lie at the western end of the Falkland Plateau and the South American continental crust that extends to South Georgia. The Falklands are surrounded by four major sedimentary basins (Figure 7-11): the Falkland Plateau Basin to the east, the South Falkland Basin to the south, the Malvinas Basin to the west, and the North Falkland Basin to the north. The North Falkland Basin is structurally isolated and is of particular interest for the proposed drilling programme.

Petroleum exploration in the region is in its infancy and the North Falkland Basin is the only one of four basins drilled to date (Section 1.3.3).

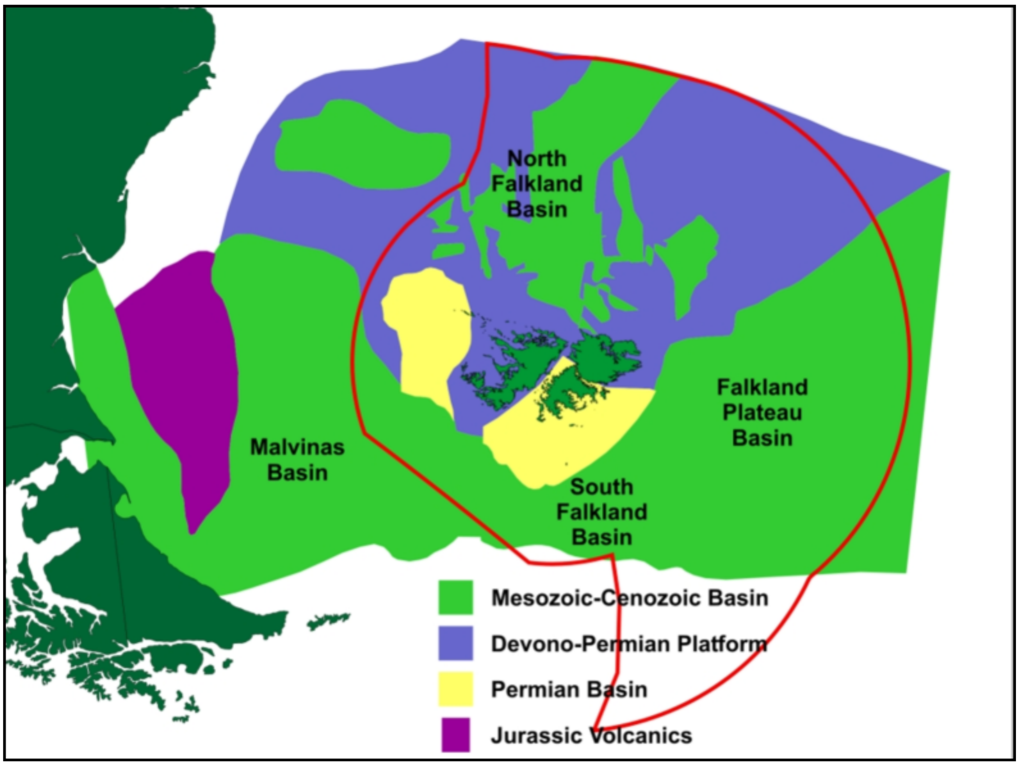


Figure 7-11 Petroleum basins of the Falkland Plateau

(Source: BGS, 2006)

The North Falkland Basin is a failed rift formed during the break-up of the ancient landmass – Gondwanaland. The Basin is further divided into a northern, or main, basin and a southern basin (Duncan, 2006). PL023 and PL024 are located in this southern basin.

The Basin is set on a Devonian platform over a Jurassic to Lower Cretaceous source rock capped by late Cretaceous and Tertiary marine deposits. The Tithonian to Aptian lacustrine is the main source rock of the basin and was discovered in the 1998 drilling campaign.

The two main structural elements—a north-south trending graben and a set of subsidiary basins to the west and south of the graben—are controlled by north-south trending extensional faults, and constrained by northwest-southwest oriented reactivated Palaeozoic thrust sheets (BGS, 2006). This graben may have influenced sedimentation during the basin evolution (Richards & Hillier, 2000).

Eight tectono-stratigraphic units have been identified from post-drilling analysis of the Basin and are described in detail by Richards & Hillier (2000).

Licences PL023 and PL024 contain as many as twenty structural leads, most of which are located on the flanks of the K Graben. This is within the southern area of the licences, in water depths of less than 150 m. The seismic data indicate that the K Graben is deep enough to contain a mature source rock, but no wells have been drilled in this area. Nine of these leads are large enough to each potentially contain over two hundred million barrels of recoverable oil.

7.2. BIOLOGICAL ENVIRONMENT

The Patagonian Shelf, on which the Falkland Islands sit, is of regional and global significance for marine resources (Croxall & Wood, 2002). It comprises of rich assemblages of seabirds, marine mammals, fish, squid and plankton populations. The following sub-sections outline the existing biological resources known to occur around the Falklands and the licence areas.

7.2.1. Marine and Inter-tidal Vegetation

Seaweeds are an important resource in the Falkland Islands for extraction and use in commercial products and as an integral part of the health and biodiversity of the natural ecosystem.

The giant and tree kelp are the most common macroalgae species in offshore zones of the Falkland Islands, extending from the 4-30 m water depths.

7.2.1.1. Giant Kelp (*Macrocystis pyrifera*)

Giant kelp (*Macrocystis pyrifera*), a species of marine brown algae, is one of the largest known 'seaweeds', able to grow to lengths of 60 m with its upper fronds forming a dense canopy at the surface. *Macrocystis* provides food and habitat for a wide range of marine invertebrates and fishes.

Kelp species prefer depths of less than 40 m, temperatures less than 20ºC and hard substrate, such as rocky bottoms, for attachment. The high nutrient rich waters of the Falklands are particularly conducive for kelp development. Studies suggest kelp fronds may grow at rates of 1–2 feet per day. Fronds of mature kelp plants become senile and deteriorate about six months after they are produced.

Macrocystis pyrifera has a bipolar distribution, occurring both in the southern and northern hemispheres. Giant kelp is ubiquitous around the shores of the Falklands and is the most widespread and common marine algae found around the Falklands (Munro, 2004). It is typically found in inter-tidal areas to a depth of between 3–6 m and may also be found up to 1 km from the shore. Little is known however of the lifecycle of the species in the Falklands. It has been suggested that the Falkland Islands *Macrocystis* population is more stable than most other giant kelp beds at high latitudes, due to absence of winter storms.

7.2.1.2. Tree Kelp (*Lessonia* sp.)

Tree kelps (*Lessonia* sp.) are found in most open coastal areas. Three species of *Lessonia* have been distinguished: *L.flavicans, L.frutescens* and *L. nigrescens. L. flavicans* is the most common, although the distribution and status of individual species is reported to be unclear (Strange, 1992).

Few studies have been undertaken on these species in the Falklands. *Lessonia* plants are likely to be found entwined with the giant kelp canopy in depths of 3–20 m, either in sub-tidal inshore or deep water offshore areas (Searles, 1978), where they form a fringing zone between the low water mark and the beginning of the offshore zone occupied by giant kelp. The tree kelp provides a valuable habitat for shorebirds, seabirds and other marine creatures as feeding grounds and spawning/nursery areas (Munro, 2004).

Distribution of free-floating kelp patches in Falkland Islands waters was reported from the at-sea surveys carried out between February 1998 and January 2001 (White et al., 2002). These areas are important for the 22 seabird species recorded as associating with free-floating patches of kelp.

7.2.2. Plankton

Plankton are marine and freshwater organisms with limited swimming capability that drift with the prevailing currents. They represent an integral part of the marine ecosystem as they provide the basis of all food for higher levels of the marine food chain. Plankton are generally divided into broad functional groups – Phytoplankton (autotrophic) and Zooplankton (heterotrophic).

Due to a lack of knowledge on the distribution and ecology of plankton species in Falkland waters, current information is based on the early 'Discovery' research expeditions undertaken during the early part of the twentieth century between the Falkland Islands and South America, complied from 1926–1986. A set of these Discovery reports are held at the Falkland Island Government archives in Stanley.

7.2.2.1. Phytoplankton

Phytoplankton is reliant on the availability of sunlight and nutrients for their photosynthetic processes. As such, it exists in the photic-zone of the ocean and in higher concentrations in summer at the polar and sub-polar regions. There may be as many as 5000 species of marine phytoplankton with diatoms, cyanobacteria and dinoflagellates amongst the most prominent groups.

The results of the Discovery expedition, focusing on diatoms, are found in the Discovery Report Vol. XVI (Ingram Hendley, 1937). At the nearest sampling station to the Falkland Islands, approximately 2–4 km offshore, 10 species of diatom were recorded. South of 44º S there were relatively few species and a marked increase in diatoms, in comparison to the dominance of dinoflagellates, ciliates and crustaceans further north. This confirms known trends that diatoms comprise a significant component of the plankton population in higher latitudes, compared to tropical waters (Barnes & Hughes, 1988).

Research on the zooplankton of the south-west Atlantic Ocean, focusing on cephalopod larvae in relation to the major oceanographic features (Rodhouse et al., 1992) indicate that the lowest zooplankton concentrations occur in the shelf seas around the Falklands.

NASA photographed a large phytoplankton bloom in December 2002 surrounding the Falklands (Figure 7-12). The image shows large chlorophyll concentrations, illustrating a phytoplankton rich region – partly due to the convergence of the Malvinas and Brazil ocean currents. The perennial winds buffering the Falklands from the east may generate waves which bring the nutrient rich waters to the surface. When sunlight penetrates, phytoplankton blooms may occur. Although large areas of the southern oceans are characterised by low productivity, inshore shelf waters where shelter, coupled with the nutrient up-welling, can increase numbers significantly.

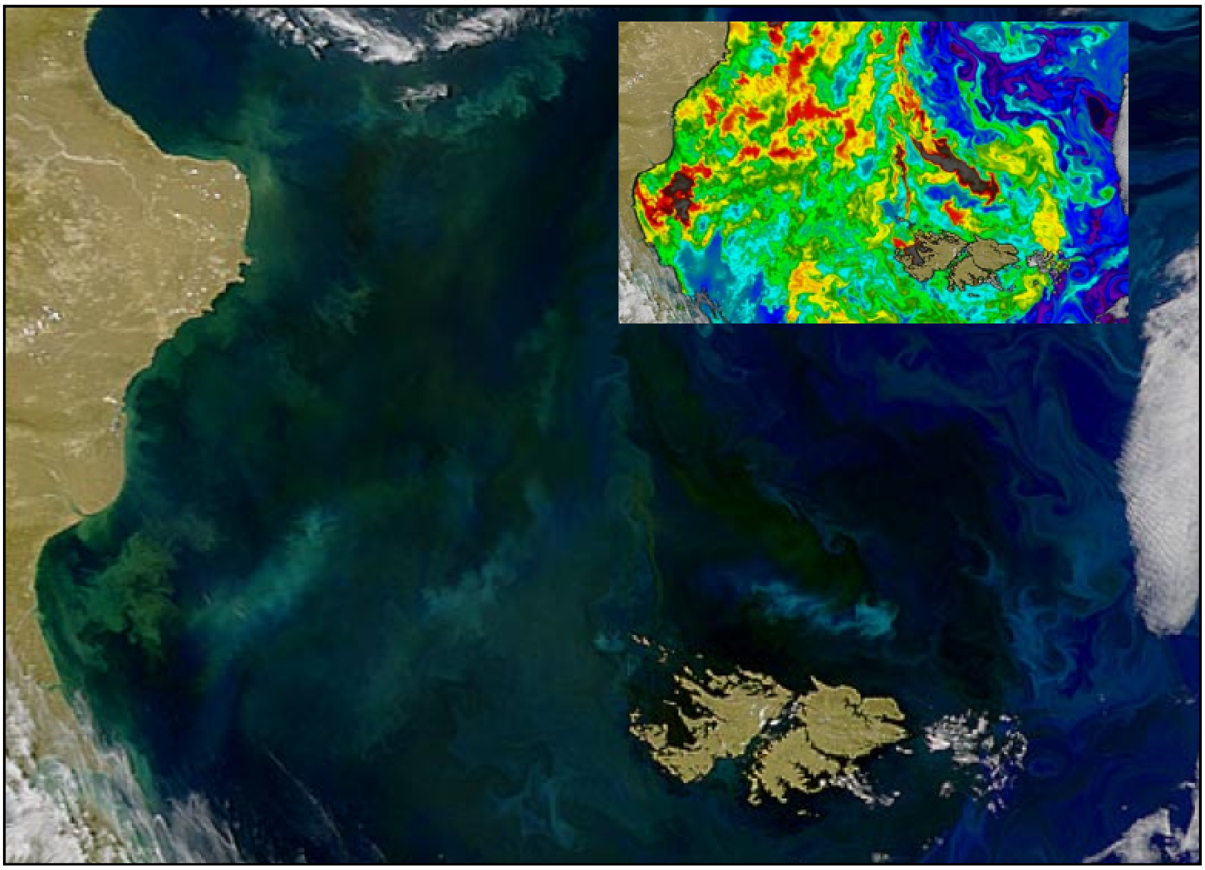


Figure 7-12 Phytoplankton bloom (areas of light blue / green) near the Falkland Islands
(Source: NASA SeaWiFS, 2002)

7.2.2.2. Zooplankton

Zooplankton, a heterotrophic species, can range in size from microscopic bacteria to larger organisms, such as jellyfish.

The complex current patterns around the Falklands, with the rising bathymetry and the extensive shelf area, create stable areas to the north and to a lesser extent in the south-west, where high salinity and loaded water wells up produce phytoplankton activity that support high levels of zooplankton (Agnew, 2002).

As with phytoplankton, numbers appear to rise sharply leading into the summer months. Ciechomski and Sanchez (1983) noted that total zooplankton around the Falkland Islands does not peak until January–February when it is dense to the north of the Falklands, along the shelf break. Species identified in Falkland Waters are presented in Table 7-1.

Table 7-1 Zooplankton Species in Falkland Island waters

	Species
Euphasids	*Sagitta gazellae*
	Euphausis lucens
	Euphausia vallentini
	Thysanoess gregaria
Amphipod	*Thermisto gaudichaudii*
Decpod	*Munida gregaria*

Zooplankton also consists of a number of juvenile fish species and cephalopods (Agnew, 2001), such as Lobster Krill (*Munida gregaria*) (Figure 7-13), which is regarded as the most important of the zooplankton species in Falkland waters. Krill, a key species in the food chain, is consumed by squid, fish, seals, baleen whales and seabirds (particularly the black-browed albatross and penguins) in the Falklands.

Figure 7-13 Lobster krill (*Munida gregaria*)

7.2.3. Benthic Fauna

Benthic fauna live on or within the seabed. The FOSA group commissioned pre and post drilling benthic survey in 1998. Rockhopper commissioned Benthic Solutions to undertaken a benthic environmental survey for its licence areas and its surrounds. The survey was conducted in August 2008, and the results support the earlier survey conclusions. The complete environmental benthic summary report is provided in Appendix III.

While the macrofaunal analysis of the benthic samples from all surveys show high biological diversity, regionally the macrofauna are described as being homogenous in a homogenous environment. There were no significant correlations between the seabed fauna and tested environmental variables (such as sedimentary parameters, metals and hydrocarbons).

All physio-chemical sediment parameters for the 2008 survey indicate uncontaminated sediments with relatively low background concentrations of both heavy metals and hydrocarbons. The uniform habitat would easily detect changes in macrofaunal communities as a result of environmental variables (that is, from drilling). The 1998 post-drill benthic sampling found no faunistic evidence to suggest the location was polluted.

The benthic fauna results from the 2008 survey are summarised below.

Summary of Macrofaunal Results

The benthic fauna of the Falkland Islands belongs to the Magellan faunal area, made up of the sea areas around the southern part of South America). Whilst this is comparable to the Northern Boreal Region, the fauna is characterised by a very high diversity within the crustacean, with the amphipod *Urothoe* sp the most dominant across all sites. Univariate parameters indicated consistent levels across the regional survey area as all sites gave moderate to high species richness, diversity and evenness throughout the survey. Previous benthic survey undertaken in the North Falklands Basin in 1998, indicated a similar benthic community in the deeper waters.

Univariate parameters indicated only weak patterns of geographical distribution across the area. Multivariate analyses, equally confirmed a relatively diverse faunal population with a relatively high level of similarity across all stations and little variability between groups of stations. A relatively poor separation of 5 clusters was delineated at around the 50% similarity, but these were predominantly separated by the presence or dominance of only a handful of key species, including the amphipod *Phoxocephaloidea* sp.C (eyeless) or the polychaetes in the family cirratulidae or the species *Aricidea* sp.A. Only one small group (of three stations including the deepest station), were separated by other taxonomic groups such as the echinoderm (ophiuroid *Ophiura cf meridionalis*) or the mollusc (*Cryptodon falklandica*).

Correlations with environmental parameters only weakly followed the multivariate trends, in that a combination of finer particle size classes, fine sands, water depth and the faunal abundance produced these trends. Correlations between clear sedimentary changes and physico-chemical variations were of a greater magnitude and whilst the mean sediment size, the proportion of finer sediments, water depth and total organic matter provided the strongest gradient for the distribution of most metals and organic components, the biological community was only weakly influenced by these factors. Overall, there was insufficient variability within the habitats recorded to clearly separate out the biological communities recorded over the regional survey area.

For this preliminary regional assessment the level of analysis has concentrated on the key separation of groups in order to identify trends within the biological community with that of the physical habitats over the northern continental shelf. Further analysis of this material will continue whilst further data, acquired at proposed well locations, is further evaluated and a more definitive species list produced.

Overall, no environmentally sensitive species or habitats considered to be of conservational value were recorded during the regional survey operations.

Summary of Epifaunal Results

Most of the sites sampled provided only marginal admixtures of coarser sediments, most of which relating to fine shell or pea gravels sized fractions. Consequently, the numbers and proportions of quantifiable epifaunal species were relatively small across all of the samples. Sediment types remained relatively constant around a slightly silty, partially reworked medium to fine sands and occasional glacial gravel.

Due to the sandy sediments encountered epifauna were sparse; nevertheless a number of Bryozoa were regularly encountered, previously recorded during the earlier surveys in the North Falklands basin (Gardline 1998). Especially common and characteristic were the upright branching Ogivalia elegans, and some colonies of the upright reticulate genus Reteporella, which can form colonies several cm high.

In addition to the bryozoans, several Hydroid fragments were also recorded. These are similar to those recorded in the northern hemisphere, and may well share a specific status. Their very wide distribution is aided by their planktonic medusa stage.

7.2.4. Fish, Squid and Shellfish

Much of the information sourced for these sub-sections is based on work undertaken by the Falkland Islands Fisheries Department (FIFD) as commercial fishing is a significant part of the local economy. Additional information has been sourced from the 2008 State of the Environment Report (Otley et al, 2008).

In addition to the harvest of commercial fisheries, fish stocks are a major component of many seabirds and marine mammal diets, and any impacts on fish stocks are likely to affect them. At least 80 species of fish have been recorded in Falklands' waters ranging from small fish such as the rock cod to larger fish such as tuna and sharks (Strange, 1992). Commercial fishing is described from a socio-economic perspective in Section 7.3.1.1.

The Falklands Interim Conservation and Management Zone (FICZ) was introduced in February 1987 to reduce uncontrolled fishing. Continuing conservation problems led to the declaration of the Falkland Islands Outer Conservation Zone (FOCZ) in December 1990, 200 nautical miles from coastal baselines.

The main fisheries resources are the squid species, *Illex argentinus* and *Loligo gahi*. The existing finfish fishery targets predominantly hake, hoki, red cod and blue whiting. Blue whiting provides the highest finfish catches with 80% of the catch targeted seasonally by large surimi trawlers. A specialised small ray fishery exists, and a small longline fishery operates targeting Patagonian toothfish.

Shellfish are not an important component of the commercial fishery although several species of crab are found around the Falkland Islands including the false king crab (*Paralomis granulosa*) and the larger southern king crab (*Lithodes antarcticus*). A small-scale scallop (*Zygochlamys patagonica*) fishery is being developed (Munro, 2004).

7.2.5. Cephalopod

Cephalopods include species from the squid and octopus families. Squid provide economic benefits through commercial exploitation and are also a food source for a variety of marine vertebrate predators (Munro, 2004). Adult squid are active predators positioned near the top of the food chain, consuming fish, crustaceans and other cephalopods (Hatfield, 1990). Squid stock varies annually, influenced by success of the spawning season based on favourable environmental conditions. Octopi, found in kelp beds and crevices in rocks, are common prey for sea lions.

Distribution of cephalopods is dependent on temperature preference and influence of currents. Larval phases concentrate on the Patagonian shelf and shelf break area, and the adult phases utilise the currents for migration between feeding and spawning grounds (Rodhouse et al., 1992).

Cephalopod paralarvae and juveniles sampled in the south-west Atlantic Ocean found that the sub-Antarctic surface waters of the Falkland Current contain the richest assemblage of species inclduing the sub-tropical/sub-Antarctic *Histioteuthis atlantica*, the sub-Antarctic *Batoteuthis* skolops, H*.eltaninae*, H*.macrohista* and the sub-Antarctic/Antarctic *Gonatus antarcticus*. In comparison, with the exception of some small *Gonatus antarcticus*, the polar frontal zone water of the Falklands Current was relatively poor in species (Rodhouse et al., 1992). Cephalopod species recorded on the Falkland Islands shelf included *Loligo gahi, Gonatus antarcticus, Martialia hyadesi, Moroteuthis* knipovitchi, *Batoteuthis skolops*, *Semirossia patagonica* and an *Octopus sp*. (Rodhouse et al., 1992).

An evaluation of the distribution of *Loligo gahi* paralarvae and *Gonatus antarcticus* found greatest concentrations around East Falkland (Rodhouse et al., 1992) and at the offshore stations sampled, particularly to the south of East Falkland, respectively. *Octopus* sp. was reported to be the most widely distributed.

7.2.5.1. Argentine shortfin squid (*Illex argentinus*)

Illex argentinus, one of the most abundant cephalopods in the Southwest Atlantic, is distributed from approximately 30ºS to 54ºS over the Patagonian shelf, slope and around the Falkland Islands. *I.argentinus* is a demersal and schooling species.

Illex argentinus is caught in the FICZ between late February and June, at depths of 80–800 m (FIFD, 2001; Rodhouse and Hatfield, 1990). Fishing catch peaks between April and May with principal catch areas to the north and north-west of the Falklands, although they can vary annually.

The migration and dispersal of *Illex argentinus* is highly dependant upon the major oceanic currents and resultant water temperature, therefore abundance in the Falklands is highly variable. The species is predominantly a warmer water species and variations in current strength and flow, that modify sea temperatures and temperature gradients, can influence major changes in migration and aggregation of the species (FIFD, 2001).

7.2.5.2. Patagonian Squid (*Loligo gahi*)

Loligo gahi is a demersal, schooling species found in shallower water around the coast to a depth of about 400 m (Boyle, 1983). They have two main spawning periods; the spring (September-October) spawning group is larger than the autumn (March-April) group.

This fishing industry is focused to the south of East Falkland, mainly around Beauchene Island from February to June, later moving northwards to north-east of East Falkland around August–October. The trawling fleet targets *Loligo gahi* during its feeding phase, in depths of 120–250 m, corresponding to the optimum commercial size.

Squid eggs have been recorded in shallow marine areas (less than 30 m depth) during dive surveys carried out in 1996 (FIG, 1996a) and by the Falkland Islands Fisheries Department (FIFD, 2000). Eggs were found in inshore waters of all islands sampled, except the offshore islands to the south. In 1999 (FIFD, 2000) egg masses were encountered around the entire coast of East Falkland with the exception of the central part of Falkland Sound. All egg masses found were associated with and attached to kelp, although there was considerable local variation in egg mass density.

A third squid species, red squid (*Martialia hyadesi*) is not widely fished. It is larger in size than *Illex argentinus* or *Loligo gahi* and is thought to be abundant in the waters of the Antarctic Convergence Zone, near South Georgia. This species forms at least 90% of the squid intake of the grey-headed albatross population during the chick rearing period resulting in approximately 1400 tonnes of squid consumed each breeding season (Brunetti & Ivanovic, 1992).

7.2.6. Finfish

Some 11 species of finfish are caught in significant quantities. Southern blue whiting catch is found to the south-west and north-east of the Falklands. Hoki, rays, red cod and Patagonian toothfish are caught widely around the Falklands in the FICZ, except in the south-east. Within the FOCZ all are caught to the north of the Falklands. Patagonian toothfish and rays are also caught to the south-east within the FOCZ (Munro, 2004).

The distribution of migratory species such as hake may be affected by fluctuations in spawning success and external environmental affects. Many of the commercially caught demersal species are likely to spawn in deep water and have planktonic eggs and larvae. Immature stages of some species may occur inshore; however, there is little information on specific nursery areas.

7.2.6.1. Hake (Merluccius sp.)

Hake are widespread throughout the FICZ and two species are caught commercially; Patagonian hake (*Merluccius hubbsi*) and common hake (*Merluccius australis*), which are similar species and often counted together in catch statistics. The common hake is distributed mainly in the offshore waters to the north of the Falklands as opposed to the Patagonian hake, which is found to the south of the Falklands. Fishing effort concentrates in the far west of the FICZ where the highest abundance of hake are found, and also to the north (Tingley et al., 1995), and around Beauchene Island to the south (Lisovenko et al., 1982; Tingley et al., 1995). *Merluccius hubbsi* is thought to spawn in September/October, and *M.australis* in June/August.

Hake are generally known to migrate diurnally, being found near the seabed during the day and migrating further up the water column to feed at night.

7.2.6.2. Southern Blue Whiting (*Micromesistius australis*)

Southern blue whiting are a food source for the Patagonian hake and consequently showing a similar distribution. Southern blue whiting migrate to the Falkland outer shelf and aggregate in dense schools to spawn. Specialised surimi vessels target feeding concentrations of southern blue whiting until the following March. Acoustic surveys of the southern blue whiting stock are conducted annually through a joint Argentine/Falkland project.

The Falkland sub-species are found at depths between 180–780 m and appear to be most abundant at depths of 200 m around the Falklands (Inada and Nakamura, 1975). Spawning occurs in August–September around the south of the Falklands and both eggs and larvae are pelagic. Pre-spawning fish congregate south of West Falkland during July (Patterson, 1986) and subsequent to spawning migrate into deeper water dispersing south and west where they are thinly distributed over the Patagonian Shelf.

7.2.6.3. Whiptail Hake / Hoki (*Macruronus magellanicus*)

Whiptail hake, or hoki, is the second most important commercial species in terms of annual catch. A pelagic and near-bottom fish, the species is present in Falkland waters year round and is generally associated with warmer waters up to 200 m deep in the north and west of the FICZ (Middleton et al., 2001). Falkland waters are primarily a feeding ground. The uniform distribution of *M.magellanicus* as a proportion of daily catch suggests that the species is taken as a part of a mixed finfish fishery rather than specifically targeted.

7.2.6.4. Cod (*Notothenia* spp.)

Antarctic cod are one of the most common fish in Antarctic and subantarctic waters, and 16 species have been recorded in Falklands waters. Of these the predominant species are *Notothenia ramsayii* (no common name) and yellow belly (*Notothenia macrocephala*); common in nearshore waters in summer but migrating to deeper waters during the winter (ERT, 1997).

7.2.7. Shellfish

Data on shellfish found in the shallow and offshore waters of the Falklands are scarce. Lobster krill is abundant in Falklands waters (Section 7.2.2.2). Crabs found in the shallow inshore waters of the Falklands include red crab (*Paralomis granulosa*) and, to a lesser extent, the king crab (*Lithodes antarcticus*). Trawling to the south of the Falklands has also shown there to be a probable significant population of sub-Antarctic stone crab (*Neolithodes* sp.).

7.2.7.1. Red Crab (*Paralomis granulosa*)

The red crab fishery utilises a small inshore vessel operating in Choiseul Sound. The operation is licensed by the Department of Fisheries with restrictions on minimum crab size. *Paralomis granulosa* is typically found in relatively shallow water of 10–40 m depth and within sheltered inshore waters. The highest concentrations of *P.granulosa* are found around the south east of the Falklands. Juveniles and adults are found at the edges of kelp beds (Hoggarth, 1993).

7.2.7.2. Patagonian scallop (*Zygochlamys patagonica*)

A small commercial fishery exists for the Patagonian scallop in the northeast of the FICZ at depths of 130–142 m. Stock assessment estimates a standing biomass in these beds of 18,000 – 27,000 MT. Distribution is mainly along the north eastern, eastern and southern edge of the Falkland shelf. Distribution is thought to be determined by three main factors: the Falkland Current, bottom morphology and suitable depth. Scallops have not been found on areas of hard rocky bottom, nor in waters greater than 145 m deep. In Falkland waters no inshore scallop beds have yet been found (Munro, 2004).

7.2.8. Marine Mammals

Little is known about the populations, distribution and habits of marine mammals in the waters surrounding the Falkland Islands. There may be more than 20 species, which may occur in Falkland Islands waters but probably only 2–3 resident species (Munro, 2004)

After the award of the initial round of hydrocarbon exploration licences in 1996, six wells were subsequently drilled. The threat to seabird and marine mammal populations was recognised and the Joint Nature Conservation Committee (JNCC) and Falklands Conservation (FC) conducted a 'Seabirds at Sea Survey' between 1998 and 2000. Post the initial round of drilling, additional funding was allocated to FC to continue a further two years of at-sea surveys. To date, the findings from these surveys are still the major body of work regarding the frequency and distribution of marine mammals, particularly cetaceans, in the region. Previous knowledge of whales and dolphins around the shores of the Falkland Islands had been based on occasional random sightings, strandings and a few records from commercial whaling (Munro, 2004).

The at-sea surveys encompassed an area defined by a box extending north and east from 56º S 64º W.

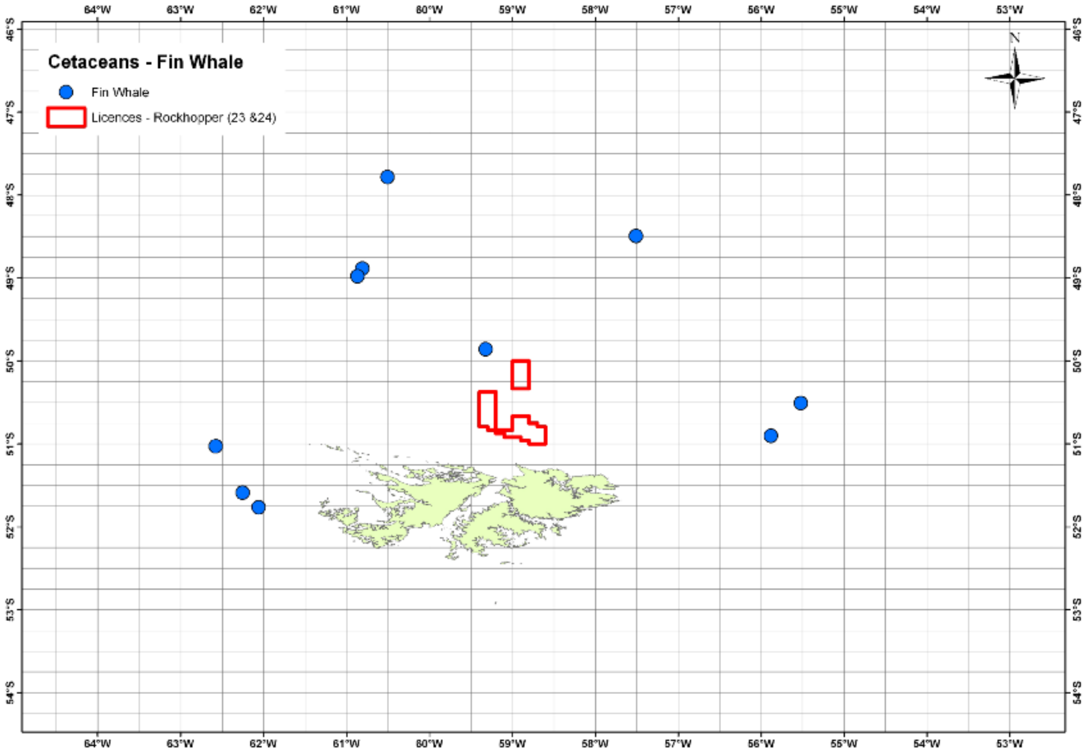
7.2.8.1. Cetaceans

Cetaceans in Falklands waters may either occur as a consequence of their passage on migration or when they enter sheltered waters to give birth or to mate.

The following results, unless stated otherwise, have been extracted from the Distribution of Seabirds and Marine Mammals in Falkland Islands Waters, 2002 and represent the findings of those surveys between 1998 and 2001. Seventeen species of marine mammals were recorded over the period including 14 species of cetacean and three pinniped species. In total, 6550 individual marine mammals were seen during the survey period.

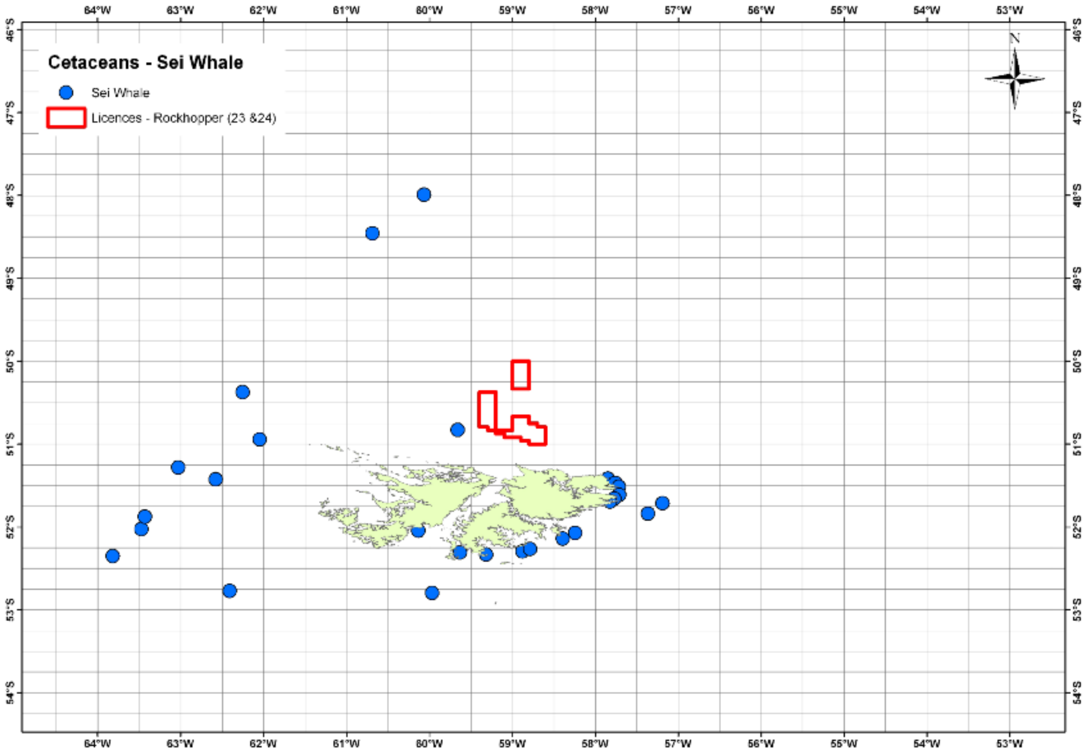
Commerson's dolphin (*Cephalorhynchus commersonii)*
A total of 336 Commerson's dolphin was recorded on 100 occasions, covering all months except May. Dip in records over May and June may be due to variation in the level of survey effort rather than seasonal variations. No individuals were recorded greater than 25 km offshore.

Figure 7-14 depicts the species and distribution of cetaceans sightings recorded during all the surveys months. The scope of this EIS encompasses licences PL023 and PL024, however the wider region has been shown on the maps below in order to allow potential impacts to the shoreline of the Falklands to be taken into account, for example in assessing the effects of offshore oil spills.



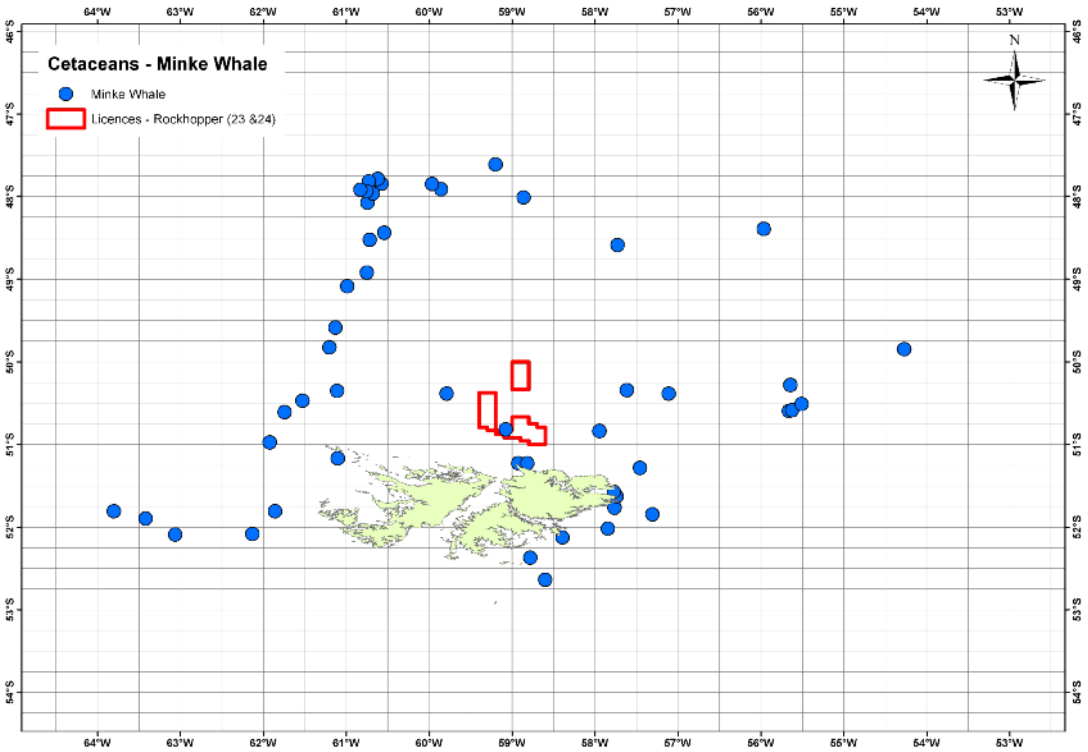
<u>Fin whale (*Balaenoptera physalus)*</u>

Majority of fin whales were recorded between November and January, with 57 recorded in total on 27 separate occasions over the survey area. Sightings were generally in water depths >200 m.



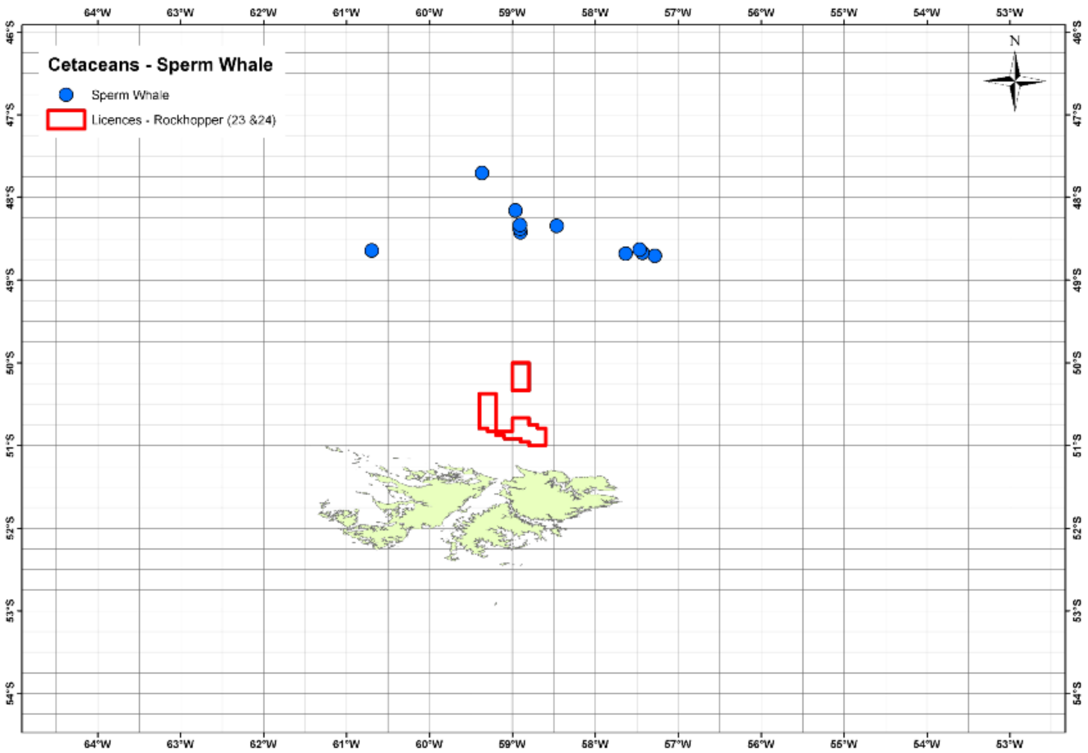
<u>Sei whale (*Balaenoptera borealis)*</u>

Most sei whale sightings were between November and April, with 45 invididuals recorded on 31 occasions. Most records were from Patagonian Shelf waters around East Falkland, with other sightings in relatively shallow waters.



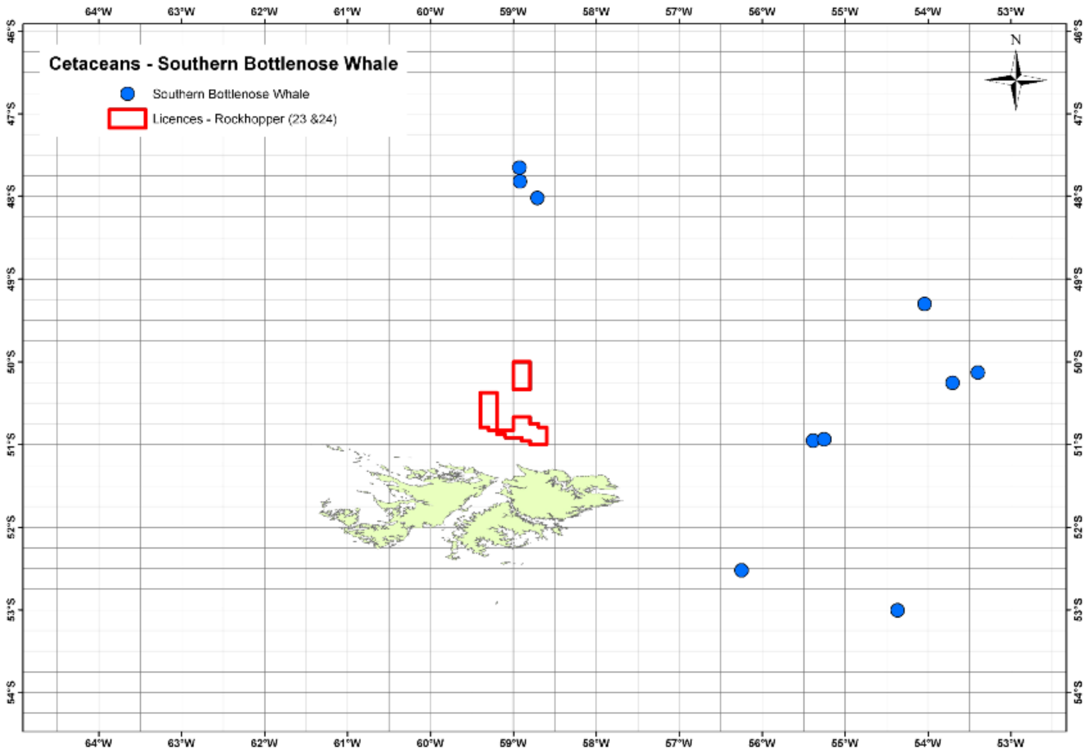
Minke whale (*Balaenoptera acutorostrata*)

Minke whale sightings peaked in April and December, with a total of 68 whales recorded on 60 occasions. The majority of records were from Patagonian Shelf waters around East Falkland and in the north-west of the survey area.



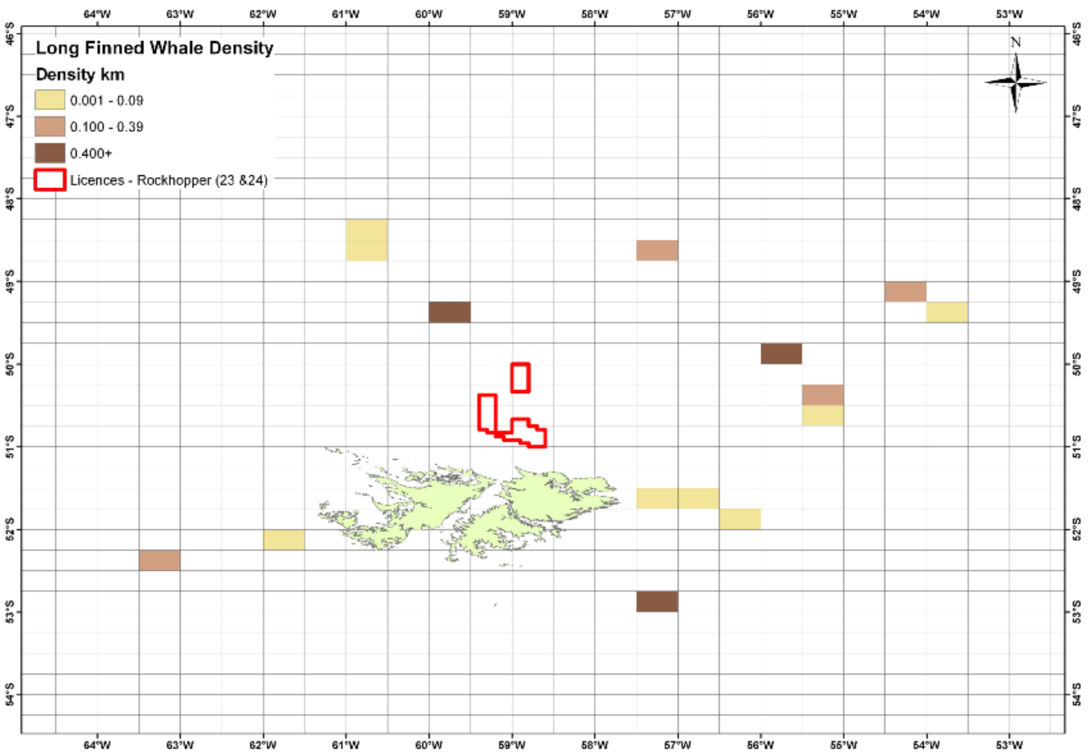
Sperm whale (*Physeter macrocephalus*)

A total of 28 sperm whales were recorded on 21 occasions, mainly in July, October and December, but also present throughout most months. All sperm whale sightings occurred in deeper waters (>200 m), with records clustered to the south and to the north of the Falklands.



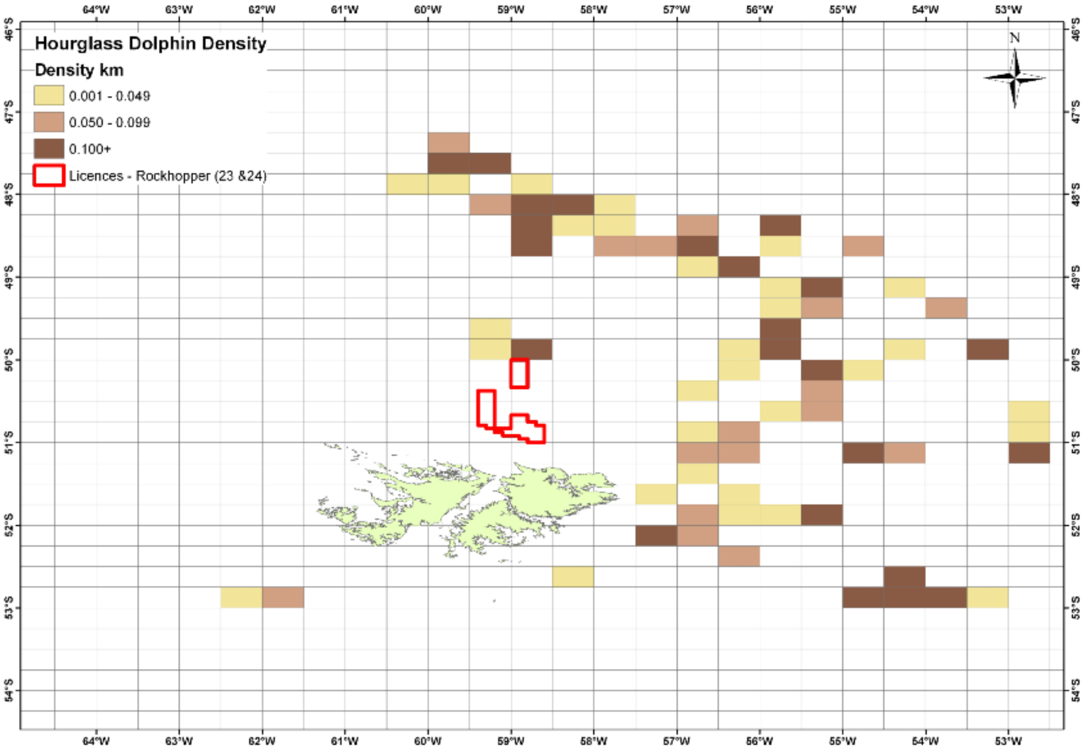
Southern bottlenose whale (*Hyperoodon planifrons)*

Southern bottlenose whales were recorded between September and February, with a total of 34 records on 18 occasions. All sightings were made in waters >1000 m, generally to the north, east and south of the Falklands.



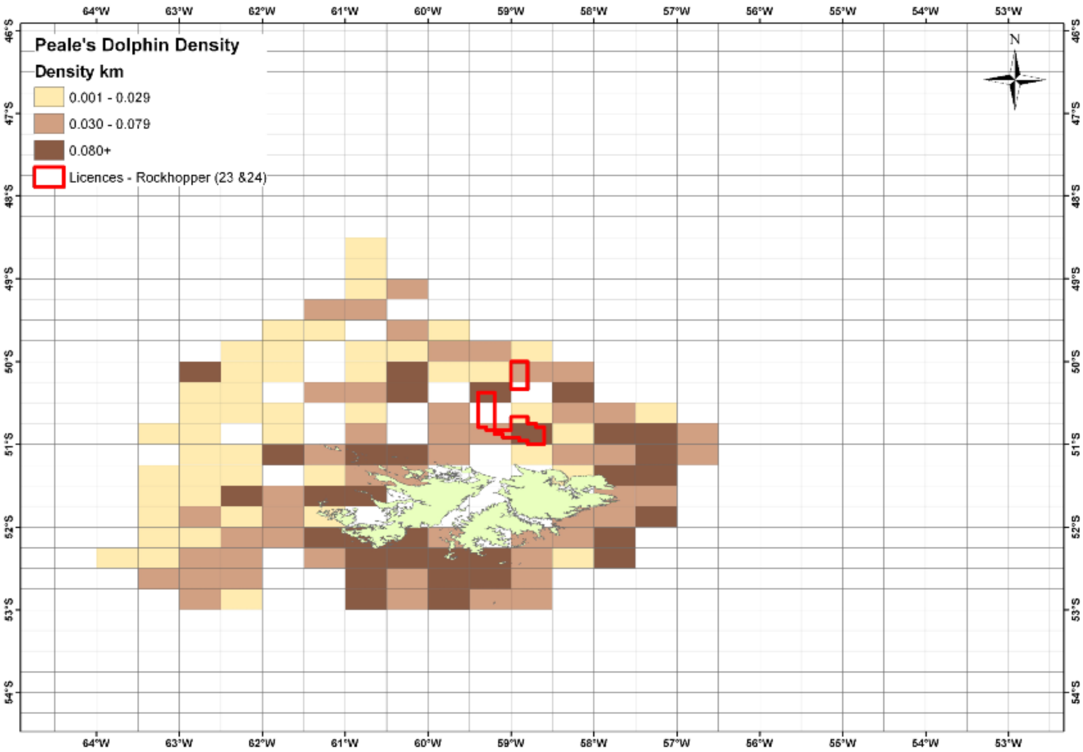
Long-finned pilot whale (*Globicephala melas)*

Large number of records were made of long-finned pilot whale (872 over 27 occasions), with group sizes of up to 200 sighted. Although these whales were recorded in all months except January, they were predominantly recorded between April and September and in waters deeper than 200 m.



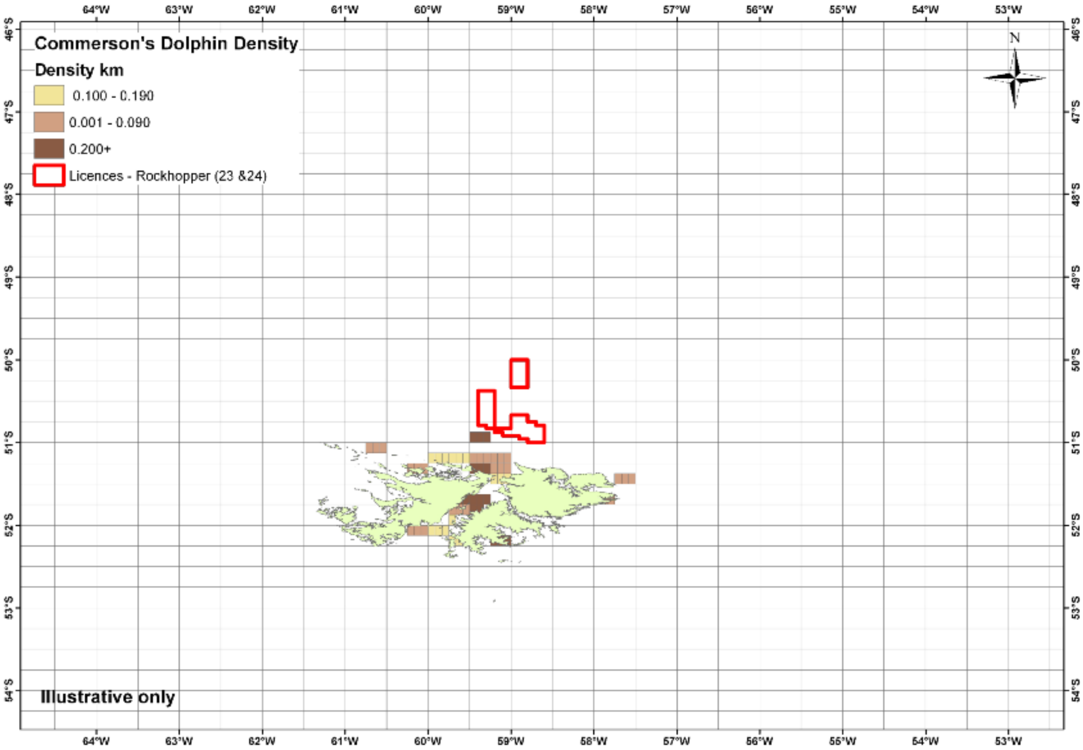
Hourglass dolphin (*Lagenorhynchus cruciger)*

Hourglass dolphins were recorded in large numbers, with 866 Sightings over 177 occasions, mainly between September and March and in water depths of greater than 200 m.



Peale's dolphin (Lagenorhynchus australis)

Peale's dolphins were the most numerous and frequently recorded cetacean with a total of 2617 animals recorded on 864 occasions. Peale's dolphins were recorded in all months with a maximum of 358 animals recorded in August. They were generally found only in waters less than 200 m deep and are therefore unlikely to be seen in the proposed drilling area.



Commerson's dolphin (*Cephalorhynchus commersonii)*

A total of 336 Commerson's dolphin was recorded on 100 occasions, covering all months except May. Dip in records over May and June may be due to variation in the level of survey effort rather than seasonal variations. No individuals were recorded greater than 25 km offshore.

Figure 7-14 Cetacean Species Distribution in the North Falkland Basin (1998–2001)

In addition to the sightings described above, several species of marine mammals were recorded on fewer than 10 occasions and are therefore described as rare in White et al. (2002).

Southern right whale (*Eubalaena australis)*

Two records, of two separate individuals, were recorded in 1998. A further record was made in June 2000 and two additional records of single animals in January 2001. Although the majority of sightings were to the north of the Falkland Islands, the low number sightings make geographic or seasonal modelling inaccurate.

Humpback whale (*Megaptera novaeangliae)*

Seven records were made over five occasions, all between October and March in Patagonian Shelf waters. Most records were made to the north-west of the Falklands.

Unidentified beaked whale species (*Mesoplodon spp*.)

There were 15 animals sighted in seven occasions, none were specifically identified. All records were in waters deeper than 1000 m to the east of the Falklands.

Killer whale (*Orcinus orca)*

A total of 18 animals were recorded in seven occasions, mainly in coastal and Patagonian Shelf waters. These sightings took place throughout the year in groups of between one and four animals. Longline fishing vessels have also reported interaction with killer whales in deep waters to the north and east, where they remove fish from the lines (Munro, 2004).

Southern right whale dolphin (*Lissodelphis peronii*)

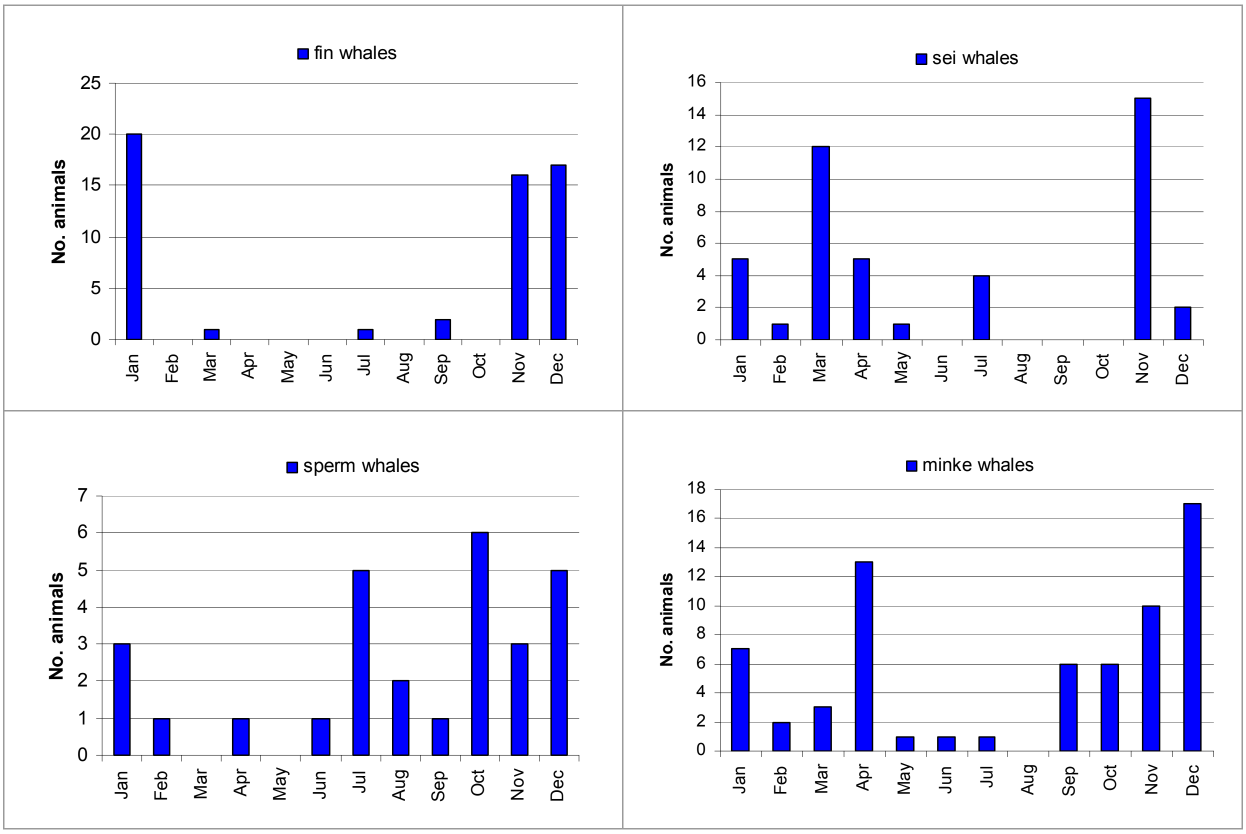
Southern right whale dolphins were recorded on five occasions totalling 231 animals, all in deep waters to the east of the Falkland Islands.

Munro (2004) states that records in Falkland Islands waters of dusky dolphins (*Lagenorhynchus obscurus*), bottlenose dolphin (*Tursiops truncatus*) and spectacled porpoise (*Phococena dioptica*) sightings have been made. The lack of any sighting over the three year survey period indicates that these animals are unlikely to be present in the licence area in significant numbers.

Based on the 1998–2001 survey results, of the 14 cetacean species likely to be present in Falkland Islands waters only Hourglass and Peale's dolphins were recorded within or bordering the licence areas of interest. Due to the migratory nature of cetaceans however, it is probable that certain cetacean species present may move through the licence areas.

Some species have also been recorded within Falkland waters in the past through anecdotal sightings or strandings, which were not recorded during the survey period. These include several species of beaked whales (Ziphiidae), the blue whale (*Balaenoptera musculus*), and several dolphin and porpoise species.

Overall, PL023 and PL024 are not considered to be an area of particularly high sensitivity for cetaceans.



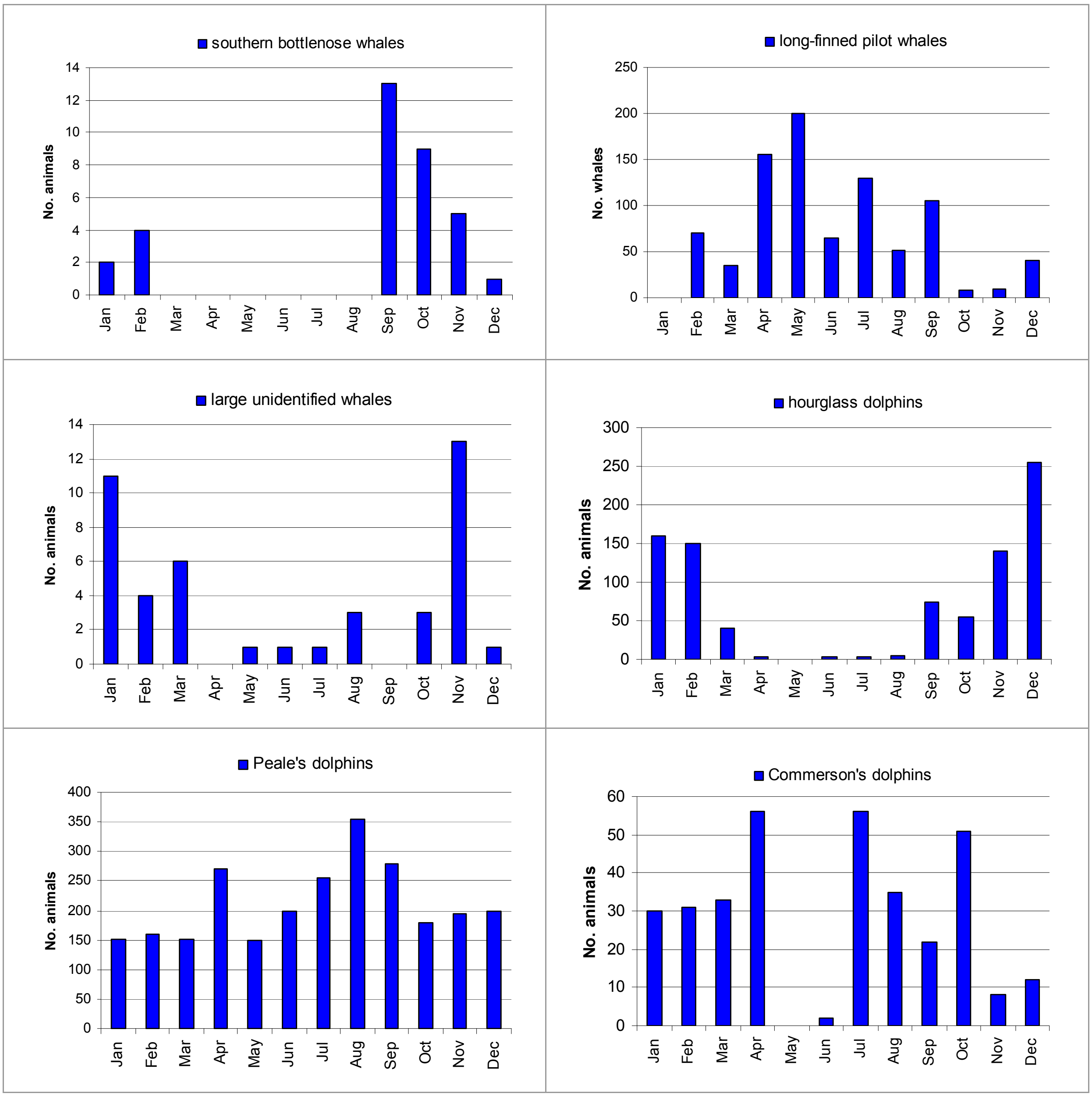


Figure 7-15 Cetacean Numbers Recorded per Month (JNCC 2002)

7.2.8.2. Pinnipeds

Four seal species occur in the Falklands – three species breeding and one occurring as a vagrant. Seal species include the predominant *Otaridae* (eared seals) group comprising fur seal and sea lion species, and the *Phocidae* (true seals) group comprising southern elephant seal and leopard seal. Figure 7-16 illustrates the distribution of Pinnipeds around the Falkland Islands during the 1998–2001 surveys.

South American sea lion *Otaria flavescens* (formally *Otaria byronia*)

The southern sea lion (*Otario* flavescens) is widely distributed along the coast of South America as far north as Peru and Brazil. Within the Falklands, sea lions breed in small colonies at around one hundred sites, mainly on remote sandy beaches with adjacent tussac grass.

Both males and females are orange-colored with upturned snouts. The manes on males are lighter than females, but female fur on the head and neck is lighter than that of males. Size varies with males having an average length of 2.6 m and weight of about 300 kg. Females are slightly smaller, having an average length of 1.8–2 m and usually weighing approximately half the weight of the males, around 150 kg. Breeding begins in December when bulls establish territories, with the females arriving during late December and January to pup. Females mate shortly after pupping, but continue to rear the pups for up to 12 months or more (Munro, 2004)

The UK Sea Mammals Research Unit (SMRU) conducted the most complete census of southern sea lions on the Falkland Islands in 1995 and repeated it in 2003 to monitor population trends. The two censuses update partial surveys conducted between 1934 and 1937 by Hamilton and aerial surveys conducted by Strange in 1990 (Strange, 1992). Population estimates have varied with the JNCC at-sea surveys estimating a Falkland resident population of 3385. Thompson (2003) estimates a current Falklands population of approximately 7047 animals, with an estimated 2744 pups born annually. The census trends concluded that while the overall population is increasing, it is still well below the peak populations recorded in the 1930's, due to heavy exploitation during the twentieth century.

<u>South American fur seal (*Arctocephalus australis*)</u>

The South American fur seal is the smallest of the pinnipeds to breed in the Falklands. It breeds at 15 known sites within the Falklands, where it tends to concentrate in fairly large numbers on elevated rocky shores. Fur seals appear to prefer to inhabit rocky coastal strips above the reach of storms (Laws, 1981) and undercut cliff edges, with access to both offshore reefs or kelp beds and coastal tussac grass habitat (Bonner, 1968).

Males of the species have a dark grey coat of fur with the females and sub-adults having lighter grey or tan colouring on the chest and muzzle. On average, adult males measure up to 2 m long and weigh 150–200kg and females measure up to 1.5 m long and weigh 30–60kg. Mating commences in early November with the establishment of territories by the dominant bulls. Pubs are generally born around 6–8 weeks later in mid-December

It is estimated that the current Falklands population stands at over 10 000 adults, however no dedicated population census has been conducted in recent years. It is probable that there may have been a steady increase this century following its near extermination by the fur trade during the last century (Munro, 2004).

<u>Southern elephant seal (*Mirounga leonine*)</u>

The southern elephant seal is the largest of all the pinniped species. Found in most sub-Antarctic waters, the Falklands only hold only a very small percentage of the world population. Only one major breeding colony exists on Sea Lion Island and it is estimated to represent around 90% or more of the breeding population of the Falklands.

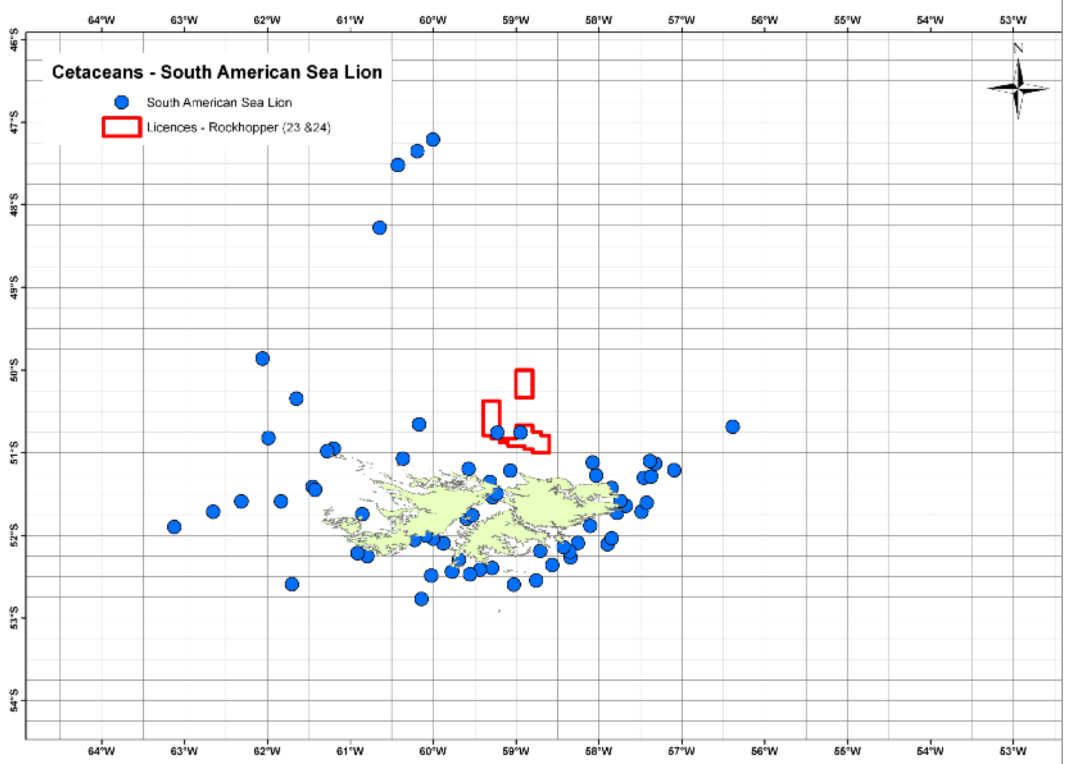
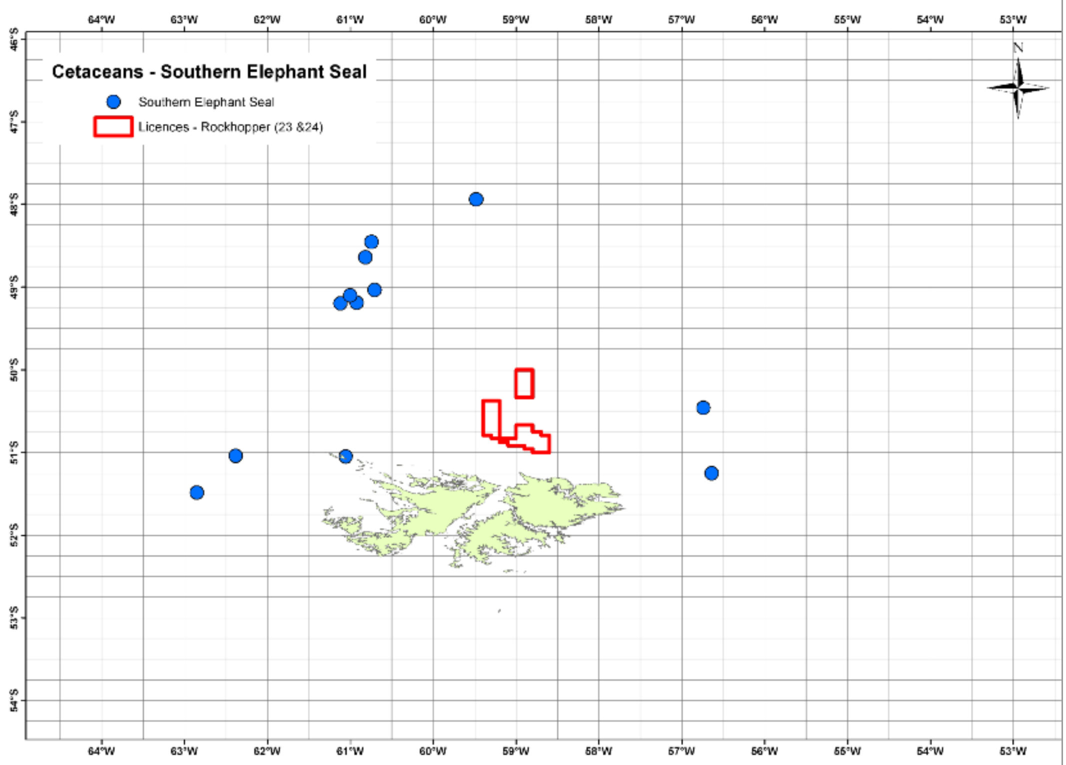
The elephant seal gets its name from both its massive size and from the large proboscis which males have. Males are much bigger than the females with bulls weighing around 2000—3000 kg and 3 m in length compared to about 600–800 kg for females. Southern elephant seals breed from August to November with the bulls arriving weeks before the females to claim territories. Pups are born 0–10 days after the females come to shore.

Falkland Island elephant seals were almost hunted to extinction by sealers in the past. A population peak of around 3500 was recorded in the 1950's, but there are indications that the Falklands population has declined over the last few years.

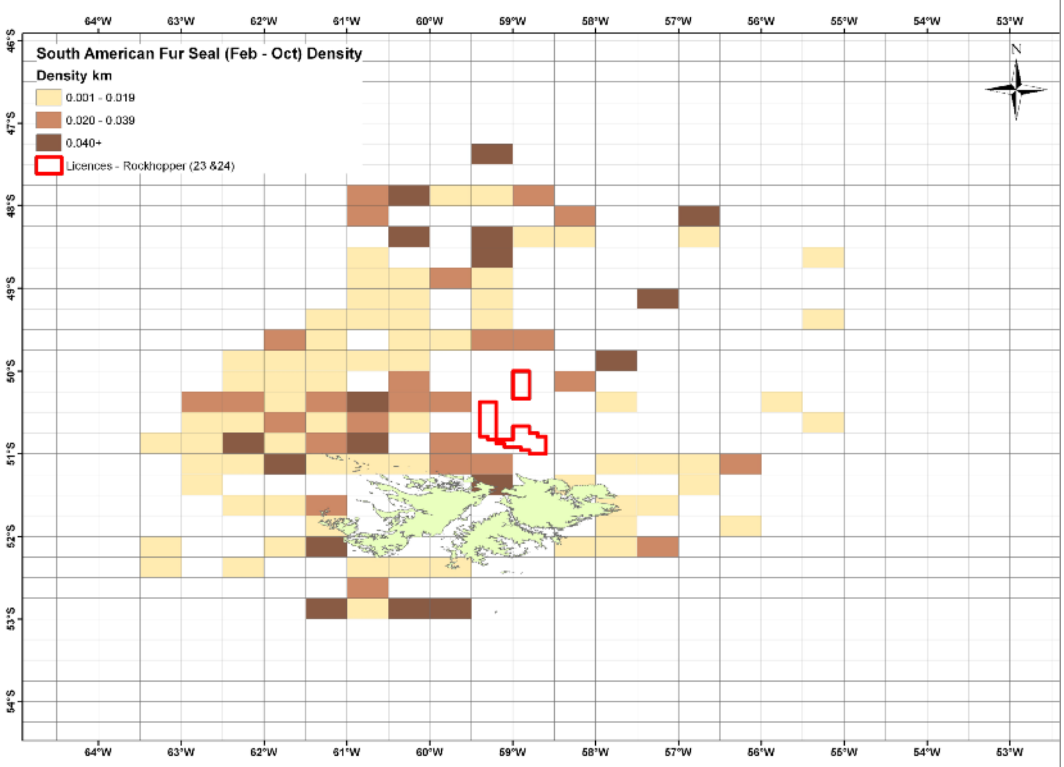
<u>Leopard Seal (*Hydrurga leptonyx*)</u>

The leopard seal is a winter visitor to the Falkland Islands, with only occasional sightings reported to Falklands Conservation. They are known to breed on sub-Antarctic pack ice and are highly unlikely to be impacted by normal offshore drilling operations.

Leopard seals have dark grey backs and light grey stomachs. They get their name from their spotted throats. Females are generally larger than males, with males about 2.8 m long and weighing up to 320 kg, with females around 3–3.5 m in length and weighing up to 370–400 kg.

South American sea lion	
Southern elephant seal	

South American fur seal (Feb-Oct)



South American fur seal (Nov-Jan)

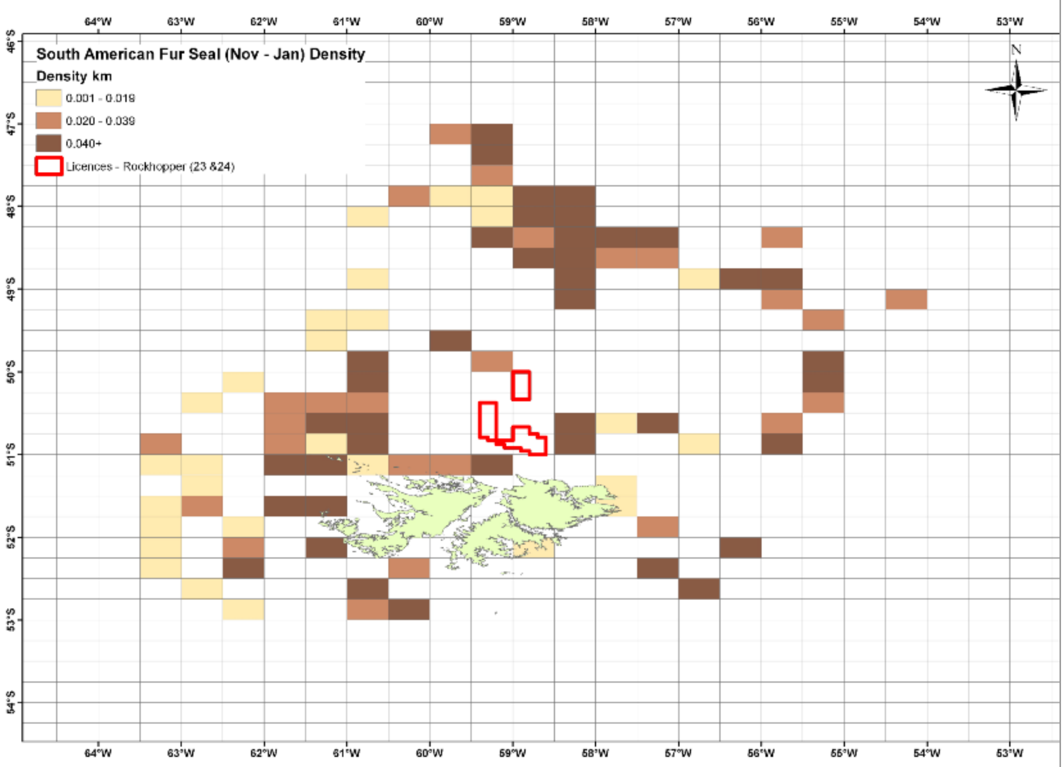


Figure 7-16 Pinniped Distribution

(Source: JNCC, 2002**)**

Based on these observations only the South American Sea Lion is likely to be encountered within the licence area, however it should be noted that coverage of the surveys is patchy and this does not discount the potential presence of any of the above species in these blocks. It is however unlikely that any species of pinniped will be found in significant numbers in the area. Based on the distribution survey and further descriptions in Munro (2004), the licence area is therefore not considered to be of particular sensitivity for pinnipeds.

7.2.9. Seabirds

The Falkland Islands are an area of global importance for birdlife, particularly seabird species of international significance. The North Falklands Current upwells nutrient rich water from Antarctic waters and provides an area of high plankton activity, forming the basis of the marine ecosystem and supporting seabird activity in the region.

The avifauna of the region is well studied and documented, and seabird distribution, breeding and foraging patterns have been studied extensively. A number of publications outlining survey efforts by those such as Croxall et al. (1984), Woods (1988; 1997), Strange (1992) have recently been supplemented by ongoing seabird monitoring and survey programmes conducted by FC/JNCC, including:

- Falkland Islands State of the Environment Report (Otely et al., 2008). This report documents the current knowledge of the Falkland Islands' environment.
- Origin, age, sex and breeding status of wandering albatrosses (Diomedea exulans), northern (Macronectes halli) and southern giant petrels (Macronectes giganteus) attending demersal longliners in Falkland Islands and Scotia Ridge waters, 2001 – 2005 (Otley et al., 2006). The report summarises three years of survey work undertaken in Falkland Island waters between 2001 and 2005.
- Patterns of seabird attendance at Patagonian toothfish longliners in the oceanic waters of the Falkland Islands, 2001–2004 (Otley, 2005). The report summarises the surveys of seabirds attending Patagonian toothfish longliners during line setting and hauling activities in deepwater to the east of the Falkland Islands made between July 2001 and June 2004.
- The distribution of seabirds and marine mammals in Falkland Island waters (White, 2002). The report summarises three years of survey work undertaken in Falkland Island waters between February 1998 and January 2001.
- Vulnerable concentrations of seabirds (White et al., 2001). The report summarises two years of survey work in the form of a vulnerability atlas, with the aim of highlighting the locations of seabird concentrations that would be the most vulnerable to the effects of surface pollution.

These reports have been used extensively to provide a synopsis of seabird species, numbers, locations and sensitivities, and the information presented below and in the following sections has been based on these sources.

Between 1998 and 2001 a total of 218 species were recorded along with some unconfirmed sightings and have been included within this list. There were 21 resident landbirds, 18 waterbirds, 22 breeding seabirds, 18 annual non-breeding migrants and at least 139 occasional visitors (Woods et al., 2004). Between 2001–2005 a total of 547 sightings of 291 banded wandering albatross *Diomedea exulans* and 21 sightings of 14 banded giant petrels *Macronectes* spp. were made (Otley, 2005).

There are five different species of breeding penguin in the Falkland Islands (rockhopper, Magellanic, gentoo, king and macaroni). The Falklands are the most important world site for the endangered rockhopper penguin and are also home to 80% of the world's breeding population of black-browed albatross. Several rare and threatened species of petrel nest on offshore islands.

The IUCN Red List classifies 24 species as threatened with five species as 'Endangered' and a further 11 species as 'Vulnerable' (Appendix I).

7.2.9.1. Penguins

Nine penguin species have been recorded in the Falkland Islands with the following six species identified during the at-sea survey period (1998–2001) (Figure 7-17). Of these, only the Chinstrap penguin (*p. Antarctica*) is not considered to be a locally breeding species.

- King penguin (*Aptenodytes patagonicus*)
- Gentoo penguin (Pygoscelis papua)
- Rockhopper penguin (*Eudyptes chrysocome*)
- Macaroni penguin (*Eudyptes chrysolophus*)
- Magellanic penguin (*Speniscus magellanicus*)
- Chinstrap penguin (*P. antarctica*)

King Penguin (*Aptenodytes patagonicus*)

The Falkland Islands population of king penguin is almost entirely concentrated at Volunteer Point, although a few individuals can be found nesting amongst gentoo penguins at four to six locations within the Falklands (Huin, 2007). The 2005/2006 Penguin Consensus observed 260 chicks at Volunteer Beach (Huin, 2007). From the 1980s to 2001, the Volunteer Beach breeding population was estimated at between 344–516 breeding pairs increasing at additional 12–15 chicks per year. This increase has somewhat slowed over the past three years (Huin, 2007).

The Falkland Islands' population makes up only 0.04% of the world population and is considered to be of local rather than global importance (Munro, 2004), however since the population is mostly limited to one site its vulnerability increases, particularly to a polluting event.

By mid-winter birds begin to forage north of the Falklands, in an area used by many bird species as a winter feeding ground (Patagonian continental shelf and slope waters within the Antarctic Polar Frontal Zone). In total 151 king penguins were recorded during the 1998–2001 at-sea surveys on 81 occasions, almost entirely between May and November.

A number of birds were identified in the vicinity of the licence areas and throughout areas to the north of the Falklands.

Gentoo penguin (*Pygoscelis papua*)

The gentoo penguin is numerous and widely distributed throughout the Falkland Islands, although most are found around West Falkland and the outer islands. The population was estimated at 64,426 breeding pairs in 1995/1996, 113,000 in 2001/2002 and 65 857 in 2005/2006 and represents, of the 12 major breeding regions, the second largest gentoo population in the world after South Georgia (Huin, 2007). The reduction in gentoo numbers between 2000 and 2005 was due to paralytic shellfish poisoning resulting from a red algal bloom in 2002.

Tracking of foraging gentoo penguins show that the birds remain in predominantly inshore waters, preferring low coastal plains close to a sand or shingle beach and an open ocean free of kelp, although in winter foraging trips may be undertaken up to 300 km from the coast.

A total of 3896 gentoo penguins were recorded during 1998–2001, covering all months but with an increase between April and September. They are only likely to be found outside coastal waters between April and November, with densities in offshore areas generally low.

During the survey period, gentoo penguins were only observed in the very southern reaches of the licence area.

Rockhopper penguin (*Eudyptes chrysocome*)

The rockhopper penguin *Eudyptes chrysocome* has been split into the northern rockhopper penguin *E. moseleyi* and southern rockhopper penguin *E. chrysocome*. It is the southern rockhopper penguin that breeds in the Falkland Islands.

Rockhopper penguins are found in greatest numbers in the outer islands of West Falkland. There are around 52 breeding sites on the Falklands, with a population estimated at 211,000 breeding pairs in 2005/2006 (Huin, 2007). Three colonies of importance in the Falklands are on Beauchêne Island (31%), Steeple Jason (28%) and Grand Jason (5%). Forty-eight percent of the world's southern rockhopper population is found on islands in southern Chile, 29% on the Falklands and 24% in southern Argentina. The decline of the rockhopper population has lead to the IUCN classifying it as 'Threatened' (BI, 2004).

Annual surveys conducted at selected sites suggest that the rockhopper population has stabilised since the early 1990's, although there are still occasional periodic annual declines from which the populations do not fully recover. Tracking of rockhopper penguins has shown that they are likely to be present in the licence area on foraging trips.

Rockhopper penguins have been observed a significant distance north of the Falklands and can be expected to occur throughout the licence areas.

Macaroni penguin (*Eudyptes chrysolophus*)

The macaroni penguin is the least common breeding penguin species in the Falklands, with 24 pairs recently recorded at 19 rockhopper penguin colonies, mostly on the eastern side of the Falkland Islands (Huin, 2007). Mixed pairs of rockhopper and macaroni penguins have been observed and suggests hybridisation may occur between the species (White & Clausen, 2002).

The macaroni penguin, however, is globally the most common species with millions of pairs present in the southern Atlantic and Indian Oceans (Munro, 2004). The occurrence of vagrant individuals in the Falklands is therefore of only local interest.

Magellanic penguin (*Speniscus magellanicus*)

The Magellanic penguin is less colonial than the other penguin species on the Falkland Islands and an estimated 200,000 breeding pairs over 90 locations on the Islands are thought to comprise one third of the world's population (Thomas, 1993). As a significant proportion of the world population, the Falkland Islands are internationally important for the Magellanic penguins.

Penguin tracking has shown that they are likely to travel through the licence area during long foraging trips into deeper waters, although they are likely to be absent from Falklands waters over winter.

In excess of 12,000 Magellanic penguins were recorded during the 1998–2001 at-sea surveys, the majority between November and April. Few were recorded between May and August, with the highest densities recorded between December and February, primarily in inshore waters. Some locally high densities were recorded over Patagonian Shelf waters and continental shelf slope waters to the north of the Falklands.

Chinstrap penguin (*P. antarctica*)

Chinstrap penguins do not breed in the Falkland Islands, however a total of 24 individuals were recorded on 10 occasions (1998–2001). All records occurred between August and October in the extreme south-east of the survey area, a considerable distance from the North Falkland Basin.

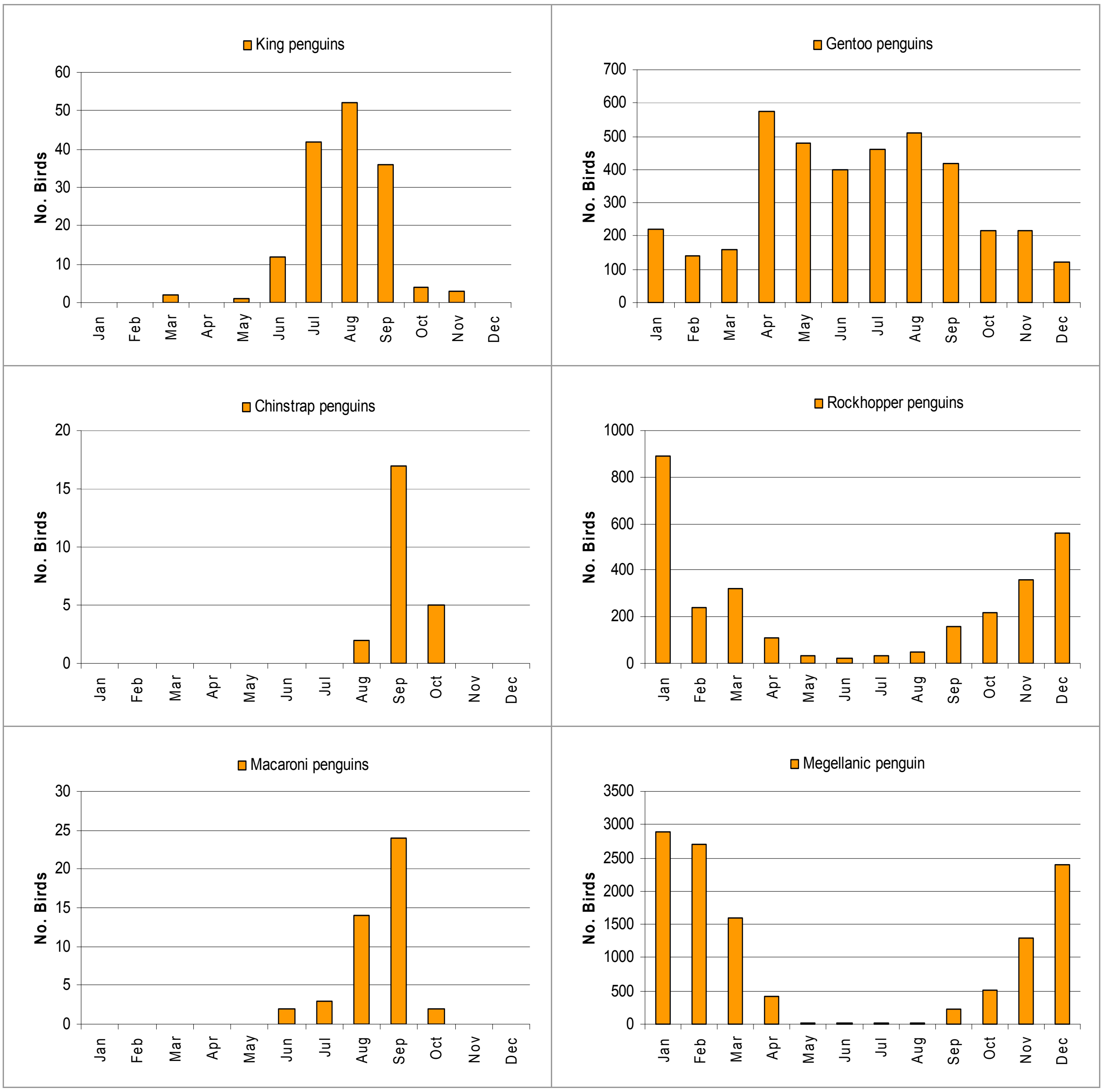


Figure 7-17 Penguin Numbers Recorded per Month (JNCC 2002)

7.2.9.2. Albatrosses

Albatross species are globally declining with populations in the Falklands reported to have dropped by 28% in the last 20 years, the rate of decline accelerating especially over the last 5 years (Woods, 1988). Eleven species of albatross have been recorded in the Falklands, although only the black-browed albatross is a resident breeding species.

Ten of the 11 species of albatross recorded in the Falkland Islands are afforded conservation status, and include:

- Black-browed albatross (T*halassarche melanophris)* – Endangered
- Buller's albatross (*Thalassarche bulleri*) – Vulnerable
- Grey-headed albatross (*Thalassarche chrysostoma*) – Vulnerable
- Light-mantled sooty albatross (*Phoebetricia palpebrata*) – Near Threatened
- Northern royal albatross (*Diomedea sanfordi*) - Vulnerable
- Shy albatross (*Thalassarche cauta*) – Near Threatened
- Sooty albatross (*Phoebetria fusca*) – Endangered
- Southern royal albatross (*Diomedea epomophora*) - Endangered

- Wandering albatross (*Diomedea exulans*) - Vulnerable
- Yellow-nosed albatross (*Thalassarche chlororhynchos*) – Endangered

The numbers of individuals of each species observed during the at-sea survey period (1998–2001) per month are shown in Figure 7-18, and are described in detail below.

Black-browed albatross (*Thalassarche melanophris*)
The population in the Falkland Islands is genetically distinct from all other populations and is the only species that breeds on the Islands. The estimated 400,000 breeding pairs represents 70% of the world population, and makes the Falklands of critical importance for the conservation of this species. Black-browed albatross is now classified as 'Endangered' by Birdlife International and the IUCN Red List.

Black-browed albatross were recorded in all months (1998–2001), with a total of 84,614 birds recorded, reaching a peak in March. Between November and January the highest densities occurred in inshore waters to the west of the Falklands. Between February and June high densities occurred throughout Patagonian Shelf waters to the north-west of the Falklands and between July and October high densities shifted to the south-west of the Falklands.

Grey-headed albatross (*Thalassarche chrysostoma*)
Grey-headed albatross visit the Falkland Islands from breeding grounds in South Georgia and Diego Ramirez. The grey-headed albatross is classified as 'Vulnerable'.

A total of 1321 grey-headed albatross were recorded, covering all months (1998–2001) with a peak between May and September. Distribution varied throughout the year, with records over the licence area occurring between February and September.

Light-mantled sooty albatross (*Phoebetricia palpebrata*)
The light-mantled albatross is also a non-breeding visitor from the South Georgia region where there are an estimated 5000–7000 breeding pairs.

In total 24 were recorded during the 1998–2001 at-sea survey, mainly between August and November and in waters deeper than 200 m to the east of the Falklands.

Northern (*Diomedea sanfordi*) and Southern (*Diomedea epomophora*) royal albatross
The royal albatrosses are also visiting species, breeding in New Zealand and using South Pacific and Patagonian feeding grounds. The southern royal albatross is classified as 'Vulnerable' where as the Northern is 'Endangered'.

Of the 4114 royal albatrosses recorded (1998–2001), 3252 were identified as southern and 447 as northern (with 415 not determined). Highest numbers of southern royal albatross were seen between March and June, particularly to the north-west of the Falklands. Highest numbers of northern royal albatross were seen between March and July, generally in the same areas as the southern.

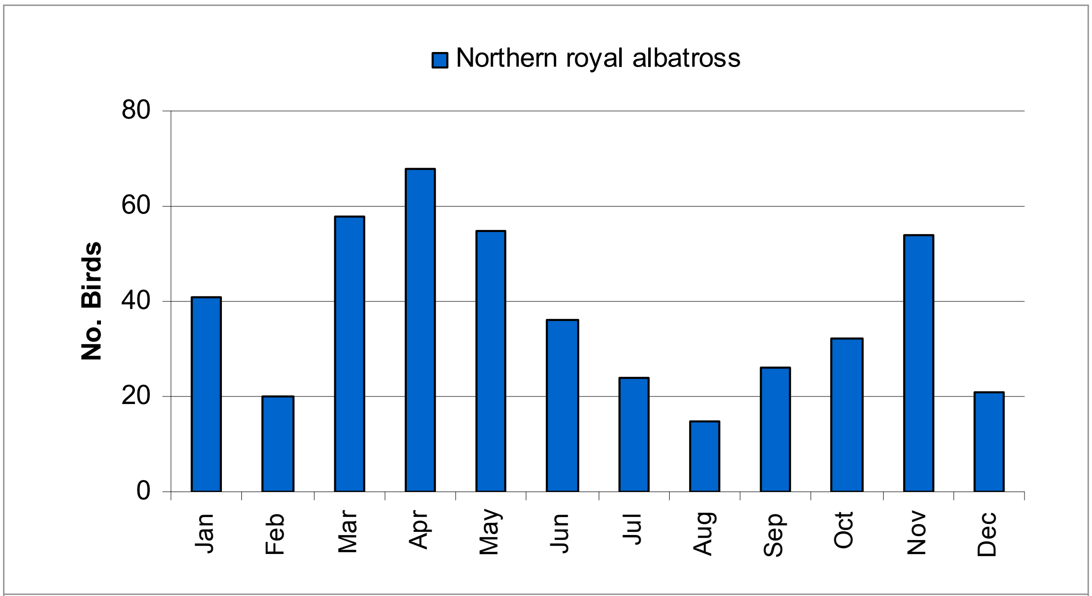
Shy albatross (*Thalassarche cauta*)
Although the shy albatross is found in Patagonian waters, there dispersal from breeding grounds in Australia and New Zealand is not well known. The shy albatross is classified as 'Near Threatened'.

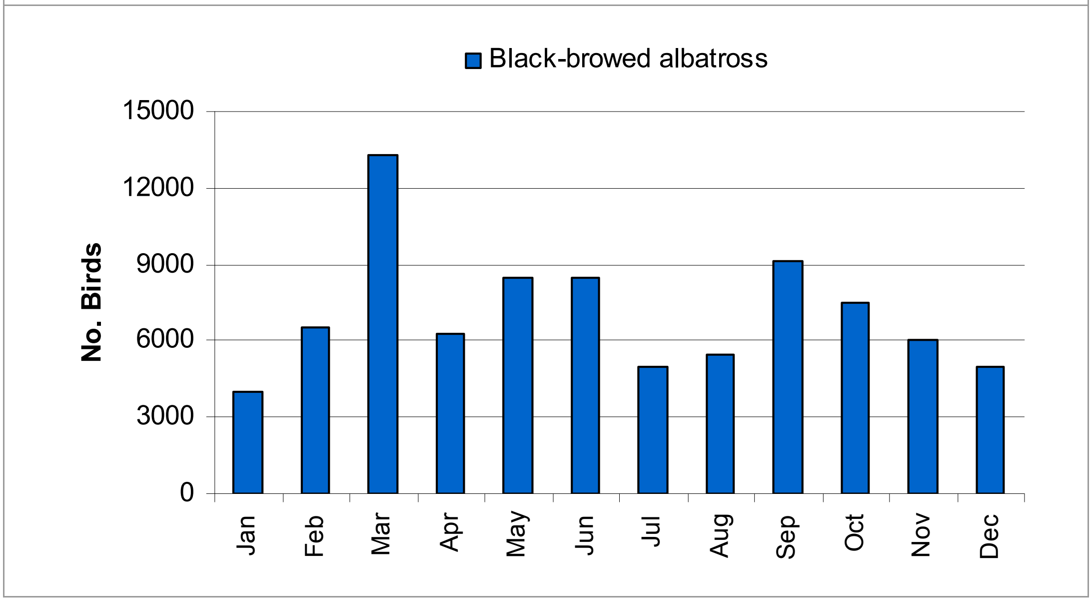
Few shy albatross have been recorded in the Falkland Islands previously. A total of 25 were recorded during the 1998–2001 at-sea survey, all between January and May. The majority of records were from the north and west of the Falklands.

Wandering albatross (*Diomedea exulans*)
The wandering albatross is a non-breeding visitor to the Falkland Islands, predominantly from

breeding colonies in the South Georgia Islands around 1300km to the east. The wandering albatross is classified as 'Vulnerable', as the population continues to decline with only 1553 breeding pairs recorded in 2003–2004.

Wandering albatross were recorded by the at-sea surveys for all months, with a peak in November and highs between January and April. They were locally abundant in all deep waters surveyed, particularly to the east of the Falklands.





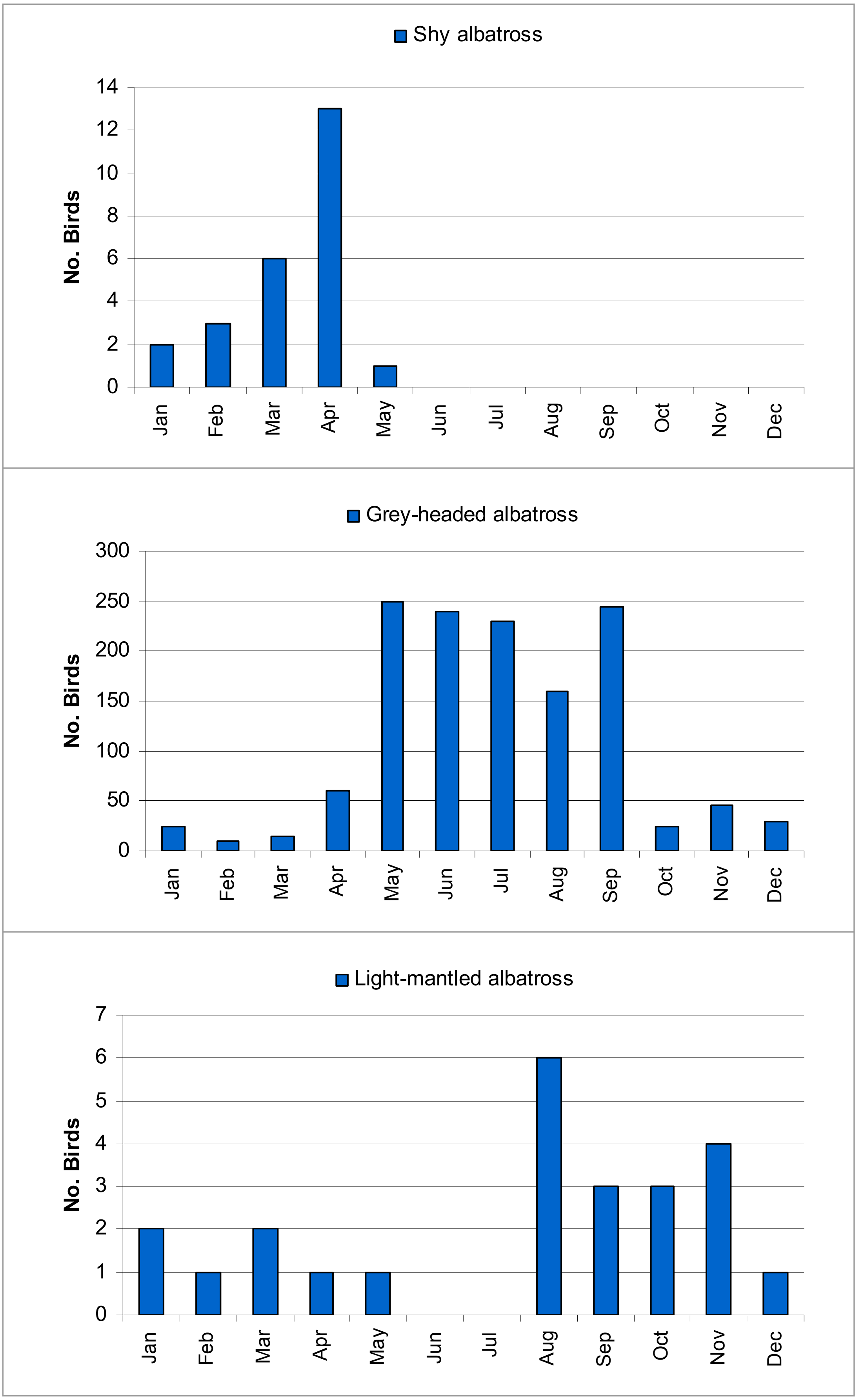


Figure 7-18 Albatross Numbers Recorded per Month (JNCC 2002)

7.2.9.3. Petrels and Shearwaters

Petrels and shearwaters form the largest group of oceanic birds, remaining at sea throughout their lives, except for a few months each year when they return to land to breed. The most common breeding species is the southern giant petrel (*Macronectes giganteus*) (Otely et al., 2008). As many as 26 species have previously been recorded in the Falkland Islands with nine species breeding on the Islands.

- Northern giant petrel (*Macronectes halli*)
- Antarctic petrel (*Thalassoica Antarctica*)
- Antarctic fulmar (*Fulmarus glacialoides*)
- Kerguelen petrel (*Pterodroma brevirostris*)
- Atlantic petrel (*Pterodroma incerta*)
- Grey petrel (*Procellaria cinerea*)
- Great shearwater (*Puffins gravis*)
- Little shearwater (*Puffins assimilis*)
- Grey backed storm-petrel (*Garrodia nereis*)
- White-bellied storm-petrel (*Fregetta grallaria*)
- Northern giant petrel (*Macronectes halli*)
- Southern giant petrel (*Macronectes giganteus*)
- Cape petrel (*Daption capense*)
- Blue petrel (*Halobaena caerulea*)
- Soft-plumaged petrel (*Pterodroma mollis*)
- Prion spp (*Pachyptila spp*)
- White-chinned petrel (*Procellaria aequinoctialis*)
- Sooty shearwater (*Puffins griseus*)
- Wilson's storm-petrel (*Oceanites oceanicus*)
- Black-bellied storm-petrel (*Fregetta tropica*)
- White-bellied storm-petrel (*Fregetta grallaria*)
- Southern giant petrel (*Macronectes giganteus*)

The Falklands hold a significant percentage of the world population of the southern giant petrel and surveys have shown at-sea distribution to be concentrated mainly over Patagonian Shelf waters. Fishing related mortality is estimated to be around 100 birds per annum in Falklands waters and world populations are declining. The species is classified as 'Vulnerable' (BI, 2000).

Giant petrels are divided between the northern and the southern, with only the southern giant petrel breeding regularly in the Falklands (population estimated at between 5000 and 10000 pairs (Woods & Woods, 1997)). In total 6672 giant petrels were recorded in the at-sea survey (1998–2001), accounting for 3535 southern and 751 northern giant petrel, with 2386 recorded as unidentified giant petrel.

Southern giant petrels were recorded in all months during the at-sea survey, peaking in June and with highest densities between March and June over Patagonian Shelf waters to the west and south of the Falklands. The southern giant petrel breeds at 38 locations around the Falklands, in colony sizes ranging between one and 110,000 breeding pairs (Reid & Huin, 2005). Most colonies concentrate around the south of South Falkland and to the west of West Falkland. Nearly 20,000 breeding pairs were counted in 2004/2005, which account for 40% of the global population (Reid & Huin, 2005).

Northern giant petrels were recorded throughout the year. Between March and August densities were highest to the north and west of the Falklands. From September to February sightings were less concentrated and more widely scattered. Northern giant petrels were less likely to be recorded in coastal or inshore waters.

A total of 56 Antarctic petrels were recorded, all between July and September in waters to the south and east of the Falklands. Antarctic petrels are winter visitors to the Falkland Islands.

Cape petrels were recorded every month, with a total of 15,199 records made over the survey. Highest numbers were recorded between May and September. Cape petrels were only recorded in abundance to the north of the Falklands over this period, lessening off between October and November with very few records in this area throughout the rest of the year.

A total of 18,061 Antarctic fulmars were recorded, all between April and December. Highest densities were recorded in the North Falkland Basin between April and June, dropping between

July and October with only occasional sightings for the rest of the year.

Blue petrels, another non-breeding visitor to the Falkland Islands, were recorded in the period May to October. A total of 573 blue petrels were recorded, the majority in deep waters to the east and south-east of the Falklands. Records in the North Falkland Basin were rare.

A total of 152 Kerguelen petrels were recorded, almost wholly between May and November and mainly in the deep waters to the east of the Falklands. Peak numbers were recorded in August.

Soft-plumaged petrels are non-breeding late summer visitors to the Falklands, with records occurring between November to April, peaking in January. In total, 861 soft-plumaged petrels were recorded, mainly in deep waters to the north-east of the Falkland Islands. Low numbers were also recorded in the North Falkland Basin.

A total of 252 Atlantic petrels were recorded, primarily between October and March but with records in all months. Most sightings were to the north-east and south-east of the Falklands in deep waters.

Due to the difficulty in identifying prions (small petrels) to species level at sea, most records from the at-sea survey were for ‘prion species’. A total of 119,610 records makes prions the most numerous seabirds encountered during the survey, with the highest numbers recorded between September and January. Highest densities were recorded to the west, north and south of the Falklands, with numerous sightings in the North Falkland Basin.

The fairy prion was identifiable at sea and has been recorded separately. In total 228 fairy prions were recorded, in all months except February, with peaks in April, August and October. This species was recorded primarily in continental shelf slope and oceanic waters, with very few records to the north of the Falklands.

Grey petrels were recorded mainly between December and March, with peak numbers in February. A total of 45 grey petrels were recorded, all in deep waters to the north and east of the Falklands.

The white-chinned petrel breed on the Falkland Islands and survey work from summers of 2004/2005 and 2005/2006 indicate that this accounts for less than 1% of the global population. A total of 8044 white-chinned petrel were recorded from the at-sea survey (1998–2001), encompassing all months but with the highest numbers between January and May. Most records were to the north and west of the Falklands.

Great shearwaters were recorded primarily between December and April during the at-sea survey, with almost none recorded between June and October. Total number of records was 6468, mainly over shelf slope and oceanic waters to the east and north of the Falklands. Although of importance at a local level, the population is not globally significant as an estimated five million breeding pairs are found on the Tristan da Cunha and Gough Island group.

Sooty shearwaters breed on the Falkland Islands, with a population estimated at 10,000 to 20,000 pairs (Woods & Woods, 1997). A total of 37,109 sooty shearwaters were recorded, mainly between September and March, with a peak in October. Most records occurred throughout inshore waters of the Falklands and shelf to the east and south-east. The population is not considered to be globally significant as the world population is estimated to be in the millions.

A total of 24 little shearwaters were recorded, all between December and April with a peak in March. All records came from waters to the north and east of the Falklands.

Of the six species of storm petrels previously recorded within Falkland Island waters, four species were recorded during the at-sea survey. Wilson's storm-petrel breeds on the Falklands with an estimated population in excess of 5000 breeding pairs (Woods & Woods, 1997). A total of 21,019 Wilson's storm-petrels were recorded during the at-sea survey, mainly between October and June. Most records were to the west and north-west of the Falklands, although high densities also occurred to the north-east between November and February. New colonies were recently found at Steeple Jason in 2004 and at South Jason in 2006 (Otley et al., 2008).

The Falkland Islands support between 1000 and 5000 breeding pairs of grey-backed storm-petrels (Woods & Woods, 1997). A total of 2758 grey-backed storm-petrels were recorded during the at-sea survey, mainly between September and March. Records occurred on all sides of the Falklands, with high densities recorded to the north of the Falklands from November to March.

Black bellied and white bellied storm-petrels were both recorded, primarily between December and February and in the deep waters to the north-east of the Falklands. There were 205 records of black bellied storm-petrels and 23 of white bellied storm-petrels during the at-sea survey. Numbers of both species peaked in January.

A total of 6078 diving petrels were recorded during the at-sea survey, incorporating both the Magellan (133 confirmed) and common (753 confirmed) diving-petrel. The remainder were not specifically identified, but have been combined with common diving-petrel numbers for the purposes of the report. Most diving petrels were recorded between September and February, with greatest densities to the west and south of the Falklands.

7.2.9.4. Shags

Three species of shags have been recorded in Falkland Island waters (Woods, 1988), of which only two are resident breeding species (rock shag and imperial shag) and the other (red-legged shag) is a vagrant (and was not recorded during the at-sea survey).

- Imperial shag (*Phalacrocorax atriceps*)
- Rock shag (*Phalacrocorax magellanicus*)

The population of rock shags is estimated at between 32,000 and 59,000 pairs (Woods & Woods, 1997). They are only found in the Falkland Islands and South America. A total of 796 rock shags were recorded during the at-sea survey, peaking in July and mainly within enclosed or partially enclosed waters. All rock shags were recorded within 27 km of the coast, with evidence of birds remaining closest to the coast during summer.

The population of imperial shag in the Falkland Islands is estimated at 45,000 to 84,000 breeding pairs (Woods & Woods, 1997). A total of 39,264 imperial shags were recorded during the at-sea survey, peaking between June and September. The average sighting is within 12 km of the shore during the summer, and 37 km during June to October (White et al., 2002).

7.2.9.5. Swans, Geese and Ducks

Twenty-one species of swans, geese and ducks have been recorded in the Falkland Islands including fourteen native and one introduced species breeding in the wild: black-necked swan, coscoroba swan, ashy-headed goose, ruddy-headed goose, upland goose, kelp goose, feral goose, crested duck, Falkland Islands flightless streamer duck, flying steamer duck, yellow-billed teal, Chiloe wigeon, yellow-billed pintail, silver teal and cinnamon teal (Woods & Woods, 1997). Most species are likely to be found in coastal areas, and are migratory.

Only one species of duck was recorded during the at-sea survey off the Falkland Islands - the Falkland Steamer duck (*Tachyeres brachydactyla*).

The Falkland steamer duck is endemic to the Falklands with an estimated of between 9000 and 16,000 pairs (Woods & Woods, 1997). A total of 699 Falkland steamer ducks were recorded during the at-sea survey, however all records were made in coastal waters with peak numbers recorded in April, tailing off to nil in December.

7.2.9.6. Skuas Stercorariidae

Five species of skua have been recorded in the waters of the Falkland Islands, of which one species breeds on the Falklands and four species were observed during the at-sea surveys.

- Falkland skua (*Catharacta Antarctica*)
- Arctic skua (*Stercorarius parasiticus*)
- Long-tailed skua (*Stercorarius longicaudus*)
- South polar skua (*Catharacta maccormicki*)
- Chilean skua (*Catharacta chilensis*)

The Falkland Islands support a population of between 5000 and 9000 pairs of Falkland skua, the majority of the world population of this subspecies. Of the 737 *Catharacta* skuas recorded during the at-sea survey, 573 were recorded as Falkland skuas, four as Chilean skuas and the remainder that could not be accurately identified were counted as Antarctic skuas for the purposes of the distribution atlas. Most records occurred between November and April in inshore waters. A few birds were sighted May to October offshore to the north of the Falkland Islands.

Arctic skuas are summer visitors to the Falkland Islands and only 35 were recorded over the at-sea survey period between January and April in inshore waters and deeper waters to the north of the Falklands.

Long-tailed skuas were recorded in the waters off the Falkland Islands between November and April. A total of 239 long-tailed skuas were recorded during the at-sea survey, mainly in deep waters to the north and east of the Falklands. It is likely they would be found in the licence area, particularly between December and March when numbers are greatest.

7.2.9.7. Gulls Laridae

Seven species of gull have been recorded in the Falkland Islands, of which three species are known to breed in the Falklands (listed above) and were recorded during the at-sea surveys.

- Dolphin gull (*Larus scoresbii*)
- Kelp gull (*Larus dominicanus*)
- Brown-hooded gull (*Larus maculipennis*)

The Falkland Islands population of dolphin gulls is estimated at between 3000 and 6000 pairs (Woods & Woods, 1997). Accounting for 85% of the world population the Falkland Islands' population is of global importance. A total of 114 dolphin gulls were recorded during the at-sea survey on 60 occasions for all months except March and peaking in July. Distribution was concentrated in coastal waters and no gulls were recorded more than 20 km from the coast.

The Falkland Islands kelp gull population is estimated at between 24,000 and 44,000 pairs (Woods & Woods, 1997). A total of 2288 were recorded during the at-sea survey, covering all months and peaking June to September. Records between November and April were primarily close to shore, whereas records from May to October were more widespread over Patagonian Shelf and continental shelf slope waters.

The Falkland Islands brown-hooded gull population is estimated at between 1400 and 2600 pairs (Woods & Woods, 1997), compared to a global population of approximately 50,000 pairs. A total of 134 brown-hooded gulls were recorded during the at-sea survey over 69 occasions, covering all months with the highest recorded number in January. The majority of records were made within 10 km of the coast, with a recorded maximum of 53 km from the coast.

7.2.9.8. Terns Sternidae

Three species of tern were recorded during the at-sea survey (listed below), although eight species have been previously recorded in Falkland Island waters (Otely et al., 2008) of which only one species is known to breed in the Falklands;

- South American tern (*Sterna hirundinacea*)
- Arctic tern (*Sterna paradisea*)
- Unidentified sterna tern (*Sterna* spp)

A total of 1894 South American terns were recorded during the at-sea survey for all months and peaking March to April. The South American tern is the only species known to breed in the Falkland Islands. Distribution was mainly in coastal waters.

Arctic terns are a summer visitor to the Falklands. A total of 21 Arctic terns was recorded during the at-sea survey, all between October and March. They were observed throughout the at-sea survey area, mostly in offshore areas. A number of unidentified sterna terns were also recorded during the at-sea survey. Of the 160 unidentified terns recorded in offshore waters, the majority were between April and November.

7.2.9.9. Rare Seabirds

Less than ten sightings of the following seabird species were recorded during the at-sea survey. Due to the low numbers observations, modelling of spatial or monthly distribution is not considered meaningful.

- Broad-billed prion (*Pachyptila vittata*)
- Ceyenne tern Sterna (*Sterna (sandvicensis) eurygnatha*).
- Chilean skua (*Catharacta chilensis*)
- Cory's shearwater (*Calonectris diomedea*)
- Great-winged petrel (*Pterodroma macroptera*)
- Grey phalarope (*Phalaropus fulicarius*)
- Manx shearwater (*Puffinus puffinus*)
- Sooty Albatross (*Phoebetria fusca*)
- Spectacled petrel (*Procellaria conspicillata*)
- White-headed petrel (*Pterodroma lessonii*)

7.2.10. Seabird Vulnerability

Seabirds are affected by a number of anthropogenic factors including, competition with commercial fisheries, mortality through longline fishing and contamination from various forms of pollution. Within Falkland waters, negative impacts on seabird productivity through competition for food with commercial fisheries have not yet been identified (White et al., 2001). Death from entanglement and snagging with longline hooks is considered to be of low risk due to a well managed fishery and a relatively low longlining.

To date, reports of adverse effects to seabirds from surface pollution such as oils is low in the Falkland Islands. Hence, the increasing oil and gas exploration activities in the area are a potential threat to seabird populations.

The following information has been sourced from 'Vulnerable Concentrations of Seabirds in Falkland Islands Waters' (1998-2000), a report produced by the JNCC under contract to Falklands Conservation, with funding support from the FIG.

Seabird vulnerability was assessed with regard to species-specific aspects of their feeding, breeding and population ecology. Maps produced in the report can be used to identify areas supporting seabird concentrations at greatest risk to the threat of surface pollution. Methods used for development of the vulnerability atlas are complex and well documented (White et al., 2001) and are not expanded upon further here.

A summary of the seabird vulnerability survey results for each month of the year, focusing on the proposed drilling area is given below.

Seabird vulnerability in January is highest in coastal and Patagonian Shelf waters, although there is also an area of high vulnerability covering large sections of the licence areas. Small petrels (prions, storm-petrels, diving-petrels and shearwaters) are the main species.

Vulnerability in the licence areas is lower over the February and March survey periods, where wide range of species present including prions, Wilson's storm-petrels, white-chinned petrels and black-browed albatrosses present. Areas of high vulnerability exist to the south of the licence areas. During April vulnerabilities are very low over the licence areas.

No survey was conducted in May. Vulnerability rises from low in the south to moderate in the north over June with small petrels and prions the predominant species. Vulnerability in July is similar to June with similar species found within the licence area.

In August, areas of high vulnerability are concentrated to the south and west of the Falklands, although there is also an increase in vulnerability around the licence blocks, with records of black-browed albatrosses, diving petrels, prions and Cape petrels.

In September, vulnerability is low over the licence areas with small petrels, shags and black-browed albatross the most common species.

Vulnerability in October is low to moderate, with black-browed albatrosses, diving petrels, prions and Cape petrels recorded in low densities.

Extensive survey coverage in November showed low to moderate vulnerability with petrels and albatrosses present. December demonstrates high levels of seabird vulnerability around the southern reaches of the licence areas particularly for black-browed albatross, Magellanic and rockhopper penguins and prions.

Based on the findings of this survey and the conclusions presented in the publication (White et al, 2001), the Austral summer months of December through to February have the highest overall vulnerability for the seabird species in the waters surrounding the Falklands. July and the winter months are the period of lowest overall vulnerability. Highest vulnerability coincides with the breeding season for most seabird species on the Falklands.

Concentrations of seabirds in coastal waters are more vulnerable to the effects of surface pollution than in all other areas. Deeper waters to the north of the licence area are of lower vulnerability than the shallower waters to the south.

Although this summary concentrates on the proposed drilling locations, the Falkland Islands' coastline has been included on the adapted maps of seabird vulnerability to account for the potential spread of oil spills towards the coastline, particularly smaller spills from near-shore activities.

The vulnerability atlases show inshore waters to be particularly important for all months of the year, largely due to the presence of resident species with a predominantly coastal distribution such as the endemic Falklands steamer duck, imperial shag and gentoo penguin.

Other areas of importance to seabirds are the Patagonian Shelf waters to the north and west of the Falklands, which support high densities of black-browed albatrosses and royal albatrosses year-round. Low densities of seabirds encountered in deep waters areas generally result in low to moderate vulnerability for all months (White et al., 2002).

Oiled seabirds were recorded for all three survey years, peaking between March and October, and coinciding with the period of highest shipping activity. Many seabirds migrate through the

Patagonian Shelf waters, so surface pollution in other areas may also have an impact on Falkland Island populations. An estimated 40 000 penguins die from oil pollution on the coast of Argentina each year due to chronic oil pollution such as the discharge of oily waste from ballast tanks.

In White et al. (2002) hydrocarbon exploration is only one of the threats facing seabird populations at sea and awareness of problems for the albatross and petrel populations from interactions with fisheries in the Southern Oceans is growing.

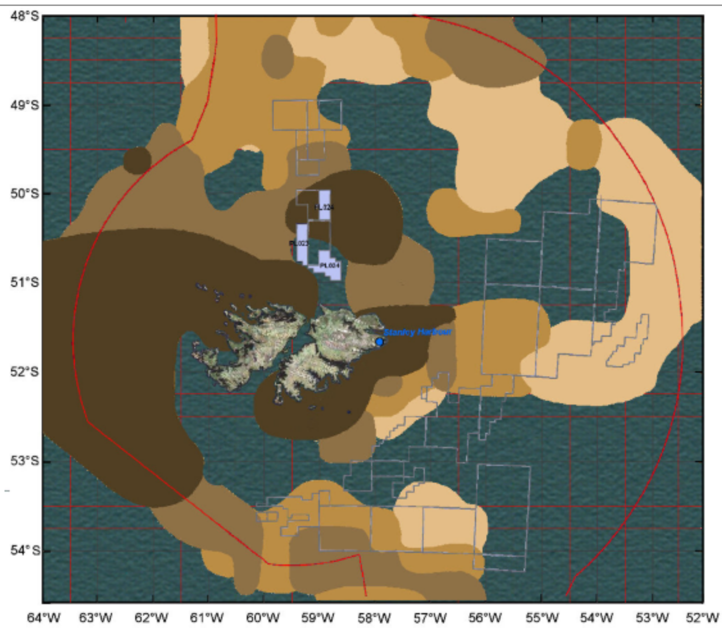
In each figure unshaded areas indicate that it was not surveyed. The grid pattern used for surveying is based on ICES Rectangles (International Council for the Exploration of the Sea), measuring 15' latitude by 30' longitude. ICES rectangles differ from the Block and Quadrant system used in offshore petroleum licensing. Vulnerability of seabirds to surface pollution is depicted in four shades ranging from pale (lowest vulnerability) to dark (highest vulnerability).

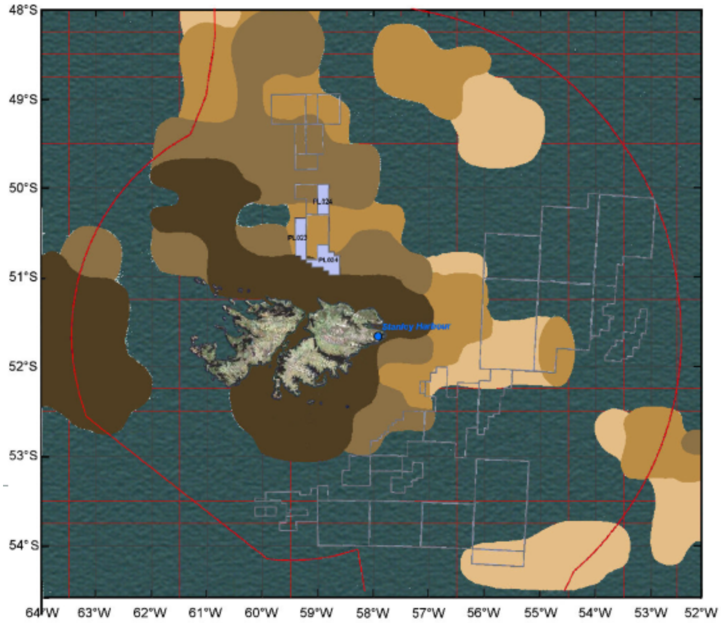
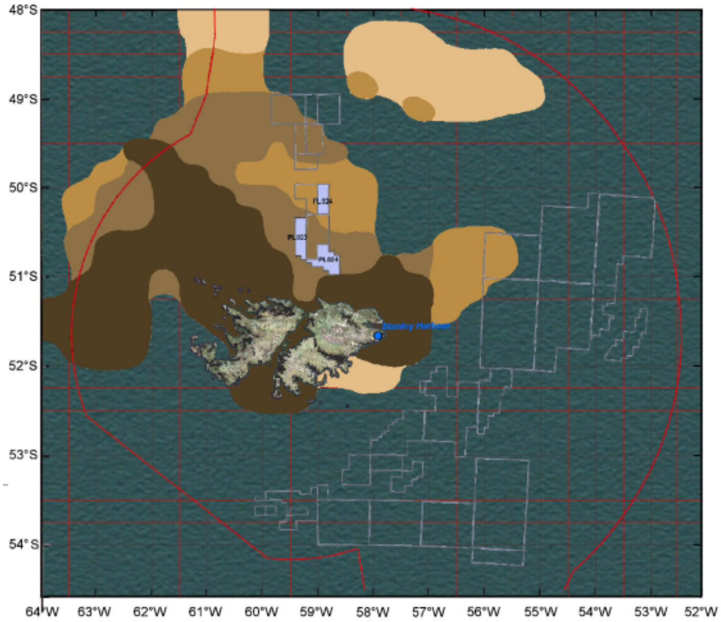
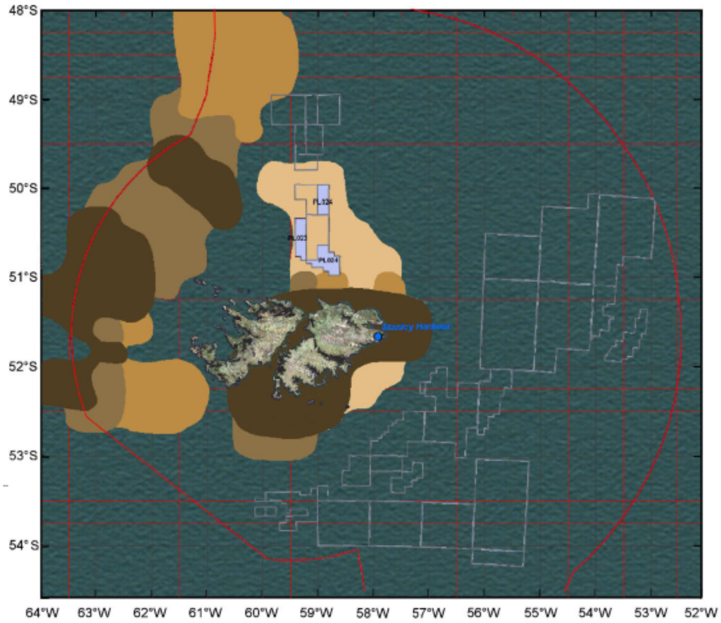
Vulnerability of seabirds to surface pollution is depicted in four shades ranging from pale (lowest vulnerability) to dark (highest vulnerability):

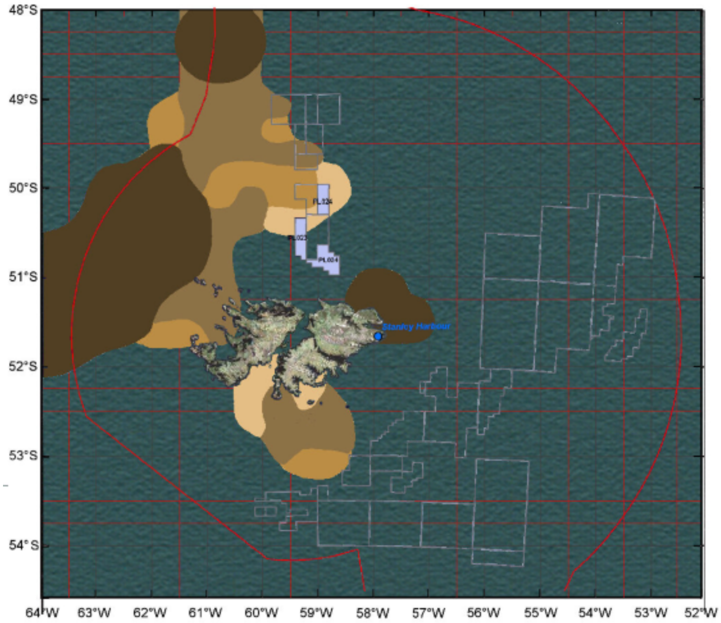
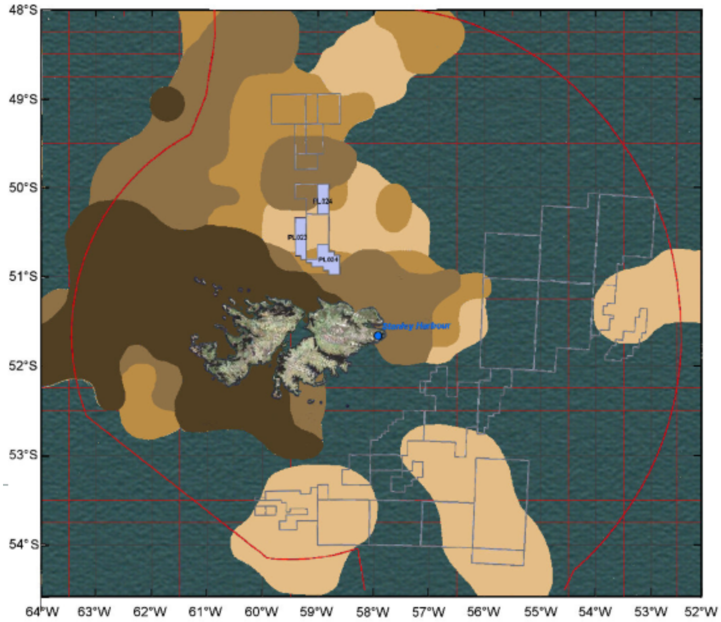
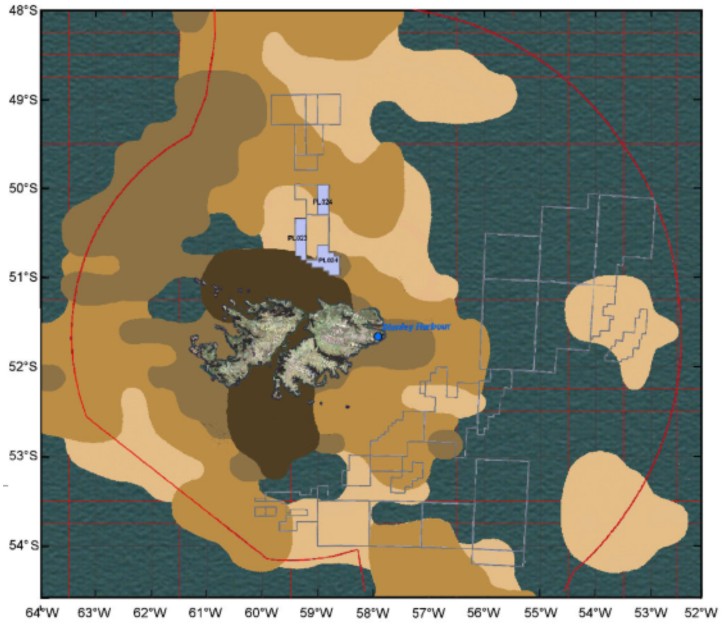
Seabird Vulnerability Mapping: Key

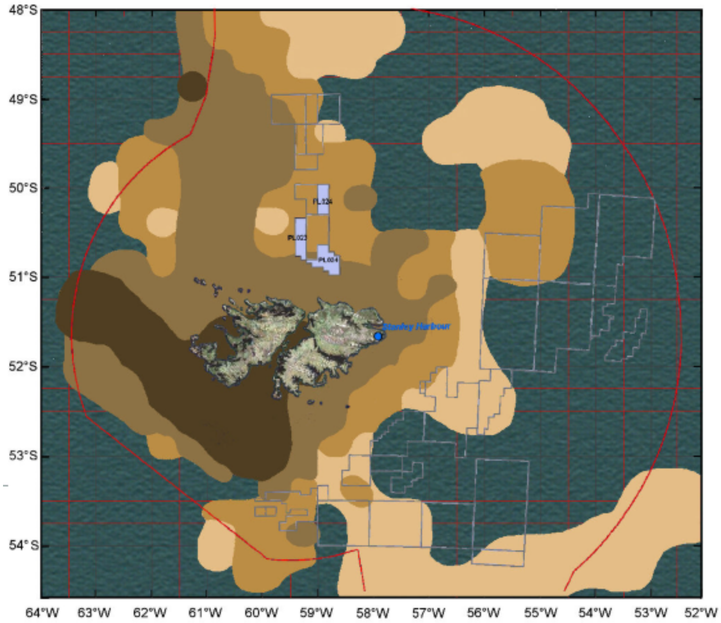
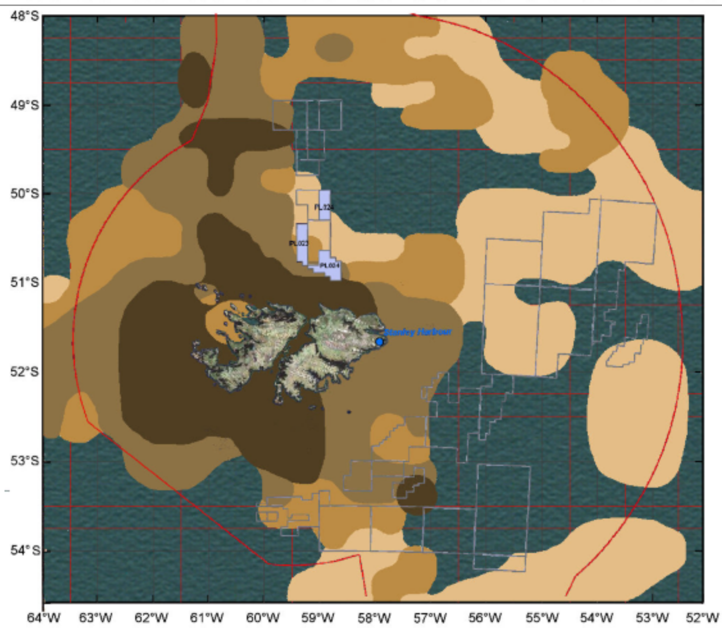
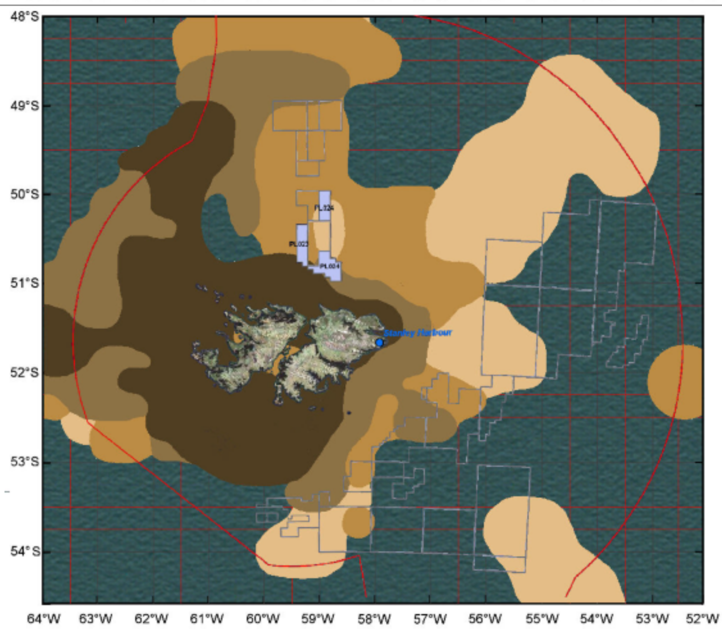
HIGH → LOW

January



February	
March	
April	

May	
June	
July	

August	
September	
October	

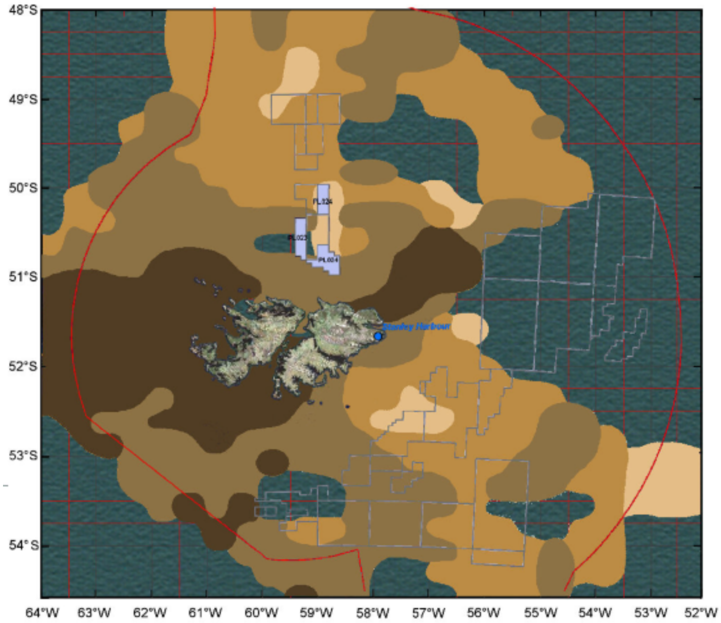
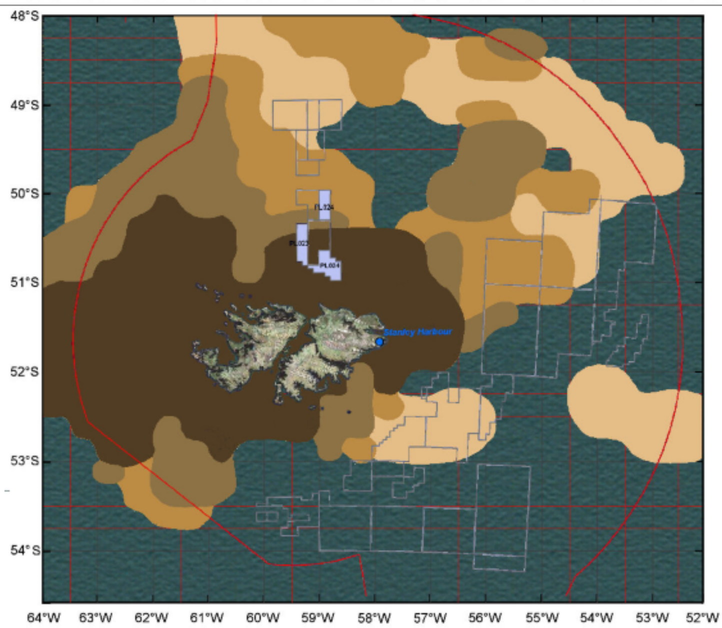
November	
December	

Figure 7-19 Monthly vulnerability of seabird concentrations to surface pollution January to June (based on surveys from February 1998 to January 2000)

Based on the above maps of seabird vulnerability to surface oil pollution, ‘High’ vulnerability is likely to be encountered over part of the licence area primarily during December and January, with areas of High vulnerability in close proximity to the licence area in February, March, July, September and October. The months of lowest seabird vulnerability in the licence area are April through to June. Based on the above maps, it can be concluded that the licence area shows significant levels of seabird vulnerability to surface pollution for much of the year.

7.2.11. Threatened Species

The IUCN Red List is a comprehensive listing of all species within the Falklands marine environment which are characterised as ‘endangered’, ‘threatened’ or ‘vulnerable’ to ‘extinction’.

A search of the Red List found 43 species recorded as threatened, and 31 classified as ‘Least

Concern'[3]. Most pinnipeds are of the latter category. There were seven species (two cetaceans and five birds) listed as endangered – the highest level of conservation status.

Overall the Red List results included:

- 17 species of cetaceans
- 2 species of fish
- 24 species of birds

The list of species identified as under threat by IUCN is given in Appendix I.

7.2.12. Protected Habitats and Areas

Three types of formal designation operate in the Falkland Islands:

- National Nature Reserves (NNR) (designated under the Conservation of Wildlife & Nature Ordinance (1999));
- National Parks (designated under the National Parks Ordinance); and
- Ramsar sites.

Although the FIG can designate marine reserves, to-date no marine NNR has been created in the Falkland Islands. Existing Nature Reserves were designated under the Nature Reserves Ordinance 1964 and Sanctuaries designated under the Wild Animals and Birds Protection Ordinance 1964 are now designated as NNR and Nature Reserves respectively (Table 7-2).

Table 7-2 Protected Areas

Date		Order	Designated Area
Nature Reserve Orders (now National Nature Reserves)	1964	Nature Reserves (Kidney & Cochon Islands) Order 1964 (1/64)	Cochon Island 51º 36'S 57º 47'W Kidney Island 51º 38'S 57º 45'W
	1966	Nature Reserves (Flat Jason Island) Order 1966 (2/66)	Flat Jason 51º 06'S 60º 53'W
	1969	Nature Reserves (Bird Island) Order 1969 (4/69)	Bird Island 52º 10'S 60º 54'W
	1973	Nature Reserves (Crown Jason Islands) Order 1973 (10/73)	Elephant Jason 51º 09'S 60º 51'W South Jason 51º 12'S 60º 53'W North Fur Is. 51º 08'S 60º 44'W South Fur Is. 51º 15'S 60º 51'W Jason East Cay 51º 00'S 61º 18'W Jason West Cay 50º 58'S 61º 25'W The Fridays 51º 03'S 60º 58'W White Rock 51º 17'S 60º 53'W Seal Rocks 51º 07'S 60º 48'W
	1978	Nature Reserves (Sea Dog & Arch Islands) Order 1978 (2/78)	Sea Dog Island 52 00'S 61 06'W Arch Islands 52 13'S 60 27'W (Inc. Arch Island East, Natural Arch, Clump Island, Tussac Island, Pyramid Rock, Last Rock & Albemarle Rock)
Sanctuary	1964	Wild Animals & Birds Protection (Sanctuaries)(The Twins) Order 1964 (2/64)	The Twins, 51º 15'S 60º 38'W Adjacent to Carcass Island, West Falkland

[3] A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

	1964	Wild Animals & Birds Protection (Sanctuaries) (Low Island) Order 1964 (3/64)	Low Island, 51º 19'S 60º 27'W Adjacent to Carcass Island, West Falkland
	1964	Wild Animals & Birds Protection (Sanctuaries) (Beauchêne Island) Order 1964 (4/64)	Beauchêne Island, 52º 54'S 59º 11'W
	1966	Wild Animals and Birds Protection (Sanctuaries) (Middle Island) Order 1966 (4/66)	Middle Island, 51º 38'S 60º 20'W King George Bay, West Falkland
	1968	Wild Animals and Birds Protection (Volunteer & Cow Bay Sanctuary) Order 1968 (11/68)	Volunteer Point and Inside Volunteer, Cow Bay area of Carysford Camp. 51º 29'S 57º 50'W
	1968	Wild Animals and Birds Protection (Cape Dolphin Sanctuary) Order 1968 (12/68)	Extreme end of Cape Dolphin. 51º 15'S 58º 51'W
	1970	Wild Animals & Birds Protection (Bleaker Island Sanctuary) Order 1970 (3/70)	Bleaker Island north of Long Gulch. 52º 18'S 58º 51'W
	1973	Wild Animals & Birds Protection (Stanley Common and Cape Pembroke Peninsula Sanctuary) Order 1973 (1/73)	Stanley Common & Cape Pembroke. 51º 43'S 57º 49'W
	1993	New island South Sanctuary Order 1993 (14/93)	New Island South 51º 43'S 61º 18'W
	1996	Moss Side Sanctuary Order 1996 (26/96)	Pond and sand-grass flats behind Elephant Beach (Top Sandgrass Camp & Sorrel Pond Camp) 51º 23'S 58º 49'W
	1998	Narrows Sanctuary Order 1998 (53/98)	Narrows Farm, West Falkland. 51º 41'S 60º 19'W
	1998	East Bay Sanctuary Order 1998 (54/98)	East Bay Farm, West Falkland 51º 48'S 60º 13'W
	Prop-osed	Wild Animals and Birds Protection (East Bay, Lake Sulivan and River Doyle)	Proposed
	Prop-osed	Wild Animals and Birds Protection (Pebble Island East)	Proposed
	Prop-osed	Wild Animals and Birds Protection (Port Harriet Point and Seal Point)	Seal Point 57°50'W 51°44'S
National Parks	Prop-osed	West Falklands – Hill Cove Mountains	Hill Cove Mountains – proposal is currently suspended
	Prop-osed	East Falklands – Wickham Heights	Wickham Heights –proposal is currently suspended
Ramsar Sites	1999	Bertha’s Beach	51°55’S 058°25’W, proposed as a NNR
	1999	Sea Lion Island	52°25’S 059°05’W, proposed as a NNR
	Prop-osed	Lake Sulivan, River Doyle and East Bay	Proposed
	Prop-osed	Pebble Island East	Proposed

Important Bird Areas (IBAs) have been defined and are an initiative of Birdlife International, a global partnership of conservation organisations. IBA identification is based on a standard set of criteria applied consistently worldwide, with Falklands Conservation responsible for the cataloguing and description of IBA’s within the Falklands. IBAs are not part of any international agreement or convention, and were created to address the increasing global threat to birds from habitat loss and fragmentation.

Currently, 22 IBA sites have been identified in the Falkland Islands. Of the 22 identified sites 17 consist of islands and island groups and four are situated on the main islands of East or West Falkland. There is currently no extension of IBA’s to marine areas. The 22 IBA sites are;

- Beauchêne Island
- Bertha's Beach (East Falkland)
- Bleaker Island Group
- Elephant Cays Group
- Hummock Island Group
- Keppel Island
- Lively Island Group
- Passage Islands Group
- Saunders Island
- Seal Bay (East Falkland)
- Volunteer Point (East Falkland)
- Beaver Island Group
- Bird Island
- Bull Point (East Falkland)
- Hope Harbour (West Falkland)
- Jason Islands Group
- Kidney Island Group
- New Island Group
- Pebble Island Group
- Sea Lion Island Group
- Speedwell Island Group
- West Point Island Group

7.3. SOCIAL AND ECONOMIC ENVIRONMENT

The information for the following sub-sections is based on the last census undertaken in 2001, sourced from the Foreign and Commonwealth Office (FCO). The population of the Falklands was recorded as 2913 with the majority living in the capital, Stanley. An additional 1700 military and civilian personnel are located at the Mount Pleasant Complex (MPC). Christianity is the major religion on the Falklands.

7.3.1. Economy

The general economic characteristics of the Falkland Islands:

Gross Domestic Product:	£70 million (2001)
Gross Domestic Product per Head:	£24,030 (2001)
Annual Growth:	2% (estimated)
Inflation:	3.5% (estimated)
Major Industries:	Fisheries, tourism and agriculture
Major Trading Partners:	United Kingdom, Spain and Chile
Exchange Rate:	UK£1 = FI£1

The economy of the Falklands has traditionally been restricted due to its small population and isolation from external markets. Since 1982 the economy has grown rapidly, initially as a result of UK aid but more recently from the development of fisheries (Section 7.3.1.1). The Falklands have received no aid from Britain since 1992 and are now self-sufficient in all areas except defence (FCO, 2007).

The three largest industries are agriculture, tourism and commercial fisheries, and are discussed in Sections 7.3.1.1, 7.3.1.2, and 7.3.1.3. Statistics for 2005/2006 indicate that £16.1 million revenue was bought in by the Fisheries industry, followed by £14.6 million from retail sales.

A workforce of over 2000 exists in the Falklands, with the FIG the largest employer, employing around 600 people. The fisheries, tourism, infrastructure development and retail industries are quickly growing and employing more people.

7.3.1.1. Agriculture

Agriculture remains a large industry on the Falklands, and the FIG funded modern abattoir meets EU standards and hopes to capitalise on the Falklands' certification as an organic country (FCO, 2007).

7.3.1.2. Tourism

The tourism industry is growing rapidly, with over 30 000 passengers arriving in Stanley each year from cruise ships. The main attractions are the Falklands' unique environment and wildlife.

Passenger numbers in recent years on cruises to the Falklands have increased significantly, and are predicted to continue to increase. In the 2006/2007 tourist season 51 000 cruise ship passengers visited the Falkland Islands. An estimated 80 000 plus visitors are expected in 2007/2008, a 57% increase on the previous season. The Falkland Islands Tourism Board aims to increase the number of cruise-ship day visitors and longer-staying tourists in a manner that is sustainable.

The Islands' main tourist lodges are located at Port Howard, Darwin, Pebble Island, Sea Lion Island and Weddell Island. Self-catering accommodation can be found at a selection of holiday cottages on island farms, and several locations in East and West Falkland. In Stanley, there are two principal hotels (the Malvina House and Upland Goose) and a choice of guest house and bed & breakfast accommodation.

Cruise ships from various points of origin travel to the Falkland Islands and there is likely to be some movement of cruise liners through the North Falkland Basin. The recent growth in cruise ship movements increases the significance of this aspect and emphasis the need for early notification, ongoing communication and the use of standby vessels to support drilling operations. Liners arriving and departing Port William in the Falkland Islands by way of Puerto Madryn in Argentina will be most relevant to the proposed drilling programme. This route passes through the North Falkland Basin and cruise ships are likely to travel through, or near to, the licence blocks in this area.

7.3.1.3. Fisheries and Aquaculture

Commercial fisheries are the largest source of income for the Falkland Islands. All fishing within 200 nautical miles of the Falklands is subject to licensing by the FIG. The fisheries generate over £21 million per annum in licence fees, roughly half the government revenue. Since 1990 Britain and Argentina have worked together to conserve fish stocks under the auspices of a UK/Argentine South Atlantic Fisheries Commission (FCO, 2005). Approximately £6 million of fisheries income is spent each year on catch and conservation monitoring, research and administration.

Target species for the commercial fisheries operating in the Falkland Islands are:

- Argentine shortfin squid (*Illex argentinus*)
- Patagonian squid (*Loligo gahi*)
- Southern blue whiting (*Micromesistius australis australis*)
- Hoki (*Macruronus magellanicus*)
- Patagonian toothfish (*Dissostichus eleginoides*)
- Patagonian hake (*Merluccius australis*)
- Common hake (*Merluccius hubsii*)
- Red cod (*Salilota australis*)
- Skates & rays (*Rajidae*)

The key catches are the squid species: *Illex argentinus* and *Loligo gahi*, followed by the southern blue whiting (Figure 7-20). Approximately 2.4 MT of *Illex*, 1.2 MT of *Loligo*, and 20,500 tonnes of southern blue whiting were caught in 2006.

Research shows that the commercial squid species are short-lived and fast growing, living for about a year and spawning once within that time (Rodhouse, 1988). Typically, species with this sort of lifecycle are susceptible to changes in environmental conditions. This can create a high level of variability in stocks on a year-to-year basis.

Illex had been in decline since 2002, but resurged in 2006 after oceanographic conditions returned to normal following years of warm anomalies. Seasonal jigging fishery for the *Illex* takes place between February and June and is concentrated over the Patagonian Shelf to the north and west of the Falklands. The trawl fishery for *Loligo* squid operates between February and May and between August and November off the east coast of the Falklands.

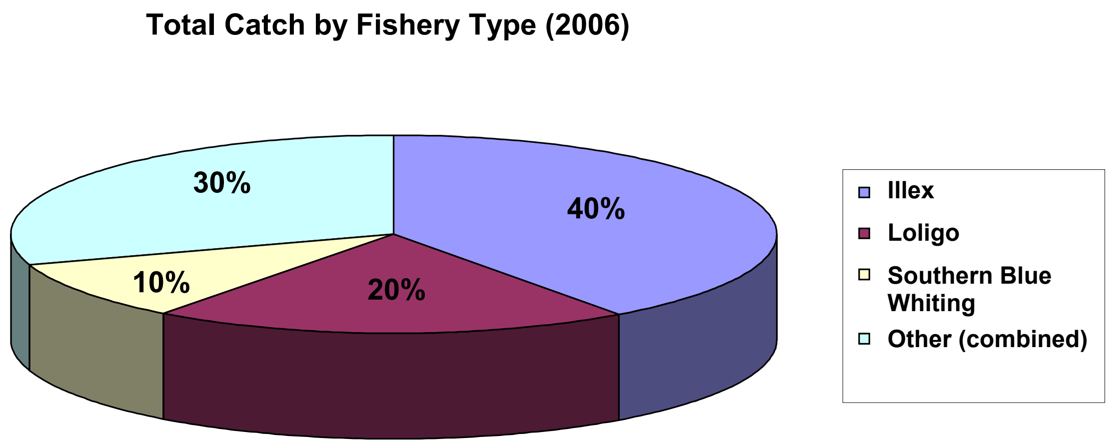


Figure 7-20 Total catch by percentage and fishery type in the Falkland Islands for 2006

Data from the FIG annual Fisheries Statistics volume 11 (1997–2006) are shown graphically in Figure 7-21 through to Figure 7-26).

In 2006, 194 fishing licences were issued predominantly for the squid and finfish species. Previous licence allocations varied from 372 in 1989 to 205 in 2005. The majority in 2006 were issued to fleets from the Falkland Islands, Spain and Korea.

To protect against poachers, the waters are patrolled by FIG aircraft and fishery protection vessels, one of which is armed.

Aquaculture in the Falkland Islands is relatively new with salmon fish-farming trialled in the early 1990s. Although commercial growth rates could be achieved, no external market for Falkland Islands grown salmon was found. *Mytilus edulis chilensis*, native blue mussel, is farmed in the Falklands over an area covering 22 ha and approximately 20 tonnes of mussels are on ropes at any one time (Otely et al., 2008). Pacific oysters (*Crassostrea gigas*) are farmed over approximately 200 ha at Darwin in the Falkland Islands for the local market (Otely et al., 2008).

The mussel and oyster farming is currently small-scale, although the aquaculture industry has been identified as a potential economic diversification sector (Otely et al., 2008).

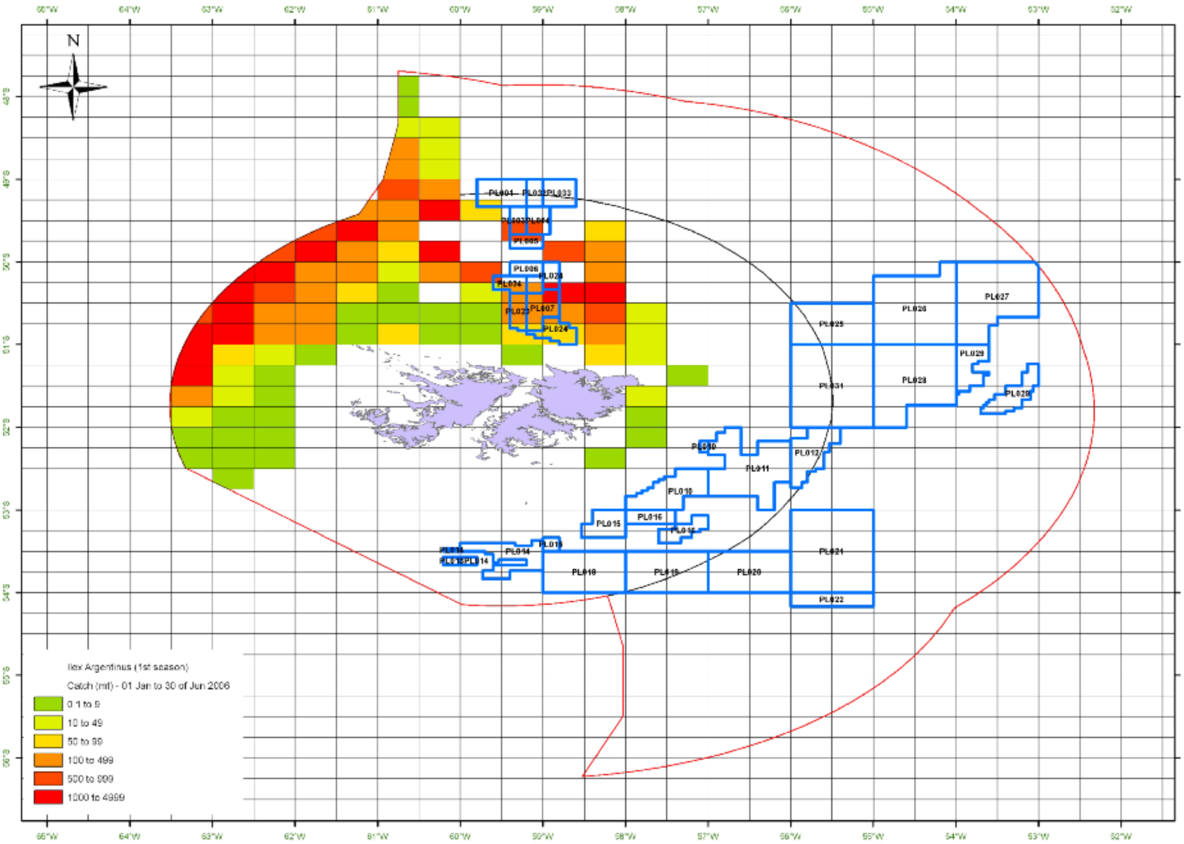


Figure 7-21 *Illex argentinus* **catches (tonnes) by grid square for Season 1 (Jan–Jun 2006)**

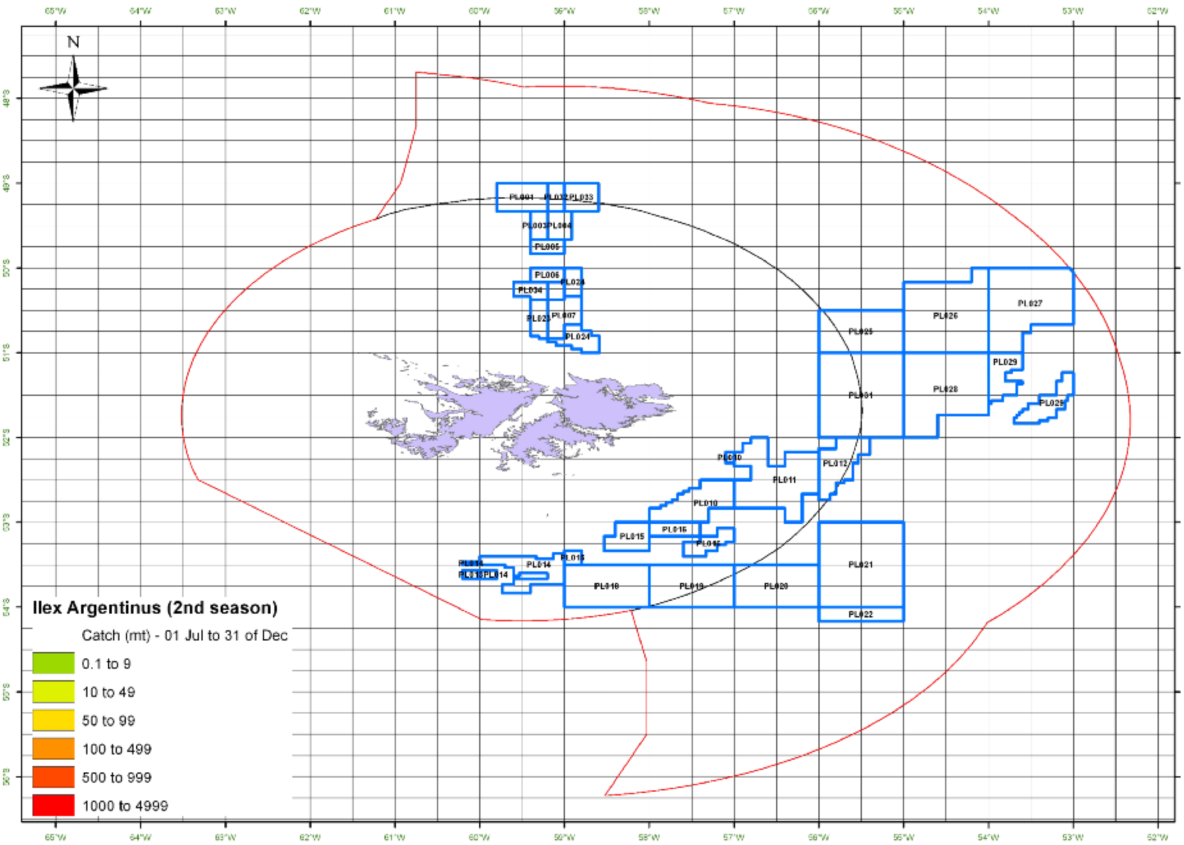


Figure 7-22 *Illex argentinus* **catches (tonnes) by grid square for Season 2 (Jul–Dec 2006)**

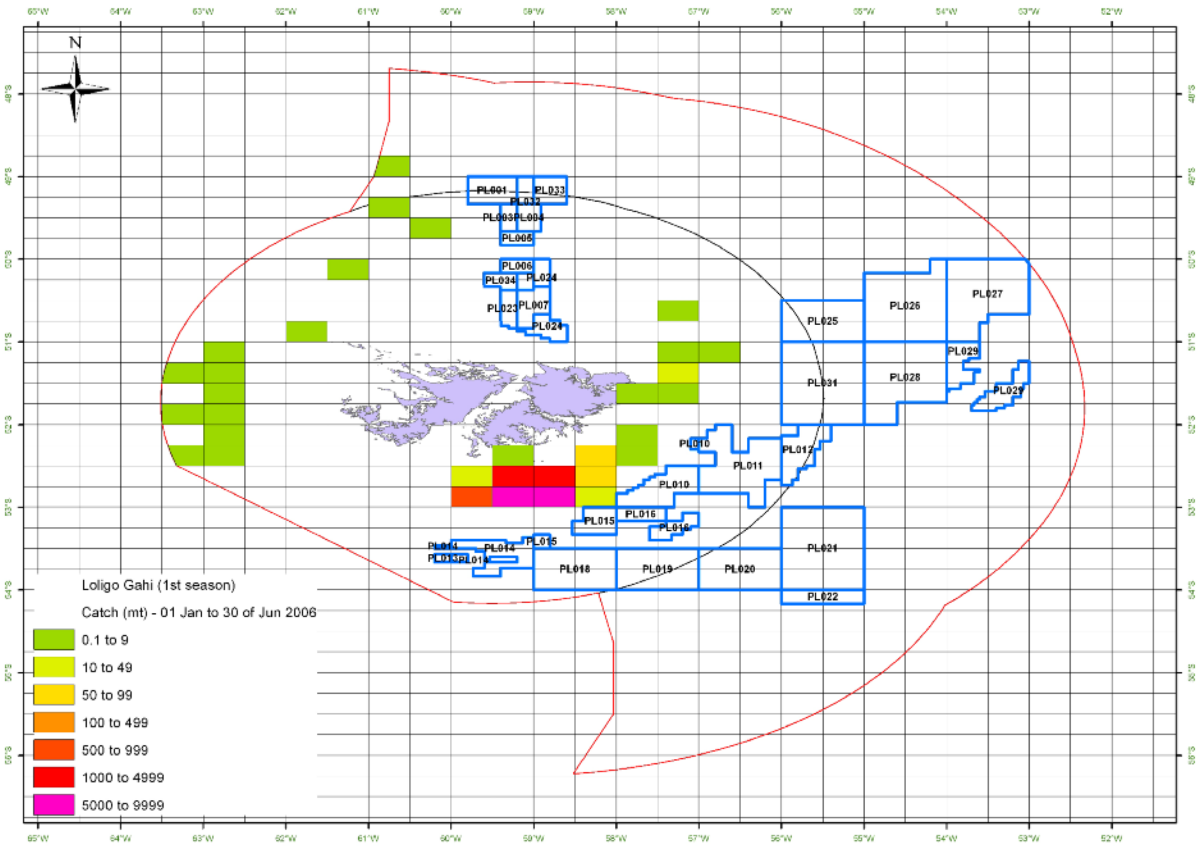


Figure 7-23 Loligo gahi catches (tonnes) by grid square for Season 1 (Jan–Jun 2006)

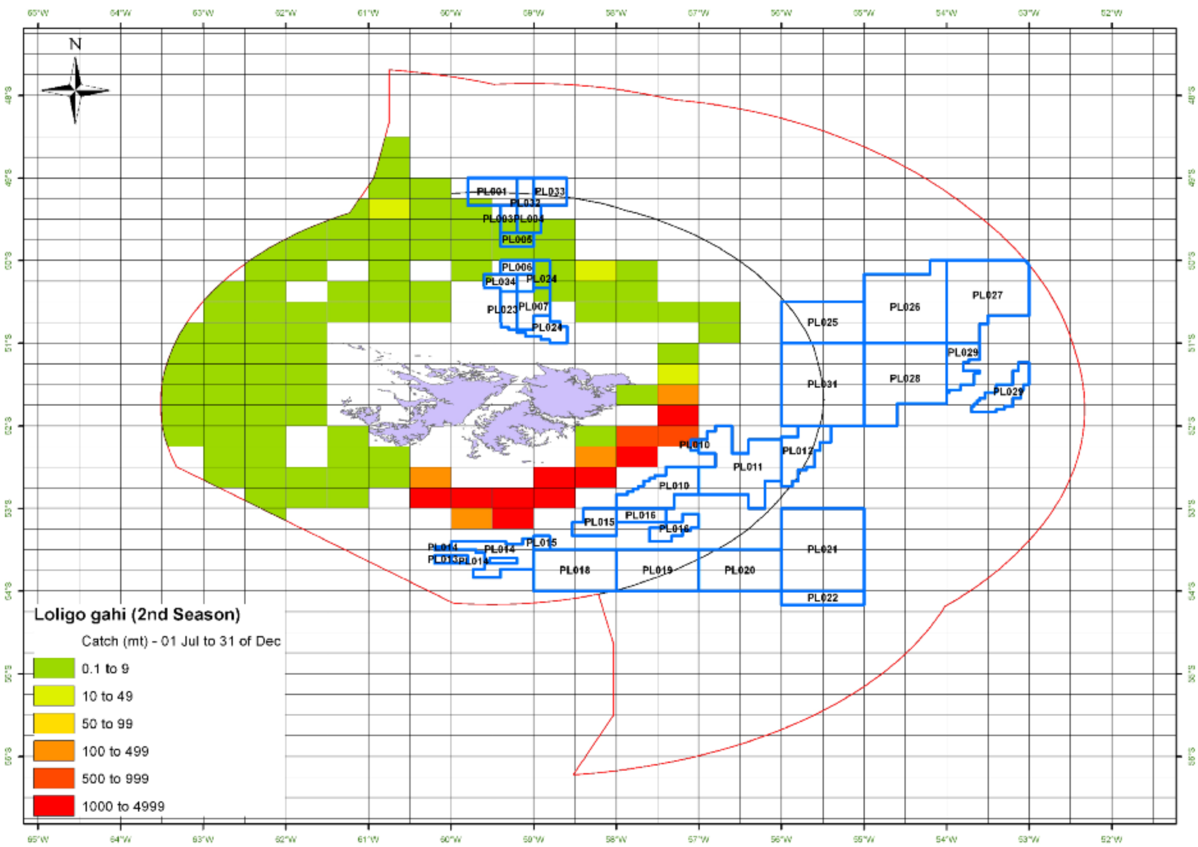


Figure 7-24 *Loligo gahi* catches (tonnes) by grid square for Season 2 (Jul–Dec 2006)

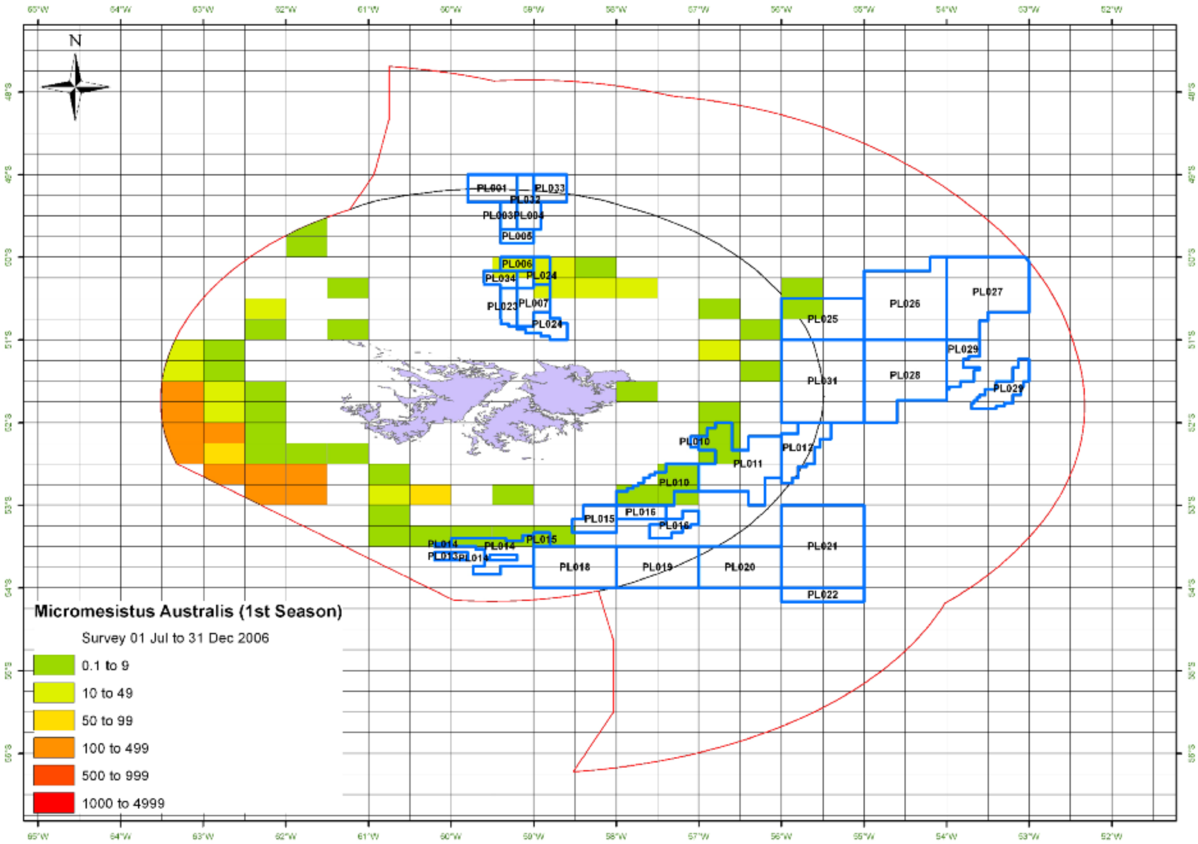


Figure 7-25 ***Micromesistius australis*** **catches (tonnes) for Season 1 (Jan–Jun 2006)**

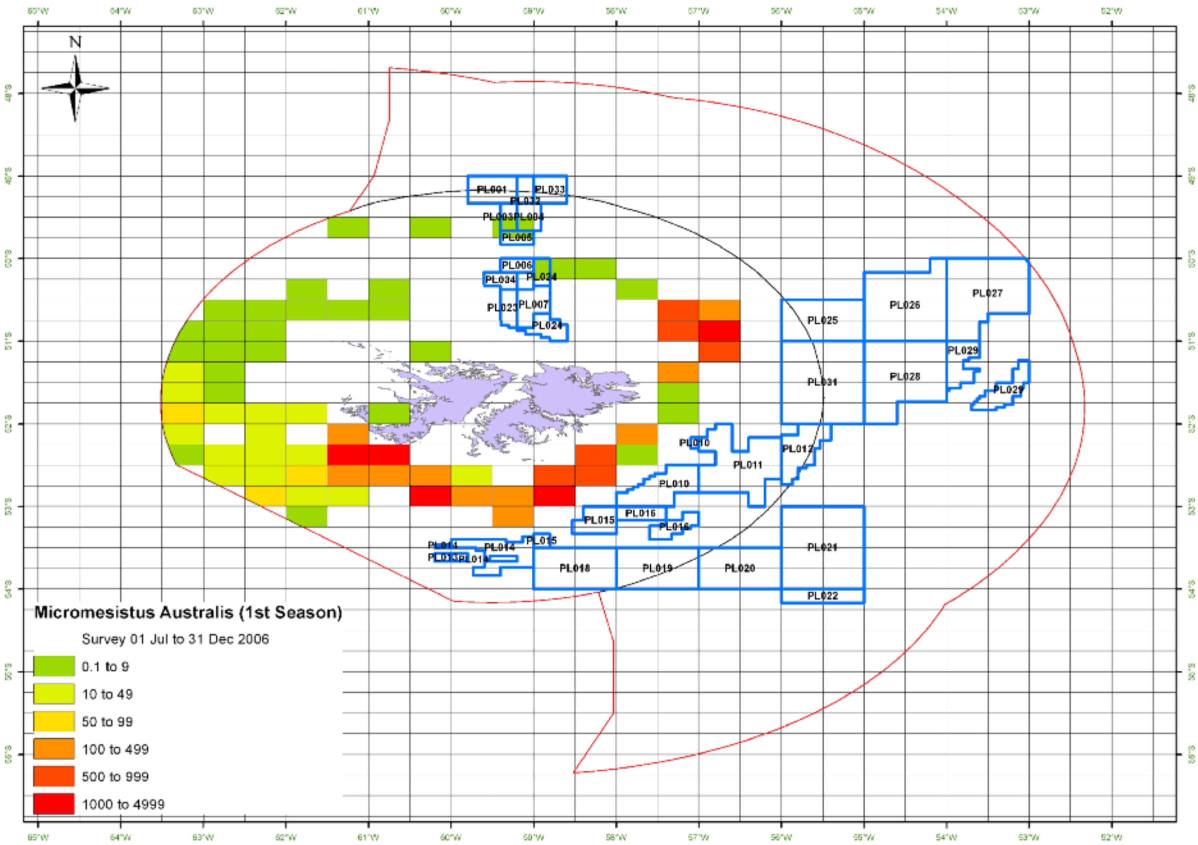


Figure 7-26 ***Micromesistius australis*** **catches (tonnes) for Season 2 (Jul–Dec 2006)**

The above figures demonstrate that the Rockhopper licence area to the north of the Falkland Islands has potential for high Illex catch during season 1 between January and June. There is low recorded Loligo catch within some parts of PL024 for season 2 between July and December, although this is considered to be a low-significance area for this species. At other times there is no significant fisheries interest for either squid species.

There is a low recorded catch of southern blue whiting within some parts of PL024 during both season 1 and season 2, although the licence area lies a considerable distance from the main catch areas for blue whiting and the potential for any disruption to this fishery is considered to be minimal.

There are also no significant fisheries interests on the landward side of the licence area, which would indicate that there is also low vulnerability to disturbance from vessel movements to and from the licence area.

7.3.2. Marine Archaeology

Numerous ships wrecks lie in the Falkland waters including 17 registered shipwrecks (six from the World War One battle of the Falkland Islands) and other designated war graves which cannot be disturbed (Figure 7-27)

Stanley harbour contains wrecks of wooden ships constructed in the 19th century, including the Lady Elizabeth and the Jhelum, which are considered important examples of ship construction of this period.

The Hydrographic Office identification number / name, co-ordinates and depths of the wrecks are presented in Table 7-3. One identified wreck is situated near to the southern boundary of one of the licence blocks (PL024). No other wrecks or significant marine artefacts are currently specified within the proposed drilling locations. However, there are currently nine listed wrecks and two lost drilling anchors identified within the North Falkland Basin. Three of these wrecks are of unknown identity and have not been awarded special designations (for example, war grave status) or restrictions.

Table 7-3 Marine Wreck Locations

Wreck	Location	Depth
Wreck No 129700356	49°55' 06"S 58°02' 30"W	300 m
Wreck No 140502865	50°17' 12"5 60°11 ' 00"W	160 m
Wreck No 140503079	50°57' 18"5 58°52' 18"W	140 m
Chin Yuan Hsing	49º 27'S 60º 57'W	N/A
Serrekunda	51º 17'S 57º 48'W	N/A
Dong Yung 510	49º 05'S 60º 45.07'W	N/A
Playa Da Coba	50º 22.08'S 61º 24.01'W	N/A
5 Dae Woong	49º 37.05'S 61º 13.38'W	N/A
Ferralemes	50º 15.504'S 58º 13.393'W	N/A
Lost drill rig anchors	49º 24.85'S 59º 30.383'W	N/A
	49º 18.407'S 59º 23.187'W	N/A

The use of 3D seabed mapping and remote operated vehicles (ROV) surveys will help prevent any potential seafloor obstacles from being impacted by the rig anchoring or drilling operations.

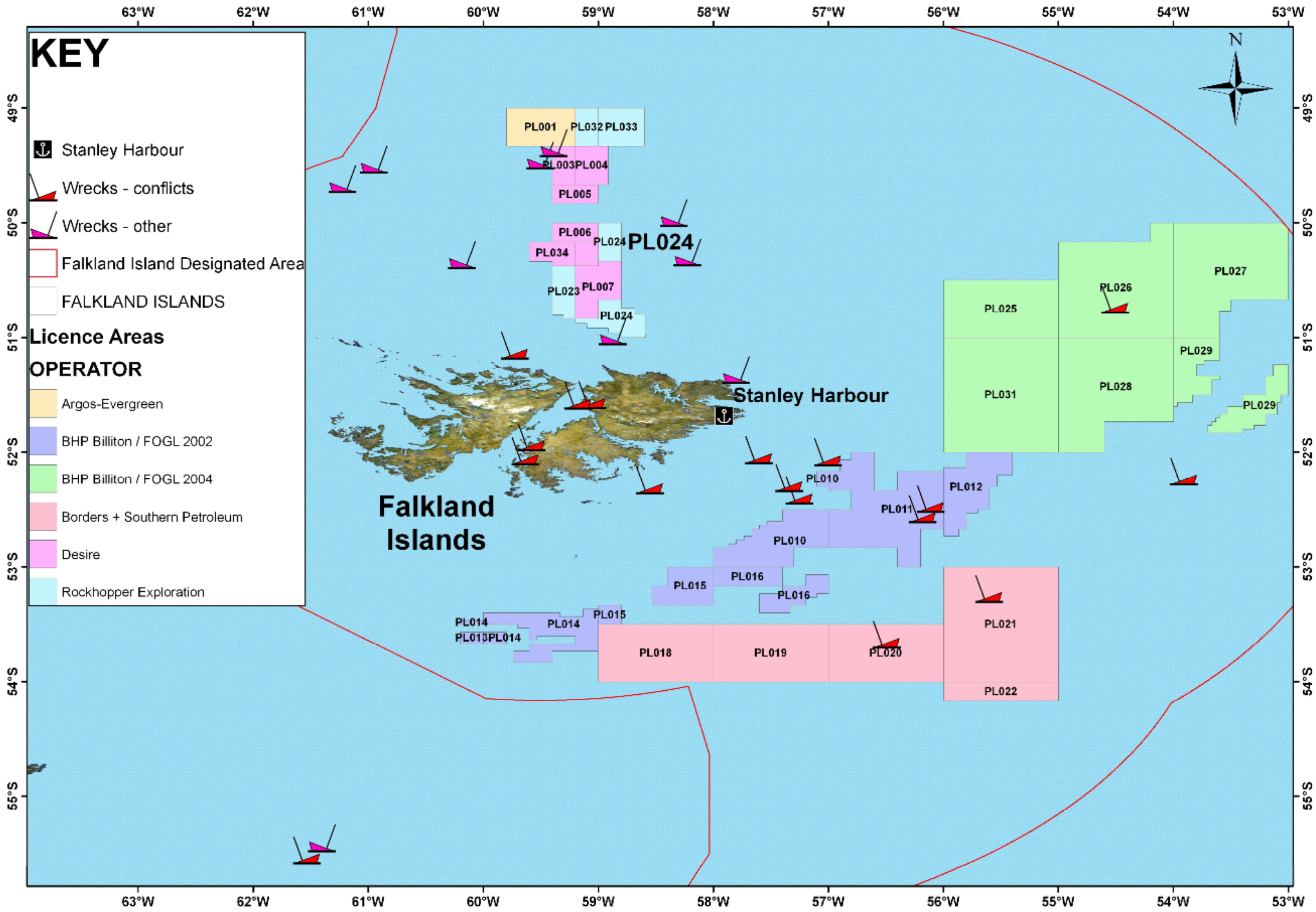


Figure 7-27 Known shipwrecks in the Falklands region

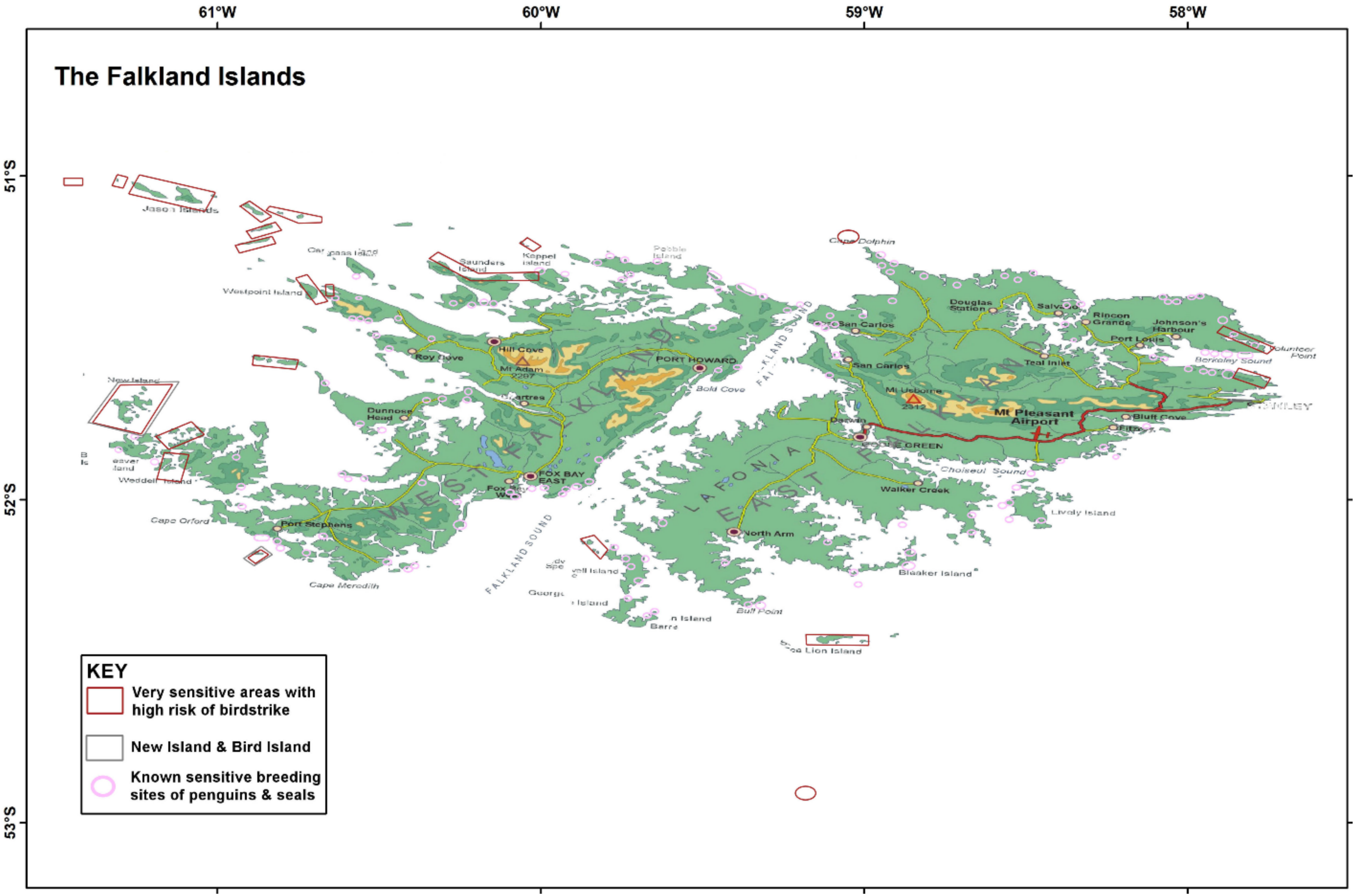


Figure 7-28 Identified ecologically sensitive areas to impacts from aircraft and helicopter activity

7.3.3. Communications

There are no recorded pipelines or cables in the vicinity of PL023 and PL024. Mobile phone reception is now available at the Falklands, and satellite communication systems will be used onboard support vessels and the drill rig.

7.3.4. Military

The Falklands are defended by a garrison comprising air, sea and land assets, backed by reinforcement capability if required. The Strategic Defence Review concluded that the composition of the land force in the Falklands was appropriate to ensure the security of the Falklands. Since 1982 the Falkland Islands have had a relatively large British military presence, with approximately 2000 personnel living at the Mount Pleasant air base complex. As well as military personnel, civilian employees of the MoD or contractors responsible for the provision and maintenance of services live at the base.

A Castle Class offshore patrol vessel is stationed in the Falklands and there are regular visits from a Guardship (either a destroyer or frigate) throughout the year. Air defence is provided by Tornado F3s, supported by VC-10 tankers, Hercules C-130s, Chinook and Sea King helicopters.

There are a number of wildlife avoidance areas around the Falklands. These are demonstrated in Figure 7-28. This map is adapted from information provided by the Defence Geographic Centre (part of the UK MoD) and is used primarily for the identification of avoidance areas for the use of military personnel. This map is under review and should not be taken as definitive for operational purposes. Any updates to the avoidance areas will be incorporated into operational management plans as they become available.

Wildlife avoidance areas currently apply primarily to military flights and use of helicopters, although they will be equally applicable to helicopter movements to and from any vessels or drill units operating offshore the Falkland Islands. These areas are shown in full on map GSGS 5563, Falkland Islands range and avoidance areas, Edition 4, as produced by the UK Ministry of Defence (classified). The map has three categories of wildlife sensitive wildlife sites, which have specific regulations.

1. Known sensitive breeding sites of penguins and seals
Not to be over-flown by helicopters below 500ft (150m). There are numerous sites identified across the Falkland Islands.

2. Very sensitive areas with high risk of bird strike
Not to be over-flown by any aircraft below 1500ft (460m) except where operationally necessary. These sites include Volunteer Point, the Kidney/Cochon/Mt Low area, Sea Lion Island, Elephant Cays Group, Eddystone Rock, Port Egmont Cays Group, Keppel Island/Saunders Island, West Point/Grave Cove area, 2nd, 3rd and 4th Passage Islands, the Jason Islands Group, the Governor/Staats/Tea Island group, the Channel/Barclay/Fox New Island group and Bird Island.

3. New Island and Bird Island
Should be avoided by helicopter below 500 feet at night due to prions and petrels which are nocturnal September–April.

Falklands Conservation and the Environmental Planning Department have made a number of recommended changes to the range and avoidance areas map, including formalising regulations concerning landing distances, updating the sensitive areas and revising the comments on sensitive species associated with the map.

7.3.5. Navigation and Maritime Transport

Levels of shipping are low with no major shipping lanes within the licence areas.

Freight is transported to the Falklands from the UK and Chile by air and sea. The primary port is located in Stanley Harbour and known as FIPASS (Falklands Interim Port and Storage System). FIPASS, a floating system installed by the military after 1982 and purchased by the FIG in 1988, is currently operated by Byron McKay Port Services Ltd.

A commercial wharf is also located in Stanley harbour in close proximity to most retail and commercial operations, and provides a 4 m draft with limited warehousing, storage areas, water and fuel supplies.

The FIG is reviewing options for port development. A feasibility study has identified a suitable site to construct a new port.

Freight is transported locally by road or sea. Island Shipping Ltd provides a coastal shipping service. A recently introduced container feeder service by South Atlantic America Shipping Ltd services the ports of Montevideo (Uruguay) and Punta Arenas (Chile). The UK Ministry of Defence provides a 35 day sailing from the UK, which offers freight facility to the FIC (Falkland Islands Company Ltd.) and through the FIC to the local civilian community.

7.3.6. Oil Industry Infrastructure

No permanent offshore oil industry infrastructure is currently in place. Shore based resources and infrastructure used for the past drilling campaign, such as FIPASS and helicopter links, are likely to be utilised for this proposed drilling programme.

8. IMPACT ASSESSMENT AND MITIGATION

This sub-section identifies and qualitatively assesses aspects of the drilling programme that may have an environmental or socio-economic impact. The potential for positive impacts from drilling (primarily socio-economic) are recognised along with negative impacts. The impacts are restricted to this proposed drilling campaign and do not include future petroleum development.

The following factors are assessed below, together with suggested mitigation measures:

- Emissions to air
- Emissions to water
- Waste materials
- Physical presence
- Use of resources
- Socio-economic impacts

8.1. QUALITATIVE IMPACT ASSESSMENT

The impact assessment process first identifies potential impacts that may result from the proposed project activities. They may either directly, indirectly or cumulatively affect the environment.

The impacts are then assessed based on these criteria:

- Nature — effect on potential receptors
- Scope — geographical area affected
- Persistence — duration of the impact
- Consequence — overall severity of the impact
- Probability — likelihood of the impact occurring
- Importance — overall significance of the impact in relative terms
- Type of effect — direct, indirect or cumulative effects.

Table 8-1 summarises the impact assessment process and its criteria that was used to assess this proposed drilling programme.

Table 8-1 Summary of the impact assessment process

Heading	Content	Detail
Activity		
Brief description of the type of activity		
Aspect		
Description of potential results of the activity that may cause impact		
Impact		
Scope	Geographical area affected	Local, regional, continental
Persistence	Duration of impact (recovery time)	Short (minutes–hours), medium (days–weeks), long (months–years), permanent or unknown.
Probability	Likelihood of incident occurring	Remote, unlikely, possible, likely or certain
Consequence	Severity of impact based on all of the above	Minor, Moderate, Serious, Major, Critical
Importance	Importance of impact based on the risk matrix below	Low, medium, high (L, M, H)
Effects		
Direct	Qualitative description of what is directly, indirectly and cumulatively impacted by the Activity/Output.	
Indirect		
Cumulative		

The environmental risk matrix (Table 8-2) categorises the consequence of risks arising from potential impacts and aids in development of mitigation measures by altering the consequences, or the probability, or both.

Table 8-2 Environmental risk matrix

	Consequence				
Probability	**Minor**	**Moderate**	**Serious**	**Major**	**Critical**
Remote	*Low*	*Low*	*Low*	*Medium*	*Medium*
Unlikely	*Low*	*Low*	*Medium*	*Medium*	*High*
Possible	*Low*	*Low*	*Medium*	*High*	*High*
Likely	*Low*	*Medium*	*High*	*High*	*High*
Certain	*Medium*	*Medium*	*High*	*High*	*High*

Table 8-5 summarises the potential impacts and their mitigation measures as discussed in the section below for each aspect of the drilling related operations. To avoid confusion, high impacts that are of a positive nature, rather than negative, have been coloured in blue in lieu of red.

8.2. EMISSIONS TO AIR

Potential Impacts

Emissions from combustion will cause negligible contamination of the local atmosphere due to rapid dispersion and dilution by the wind. Gas emissions of CO_2 and NO_X from drilling activities may contribute to global warming, albeit in a minute scale when considered regionally or globally.

Impacts to air from engine and generator emissions are assessed to be of low importance due to their local scope, short-term effect, minor consequence, likely probability and capacity for direct and cumulative effects.

Fugitive emissions from unsealed containers, maintenance operations, testing of fire fighting systems and poor housekeeping practices were assessed to be of low importance due to the local scope, short-term effect, minor consequence, likely probability and capacity for direct and cumulative effects.

Impacts to air from flaring are considered to be of low importance due to local scope, short-term effect, minor consequence, likely probability and capacity for direct and cumulative effects.

Proposed Management Measures
Mitigation of air emission impacts is possible through:

- Use of high efficiency flare tip design.
- Accurate management of the mix to flare during well tests.
- Regular maintenance of engines, compressors and generators.
- Routine maintenance of vehicles, helicopters and vessels.
- Good operational controls and a high level of housekeeping.
- Structured monitoring in accordance with EEMS.

8.3. EMISSIONS TO WATER

8.3.1. Controlled Discharges

8.3.1.1. Routine Waste Water

Potential Impacts
Direct impacts from these controlled discharge emissions will include localised nutrient enrichment, saprogenic effects, temperature increase and low level pollution from trace oils and chemicals. Indirectly these localised impacts may lead to increased pollution of the ecosystem with a cumulative impact on biodiversity.

Volumes and rates of waste water discharge are currently not known, but due to the limited size and temporary nature of the drilling programme the treated water discharged overboard will have a short-term localised impact on water quality. However, the open waters and relatively small volumes of discharge expected mean that it will be highly dispersed with no adverse impact on water quality and wildlife.

The discharge of sewage, drainage waters, cooling water and run-off / wash waters are assessed to be of low importance due to the local scope, low to medium persistence and minor consequence and likely possibility of these impacts.

Proposed Management Measures
Any oily or contaminated drainage from the drilling unit and vessels will pass through an oily water separator prior to discharge. Concentration of oil in water discharge will be restricted to less than 15 ppm, in accordance with the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78) Annex 1 requirements for disposal of oil or oily mixtures at sea. Oily water separators will be equipped with sensors and an alarm to ensure that the discharge limit is not exceeded.

Other mitigation measures of impacts from routine emissions to water are possible through:

- Treatment and maceration of sewage prior to discharge.

- Operational controls covering materials storage, wash-downs and drainage systems.
- Maintaining a high level of housekeeping on board.
- Use of only low toxicity chemicals on board.

8.3.1.2. Cuttings

Potential Impacts
The discharge of cuttings from top-hole sections to the seafloor (using seawater) and lower hole sections to the water column (following separation of WBMs) are assessed to be of low importance. Benthic sampling has shown a homogenous environment that is represented throughout the region, and no species or habitats of significance are found with the licence blocks.

Using water based drilling muds and only low toxicity chemicals (OCNS category Gold / E) removes toxicity effects. Seafloor smothering resulting from cuttings discharge is unlikely due to the water depths, quick dispersion of the sediments, and lack of filter feeders and marine vegetation in the area.

Direct impacts will be the localised smothering of the seabed around the well site, localised increase in turbidity and the depletion of oxygen in surface sediments. Drill cutting modelling has been carried out for this location and is summarised below.

The importance of cement release to the seafloor and chemical discharge from well completion were assessed to be medium due to the localised scope, short to medium term persistence and likely probability of minor smothering or toxicity effects occurring. The quantities of cement able to escape to the seabed will be small and contain only low toxicity chemicals. The release of well completion chemicals such as corrosion inhibitor, biocides and oxygen scavengers will be on a very small scale, limited to approved low toxicity chemicals which will disperse rapidly in the water column.

Cuttings Discharge Modelling
Full results from the cuttings discharge modelling are included in Appendix II. The results below are for the proposed Ernest and Weddell wells.

At the start of the drilling operations, drill cuttings will be discharged onto the seabed. Following the establishment of the initial well section the drill cuttings will be lifted to the surface inside the drill and treated on the platform. Oil contaminants are extracted and fine sediment particles are mixed with seawater and generally used as lubricants and/or coolants. The coarser material will be discharged at approximately 10 m below the surface. Table 8-3 shows the predicted drill residue particle sizes from the proposed drilling operations.

Table 8-3 Drill cuttings residue particle size

Particle size (microns)	<50	50 to 100	100 to 1000	1000 to 2000
% Particles	5	15	50	30

The release rate of sediment was assumed at 1.5 kg/second and the fate of the drill cuttings material was simulated over a total period of 21 days. The sediment release was assumed to be continuous giving a total mass of 2722 tonnes released into the water column over the 21 days.

The MIKE 321 PA model simulated the disposal process by releasing particles into the water column and tracking each particle. Results indicate that the drill cuttings residue deposition varies significantly between the different well locations.

The proposed Ernest and Weddell well locations do not have large footprint with respect to the modelled drill cuttings residue (Figure 8-1 and Figure 8-2). Water depths at these locations are in excess of 150 m, requiring a significant amount of time for the plume to settle on the seabed and are scattered over a larger area. While the total amount of cuttings per area is small, the net sedimentation of 0.05 kg/m^2 is less than one grain size in thickness putting it in the same order of magnitude as naturally occurring sedimentation due to the prevailing organic and inorganic suspended material in the sea water. Hence, the plumes appear to cover a large area but the actual amount on the seafloor is below the measureable value.

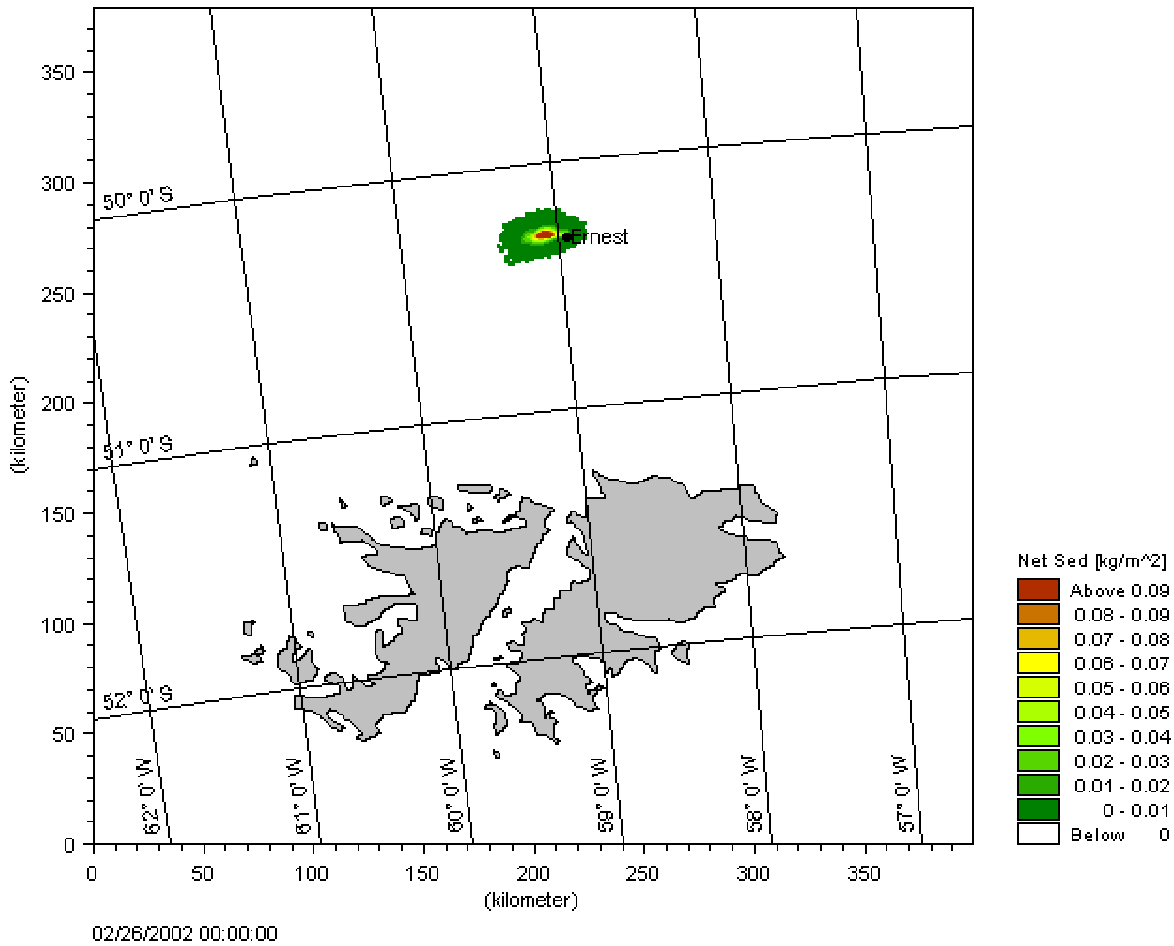


Figure 8-1 Drill cuttings sedimentation pattern after 21 days at Ernest well site

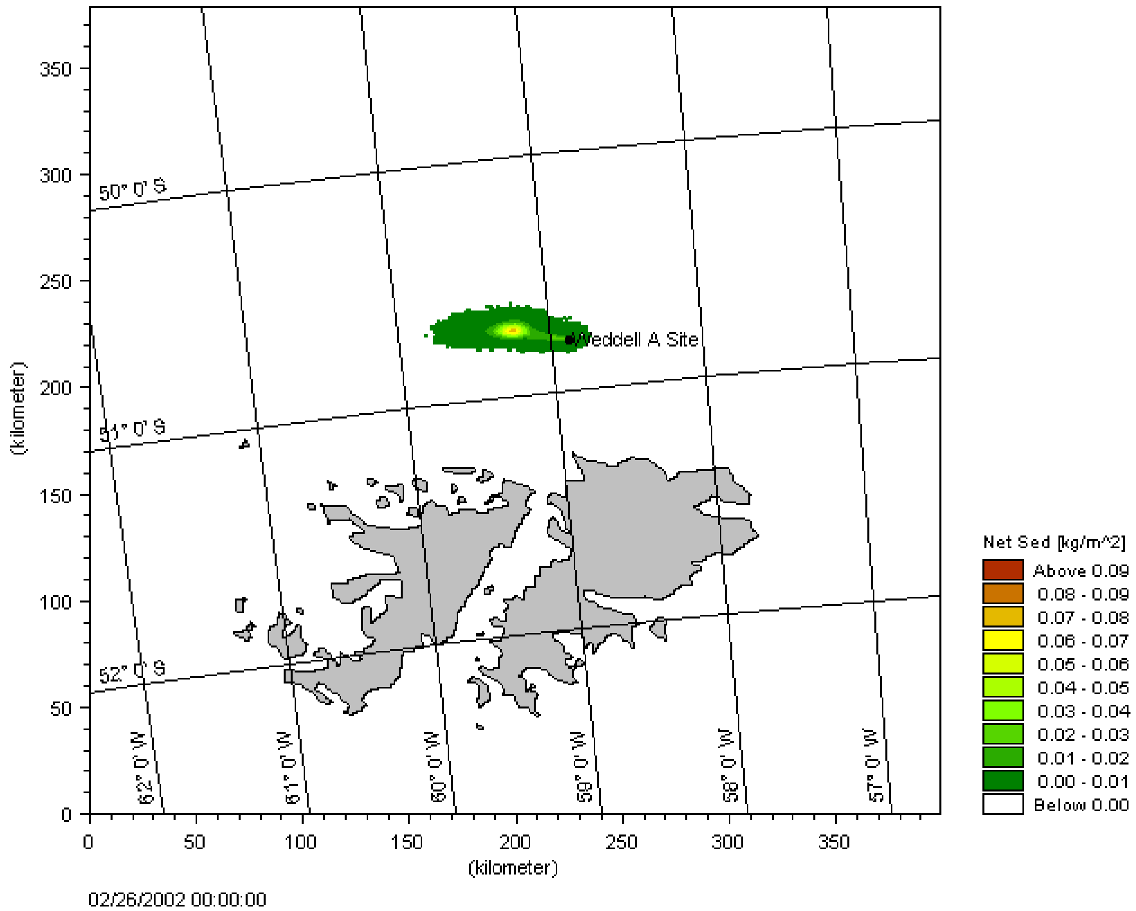


Figure 8-2 Drill cuttings sedimentation pattern after 21 days at Weddell well site

Proposed Management Measures
Mitigation of impacts from cuttings, cement and chemical discharge is possible through:

- Use of WBMs
- Use of OCNS category Gold / E chemicals and additives
- Use and regular maintenance of solids control package
- Discharge of cuttings from lower holes via the cuttings caisson several metres below the sea surface to aid dispersion.

8.3.1.3. Noise

Potential Impacts
Underwater noise emissions from drilling and vessel activities are not considered to be of sufficient amplitude to cause direct harm to marine life. Therefore marine observers or acoustic monitoring for standard drilling and vessel operations are not required. Underwater noise from drilling and vessel activities may induce localised behavioural changes in some marine species, however there is no evidence of significant behavioural changes due to drilling that may impact on the wider ecosystem.

Marine mammals are typically more tolerant of fixed location noise sources than moving sources and reactions to semi-submersible noise has been observed to be less severe than reactions to motor boats with outboards (LGL, 2000). Dolphins and other toothed whales show considerable tolerance of drill rigs and support vessels (Richardson et al, 1995). Baleen whales have been reported within visual distance of drill ships off West Greenland (LGL, 2000) and bowhead whales have been observed to avoid an area with radius 10 km around a drill-ship, corresponding to received sound levels of 115 dB re 1 µPa (Richardson et al, 1995). Sound levels produced from a semi-submersible be approximately 150 dB re 1 µPa, this will be attenuated to 115 dB re 1 µPa within 100 m (assuming spherical spreading) limiting behavioural reactions to a very small area.

The cumulative impact of increased background noise levels in the marine environment is an ongoing and widespread issue of some concern. Secondary and cumulative impacts for this project are considered negligible when compared to operations such as marine seismic surveys, use of active sonar, pile-driving and offshore construction or even high intensity fisheries and vessel traffic (which are absent from the proposed well locations).

Impacts due to underwater noise are therefore considered to be of low importance due to the local scope, short term duration of the project (approximately one month per well), minor consequence and possible likelihood of impacts on marine fauna from noise emissions.

Despite the high probability of occurrence and potential for disturbance to wildlife and impacts to human health, noise emissions to the atmosphere from operations, vessel and helicopter use were assessed to be of low importance due to the local scope and short term duration of the project.

Proposed Management Measures
No specific management measures are required however machinery and vessels will be regularly maintained to optimise efficiency.

8.3.2. Non-routine Discharges

8.3.2.1. General

Potential Impacts
Loss of non-liquid materials from loading / unloading and transfer is assessed to be of low importance due to the local scope, medium to long term persistence, moderate concern and unlikely probability. Loss of powders, plastics, wood, metal, items of equipment or packaging material at sea will cause localised pollution and may cause physical harm to marine animals including snaring and ingestion. It will also contribute to the wider pollution of the ecosystem and impact on biodiversity.

Ballast water discharge from support vessels may expel exotic species contained in the ballast water. The introduced species could displace native species impacting the function of the natural ecosystem, however this is unlikely as ballast water will be discharged in open waters where the species are not likely to colonise due to unfavourable deep water conditions. Discharge of ballast water from the drilling unit and vessels in operational areas may release low levels of oils and chemicals into the marine environment, but as this will occur in deep, open waters dispersion will occur rapidly. Though the probability of ballast water discharge during drilling is high, the scope of impact will be local and persistence will be short term. Impact is therefore considered to be of low consequence. Any discharge of ballast water will comply with established international maritime guidance and legislation.

The fall-out of unburned hydrocarbons from well test flaring may create localised surface oil pollution and lead to a visible sheen on the sea surface. The importance of hydrocarbon drop-out is considered to be low based on local scope, low persistence (based on likely length of possible well tests) and probable likelihood (well tests may or may not be carried out).

Chemical spills are assessed to be of low importance due to the local scope of impact, short to medium term persistence, moderate consequence and remote probability. The impact of any chemical spills will be direct toxicity effects on marine biota, which would be limited by the use of only UK OCNS approved low toxicity chemicals throughout operations. Chemical spills could impact human health and safety leading to increased ecosystem pollution.

Proposed Management Measures
Mitigation of impacts from chemicals spills, flare drop-out, ballast water discharge and the accidental lose of non-liquid materials at sea is possible through:

- Use of a high efficiency flare tip
- Careful control of the mix going to flare during well tests
- Minimisation of chemical transfers and loading operations
- Operational controls for loading, unloading and movement of materials
- Double-checking containment of all materials for transfer to/from the rig
- Storage of chemicals within bunded areas and away from any discharge point from the rig, vessel or onshore storage location
- Strict adherence to the rules governing discharge of ballast waters at sea
- Emergency response procedures in the event of a chemical spill
- Availability of materials safety data sheets and personal protective equipment for all chemicals in use

8.3.2.2. Hydrocarbon Spill

Surface pollutants, particularly mineral oils, are one of the most widely acknowledged threats to seabirds, although the reported incidence of oiled seabirds in the Falkland Islands is low, helped by the low levels of shipping in this area (Smith et al., 2000).

Oil spills from the project could result from small accidental spills during re-fuelling to loss of well control or blow-out leading to a large (>10,000 litre) spill. Storage failure (for example, from collision), accidents during bunkering or mechanical failure could also lead to small or medium sized spills of hydrocarbons, most likely of fuel oils. The risk of an offshore spill beaching is considered unlikely based on meteorological and current modelling from the oil spill modelling (see the sub-section below), and the impacts of such a spill will therefore be focussed on the offshore environment. A large oil spill occurring as a result of well blow-out is highly unlikely, as described in Sections 5.9 and 6.2.2.1.

Oil spills in the marine environment immediately have a detrimental effect on water quality. Oil is most toxic first few days after the spill, then weathers to lose some of its toxicity and begins to emulsify. Once the oil emulsifies the effectiveness of dispersants is reduced. The window of opportunity for dispersant use will depend on the type of oil and the metocean conditions at the time of the spill, however it is unlikely to exceed several days in the proposed drilling area.

Surface spills in deep waters are unlikely to immediately affect the seabed. Oil in sediments as a result of accidental spills can result in physical smothering or chronic pollution of the benthos, demonstrated by the results of post-drill benthic sampling.

North Sea research has identified potential toxic effects of oil on plankton (particularly copepods), fish eggs and larvae, however, the effects of petroleum-derived hydrocarbons in seawater are largely unknown (Munro, 2004). If pollution is severe, plankton will be killed, but fish can generally avoid the polluted area.

Small accidental spills are of low importance due to the local scope, medium persistence, minor consequence and unlikely probability. Large accidental spills are of medium importance due to the local to regional scope, long term persistence, major consequence and remote probability.

Oil Spill Modelling
Full results from the oil spill modelling are included in Appendix II.

A number of modelling simulations were undertaken to assess the fate of any potential oil spills from the drilling of the wells. The analysis was simulated using a 1 km x 1 km grid to provide sufficient detail of the predicted impact.

The spill simulations were undertaken using oil composition for a typical crude oil. The oil used in the simulation has a relatively high percentage of heavy oils, which, although highly unlikely from these wells, represents the worst case scenario for oil impact. The spill scenario was based on a continuous release of oil, at a volume of 1000 m^3 per hour for 12 hours (totalling 12,000 m^3). The model was then run for eight days.

For each proposed well location, two different simulations were run:

- Simulation 1 represents the worst case scenario, a constant onshore wind of 10 m/s using 15° intervals ranging from north-north-east to 315°.
- Simulation 2, uses a historical wind data set to give an indication of typical wind conditions and the most probably spill trajectories.

Both scenarios were incorporated with the hydrodynamic modelling undertaken for the area (Section 7.1.2.1).

Simulation 1 – Worst Case Conditions

The modelling output showed that under worst case conditions (wind at 10 m/s at 15°, N and 345°) it would take a minimum of 140 hours for a spill to reach the shore for the Ernest well and about 80 hours from the Weddell well (wind at 10 m/s from the NE) (Figure 8-3 to Figure 8-5).

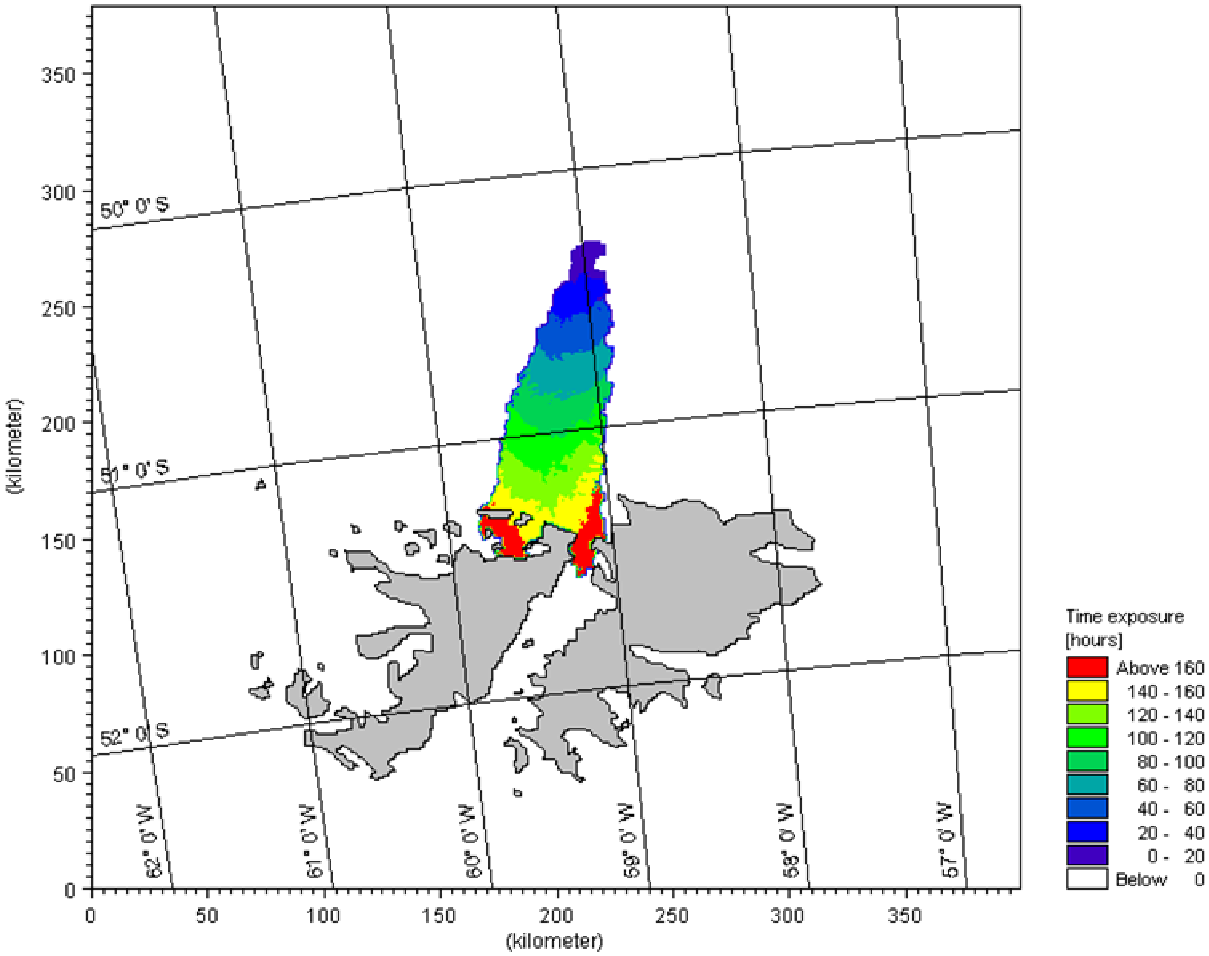


Figure 8-3 Simulation results showing exposure to oil following a major spill from the proposed Ernest well location with wind 10 m/s from 15° after 8 days

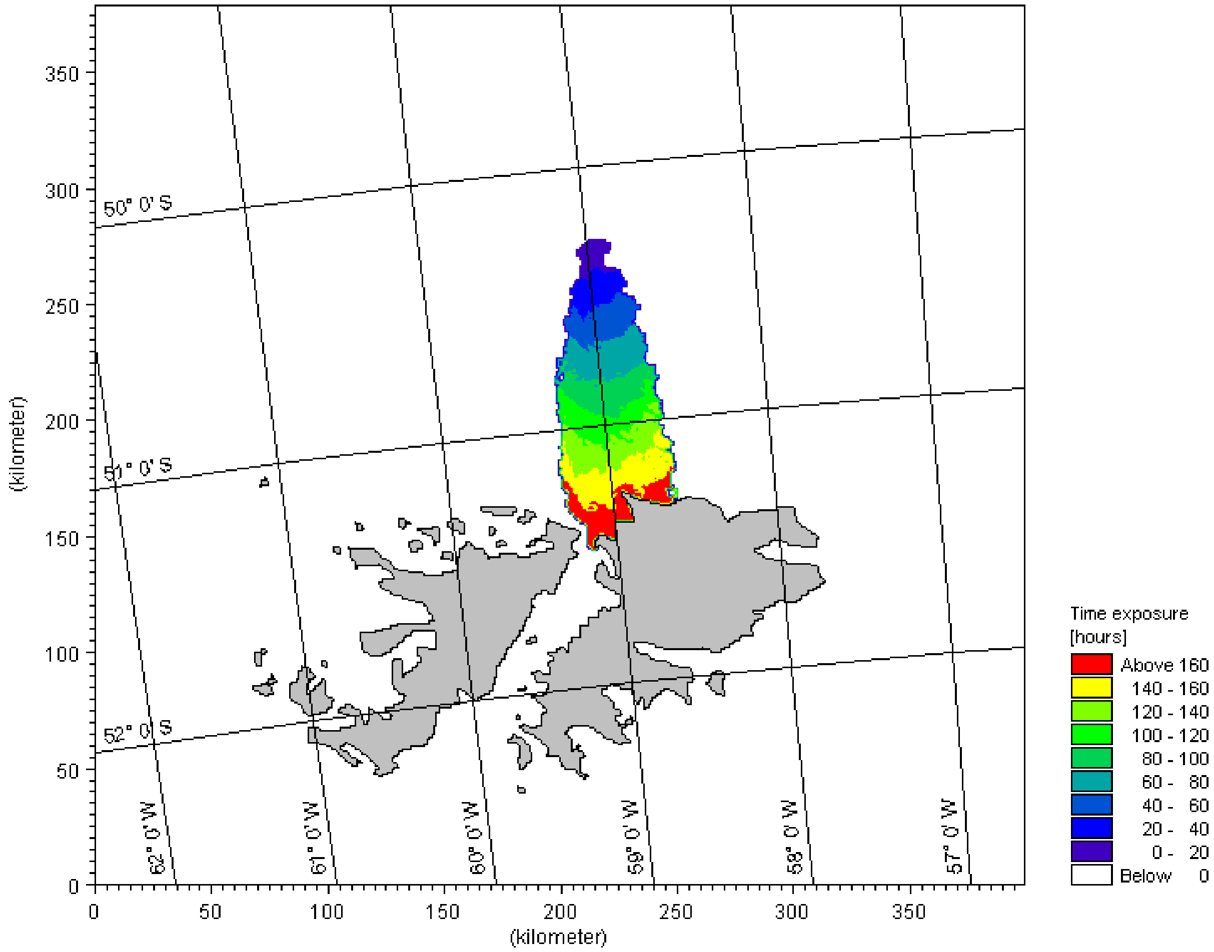


Figure 8-4 Simulation results showing exposure to oil following a major spill from the proposed Ernest well location with wind 10 m/s from N after 8 days

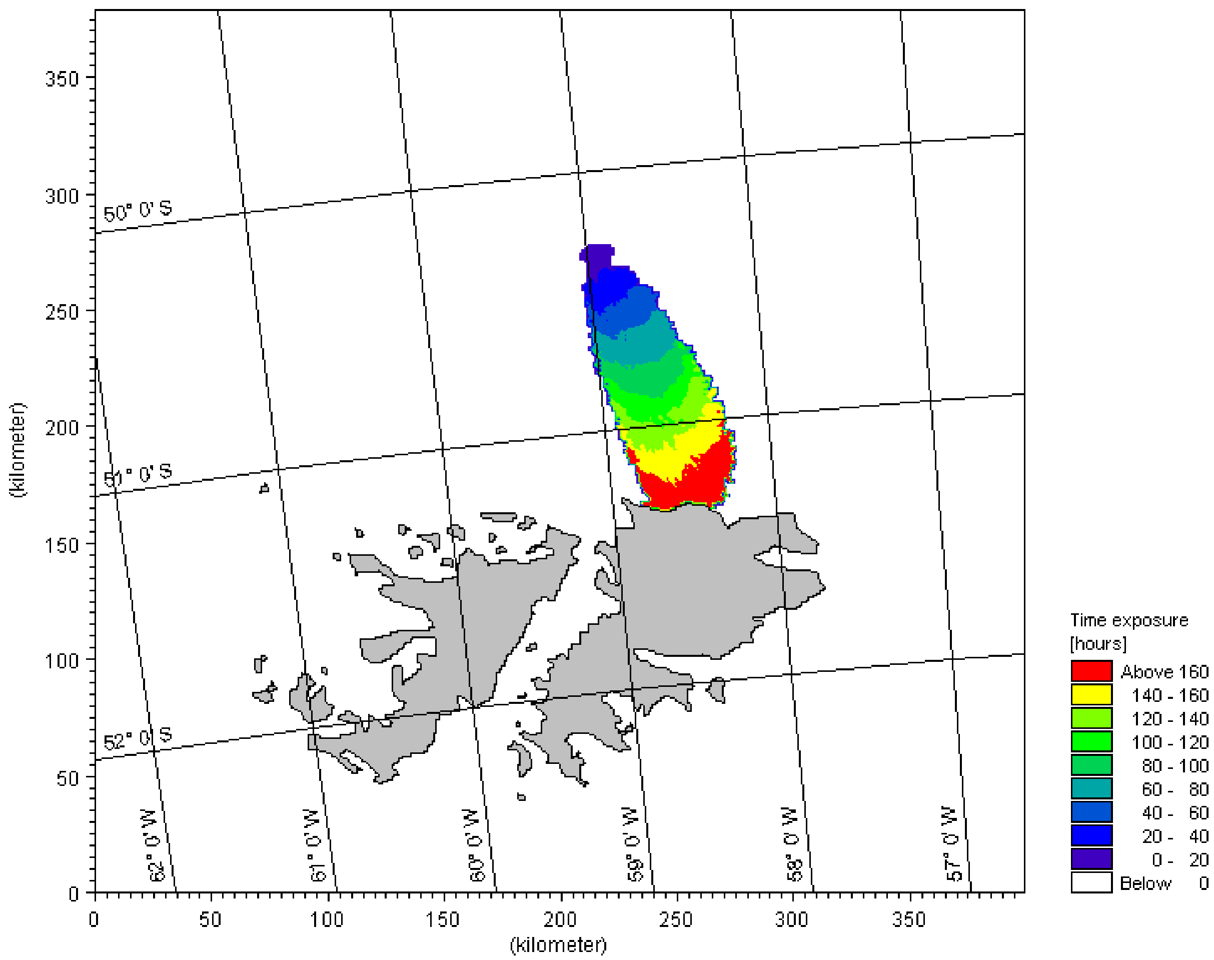


Figure 8-5 Simulation results showing exposure to oil following a major spill from the proposed Ernest well location with wind 10 m/s from 345° after 8 days

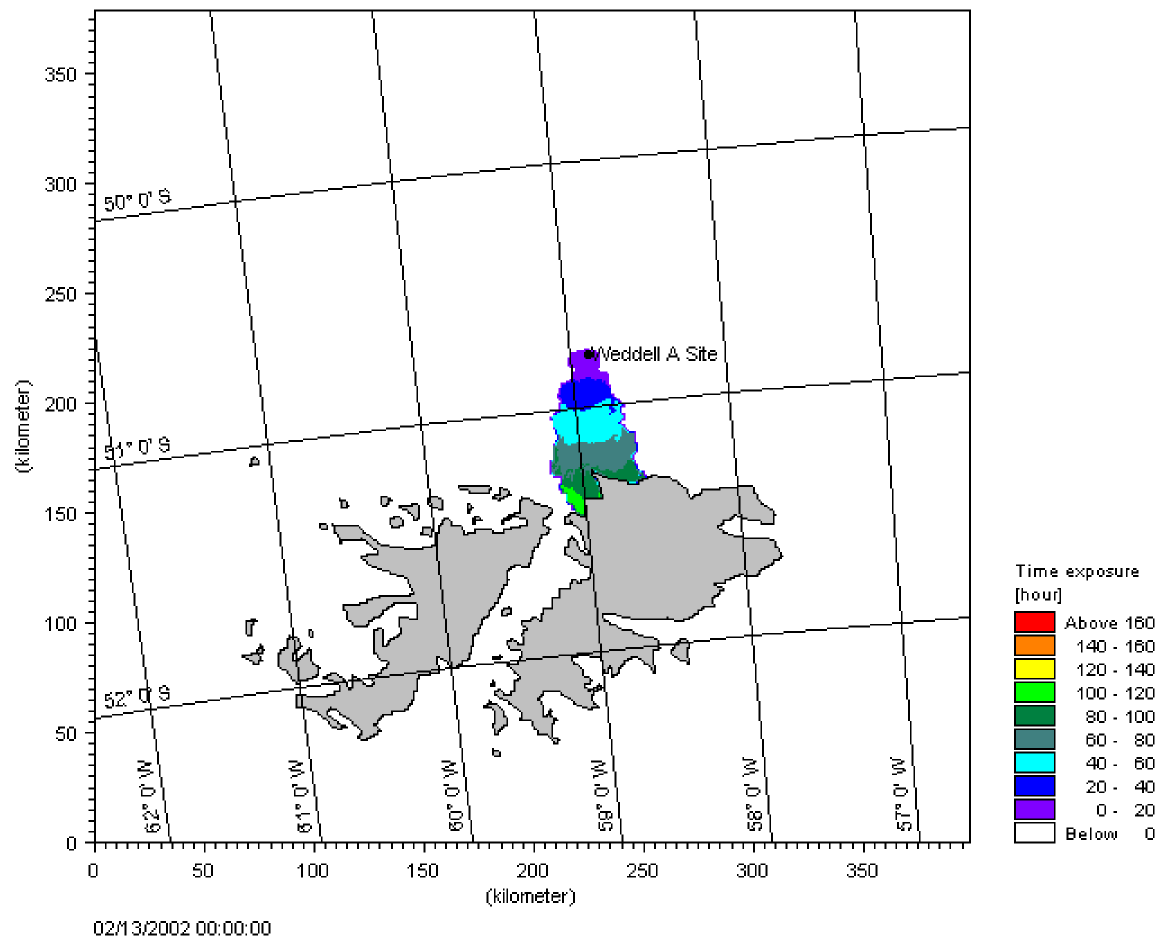


Figure 8-6 Simulation results showing exposure to oil following a major spill from the Weddell site with wind 10 m/s from 0° after 8 days.

Maximum oil slick thickness for the most southerly site in the adjacent Desire licence area indicates a 0–0.05 mm thickness at the northern shorelines of East Falkland Island. The proposed Ernest well location is further north to this Desire proposed well location, so will presumably have a lesser oil slick thickness should it reach the shore.

Table 8-4 provides an overview of the scenarios that would lead to beaching and an estimate of the total amount found ashore after six days of discharge cessation.

Table 8-4 Simulation 1 (worst case) total oil beached after 6 days (m^3)

Wind Direction	Ernest	Weddell
10°	–	4827.34
15°	<1.0	4390.02
N	–	4740.72
345°	–	4751.65
330°	–	815.00
315°	–	0.00

Simulation 2 – Typical Conditions
The historical wind data was used to simulate scenarios for exposure time plots with increasing wind speeds. The results indicate that using typical wind data, oil beaching only occurs from the

proposed Barbara well location, belonging to Desire, to the south of Ernest. The total amount of oil beached was calculated to be less than 1 m^3, as the wind turns shortly afterwards, moving the oil away from the shoreline. The simulation for the neighbouring well location, Ruth (also belonging to Desire), does not show any beached oil. Hence, beaching of oil from a spill at Ernest is highly unlikely.

Based on the limited wind data set for the southern Atlantic Ocean, it was assumed that there is less than 2% (p.a.) probability for the relevant wind conditions to cause beaching of oil from the drilling of the Ernest well and less than 12% (p.a.) for the Weddell well.

In the unlikely case that a major spill spreads and beaches, total oil thickness is likely to be 0–0.003 mm for Ernest and 0–0.05 mm for Weddell; which is unlikely to result in significant impacts.

In summary, the oil spill modelling shows that there is the potential for oil to reach the shoreline of the Islands, however the probability and volumes of oil that would reach the shore would be low. The modelling assumes that no oil spill response would be undertaken. Measures will be in place as part of an OSCP to reduce the potential for impacts at sea and on the shoreline.

In the unlikely event that the oil spill reaches the nearshore and coastal areas to the north of the Falklands, seabird vulnerability of small and large petrels, penguins and shags is medium to high all year round.

The effects of oil pollution on marine mammals are currently not fully understood (White et al., 2001). The risk of cetaceans inhaling oil vapours after a spill is the most likely immediate impact. Level of marine mammal sightings is low in the proposed drilling locations and high mobility of these species makes it unlikely that there would be significant direct impacts.

Chronic and acute oil pollution is recognised as a significant threat to both pelagic and inshore seabird species, ducks, wildfowl and waders. The majority of deaths attributed to oil pollution amongst seabirds are due to the physical properties of the oil and damage to the water repellent properties of the birds' plumage. This allows water to penetrate, decreasing buoyancy and leading to sinking and drowning. Additionally, thermal insulation capacity is reduced requiring greater use of energy to combat cold. Oil is also ingested as the birds preen in an attempt to clear oil from plumage and may furthermore be ingested over the medium to long term as it enters the food chain (Munro, 2004).

Stranded oil from near-shore operations would be quickly removed from high-energy beaches by wave action and water movement, but would not be readily removed from low energy sedimentary beaches and may become incorporated into the sediment.

The atlas of vulnerable concentrations of seabirds to surface pollution (White et al., 2001) further defines areas of high vulnerability to surface pollutants, particularly oil from offshore hydrocarbon development.

The atlas uses an Oil Vulnerability Index (OVI) to calculate vulnerabilities of different species to surface pollution. The OVI includes four factors within its calculation:

- The proportion of the time spent on the surface of the sea by that species;
- The size of the biogeographical population of that species;
- The potential rate of recovery of the species after a reduction in numbers; and
- The reliance on the marine environment by that species.

Nearshore areas are particularly vulnerable to surface pollution and adequate preventative and response measures will be put in place to address the risk of near-shore pollution.

Impacts on marine mammals:
Marine mammals may be seriously affected by oil pollution through coating, inhalation and ingestion of oil. However, they would normally be expected to actively avoid spilled oil. It is graver if coastal pollution occurs during the breeding season when animals are associated with breeding colonies and lactating pups cannot escape.

Marine mammal species that are reliant on shallow benthic prey species or closely associated with kelp beds may be affected by oil pollution as a secondary effect (Munro, 2004). The presence of Commerson's and Peale's dolphins in nearshore areas may make them particularly vulnerable to disturbance and or pollution effects.

Impacts on humans:
Petroleum hydrocarbons are potentially carcinogenic and can cause severe dermatitis. Human health could be affected through contaminated seafoods if acute hydrocarbon pollution occurs as a result of oil spills, although there is little evidence that petroleum hydrocarbons accumulate in marine organisms (Munro, 2004).

Proposed Management Measures
Mitigation of impacts from nearshore and offshore oil spills is possible through:

- Managing potential drilling hazards, such as shallow gas, and following established drilling safety standards to minimise the risk of control loss.
- Establishing comprehensive Oil Spill Response Planning.
- Training of key personnel in oil spill response.
- Consultation with the Fisheries Department and ongoing communications with all concerned parties regarding spill response.
- Collaboration with the national OSCP and availability of nearshore defences (i.e. booms), as well as trained personnel, spill surveillance services etc.
- Availability of dispersants and spill response kits on the rig and vessels for initial spill response.
- Membership to an oil spill response company to provide external oil spill response capability.
- Operational controls covering materials loading, transfer and storage
- Supervision of all loading / bunkering operations.
- Loading / bunkering during suitable weather conditions and light levels only.
- All oil stored in tanks or drums on board the vessel in accordance with maritime safety requirements.
- Comprehensive operational planning and risk assessment and provision of suitable specification equipment for drilling (BOP etc).

8.4. WASTE MATERIALS

8.4.1. Offshore Waste Management

Potential Impacts
Impacts from the discharge of food waste was assessed to be of low importance due to the local scope, medium to long term persistence (length of drilling), low intensity and high probability. Food waste will be macerated and discharged overboard in accordance with MARPOL 73/78 Annex V requirements. The discharge of macerated food waste can cause localised organic enrichment, however there are not expected to be any adverse impacts due to the discharge of food waste in this area.

The potential transfer of viruses from discharged poultry waste to local bird populations has also been raised as a potential issue. The likelihood of macerated food waste transferring viruses (for example, the Asian bird flu) to scavenging seabirds is believed to be extremely small as they are unlikely to get hold of macerated wastes.

The segregation, compaction, storage and transfer of waste materials from the drilling operations were all considered to be of high importance due to the local to continental scope, short to long term persistence and possible likelihood of impacts resulting in landfill sites and risks involved in long-haul transport. The probability of impacts due to waste material escaping during transfer was also assessed to be low.

Proposed Management Measures
It is recommended that poultry is sourced from a reputable and traceable supply, for example from the UK. Alternatively, should evidence of viral transfer show, all poultry waste will be segregated for disposal by incineration.

The disposal of any garbage at sea is prohibited by legislation. Waste will therefore be transferred from the rig and vessels back to shore for storage, disposal and/or transfer depending on the waste type and the options available.

All wastes will be sorted, compacted where practical and stored according to type and disposal route for subsequent transfer to shore. Hazardous or special waste should be stored in appropriate containers separately from non-hazardous wastes. Vessels are required by MARPOL 73/78 Annex V regulations to have a garbage management plan and a garbage record book where garbage volumes, types and disposal routes are recorded.

8.4.2. Onshore Waste Management

Potential Impacts
Should suitable incineration facilities exist or be imported to the Falkland Islands, impact from incineration of waste material is assessed to have low importance for emissions to air and medium importance for disposal of ash.

Emissions to air from a correctly specified and operated incinerator will have local scope, short term persistence, minor consequence and likely probability. The disposal of incinerator ash to landfill would have local scope, medium to long persistence, moderate consequence and likely probability (it may be disposed of elsewhere). The impact is assessed as being of medium importance due to the lack of suitable landfill sites in the Falkland Islands. Should existing waste facilities be improved or the ash exported with other wastes, the impacts would be low or negligible.

Landfilling of waste onshore is considered to be of high importance with potential direct impacts including potential contamination of soil and groundwater, amenity impacts (litter, odour) and emission of polluting releases to air. Indirect impacts of landfilling include potential impacts to human health, the take-up of land and damage to flora and fauna. The importance of landfilling is considered to be high due to the lack of suitable landfill sites in the Falkland Islands. Should waste facilities be improved the impacts of landfilling would decrease.

Storage, reuse and shipment of waste back to the UK are assessed as being of medium importance. Materials which can be safely and securely stored for future use will minimise waste disposal and use of resources. Materials not considered suitable for either re-use or disposal via incineration or landfilling (particularly hazardous materials) will be transferred to a suitable location for treatment and disposal.

Political and logistical reasons limit the destination for such wastes to the UK. A third party waste contractor may be used for the drilling operations to transport the wastes via the existing military shipments of hazardous materials or through regular cargo shipments (suitably segregated and sealed). The impact of waste storage, re-use and transfer will have a positive impact on the Falklands by reducing the stress that would be placed on existing landfill sites (analysis of the various options is ongoing).

Oily waste for local heating purposes will be reused and is considered to have a positive impact of medium importance due to the local scope, long term persistence, moderate consequence and likely probability. Reuse of oily waste will reduce waste disposal and encourage efficient local heating. Indirectly it will cut down on potential waste shipments and on a cumulative basis will provide financial assistance to local businesses.

Rockhopper will work with the drilling contractor to ensure that a stringent waste management plan is developed and implemented which will also include the planning phase so that waste production at the source of the activities is minimised.

Proposed Management Measures
Mitigation of impacts from waste materials is possible through:

- Reduction of waste at source and recycling of waste on board wherever possible.
- Maceration of food waste prior to disposal in accordance with MARPOL 73/78 Annex V and sourcing of poultry from a reliable supplier.
- Sighting of incinerator (if used) to minimise impacts to the public.
- Use of correctly specified incinerator for the types of waste being generated and suitable operation of incinerator.
- Incinerator residues should be disposed of to a suitable location or shipped to the UK.

8.5. PHYSICAL PRESENCE

Potential Impacts
Impacts to fishing and shipping operations caused by mobilisation of the rig are assessed to be of low importance due to the local scope, short duration of the project, minor consequence and unlikely probability. Direct impacts include hazards and disruption of fisheries and vessel traffic along the mobilisation route (currently unknown) with indirect financial impacts to industry.

Impacts to fishing and shipping operations caused by the presence of the rig in Falkland Island waters are assessed to be of low importance due to the local scope, short duration of the project, moderate consequence and unlikely probability. The direct effect will be the exclusion of fisheries and vessel traffic around the drilling area, with indirect impacts including economic costs and risk of collision. The use of support vessels will help prevent other vessels encroaching too close to the drilling operation. Impacts to fisheries and vessels will also be minimised due to the short duration of the campaign.

The impact from interference with other sea users by support vessels is assessed to be of low importance due to the local to regional scope, short duration of the project, moderate consequence and unlikely probability. It is expected that one vessel will remain on hand at the rig to enforce the exclusion zone and act as support, while a second vessel remains on standby in Stanley. Interference to other sea users from these vessels will therefore be minimal.

Disturbance of the seabed from anchoring operations is considered to be of low importance due to the local scope, medium persistence, minor consequence and unlikely probability. If a drill ship is used and anchors rather than dynamic positioning are utilised, then the impact may be of medium importance as the probability of seabed disturbance becomes more certain. However the small footprint and short-lived nature of the operations will mitigate potential impacts to the seafloor.

High definition seafloor mapping will be carried out for the proposed drilling locations and will be used to aid rig positioning to avoid seafloor hazards and significant topographic features. The direct effects will include damage to marine biota and to seafloor habitats. There is also likely to be an indirect increase in turbidity which will disperse and re-settle. A benthic survey programme has been carried out and revealed a relatively homogeneous macrofauna in a relatively homogenous environment. There is no evidence to indicate active pock marks or other seafloor habitats that may be particularly rich or unique environments. ROV video footage will assist with rig positioning and should also help to ensure anchoring avoids significant seafloor features.

Damage to potential seabed artefacts from anchoring operations is considered to be of low importance due to the local scope, permanent persistence, moderate consequence and remote probability. There are no known wrecks or significant artefacts at the drilling locations. ROV video footage will assist rig positioning and should help to ensure the area is free of obstacles and seabed artefacts.

Any items left on the seabed following demobilisation of the drilling rig could be a potential hazard to trawl fishing in the area. Lost anchors, protruding casing and well apparatus proud of the seafloor could snag nets and damage equipment, with indirect financial costs to fisheries and cumulative impacts to the local economy. There is likely to be a limited, local positive environmental impact from any area of the seafloor excluded to trawl fishing due to seafloor hazards. This impact is assessed to be of low importance due to the local scope, long term persistence, minor consequence and unlikely probability.

The aesthetic/visual impacts of the drilling operation are not considered to be significant due to the considerable distance from any land mass.

Proposed Management Measures
Mitigation of impacts from physical presence is possible through:

- Programme of consultation and notification with Fisheries Department and vessel operators.
- Use of support vessels throughout operations to maintain exclusion zone.
- Use of previous 3D seafloor mapping and accurate rig positioning with GPS.
- Use of ROV video footage for rig positioning.
- Subsequent availability of seafloor footage to environmental and research bodies.
- Location of the well sites away from the main fisheries areas.
- Ongoing communications with key stakeholders (fisheries and shipping) throughout operations to prevent conflicts.
- Follow established procedures for suspending / abandoning well and removing seafloor hazards.
- Demobilisation survey with ROV to look for any remaining seafloor hazards.

8.6. USE OF RESOURCES

Potential Impacts
Resource consumption from acquisition of drilling consumables and equipment (casing, cement, mud, and chemicals) is assessed to be of low importance to the Falkland Islands as it is unlikely that these resources will be sourced in the Falklands, and are more likely to be sourced from elsewhere. The remote drilling location will require sufficient materials, equipment, spares and contingency supplies to be ordered in advance and shipped prior to rig mobilisation. Reordering and transporting replacement parts or additional materials during drilling will be financially and logistically impractical.

Fuel consumption throughout the drilling campaign is considered to be of low importance to the Falkland Islands as it is not likely that the fuel will be sourced from the Islands. The consumption of helifuel, aviation fuel for flights, diesel and marine fuel oil is an operational necessity, although fuel consumption can be minimised by a regular programme of maintenance and servicing. Advanced planning has been undertaken and should help to ensure flights and transfers are kept to a minimum, however regular crew changes are a necessity both for operational and health and safety reasons.

Seawater use for drilling is assessed to be of low importance to the Falkland Islands it will not impact on seawater use of the Islanders and the cooling water will be discharged back into the sea. The use of potable water is assessed to be of low importance to the Falkland Islands as it is likely that desalinated seawater will be used rather than sourcing from the Islands.

Proposed Management Measures
Mitigation of impacts from resource use is possible through:

- Loading potable water outside peak times
- Regular maintenance and servicing of engines, generators and compressors
- Monitoring and reporting figures for resource consumption in accordance with established protocols
- Advanced operational planning to ensure sufficient availability of materials and equipment and waste minimisation.

8.7. SOCIO-ECONOMIC

Potential Impacts
Fisheries, tourism operators and shipping will not be impacted significantly from the drilling activities, due to low levels of fishing, tourism and shipping operations within the licence areas.

Socio-economic impacts from the need for accommodation and office space during mobilisation are assessed as being of low importance due to the local scope, long term persistence and serious consequence due to limited availability and increased competition with tourists. It is of low importance as it is likely that during crew changes use will be made of special accommodation.

The mobilisation of personnel to the Falkland Islands is likely to generate income for local individuals and businesses and provide a short term boost to the economy.

The impact of flying personnel to the Falkland Islands is assessed to be of medium importance due to the short duration of the project, serious consequence (from increased competition for flight availability with locals and tourists) and possible likelihood if chartered flights to and from the UK are not used.

The drilling campaign is likely to directly boost jobs and the economy, and is assessed to be of high positive importance despite the limited duration. The scope of this impact is assessed as local to regional, with medium term persistence, serious consequence (positive economic flow ons) and likely probability. Indirect impacts may lead to a change in the focus of the local economy towards servicing drilling activity, with the cumulative effect of local services providers adapting to the exploration industry.

Proposed Management Measures
Mitigation of socio-economic impacts is possible through:

- Awareness of drilling personnel to the unique nature of the Falkland Islands
- Utilising local goods and service providers wherever feasible
- Advanced planning for mobilisation of personnel and notification in the Falkland Islands where this may impact on the local population.

8.8. CUMULATIVE IMPACTS

Low levels of oil and gas, shipping and fishing activities currently cumulatively impact the surrounding environment within the proposed drilling locations and at the supply base in Stanley. The short-term exploratory drilling campaign will not significantly, or permanently, add to these existing cumulative impacts.

As drilling resources are to be shared between Rockhopper and Desire, the footprint is minimised and the impacts will not overlap.

Table 8-5 Summary matrix of potential impacts

Activity	Aspect	Impacts					Impact Description		
		Scope L R C	Persis S M L P	Prob R U P L C	Conse Mi Mo S Ma C	Import L M H	Direct Effects	Indirect Effects	Cumulative Effects
Emissions to Air									
Rig mobilisation	Rig engine emissions	L	S	L	Mi	L	Local reduction in air quality Contribution of GHGs	Impacts to human health	Contribution to regional air pollution
Drilling	Generator emissions	L	S	L	Mi	L			
Vessel use	Engine emissions	L	S	L	Mi	L			
Helicopter operations	Engine emissions	L	S	L	Mi	L			
Well testing	Flare emissions	L	S	L	Mi	L			
Drilling	Fugitive emissions	L	S	L	Mi	L			
Fire control	Fugitive testing emissions	L	S	L	Mi	L			
Drilling / vessels	Noise	L	S	L	Mi	L	Disturbance to wildlife		Injury to or loss of individual marine species
Helicopter operations	Noise	L	S	L	Mi	L			
Emissions to Water									
Drilling	Sewage discharge	L	S	L	Mi	L	Local reduction in water quality from nutrient enrichment and/or toxicity effects of low levels of oil / chemical spills Limited localised	Pollution of ecosystems Localised behavioural changes in marine life	Local organic enrichment Loss of biodiversity
Drilling	Rig drainage discharge	L	S	L	Mi	L			
Drilling	Cooling water discharge	L	S	L	Mi	L			

Activity	Aspect	Impacts					Impact Description		
		Scope L R C	Persis S M L P	Prob R U P L C	Conse Mi Mo S Ma C	Import L M H	Direct Effects	Indirect Effects	Cumulative Effects
Drilling	Run-off / wash water discharge	L	S	L	Mi	L	temperature increase		
Top hole drilling	Cuttings discharge	L	M	L	Mi	M	Localised smothering of the seabed around the well site. Localised turbidity. Depletion of oxygen in surface sediments. Low level toxicity impacts to marine biota.	Pollution of ecosystems Loss of seafloor habitat	Loss of biodiversity.
Drilling lower hole sections	Cuttings discharge	L	M	L	Mi	M			
Top hole drilling	Cement release	L	M	L	Mi	M			
Well completion	Chemical discharge	L	S	L	Mi	M			
Well testing	Hydrocarbon drop-out	L	M	P	Mi	L	Low level toxicity impacts to marine biota.	Pollution of ecosystems.	Loss of biodiversity.
Supply / re-supply of rig.	Loss of materials to sea	L	M-L	U	Mo	L	Localised pollution Physical harm / snaring from lost materials	Pollution of ecosystems.	Loss of biodiversity.
Rig / vessel ballast water	Ballast water discharge	L	S-M	U	Mo	L	Localised pollution. Introduction of exotic species	Displacement of native species	Loss of biodiversity.
Drilling / offshore bunkering	Large (>10,000 litre) fuel / oil spill	L-R	L	R	C	M	Physical oiling and toxicity impacts to wildlife Localised mortality to krill, eggs and larvae Contamination of coastal habitats	Decreased food resource from krill mortality, impacts to fishing and tourism. Political problems from transboundary issues (large spill only). Issue of waste disposal.	Accumulation of oil in the food chain and in sediments. Loss of biodiversity and revenue.
Drilling / offshore bunkering	Small-med (<10,000 litre) fuel / oil spill	L-R	M-L	R	Ma	M			
Near-shore loading / unloading	Small-med (<10,000 litre) fuel / oil spill	L	M	U	Mo	L	Physical oiling and toxicity impacts to wildlife, contamination of coastal habitats	Habitat loss, impacts to tourism and nearshore fisheries. Human health and disposal	

Activity	Aspect	Impacts					Impact Description		
		Scope L R C	Persis S M L P	Prob R U P L C	Conse Mi Mo S Ma C	Import L M H	Direct Effects	Indirect Effects	Cumulative Effects
								issues from cleanup.	
Drilling	Chemical spill	L	S-M	U	Mi	L	Toxicity effects on marine biota.	Pollution of ecosystems. Human health and safety.	Bioaccumulation of toxic substances.
Drilling	Underwater noise	L-R	M	P	Mi	L	Disturbance of animals in close proximity to the rig and vessels	Potential behavioural effects in marine mammals	Increase in background marine noise levels
Waste Materials - Offshore Aspects									
Drilling	Food waste discharge	L	M	L	Mi	L	Organic enrichment, food source for marine fauna.	Changes to localised ecosystem	Organic enrichment
Waste transfer	Escape of waste material	L	M-L	U	Mo	L	Localised pollution. Physical harm / snaring from waste items	Pollution of ecosystems	Loss of biodiversity
Waste Management	Segregation & compaction	L	S-M	C	S	H	Positive effect: improved waste management option. Reduced volume of waste material	See onshore waste management below	Reduced landfill take-up
Onshore waste management									
Incineration	Air emissions	L	S	L	Mi	L	Air pollution	Pollution of ecosystems	Contribution to regional and continental air pollution
Incineration	Landfill of ash	L	L-P	L	Mo	M	Visual impact. Possible soil and groundwater pollution	Human health and safety effects Amenity impacts Damage to flora and fauna	Reduced landfill availability. Increasing footprint of operations.
Disposal on shore	Landfill	L	L-P	U	Ma	H	Possible contamination of soil and groundwater Amenity impacts	Human health and safety effects Land take-up	Increasing footprint of operations.

Activity	Aspect	Impacts					Impact Description		
		Scope L R C	Persis S M L P	Prob R U P L C	Conse Mi Mo S Ma C	Import L M H	Direct Effects	Indirect Effects	Cumulative Effects
							Polluting emissions to air	Damage to flora and fauna	
Transfer to UK	Trans-frontier shipment	C	M	L	Mo	M	Impacts from long distance shipping of waste material (air emissions, fuel use, risk of spills etc)	Impacts from treatment / disposal of waste in the UK	Increasing footprint of operations
Waste Management	Storage & reuse	L	M-L	C	S	H	Positive effect - reduced incineration / landfill take up	Potential for releases from waste storage	Reduce waste disposal. Reduce raw material consumption
Re-use of oily wastes	Re-use for heating	L	M-L	L	So	H	Positive impacts: reduction in waste, local heating	No trans-frontier shipment of oily waste required	Boost to local business
Physical Presence									
Rig mobilisation	Interference with other sea users	L	M	P	Mi	L	Hazard to fisheries and shipping on route	Economic costs to shipping and fisheries.	Negligible
Rig presence	Interference with other sea users	L	M	U	Mo	L	Exclusion of fisheries and shipping from drilling areas	Economic costs to shipping and fisheries Collision risk	Impacts to local economy
Anchoring	Seabed disturbance	L	M	U	Mo	L	Harm to marine biota Damage to seafloor habitats	Increased turbidity in the water column.	Loss of biodiversity
Anchoring	Damage to seabed artefacts	L	L-P	R	S	L	Damage to any unlisted artefacts or archaeological remains in the area	Potential emergency situation should explosives be impacted	Loss of items of historic value
Support vessels	Interference with other sea users	L-R	M	U	Mo	L	Disruption to fisheries, shipping, harbour operations.	Potential emergency situation from vessel collision	Impacts to local economy
Well suspension / abandonment	Residual seabed hazards	L	L-P	P	Mi	L	Any items or extruding equipment will be a potential trawl fishing	Impacts to local fisherie Some positive environmental	Impacts to local economy

Activity	Aspect	Impacts					Impact Description		
		Scope L R C	Persis S M L P	Prob R U P L C	Conse Mi Mo S Ma C	Import L M H	Direct Effects	Indirect Effects	Cumulative Effects
							hazard	effect from seabed exclusion	
Use of Resources									
Pre-mobilisation	Purchase of drilling consumables	L-C	M-L	P	Mi	L	Consumption of resources - steel, mud, cement, chemicals etc	Effects of mining, processing and manufacturing	Loss of natural resources Pollution of the environment
Mobilisation & transfers	Fuel use	L-C	M-L	P	Mo	M	Consumption of helifuel, aviation fuel, diesel etc	Effects of extraction and processing, price of fuel	Loss of natural resources Pollution of the environment
Drilling	Fuel use	L	M-L	P	Mo	M	Consumption diesel	Effects of extraction and processing, price of fuel	Loss of natural resources Pollution of the environment
Drilling	Use of seawater	L	M-L	C	Mi	L	Extraction and use of seawater	None	Negligible
Drilling	Use of potable water	L	M-L	L	Mo	M	Consumption of water from the town supply.	Drop in towns' pressure while loading into vessels	Reduced resource availability
Socio-Economic Impacts									
Mobilisation / demobilisation	Accommodation & offices	L	L-P	U	S	L	Positive effect - Financial income for local people / businesses	Increased competition for available accommodation	Pressure on local resources. Localised economic growth
Mobilisation / demobilisation	Flights	L-C	M-L	P	S	M	Potential increased pressure on available airline seats	Development of new travel options / routes in the long term	Negligible
Drilling	Direct / indirect economic flow-on	L-R	M-L	L	S	H	Positive effect - Increase in jobs and income	Change in focus of local economy towards servicing the drilling operations	Adaptation of local service providers to exploration industry

9. MANAGEMENT FRAMEWORK

9.1. INTRODUCTION

This section describes Rockhopper's approach to environmental management. Environmental management is an integral part of the Rockhopper's HSE Management System and below is an outline of how Rockhopper plans and manages all of its' projects, operations and assets to minimise the impact of the Company's activities on the environment.

The key environmental management process begins by identifying and assessing the significance of all environmental issues. Management plans are developed to reduce the consumption of energy and raw materials and minimise the impact on air, water, land and social resources. This is achieved by minimising the volume and/or toxicity of emissions, discharges, solid and liquid wastes and the disruption to ecosystems, industries and social groups.

The process (Figure 9-1) applies to all elements of the exploration, development, production and abandonment lifecycle, applying equally to Rockhopper's operated and non-operated activities.

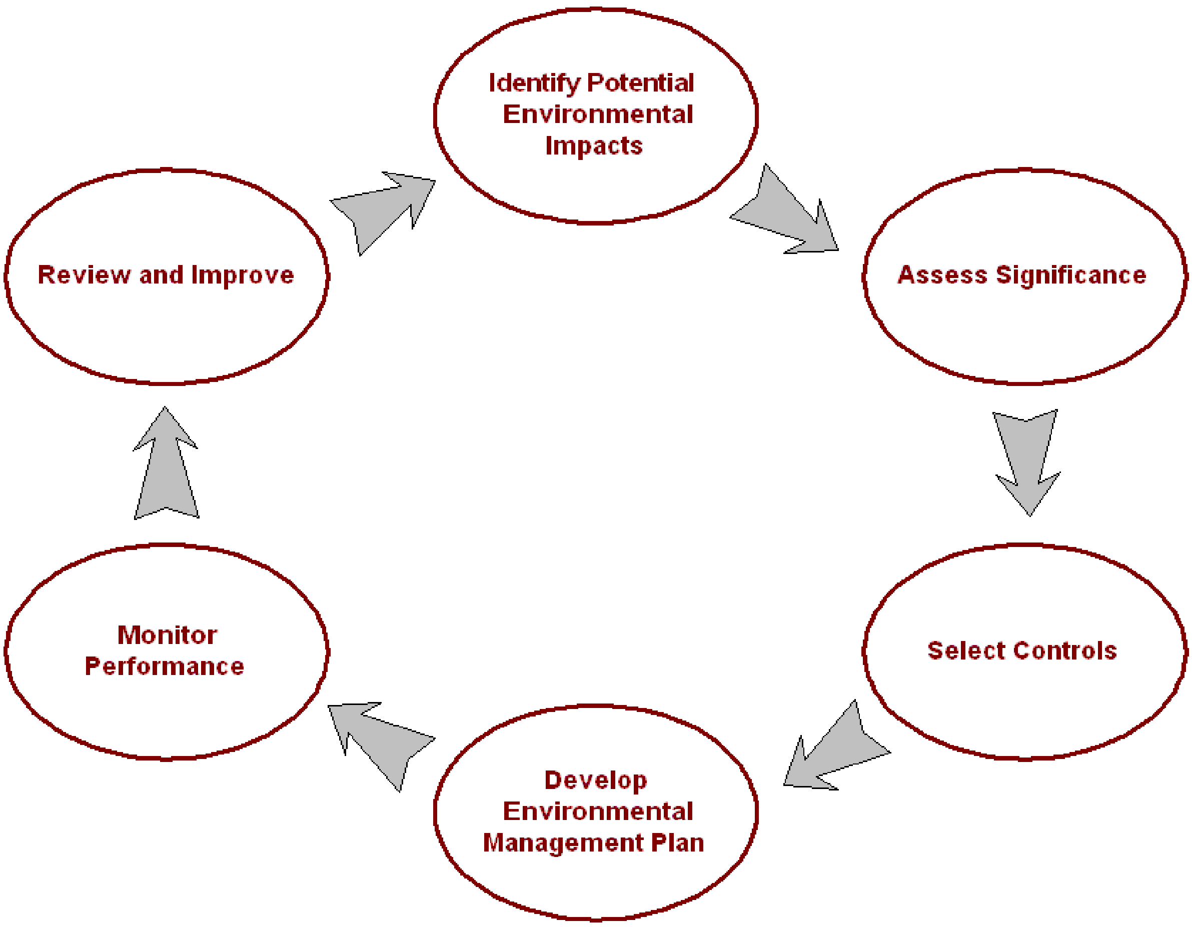


Figure 9-1 Environmental management process

9.2. RESPONSIBILITIES

Responsibilities for ensuring that the appropriate levels of environmental management are undertaken are identified below:

- Establish environmental policy objectives as part of Rockhopper's HSE Policy.
- Ensure that environmental impacts and opportunities are identified and assessed.
- Introduce appropriate controls and management plans to mitigate negative impacts and maximise opportunities.
- Monitor performance and introduce improvements where possible.
- Ensure that a system for managing environmental resources is in place.
- Monitor the environmental management plans in place to ensure their compliance with the Rockhopper's HSE Management System.
- Maintain an up-to-date record of environmental management plans.
- Ensure periodic audits and inspections are conducted to assure Rockhopper management that operations and assets are fully compliant with environmental management plans.
- Identify to management/supervisors any unmonitored or potential risks to the environment.
- Participate in environmental management schemes such as waste reduction.

9.3. ENVIRONMENTAL MANAGAMENT PROCESS

9.3.1. Identify Potential Environmental Impacts

For all operated projects and operations, potential environmental interactions have been identified in this EIS. Environmental interactions and the associated impacts have been identified as being either short or long term, temporary or permanent, direct or indirect, local or strategic.

9.3.2. Assess Significance of Impacts

The significance of the environmental interactions have been determined using significance criteria, legislation, industry standards and practices and this EIS contains an assessment of the environmental impact associated with the use of that resource.

9.3.3. Select Control Measures

Long-term objectives have been set for each significant interaction in this EIS. These may be control, study or improvement objectives.

Appropriate mitigation measures have been identified, evaluated and selected (for example, waste reduction measures based on the waste management principle hierarchy of Reduce, Recycle, Recover, Residue (disposal)).

9.3.4. Develop Environmental Management Plan

Environmental management plans should be prepared as an integral part of project/asset activity specific plans. A corporate environmental management plan capturing activities resulting from both long-term objectives and activity specific mitigation measures will be prepared alongside annual asset work plans and project/asset specific plans.

9.3.5. Monitor Performance

Auditable arrangements will be established for monitoring environmental management plans and control measures against agreed objectives.

9.3.6. Review and Improve

The significance of environmental impacts shall be reviewed annually as part of Rockhopper's Management Review process, to take into account any changes that may have taken place in the significance criteria.

Environmental interactions and associated impacts of projects will be reviewed in light of internal or external changes.

9.4. PROJECT ENVIRONMENTAL MANAGEMENT FRAMEWORK

Environmental management of the Project will be conducted within a comprehensive framework comprising:

- Rockhopper's Health, Safety and Environmental Policy Statement
- Rockhopper's Health, Safety and Environmental Management System (HSE MS)
- Drilling contractors Management HSE Policy Statement
- Drilling contractors Well Management Safety Management System
- Management System Interface Document
- Drilling contractor operational controls and specific environmental procedures within the project Environmental Management Plan (EMP).

This section provides an overview of the current and proposed management framework as it relates to the environmental aspects of the drilling programme.

9.4.1. Rockhopper Petroleum Environmental Management System

Rockhopper's Health, Safety and Environmental (HSE) management system incorporates an HSE Policy Statement (Appendix IV). The management system is not certified and, as Rockhopper does not undertake operations itself, is based on the supervision and administration of contractors.

The HSE Policy Statement and management system set out Rockhopper's priority goals and commitments, and the framework within which these will be applied. The drilling contractors will describe their operational controls and management procedures detailing how specific operations will be carried out, for example bunkering of fuel, radio communications, drilling and well testing. Bridging these two levels of control will be a Management System Interface Document. This document outlines the systems and procedures developed to ensure that the well operations carried out by the drilling contractor on behalf of Rockhopper are managed safely, with due regard for the environment and in a quality manner. Included within this document are:

- Policy, Standards and Procedures
- Safety Management
- Emergency Response
- Environmental Considerations
- Risk Management
- Quality Assurance
- Organisation
- Document Control

The Management System Interface Document will be implemented when a contractor is finalised and their existing systems are known.

9.4.2. Operational Controls and Procedures

Relevant operational controls and operating procedures will together form the project specific Environmental Management Plan (EMP). The EMP will detail the mitigating measures to be carried out, together with the roles and responsibilities of key parties. The rig operator and drilling crew will have in place existing environmental procedures covering aspects such as bunkering, fire fighting, spill prevention and response, waste management and emissions recording and reporting.

The EMP will reference existing controls and highlight those areas where additional controls are required. This will take place once the drilling rig, vessels and contractors have been selected as the EMP will need to tie-in with these existing operational controls and will need to be specific to the rig and personnel to be used.

The drilling contractor should comply with all applicable legislation, standards and conditions, including the environmental expectations of the client. All crew members, including support vessel crew, will be made aware of the standards and controls applicable to the conduct of this operation before drilling commences. Key personnel will need to be trained in oil spill response procedures prior to drilling.

All equipment on board (for example, engines, compressors, generators, sewage treatment plant, oily water separators, mud and chemical systems, and solids treatment package) should be regularly checked and maintained in accordance with manufacturer's guidelines in order to maximise efficiency and minimise malfunctions and unnecessary discharges to the environment.

Solid and hazardous wastes should be appropriately segregated and stored onboard prior to disposal via previously agreed and approved disposal routes, either to the Falkland Islands or via transfer to a different licensed location.

Clear lines of communication and operational procedures will be established between the drilling rig, onshore support facilities, support vessels and helicopter facilities before the start of drilling. Organograms showing the management structure and lines of reporting for both the operational phase and the project initiation and definition phases will also be drawn up to illustrate the lines of communication.

9.4.3. Reporting

The UK standard Environmental Emissions Monitoring System (EEMS) reporting format will be used for monitoring the consumption of resources and emissions to air and water. Shipping manifests will be completed for all shipments to and from the drill rig and will be logged and reported in line with documented management procedures.

Monitoring of emissions to air and water, waste production and resource consumption will be undertaken in accordance with established procedures for similar operations in the UK based around the EEMS and Petroleum Operations Notice (PON) systems. Monitoring, calculating and reporting of greenhouse gas emissions requires various assumptions to be made and relies on a multiple tier approach based on degrees of uncertainty. The different levels of certainty and accuracy in emissions reporting are shown in Figure 9-2.

Types of Approaches	Hierarchy
Published emission factors	**Improved accuracy** **Additional data requirements** **Higher cost**
Equipment manufacturer emission factors	

Engineering calculations	
Monitoring over a range of conditions and deriving emission factors	
Periodic monitoring of emissions or parameters for calculating emissions	
Continuous emissions* or parameters monitoring	

*Continuous emissions monitoring applies to most types of air emissions, but may not be directly applicable nor highly reliable for greenhouse gas emissions.

Figure 9-2 Emissions Estimation Approaches

During well operations, an Operational team will be established in Stanley, Falkland Islands. Daily reports will be sent from the rig to the drilling contractor Team Leader.

The following reports shall be forwarded to the offshore Rockhopper representative in the Falkland Islands and (via the drilling contractor Manager) to the Rockhopper representative in the United Kingdom:

- Daily Drilling/ Testing Report
- Daily Geological Report
- Mud logging report
- Six day look ahead
- Persons on board list
- Vessel and Helicopter Movements
- All accident or incident reports.

A weekly operational report and summary will be prepared by the drilling Team Leader and forwarded to the relevant Service companies (by way of an Operational update) to ensure that operational support is available.

At the end of operations an End of Well report including operational and financial sections will be compiled. The operational section of this report will include:

- Daily activities
- Time/depth curve
- Casing running and cementing report
- Materials usage report
- Bit record
- Mud logging report
- Formation evaluation report.
- Directional drilling report
- Testing report
- Abandonment/suspension/completion status report
- Down time Analysis/Lessons Learnt

EEMS reports and PONs will be completed in accordance with the production licence and regulatory requirements and submitted to FIG. Relevant EEMS reports encompass the following datasets:

- Form EEMS/005 - Oil/Base Fluid on Cuttings Summary
- Form EEMS/007 - Chemical Term Permits
- Form EEMS/014 - Waste Report
- EEMSATMO - atmospheric emissions inventory - Form 2002

For UK operations, the EEMS data submission timetable for drilling activity is as follows:

Table 9-1 EEMS Data Submission Matrix
(Source: www.eems-database.co.uk)

Activity	EEMS/001	EEMS/004	EEMS/005	EEMS/006	EEMS/007	EEMS/008	ATMOS	EEMS/014
Drilling	N/A	N/A	One month from completion	N/A	One month from completion	N/A	One month from completion	Annually by 1st Mar

9.4.4. Oil Spill Contingency Plan

A dedicated oil spill contingency plan (OSCP) will be developed in support of the proposed drilling campaign in the North Falkland Basin. It will be developed when the contract for the drill rig and crew has been awarded, and will be based on the results of the oil spill modelling scenarios. The OSCP will provide for a multi-tier response dependent on the scale and type of spill. At the most extreme end of the scale (Tier 3) the OSCP will rely on mobilising specialist aircraft and personnel from Oil Spill Response Limited (OSRL) in the UK to provide aerial dispersant spraying capability.

The OSCP will also correspond with the plans of the FIG and its national oil spill contingency plans.

10. CONCLUSIONS

Sufficient baseline data exists for this part of the North Falklands Basin and with the additional surveys and modellings commissioned by Rockhopper for its licence blocks, this EIS makes a thorough assessment of its potential impacts. Mitigation measures have been proposed for all impacts with extra attention given to those deemed to be of high to medium significance. This will allow operations to proceed without any significant long lasting impacts to the marine or coastal environment of the Falkland Islands.

To successfully implement the proposed mititgation measures the focus is now on ensuring the operations follow established procedures, key personnel are trained in emergency response such as oil spill response, joint exercises are run with the Falkland Island oil spill response plan, all personnel receive basic environmental awareness training and contingency plans are in place to prevent any environmental incidents from occurring.

The operations specific addendum to this EIS that will be produced, will further define the environmental management, operational controls and employee training necessary to keep impacts to ALARP (as low as reasonably possible) levels.

Finalising the drilling unit and crew is not likely to cause a significant deviation from the operation aspects identified in this EIS. Should there be any operational changes likely to cause a significant change to the assessment of impacts, they will be incorporated within the operational addendum. At this stage it is thought most likely that potential changes will be minor and that these will not significantly alter the results of the impact assessment.

The Desire EIS for Tranches C and D, recently submitted to FIG, touched on wider issues such as waste management in the Islands and the interaction of the national oil spill contingency plan with project specific plans. FIG recently commissioned OSRL to make some recommendations regarding the national oil spill response and a consultant from OSRL visited the Islands at the end of last year and submitted a report for consideration by FIG. FIG also continues to review the situation regarding onshore waste management and is seeking ways to better deal with waste onshore, commensurate with the resources available.

The socio-economic aspects of the oil and gas industry have been deliberately limited at the request of the FIG to avoid overlaps with existing studies.

In conclusion, despite the high sensitivity and international importance of the Falkland Islands' waters, there is obvious dedication to carrying out these operations to a high environmental standard. Given the current operational commitments and proposed mitigation measures, it is considered that the proposed operations can be undertaken without significant impacts to the Falkland Islands' environment.

11. ACKNOWLEDGEMENTS

In undertaking this environmental assessment we have been provided with a great deal of assistance and information from both the authorities and NGOs within the Falkland Islands. In particular Falklands Conservation and various departments of the Falkland Islands Government (primarily Environmental Planning, Mineral Resources, Fisheries and Public Works) have been extremely helpful in providing data, reports and responding to technical queries. In addition we would like to acknowledge the assistance of both the British Geological Survey and the JNCC in the UK.

The Falkland Islanders have always shown a tremendous level of hospitality during each of the stakeholder engagement and information gathering trips to the Islands. They have also demonstrated a keen interest in the issues surrounding these operations and in maintaining the unique environment of the Islands and the surrounding waters. A great deal of thanks is due to the people of the Falkland Islands for their friendliness and support throughout this process.

Acknowledgement is also due to Rockhopper Exploration, which has provided operational and planning information, geological data and regular updates during the compilation of this Environmental Statement. Finally we would like to acknowledge the benthic studies carried out by Ian Wilson in testing conditions and the modelling work performed by RPS Belfast. These valuable studies continue to add to our level of knowledge for this area and improve our understanding of this special environment.

12. REFERENCES

www.falklands.gov.fk

www.falklands-oil.com

API 2004; Compendium of Greenhouse Gas Emissions Methodologies for The Oil and Gas Industry. American Petroleum Institute February 2004, 489pp.

Barnes, R.S.K. and Hughes, R.N. (1988) An introduction to marine ecology. 2nd. Ed., Blackwell Scientific Publications, Oxford.

Birdlife International (2004) Threatened birds of the world 2004. CD ROM Cambridge, UK: Birdlife International.

Boyle, P.R. (1983) (Ed.) Cephalopod life-cycles Vol 1 Species Accounts. Academic Press Inc. (London) Ltd.

Broughton, D.A. & McAdam, J.H. (2002) A red data list for the Falkland Islands vascular flora. Oryx 36 (3): 279-287.

Brown & Root Environmental (1997), Falkland Islands Environmental Baseline Survey Desk Study report.

2001 Falkland Island Census, UK Foreign and Commonwealth Office Country Profiles: The Falkland Islands (www.fco.gov.uk)

BP (2002); Azeri, Chirag & Gunashli Full Field Development Phase 1 Environmental & Socio-economic Impact Assessment, Section 5a.

Ciechomski JD and Sanchez RP (1983) Relationship between ichthyoplankton abundance and associated zooplankton biomass in the shelf waters off Argentina. *Biol. Ocean*, **3**: 77-101.

Clausen, A. & Huin, N (2003) Status and numerical trends of king, gentoo and rockhopper penguins breeding in the Falklands. *Waterbirds* **26**(4): 389-402.

Coopers & Lybrand (1997) Socio-Economic Study of the Falkland Islands. Prepared for the Falkland Islands Government. (http://www.bgs.ac.uk/falklands-oil/download/socio-economicstudyfinalreport.pdf).

Croxall JP,McInnes SJ, and Prince PA (1984) The status and conservation of seabirds at the Falkland Islands. In Status and Conservation of the World's seabirds (J. P. Croxall, P. G. H. Evans and R. W. Schreiber, Eds.). ICBP, Cambridge.

Croxall JP and Wood AW (2002) The importance of the Patagonian Shelf to top predator species breeding at South Georgia. *Aquatic Conservation: Marine and Freshwater Ecosystems* **12**:119–126.

Duncan 2006, Falkland Islands Newsletter, May 2006.

E&P Forum report No. 2.59/197, 1994, 'Methods for Estimating Atmospheric Emissions from E&P Operations', Table 4.11 Tier Three Estimation: Draft Emission Factors for Transportation Fuel Combustion (tonnes emission/tonne fuel), Sea Transport emission factors.

ERT (Environment & Resources Technology Ltd) (1997) Environmental assessment for the proposed exploration drilling operations offshore the Falkland Islands. Prepared for Shell Exploration & Production South West Atlantic.

Falkland Islands Government Fisheries Department (FIGFD 2000) Fisheries Statistics Volume 9 (1995-2004): 70 pp Stanley, FIG Fisheries Department.

Falkland Islands Fisheries Department (FIGFD 2004) Scientific Report Fisheries Research Cruise ZDLH1-11-1999.

Falkland Islands Government (FIG) (1996) The first shallow marine survey around the Falkland Islands. Falkland Islands Environmental Baseline Survey, Brown and Root Environmental/ICON.

FCO (2005) Foreign and Commonwealth Office Country Profiles - Falkland Islands; www.fco.gov.uk

FCO (2007) Foreign and Commonwealth Office Country Profiles - Falkland Islands; www.fco.gov.uk

FUGRO (1999) North Falklands Metocean Survey Final Report - Volume 1 19-June-97 to 30-Sep-98. C10317/1762.

Gardline Surveys Limited (1998) Benthic Environmental Basline Survey of the Sediments around the Exploration '14/14-A' Well.

Gardline Surveys Limited (1998) Post-Drill Environmental Survey of the Sediments around the Exploration Well 'Little Blue A'.

Glorioso, P.D. & R.A.Flather (1995) A barotropic model of the currents off SE South America. *Journal of Geophysical Research.*, **100**, 13427-13440.

Guo, Q. and Geehan (2004), T. "An Overview of Drill Cuttings Re-Injection –Lessons Learned and Recommendations", 11th International Petroleum Environmental Conference, New Mexico, October 12-15, 2004.

Halcrow (1998) Falkland Islands Waste Disposal Report. Prepared for the Falkland Islands Government.

Hatfield, E.M.C. (1990) The squid of the Falkland Islands Fishery; A profile. *Falkland Islands Newsletter*, **10**, 2-5.

Hoggarth, D.D. (1993) The life history of the Lithoid crab, *Paralomis granulosa*, in the Falkland Islands. *ICES J Mar Sci.*, **50**, 405-424.

Holland P (1997) Offshore blowouts – Causes and controls., Gulf Publishing Company.

Hydrographer of the Navy (1993). *South American Pilot Volume II.* (*16th ed*). Southern coasts of South America from Cabo Tres Puntas to Cabo Raper and the Falkland Islands. Hydrographic Office, Ministry of Defence, Taunton. 457pp.

Inada, T., & Nakamura, I. (1975) A comparitive study of two populations of the Gadoid fish, *Micromesistius australis* from the New Zealand and Patagonian-Falkland regions. *Bulletin of Far Seas Fish Resource Laboratory*, **13**, November 1975.

Hendley, N., (1937) The plankton diatoms of the Southern Seas. *Discovery Reports* Vol XVI, 151-364, Plates VI-XIII.

Huin N (2007) Falkland Islands penguin census 2005/06. no. Falklands Conservation, Stanley.

LGL (2000) Environmental Assessment of Exploration Drilling off Nova Scotia. LGL Limited Environmental Research Associates August 2000.

Lisovenko, L.A., Barabanov, A.V., Yefremenko, V.N. (1982) New data on the reproduction of the "Southern Putassu", *Micromesistius australis* (Gadidae), from the Falkland-Patagonian Zoogeographic Region. *Journal of Ichthyology*, **22**, 55-67.

Middleton, D.A.J., Arkhipkin, D.I., Grzebielec, R. (2001). The biology and fishery of *Macruronus magellanicus* in Falkland Islands waters. *Workshop on hoki and southern blue whiting, Chile, 3-7th July 2001.*

Munro 2004, Draft Falkland Islands Baseline Environmental Survey.

Otley, H. 2005. Nature-based tourism: experiences at the Volunteer Point penguin colony in the Falkland Islands. *Marine Ornithology* **33**: 181-187.

Otley H, Clausen A, Christie D, Huin N, and Pütz K, 2006. Breeding patterns of King Penguins on the Falkland Islands. *Emu Austral Ornithology* 107(2): 156-164. CSIRO Publishing.

Otley H, Munro G, Clausen A and Ingham B. 2008. Falkland Islands State of the Environment Report 2008. Falkland Islands Government and Falklands Conservation, Stanley.

Patterson, K.R. (1986) The Polish fishery for Southern Blue Whiting in the FICZ from July to October 1985. Source; Falkland Islands Fisheries Department.

Richards, P BGS (December 2001), Falkland Islands: past exploration strategies and remaining potential in underexplored deepwater basins.

Reid T and Huin N (2005) Census of the southern giant petrel population of the Falkland Islands 2004/2005.

Richardson, W.J., Greene, C.R. Jr., Malme, C.I. & Thomson, D.H., 1995. Marine mammals and noise. Academic Press, San Diego.

Rodhouse, P G, Symon, C and Hatfield, E M C (1992). Early life cycle of aphalopods in relation to the Major Oceanographic features of the southwest Atlantic Ocean. Marine Ecology Progress Series 89, p183-195.

Searles, R.B. (1978) The genus *Lessonia* (Phaeophyta, Laminariales) in Southern Chile and Argentina. *Br. Phycol. J.*, **13**, 361-381.

Strange, I J (1992) A field guide to the wildlife of the Falkland Islands and South Georgia, HarperCollins, London.

Tingley, G.A., Purchase, L.V., Bravington, M.V., & Holden, S.J. (1995) Biology and fisheries of hakes (*M.hubsii* and *M.australis*) around the Falkland Islands. Ch 10. In Alheit, J., Pitcher, T., (Eds) Hake: Biology, Fisheries & Markets, Chapman & Hall, London.

Upton J and Shaw CJ (2002) An overview of the oceanography and meteorology of the Falkland Islands. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **12** (1): 15-25.

White, R.W., Gillon, K.W., Black, A.D. & Reid, J.B. (2001) Vulnerable concentrations of seabirds in Falkland Islands waters. JNCC, Peterborough.

White RW and Clausen AP (2002) Rockhopper *Eudyptes Chrysocome Chrysocome* × *Macaroni E. Chrysolophus* Penguin Hybrids Apparently Breeding in the Falkland Islands. *Marine Ornithology*, **30**: 40-42.

White, R.W., Gillon, K.W., Black, A.D. & Reid, J.B. (2002) The distribution of seabirds and marine mammals in Falkland Island waters. JNCC, Peterborough

Woods, R., Stevenson, J., Ingham, R., Huin, N., Clausen, A., & Brown, A. (2004) Important Bird Areas in the Falkland Islands. A Falklands Conservation Report to Birdlife International.

Woods, R.W. and Woods, A. (1997) Atlas of Breeding Birds of the Falkland Islands. Anthony Nelson, Owestry, Shropshire, England.

APPENDIX I IUCN SPECIES UNDER THREAT AND STATUS

Scientific Name	Common Name	IUCN Category
Cetaceans		
Balaenoptera borealis	Sei whale	**Endangered**
Balaenoptera musculus	Blue whale	**Endangered**
Berardius arnuxii	Arnoux's beaked whale	Low Risk/Cons. Dependant
Cephalorhynchus commersonii	Commerson's dolphin	Data Deficient
Eubalaena australis	Southern right whale	Low Risk/Cons. Dependant
Hyperoodon planifrons	Southern bottlenose whale	Low Risk/Cons. Dependant
Lagenorhynchus australis	Peale's dolphin	Data Deficient
Lagenorhynchus obscurus	Dusky dolphin	Data Deficient
Lissodelphis peronii	Southern right whale	Data Deficient
Megaptera novaeangliae	Humpback whale	Vulnerable
Mesoplodon grayi	Gray's beaked whale	Data Deficient
Mesoplodon hectori	Hector's beaked whale	Data Deficient
Mesoplodon layardi	Layard's beaked whale	Data Deficient
Orcinus orca	Killer whale	Low Risk/Cons. Dependant
Phocoena dioptrica	Spectacled porpoise	Data Deficient
Physeter macrocephalus	Sperm whale	Vulnerable
Ziphius cavirostris	Cuvier's beaked whale	Data Deficient
Fish		
Carcharhinus longimanus	Oceanic whitetip shark	Vulnerable
Cetorhinus maximus	Basking shark	Vulnerable
Birds		
Diomedea epomophora	Southern royal albatross	Vulnerable
Diomedea exulans	Wandering albatross	Vulnerable
Diomedea sanfordi	Northern royal albatross	**Endangered**

Eudyptes chrysocome	Rockhopper penguin	Vulnerable
Eudyptes chrysolophus	Macaroni penguin	Vulnerable
Eudyptes robustus	Snares crested penguin	Vulnerable
Eudyptes schleqeli	Royal penguin	Vulnerable
Eudyptes sclateri	Erect-crested penguin	**Endangered**
Macronectes giganteus	Southern giant petrel	Vulnerable
Macronectes hali	Northern giant petrel	Near Threatened
Phalacrocorax gaimardi	Red-legged cormorant	Near Threatened
Phoebetria fusca	Sooty albatross	**Endangered**
Phoebetria palpebrata	Light-mantled albatross	Near Threatened
Procellaria aequinoctialis	White-chinned petrel	Vulnerable
Procellaria cinerea	Grey petrel	Near Threatened
Pterodroma incerta	Atlantic petrel	Vulnerable
Puffinus griseus	Sooty shearwater	Near Threatened
Pygoscelis papua	Gentoo penguin	Near Threatened
Spheniscus magellanicus	Magellanic penguin	Near Threatened
Thalassarche bulleri	Buller’s albatross	Vulnerable
Thalassarche cauta	Shy albatross	Near Threatened
Thalassarche chlororhynchos	Atlantic albatross	**Endangered**
Thalassarche chrysostoma	Grey-headed albatross	Vulnerable
Thalassarche melanophrys	Black-browed albatross	**Endangered**

APPENDIX II MODELLING RESULTS

Falklands Island Oil Exploration Oil Spill Analysis and Drill Plume Modelling

DOCUMENT CONTROL SHEET

Client	RPS Group / Energy					
Project Title	Falklands Island Oil Exploration Oil Spill Analysis and Drill Plume Modelling					
Document Title	Oil Spill Analysis and Drill Plume Modelling					
Document No.	IBE0114/R02/BE					
This Document Comprises	DCS	TOC	Text	List of Tables	List of Figures	No. of Appendices
	1	1	63	1	1	3

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TABLE OF CONTENTS

1 INTRODUCTION 5
2 HYDRODYNAMIC MODELLING 6
2.1 OVERVIEW OF THE HYDRODYNAMIC MODEL USED IN THE PORJECT 6
2.2 COMPARISON OF HYDRODYNAMIC MODEL AND PREDICTED TIDAL ELEVATIONS AND CURRENTS .. 11
2.3 CONCLUSIONS ON HYDRODYNAMIC MODEL VALIDATION........ 11
3 OILS SPILL ANALYSIS 12
4 DRILL PLUME MODELLING 21
4.1 MODELLING THE FATE OF THE DRILL RESIDUE 21
4.2 RESULTS OF THE DISPERSION MODELLING SIMULATIONS 22
5 SUMMARY AND CONCLUSIONS 24
6 REFERENCES 25
APPENDIX A: HYDRODYNAMIC MODEL CALIBRATION 26
APPENDIX B: OIL SPILL ANALYSIS 34
APPENDIX C: DRILL CUTTINGS PLUME AND DEPOSITION 59

LIST OF FIGURES

Figure 1: General overview of proposed oil well sites in the South Western Atlantic Ocean 5
Figure 2: Extent of hydrodynamic model and selection of calibration locations..................................... 7
Figure 3: Current direction at different depths and depth averaged direction at Location A over three day period.. 8
Figure 4: Current magnitude at different depths and depth averaged magnitude at Location A over three day period (as above) 8
Figure 5: Current direction at different depths and depth averaged direction at Location A................... 9
Figure 6: Current magnitude at different depths and depth averaged magnitude at Location A 9
Figure 7: Wave height, period and direction over same period as Figure 2-4 & Figure 2-5 9
Figure 8: Current direction at different depths and depth averaged direction at Location B................. 10
Figure 9: Current magnitude at different depths and depth averaged magnitude at Location B 10
Figure 10: Water temperature at different depths direction at Location A over 7 month period 10
Figure 11: Bathymetry and extend of oil spill model used in this study 12
Figure 12: Exposure to oil following spill from site Barbara with wind 10m/s from 330° after 8 days... 14
Figure 13: Maximum oil slick thickness during 8 day simulation following spill from site Barbara with wind 10m/s from 330° 15
Figure 14: Wind rose for offshore location near oils wells from NOAA's global wave model (in 15° sectors).. 16
Figure 15: Historic wind field with longest spell and persistent high wind speeds within sector critical for beaching of oil 17
Figure 16: Exposure to oil following spill from site Barbara with historic wind field 18
Figure 17: Exposure to oil following spill from site Ruth with historic wind field.................................. 19
Figure 18: Maximum oil slick thickness during 8 day simulation following spill from site Barbara for historic wind field 20
Figure 19: Drill cuttings sedimentation pattern after 21 days 23
Figure 20: Comparison between simulated and predicted surface elevation at Caleta San Pablo 26
Figure 21: Comparison between simulated and predicted surface elevation at New Island 26
Figure 22: Comparison between simulated and predicted surface elevation at Port Stanley............... 26
Figure 23: Comparison between simulated and predicted surface elevation at Location A 27
Figure 24: Comparison between simulated and predicted surface elevation at LocationB 27
Figure 25: Comparison between simulated and predicted current magnitude at Location A 28
Figure 26: Comparison between simulated and predicted current direction at Location A................... 28
Figure 27: Comparison between simulated and predicted current magnitude at Location B 29
Figure 28: Comparison between simulated and predicted current direction at Location B................... 29
Figure 29: Residual current flow and mean sea level for one month (05 Feb to 05 Mar 2002) without atmospheric influence 30
Figure 30: Instantaneous surface elevation and currents at High Water (MHWS) at Port Stanley 31
Figure 31: Instantaneous surface elevation and currents at Mid Tide (MHWS) at Port Stanley........... 32

Figure 32: Instantaneous surface elevation and currents at Low Water (MHWS) at Port Stanley 33
Figure 33: Exposure to oil following spill from site Ernest with wind 10m/s from 15° after 8 days 34
Figure 34: Exposure to oil following spill from site Ernest with wind 10m/s from N after 8 days 35
Figure 35: Exposure to oil following spill from site Ernest with wind 10m/s from 345° after 8 days 36
Figure 36: Exposure to oil following spill from site Ernest with wind 10m/s from 330° after 8 days 37
Figure 37: Exposure to oil following spill from site Ernest with wind 10m/s from 315° after 8 days 38
Figure 38: Exposure to oil following spill from site Ruth with wind 10m/s from 15° after 8 days 39
Figure 39: Exposure to oil following spill from site Ruth with wind 10m/s from N after 8 days 40
Figure 40: Exposure to oil following spill from site Ruth with wind 10m/s from 345° after 8 days 41
Figure 41: Exposure to oil following spill from site Ruth with wind 10m/s from 330° after 8 days 42
Figure 42: Exposure to oil following spill from site Ruth with wind 10m/s from 315° after 8 days 43
Figure 43: Exposure to oil following spill from site Dawn with wind 10m/s from 15° after 8 days......... 44
Figure 44: Exposure to oil following spill from site Dawn with wind 10m/s from N after 8 days 45
Figure 45: Exposure to oil following spill from site Dawn with wind 10m/s from 345° after 8 days....... 46
Figure 46: Exposure to oil following spill from site Dawn with wind 10m/s from 330° after 8 days....... 47
Figure 47: Exposure to oil following spill from site Dawn with wind 10m/s from 315° after 8 days....... 48
Figure 48: Exposure to oil following spill from site Barbara with wind 10m/s from 15° after 8 days 49
Figure 49: Exposure to oil following spill from site Barbara with wind 10m/s from N after 8 days........ 50
Figure 50: Exposure to oil following spill from site Barbara with wind 10m/s from 345° after 8 days ... 51
Figure 51: Exposure to oil following spill from site Barbara with wind 10m/s from 330° after 8 days ... 52
Figure 52: Exposure to oil following spill from site Barbara with wind 10m/s from 315° after 8 days ... 53
Figure 53: Exposure to oil following spill from site Alpha with wind 10m/s from 15° after 8 days......... 54
Figure 54: Exposure to oil following spill from site Alpha with wind 10m/s from N after 8 days 55
Figure 55: Exposure to oil following spill from site Alpha with wind 10m/s from 345° after 8 days....... 56
Figure 56: Exposure to oil following spill from site Alpha with wind 10m/s from 330° after 8 days....... 57
Figure 57: Exposure to oil following spill from site Alpha with wind 10m/s from 315° after 8 days....... 58
Figure 58: Deposition footprint of drill residue for well site Ernest 59
Figure 59: Deposition footprint of drill residue for well site Alpha 60
Figure 60: Deposition footprint of drill residue for well site Barbara.. 61
Figure 61: Deposition footprint of drill residue for well site Dawn 62
Figure 62: Deposition footprint of drill residue for well site Ruth 63

LIST OF TABLES

Table 1: Oil well locations 13
Table 2: Oil characteristics used for oils spill simulations 13
Table 3: Total oil beached after 6 days (in m^3) 15
Table 4: Occurrence of spells with wind speeds above a given threshold within 315° to 30° tN 17
Table 5: Drill residue from drilling operations 21
Table 6: Drill residue disposed at drill rig 22

1 INTRODUCTION

RPS Energy is currently undertaking an Environmental Impact Study of proposed oil well drilling and exploitation operations at a number of sites north of the Falkland Islands in the Southern Atlantic. To facilitate this EIS an assessment of the impact of possible oil spill and drill cuttings are required. In order to carry out the necessary plume analysis RPS have developed a hydrodynamic model of the South Western Atlantic Ocean. Using the hydrodynamic model a number of scenarios for oils spills as well as the typical drill cuttings plume and depositions have been investigated.

The following report provides details on the model used as well as the calibration of the model. It also details the oil spill analysis carried out as well as the effect of the release fo the drill cuttings from the well drilling operations.

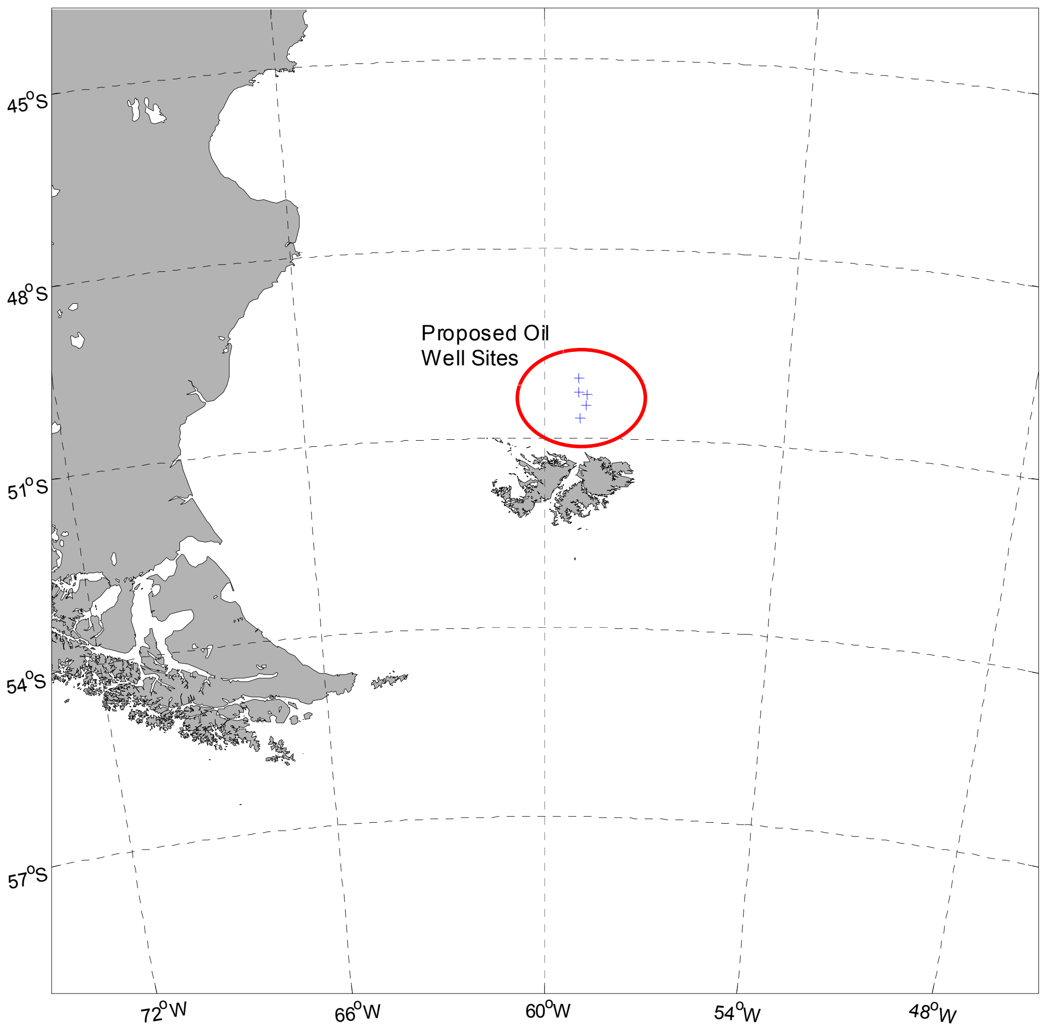

Figure 1: General overview of proposed oil well sites in the South Western Atlantic Ocean

2 HYDRODYNAMIC MODELLING

2.1 OVERVIEW OF THE HYDRODYNAMIC MODEL USED IN THE PORJECT

The basic hydrodynamic model employed in this study is the MIKE21HDFM, a flexible mesh barotropic finite volume model.

The modelling system is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used.

The spatial discretisation of the primitive equations is performed using a cell-centred finite volume method. The spatial domain is discretised by subdivision of the continuum into non-overlapping element/cells. In the horizontal plane an unstructured grid is used comprising of triangles or quadrilateral element. An approximate Riemann solver is used for computation of the convective fluxes, which makes it possible to handle discontinuous solutions. For the time integration an explicit scheme is used.

The extent of the model is shown in

Figure 2. The model covers the eastern coast of South America from the Cabo San Diego (Grand Isla de Terra Fuego) to the Rio Grande on the coast of Uruguay. From there it extends to 40°W in south easterly direction having an open boundary along the 40th western meridian. This boundary terminates close to the Coronation Islands in the South, where it cuts across to the South Shetland Islands (Antarctic) and crosses the Drake Passage. Both the south Shetland Islands and the Coronation Islands are not included in the model.

The model area encompasses one of the most challenging sea areas worldwide. The area features some of the largest tidal ranges worldwide close to the Magellan Strait, with significant currents along the edge of the continental shelf caused by both astronomic and topographically influence. Density driven currents are reported to be relatively small, however the Falklands/ Malvinas Current, part of the Antarctic Circumpolar Current (ACC), which originates in the Drake passage and travels north forced by the bathymetry of the sea area, dominates the ocean currents in this section.

The model bathymetry was derived from C-Map Chart data sets for the area. Based on this data the mesh was constructed with particular detail to the edges of the continental shelf and the area immediately around the Falkland Islands, where the mesh has an average cell size of 12 km^2 (5km cell size). In the Atlantic Ocean the cell size is increase and can be up to 60km. The model bathymetry was corrected for mean sea level to allow for the large tidal ranges on the continental shelf, though for the majority of the model this is irrelevant due to the large water depths.

The boundary conditions were derived from an 0.25 degree global tidal model providing 8 harmonics for the generation of surface elevation along the open boundaries. The global tidal model is based on a study as part of the TOPEX/POSEIDON study and details can be found in Andersen (1995). The boundaries derived from the above model were corrected to take into account the influence of the Antarctic Circumpolar Current in the Drake Passage.

A number of numerical models have been developed for this area and details can be found in Glorioso & Flather (1995). Data for calibration of the model is relatively scarce with limited tidal elevation and tidal current data available. Two sources for direct comparisons were used, the tidal elevations predicted for a number of ports by C-Map and field data obtained on behalf of the Falklands Operations Sharing Agreement (FOSA) and published by Upton and Shaw (2002). In particular the latter data sets were post processed and tidal elevations at two sites, as well as the depth averaged current velocities and directions were produced for comparison with the model. In this summary three tidal locations are used for comparison, Port Stanley on the eastern side of the Falklands and New Island, located at the most western side of the Falklands Islands Group, as well as Caleta San Pablo, which is on the main land of the Grand Isla de Terra Fuego of South America. The locations are indicated in

Figure 2.

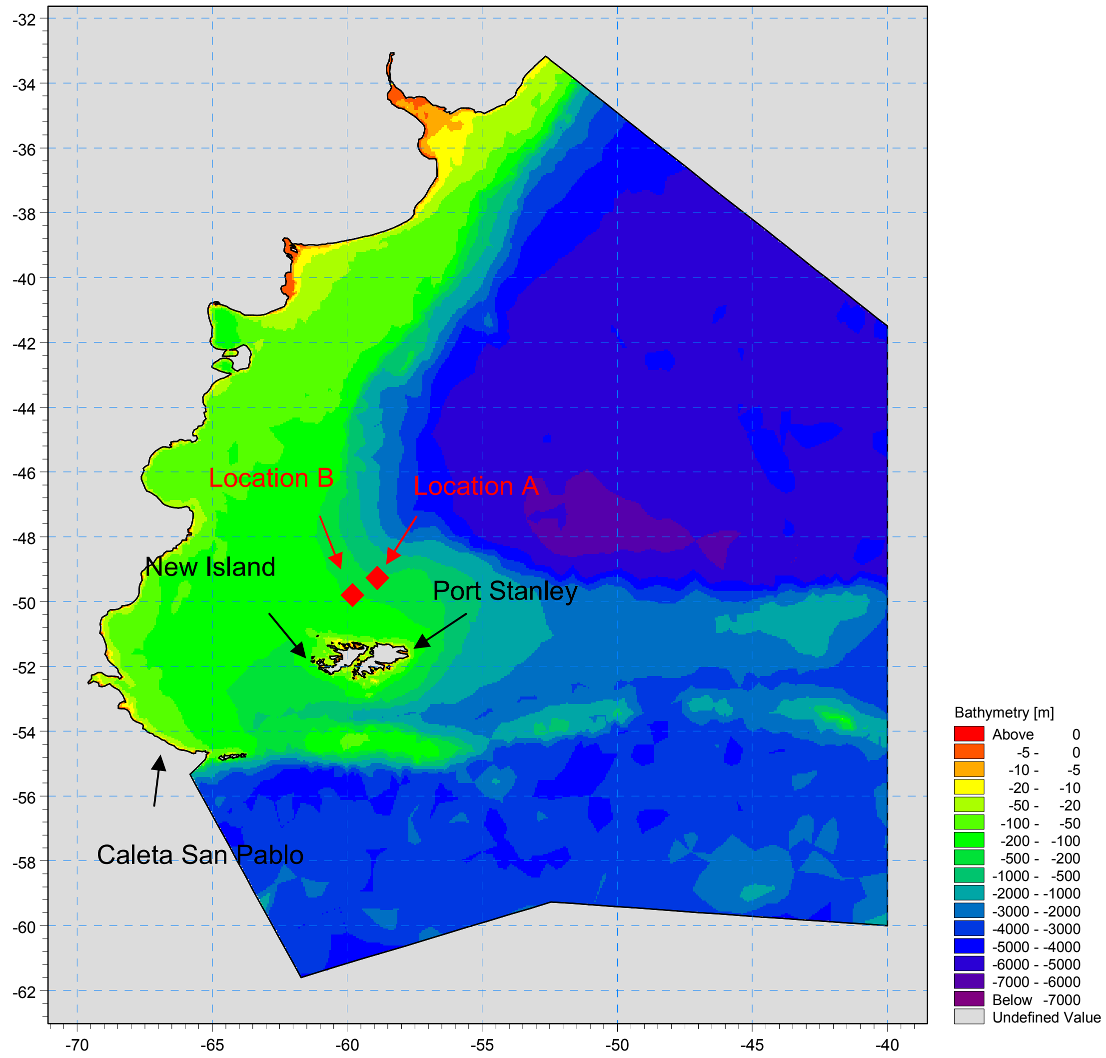

Figure 2: Extent of hydrodynamic model and selection of calibration locations

The FASO data sets were analysed and harmonics for tidal elevation, current speed and direction were derived at two locations, locations A (49.1667°S 58.9167°W) and location B (49.6667°S 59.75°W). Examples of the data analysed are given in

Figure 2 to Figure 10.

Overall the velocities in the two current meter locations are relatively small, primarily due to the fact that the FM current is found further north and the water depths are relatively large (Location A 490 metre, location B 210 metre), thus tidal velocities components are expected to be low. In turn these low velocities are rather difficult to measure over a long period and the underlying fluctuations can be of the same magnitude as the average velocities. This can be seen in Figure 3 & Figure 4. In these figures the current direction and magnitude is plotted over a three day period. It can be seen, that the velocities vary between the different depths and where the current magnitude drops below 0.1m/s the directions show considerable scatter.

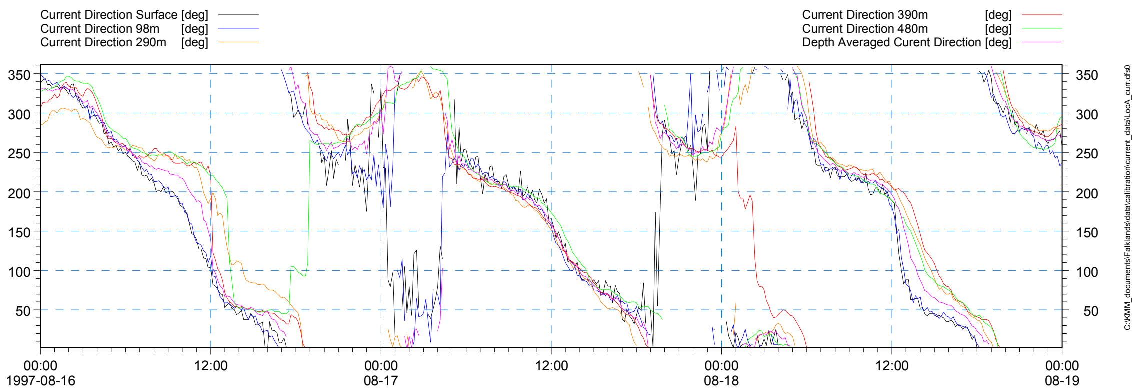

Figure 3: Current direction at different depths and depth averaged direction at Location A over three day period

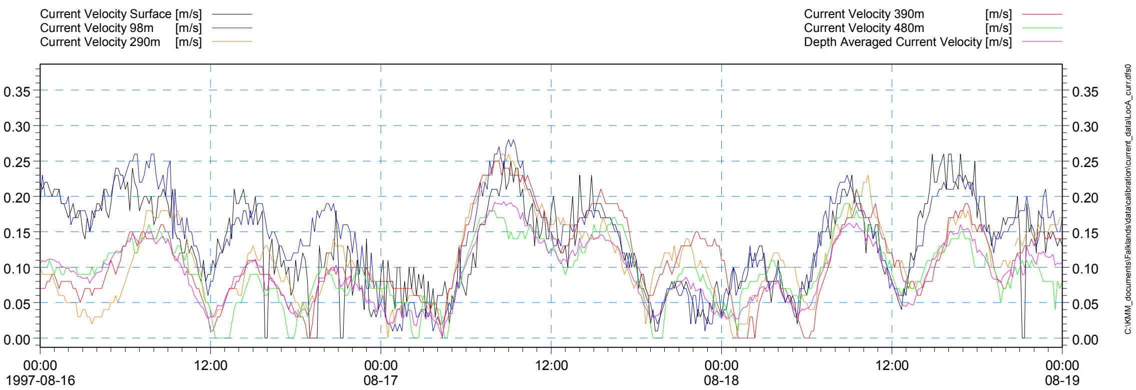

Figure 4: Current magnitude at different depths and depth averaged magnitude at Location A over three day period (as above)

Given the low current velocities in this area wind driven currents are of significant importance and can dominate the overall current field in particular in the upper layers. This is illustrated in the following three diagrams, providing current direction, current magnitude and wave condition for an eight day period. While the three measurements taken at greater depth follow a similar pattern both in terms of direction and velocity, the near surface current differs from these. Over the 48 hour period starting on the 15th December 1997 the surface current direction ranges between 270° and 340° with significant scatter, which coincides with the wave direction shown in Figure 7. Similar the current speeds near surface are significantly higher compared to the currents at greater depth.

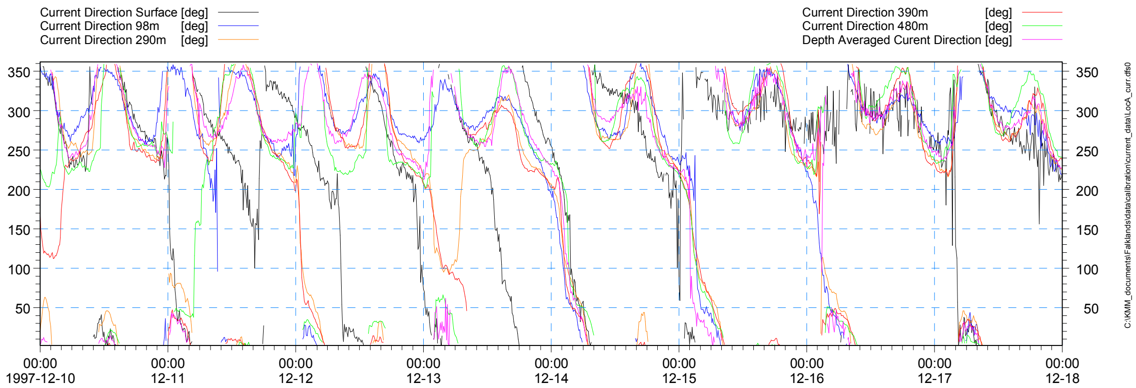

Figure 5: Current direction at different depths and depth averaged direction at Location A

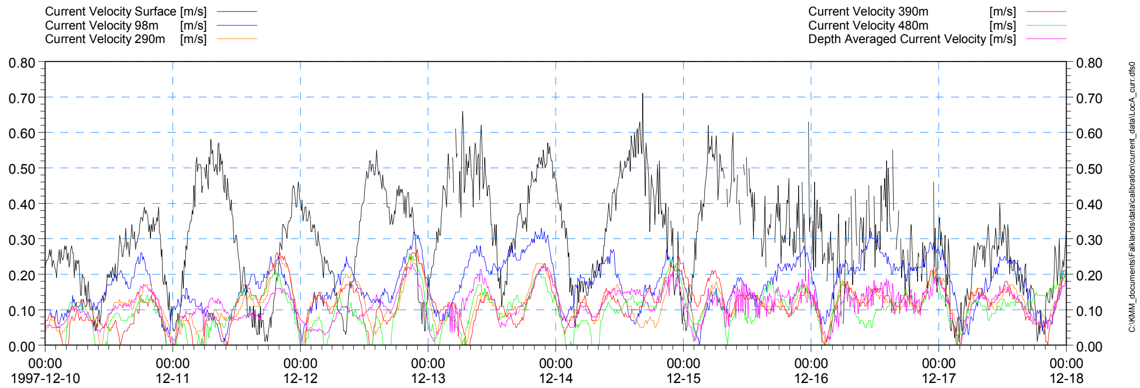

Figure 6: Current magnitude at different depths and depth averaged magnitude at Location A

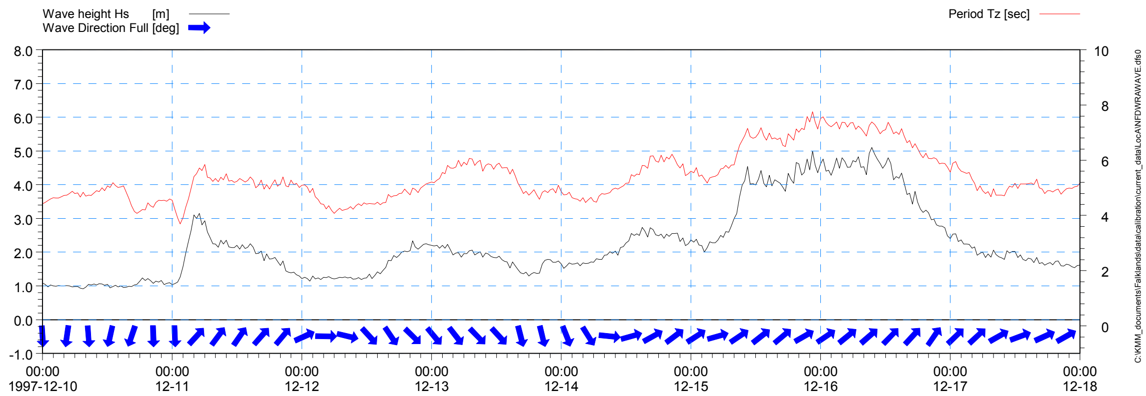

Figure 7: Wave height, period and direction over same period as Figure 5 & Figure 6

In a similar way to the above the current directions and velocities are shown in Figure 8 & Figure 9 for the observed currents and depth averaged current at location B.

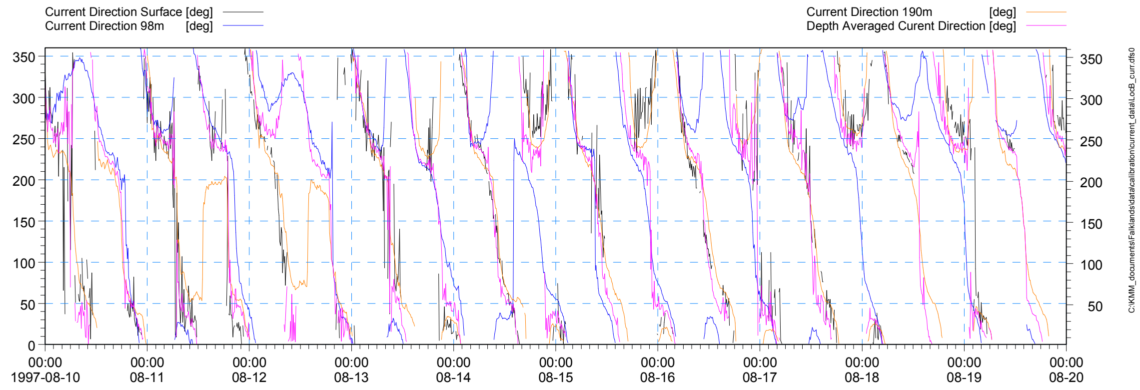

Figure 8: Current direction at different depths and depth averaged direction at Location B

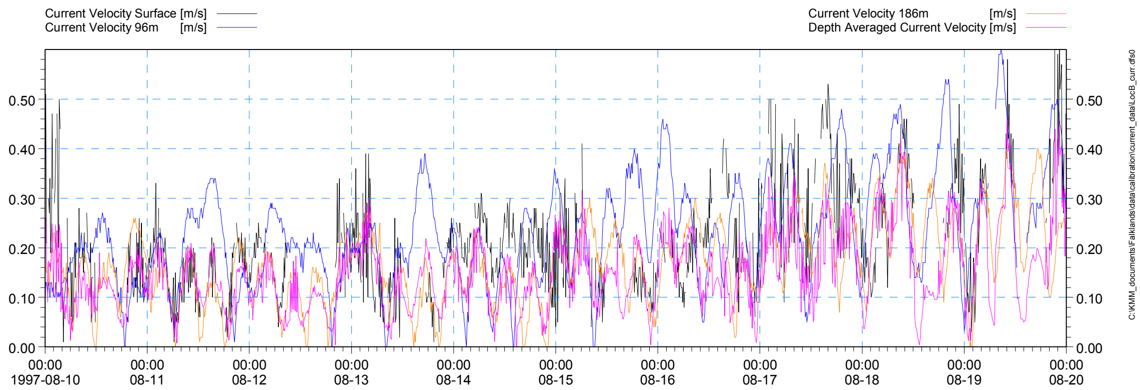

Figure 9: Current magnitude at different depths and depth averaged magnitude at Location B

The water temperature at different depths over a 7 month monitoring period is given in Figure 10. It can be seen that the temperature at depths of 100 metre and more is almost constant throughout the year with variation of 5° C near the surface between January and June that year.

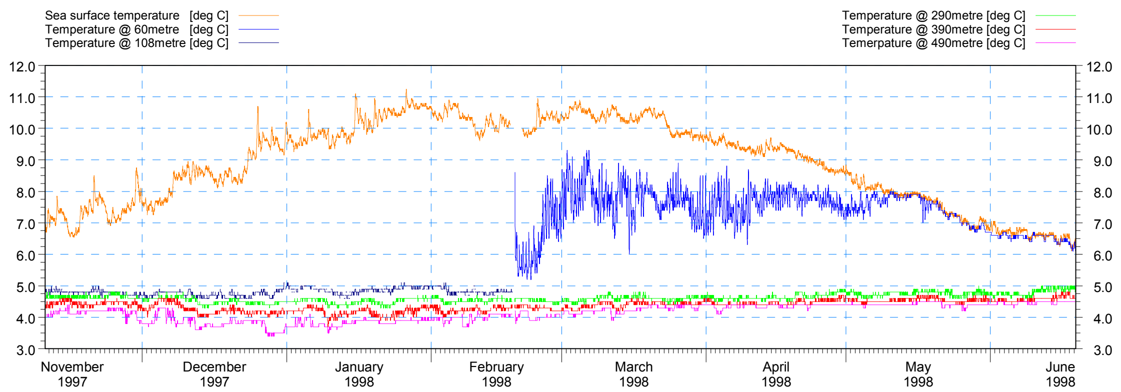

Figure 10: Water temperature at different depths direction at Location A over 7 month period

Harmonic analysis of the tidal elevations and currents based on the depth averaged current velocities and directions was undertaken and the predicted currents and elevations for the two locations were derived. These were used to calibrate the hydrodynamic model. The results are presented in the following section.

2.2 COMPARISON OF HYDRODYNAMIC MODEL AND PREDICTED TIDAL ELEVATIONS AND CURRENTS

Figure 20 to Figure 24 illustrate the correlation of the simulated water levels at the three tidal ports detailed above and at the two monitoring locations A & B. Overall the model show good correlation with the predicted astronomic water levels with the tidal range slightly underestimated at New Island. At Port Stanley the high water levels are well matched, however the low waters are 0.3 metre lower in the hydrodynamic model compared to the observed values. This is due to the model resolution in this area and the approach channel to Port Stanley being too deep in the model. However in terms of the overall model correlation this is acceptable. The two locations obtained from the FOSA field observations which are also close to the proposed oil well sites show very good correlation in terms of phasing and good correlation with respect to tidal elevation. Again the model is slightly over estimating the tidal range.

Figure 25 to Figure 28 show the model correlation between observed (predicted) tidal currents and directions and the simulated values produced by the hydrodynamic model. The tidal current directions are well represented both in terms of phase and orientation; similarly the tidal velocities correlate well for both locations.

In addition Figure 29 gives the residual flows for part of the model. A similar diagram can be found in Glorioso & Flather (1995), which shows great similarity in terms of current directions and magnitude. In the report a number of observations of the flow velocities in the FM current made by various studies are mentioned with velocities of 0.16 to 0.45 m/s around 46°S. In the model the Falkland Malvinas Current is around 0.45 m/s at 46°S, which is higher than simulated by Glorioso & Flather, but of similar magnitude compared to the observed values.

Finally Figure 30 to Figure 32 show the instantaneous current flows for the area of interest with respect to the oil spill analysis at three different time steps, high water, mid tide and low water at Port Stanley.

2.3 CONCLUSIONS ON HYDRODYNAMIC MODEL VALIDATION

The hydrodynamic model developed for the oil spill and drill cuttings simulation shows a good correlation between observed surface elevations and current magnitude and direction in the area of interest and is therefore considered fit for the purpose of .

3 OILS SPILL ANALYSIS

In order to assess the fate of the oil spill a number of numerical simulations were undertaken, utilising the output form the hydrodynamic model described above. A subsection of the RPS Patagonian shelf model was used to cover the area likely to be affected by the oil spill. The model domain is shown in Figure 11, the oils spill analysis was simulated using a 1km x 1km grid which provided sufficient detail with respect to the different islands and included detailed information on tidal velocities required for the simulation.

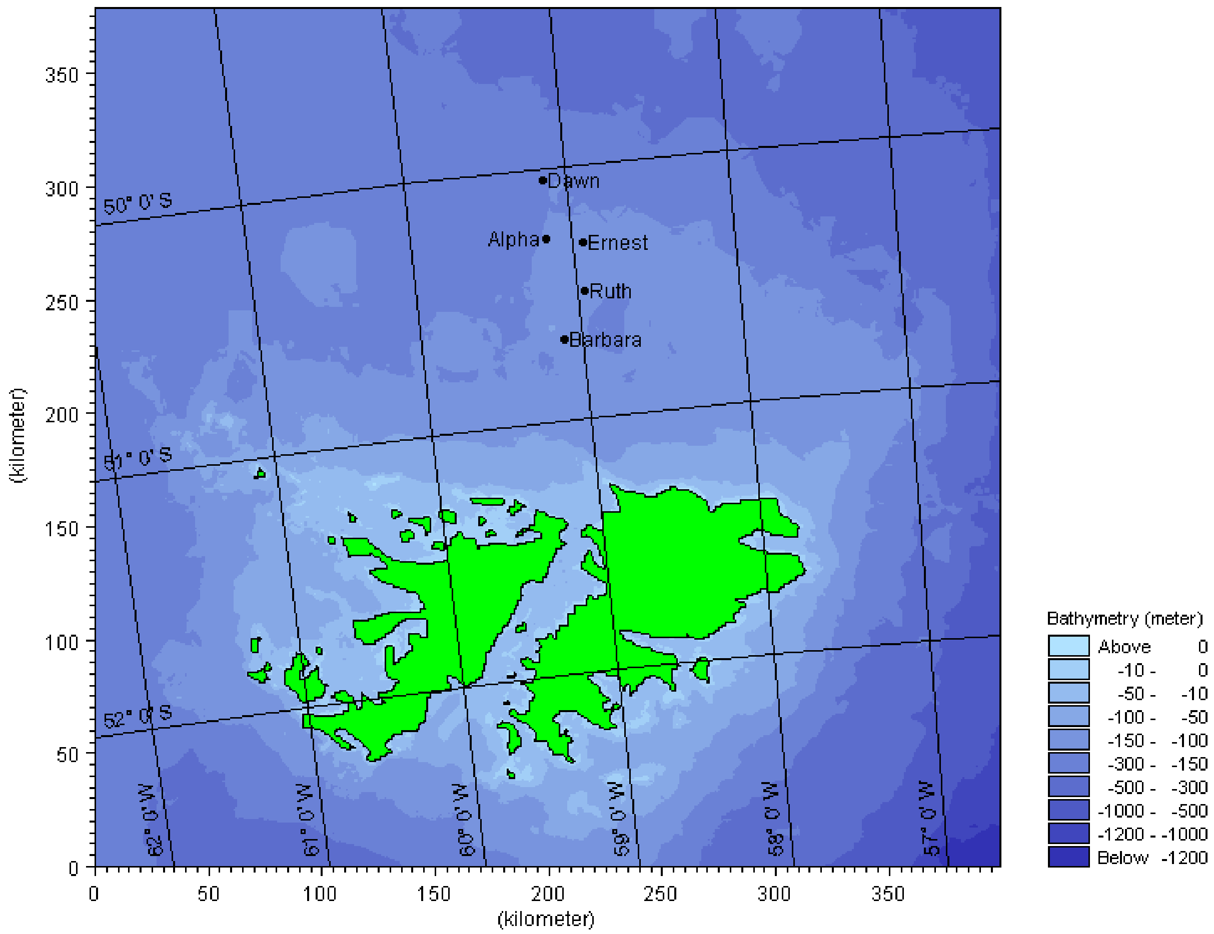

Figure 11: Bathymetry and extend of oil spill model used in this study

The simulations were undertaken at five different locations with precise locations of the release sites given in the following table.

Table 1: Oil well locations

Well Name	Latitude	Longitude
25/10-Alpha	50° 16’ 29.10” S	59° 09’ 53.09” W
25/25-Barbara	50° 40’ 51.36” S	59°06’ 49.29” W
25/5-Dawn	50° 02’ 50.16” S	59° 08’ 47.67” W
26/11-Ruth	50° 28’ 10.87” S	58° 57’ 47.74” W
-/- Ernest	50° 18’ 17.305" S	58° 56’ 37.292" W

The oils spill simulation were undertaken using one particular oil composition typical for crude oil. The details are given in the table below. It has to be pointed out, that the oil used in the simulation has a relative high percentage of heavy oils with paraffins with a Tb > 230° and naphtheons and residuals (Tb >400) nearly 50% of the total fractions. As at present the exact oil composition is not known it was considered appropriate to use heavier oil with less dissipation, as it was expected to take considerable time to beach. Thus if a lighter oil was found at the well site in the event of an oil spill significant amounts would evaporate and dissipate thus making the total amount of material beached less compared to the simulations shown. The spill scenario was based on an on-going release of 1,000 m3 per hour for 12 hours (i.e. low risk of occurrence).

Table 2: Oil characteristics used for oils spill simulations

Oil Properties	Boiling temperature (Tb °C)	Fraction (weight %)
C6-C12 (Paraffin)	69 – 230	6.3
C13-C25 (Paraffin)	230 – 405	19.3
C6-C12 (Cycloparaffin)	70 – 230	15.3
C13-C25 (Paraffin)	230 – 405	5.2
C6-C11 (Aromatic)	80 – 240	3.9
C13-C25 (Aromatic)	240 – 400	10
C9-C25 (Naphtheon)	180 – 400	10
Residual	> 400	20
Reference Temperature (°C)		15
Vicosity at Reference Temp (cs)		3.64
Oil Temperature at surface (°C)		25

For each site two different simulation were undertaken: In the first set of modelling scenarios a constant wind speed and direction was used at 15° intervals ranging from NNE to 315° with a 10m wind velocity of 10m/s. This gave an indication of the interference of wind and currents and helped to identify likely scenarios that would lead to beaching of oil on the Falkland Islands. A sample output is given for the most southerly site (Barbara). The full set of diagrams is given in the appendix B. This provide time of exposure to oil during the simulation. This shows both the area covered as well as the duration the environment was exposed to oil at a given location.

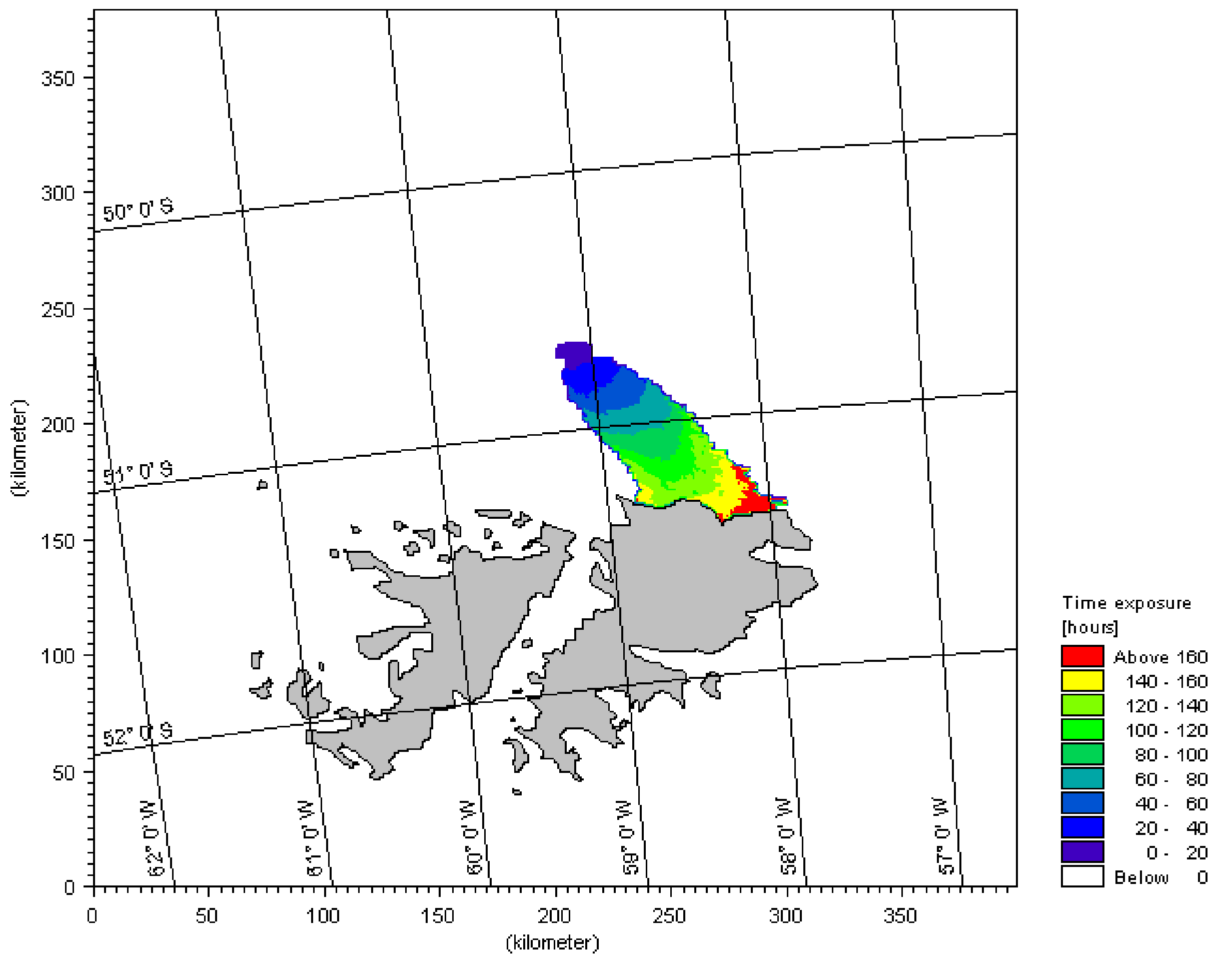

Figure 12: Exposure to oil following spill from site Barbara with wind 10m/s from 330° after 8 days

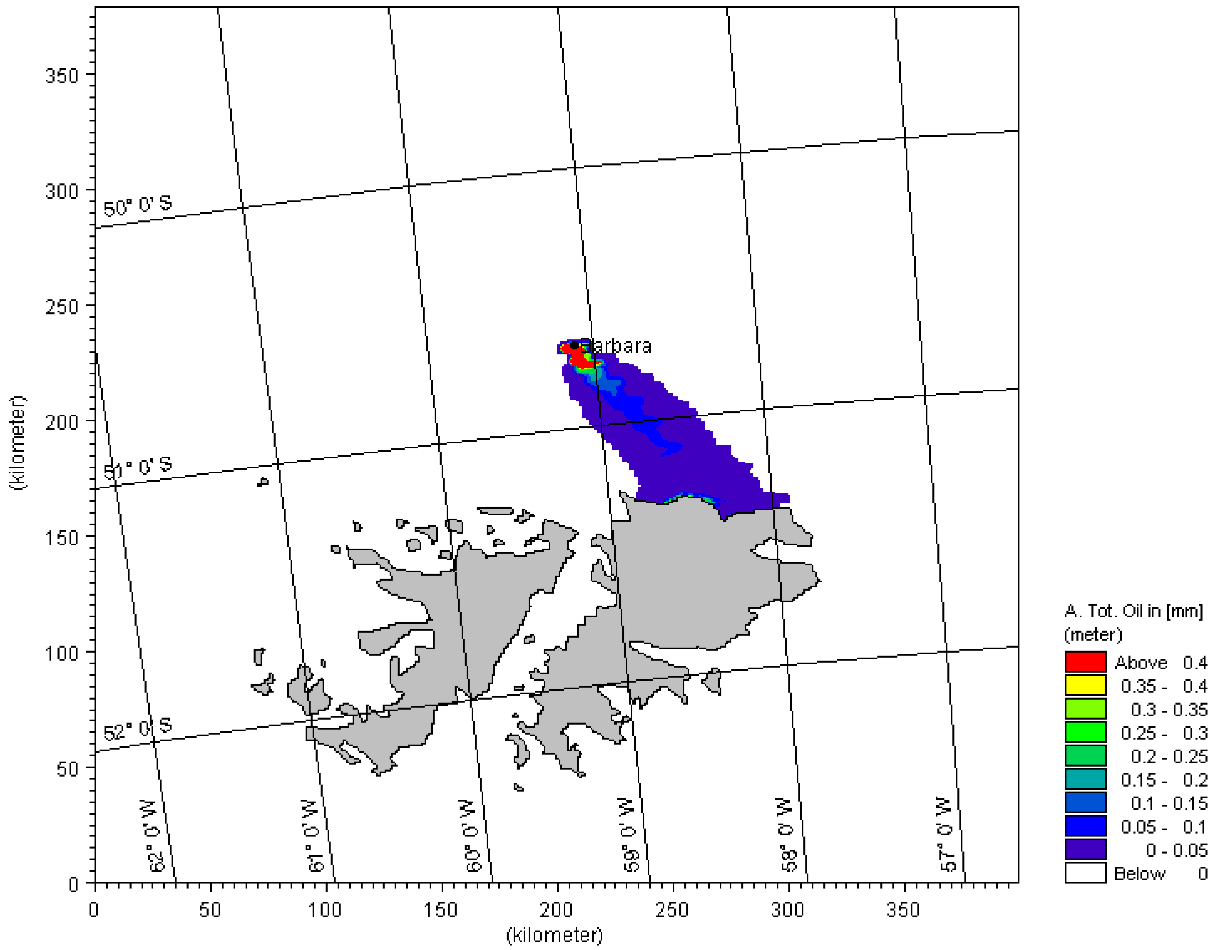

Figure 13: Maximum oil slick thickness during 8 day simulation following spill from site Barbara with wind 10m/s from 330°

The following table provides and overview of the scenarios which would lead to beaching and an estimate of the total amount found ashore after 6 days of cessation of discharge.

Table 3: Total oil beached after 6 days (in m^3)

Wind direction	Alpha	Barbara	Dawn	Ruth	Ernest
15°	5.9	96.6	-	65.3	<1.0
N	-	91.1	-	9.8	-
345°	-	64.1	-	3.4	-
330°	-	3.1	-	--	-
315°	-	-	-	-	-

The above simulation can only give an indication of possible oil spill location. In reality at this site the wind will not persist from one particular direction for the oil to beach similar to the simulations discussed above. Thus wind data for the southern Atlantic Ocean was analysed to give an estimate of the frequency of occurrence for events similar to those above, which subsequently would lead to a beaching scenario. Two datasets were analysed, climatological data from the UK Metoffice and time series data from NOAA. It was found that for the same period the climatological records and the NOAA data set provided different figures with more northerly wind in the UK Metoffice data set. A similar discrepancy was discussed in Upton & Shaw (2002), found between observed records and UK Metoffice data. The data from NOAA was compared against the wind rose provided in Upton & Shaw (2002) for the same period and a reasonable consistency was found, thus the NOAA data set was favoured. The following figure shows the distribution of wind directions and strengths for the 11.3 year period. It is evident, that the prevailing winds occurs from a westerly direction with strengths between 6 and 14 metre/seconds contributing nearly 50% of the time. The mean wind speed is 9.13m/s. Only a very small percentage of the time the wind occurs from NE to S direction.

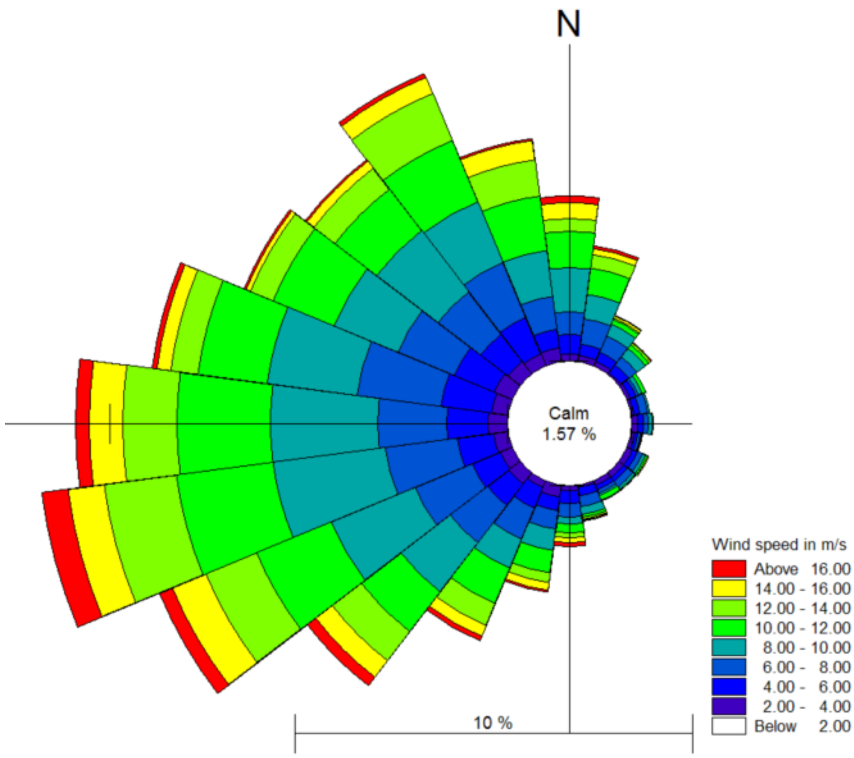

Figure 14: Wind rose for offshore location near oils wells from NOAA's global wave model (in 15° sectors)

The NOAA data set covering 11.3 years continuously with three hourly intervals provided sufficient data to undertake a spell analysis and to identify periods of wind exceeding a particular strength within a sector of >315° and <30°. The output form this analysis is given in the following table.

Table 4: Occurrence of spells with wind speeds above a given threshold within 315° to 30° tN

	wind direction >315° & <30° to North				
	>6 m/s	>9 m/s	>12 m/s	>15 m/s	>18 m/s
>6 hours	103.4	77.7	33.9	6.6	0.6
>12 hours	62.6	39.9	10.9	1.8	0.0
>18 hours	38.8	21.8	5.3	0.7	0.0
>24 hours	24.3	12.4	1.5	0.0	0.0
>30 hours	15.3	6.6	0.8	0.0	0.0
>36 hours	10.1	3.5	0.4	0.0	0.0
>42 hours	6.2	2.2	0.3	0.0	0.0
>48 hours	3.7	1.1	0.3	0.0	0.0
>54 hours	2.4	0.8	0.2	0.0	0.0
>60 hours	1.9	0.6	0.1	0.0	0.0
>66 hours	1.1	0.3	0.0	0.0	0.0
>72 hours	0.9	0.2	0.0	0.0	0.0
>78 hours	0.5	0.1	0.0	0.0	0.0
>84 hours	0.4	0.0	0.0	0.0	0.0
>90 hours	0.2	0.0	0.0	0.0	0.0

The data given in the above table provide the number of occurrences of a spell above a certain wind speed and duration with in the sector of 315 to 30 degrees to North per year.

From the wind spell data the event was selected, which would have most likely lead to beaching of oil. A number of events were identified, which had wind strengths of over 9m/s, there was however only one vent with a duration sufficiently long to casue beaching which was starting the 17th of June 2004. The wind speeds and direction over a 10 day period are shown in the diagram below.

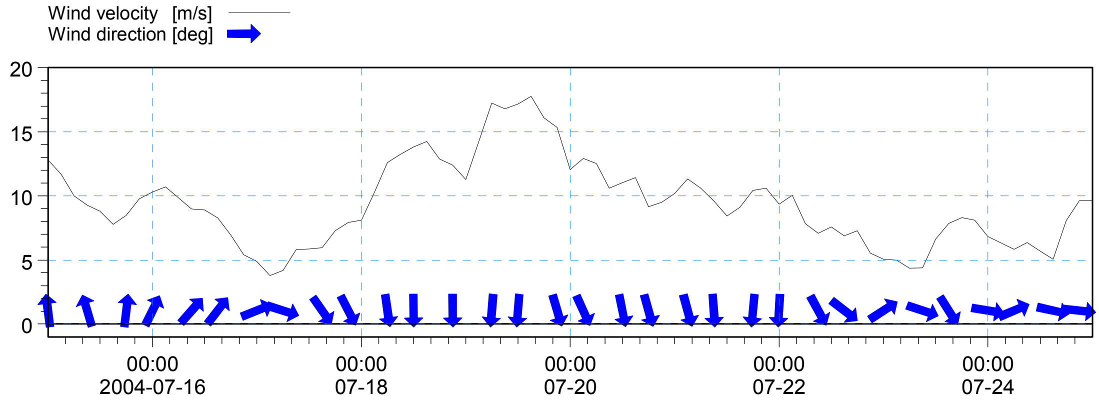

Figure 15: Historic wind field with longest spell and persistent high wind speeds within sector critical for beaching of oil

Using this historic data set an oils pill was simulated coinciding the release of oil with the increase in wind speed to above 10 m/s. This simulation was carried out for two sites Barbara (the most southerly one) and Ruth (the site adjacent to it). Again the exposure time plots are presented below for both sites. It can be seen that despite the higher wind speed for a number of hours beaching only occurs from oil well Barbara. The total amounts are however estimated to be less than 1 m^3, as the wind turns shortly afterwards, thus making the oil drift away from the shoreline. The simulation undertaken for site Ruth does not show any beached material.

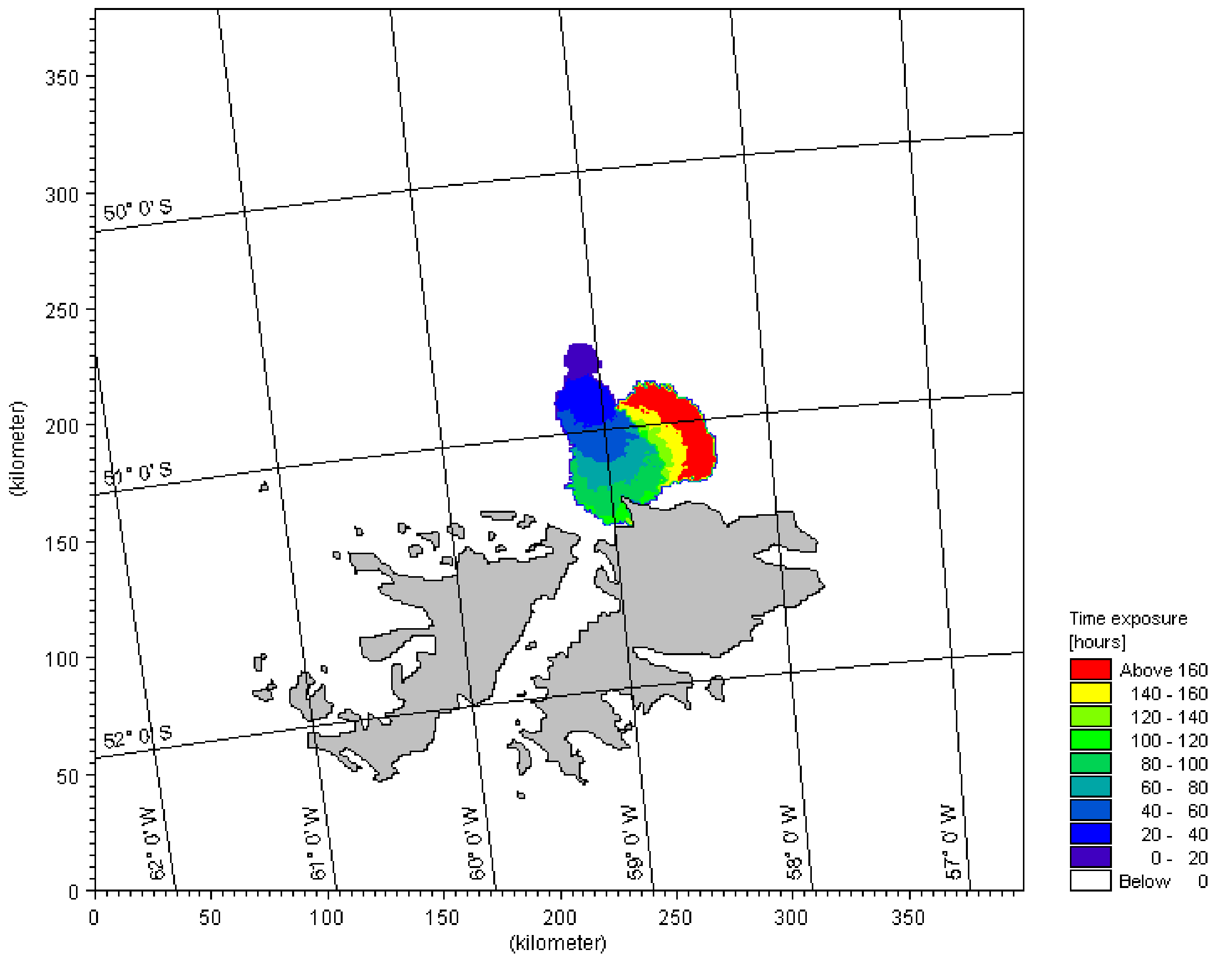

Figure 16: Exposure to oil following spill from site Barbara with historic wind field

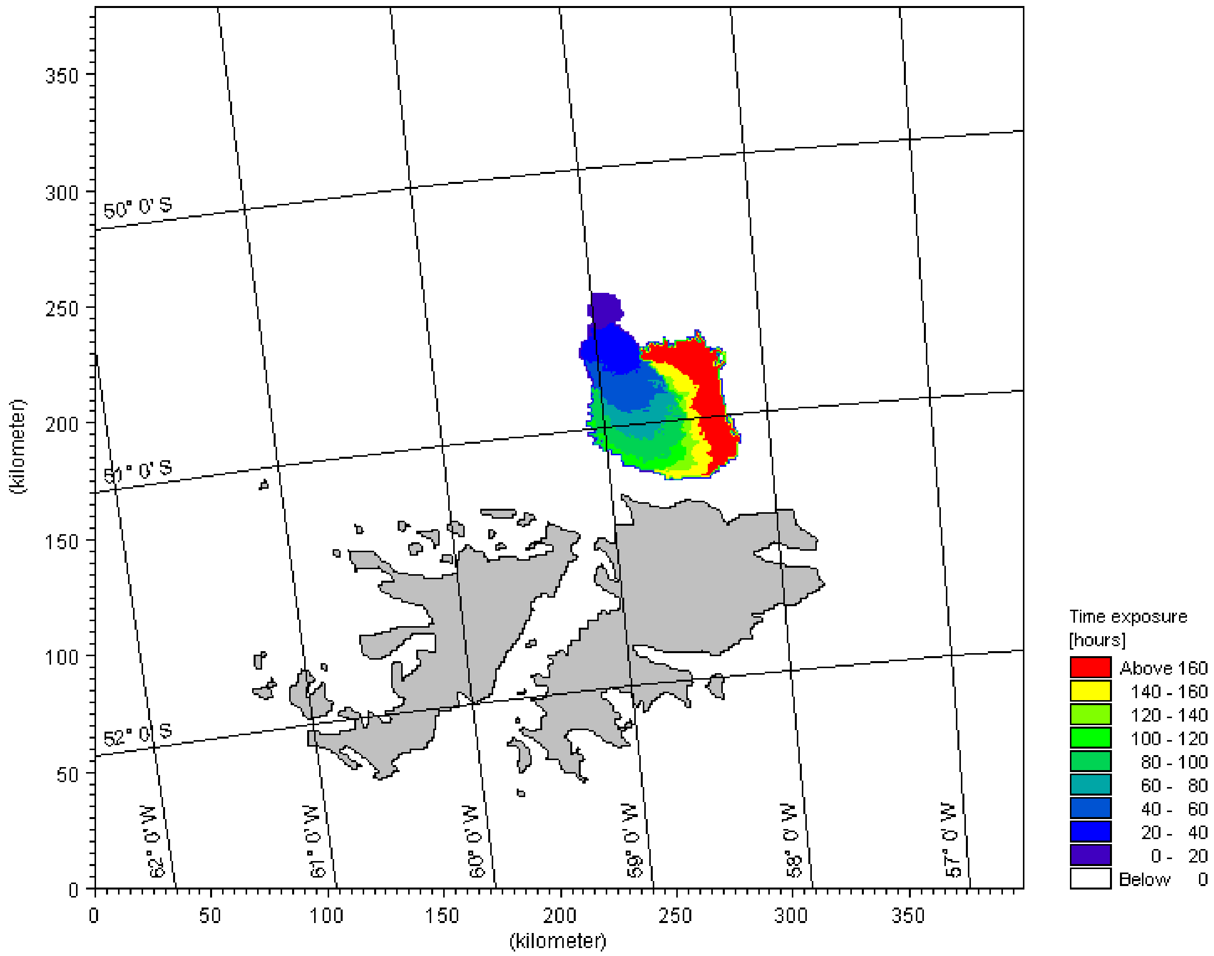

Figure 17: Exposure to oil following spill from site Ruth with historic wind field

Finally the maximum oils slick thickness is given in the last diagram. Based on the relatively short wind data set it is assumed that there is a probability of 10% p.a. for the relevant wind condition to occur to casue beaching of oil spilled at the start of the event from site Barbara. For site Ruth this is reduced to 4% p.a. and for sites Ernest, Dawn and Alpha this is further reduced to less than 2% p.a.

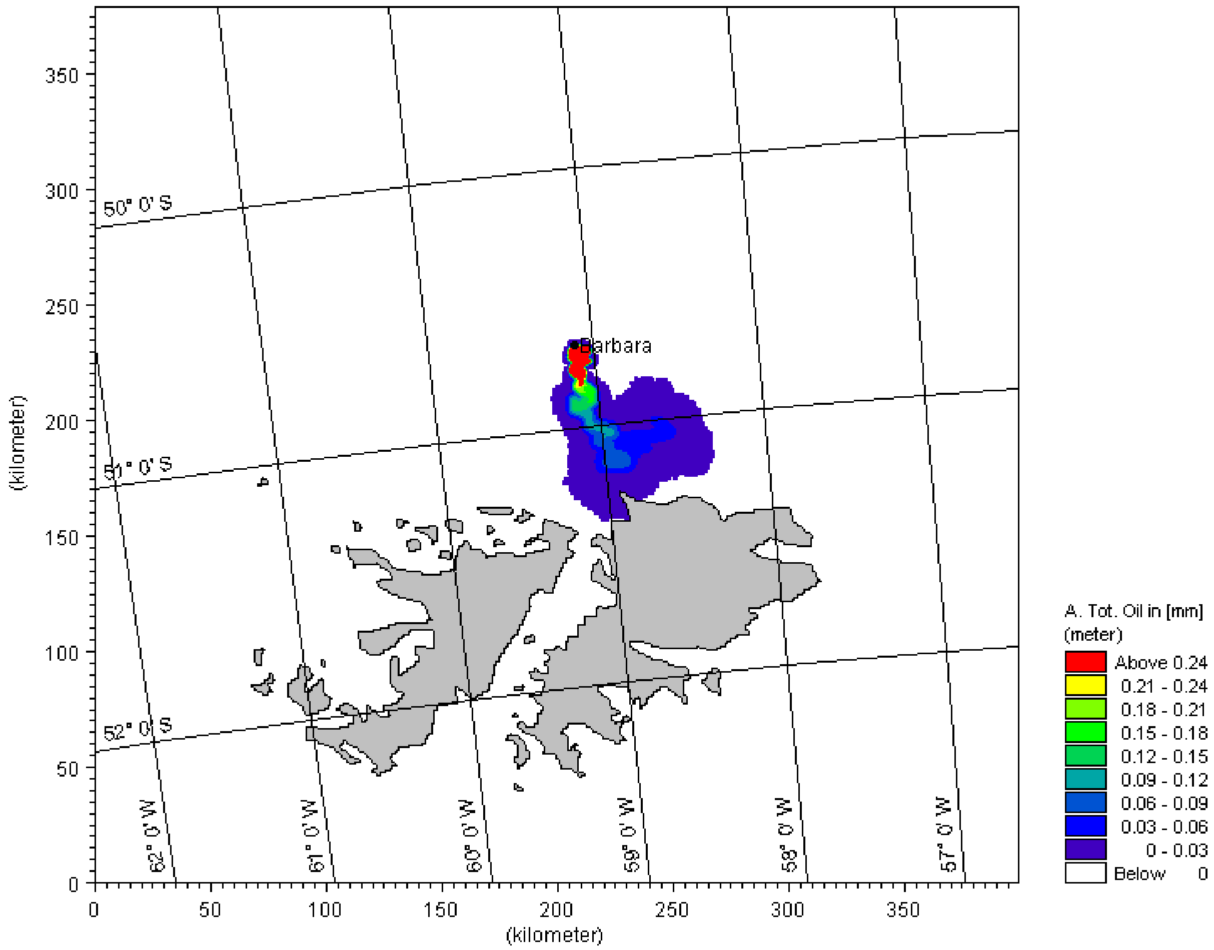

Figure 18: Maximum oil slick thickness during 8 day simulation following spill from site Barbara for historic wind field

4 DRILL PLUME MODELLING

The fate of the drill cuttings was assessed in a number of simulations for each of the sites. The site locations are listed in Table 2. The drilling operation will initially disperse the drill cutting on the seabed only. Following the establishment of the initial well section the drill cuttings are lifted to the surface inside the drill and treated on the platform. Any oil contained is extracted and fines are mixed with seawater and used to act as lubricant and coolant for the drill operation. The courser material is discharged at approximately 10m below the surface. The drill depth will be between 3000 and 4500m and the drilling operation will be virtually continuous except for the occasional breaks to add extensions to the drill string.

The rock is ground by the drill cutter so the particulate size grading of the drill residue will be as shown below:

Table 5: Drill residue from drilling operations

particle size (microns)	< 50	50 to 100	100 to 1000	1000 to 2000
% particles	5	15	50	30

4.1 MODELLING THE FATE OF THE DRILL RESIDUE

The fate of the drill residue released into the waters around the drill rig was modelled by placing a sediment source in the model at 10m below the water surface of the location of the proposed wells sites.

The rate of release of sediment was assumed at 1.5kg / second, the fate of the drill material was simulated over a total period of 21 days. The release of sediment was assumed to be continuous for the 21 day period giving a total mass of 2722 tonnes released into the water column.

The MIKE 321 PA model simulated the disposal process by releasing particles into the water column and tracking each particle through the simulation period. For the dispersal of the drill spoil from the foundation hole, more than 150 000 particles were released over the 21 day period and tracked over the same simulation period.

A variable grading of the sediment has been used in the model in order to cater for grading of the drilling residue discharged to the water column. In the model simulations, a particle size and thus a settling velocity was chosen at random from the specified grading distribution and assigned to each particle when it was released. The sediment grading distribution of the source material used in the model simulations was as follows:

Table 6: Drill residue disposed at drill rig

Dn50 Size (mm)	Percentage Occurrence
1.75	5
1	15
0.5	20
0.25	25
0.075	25
0.05	5

The MIKE321 PA model includes re-suspension of deposited material when the shear stress at the seabed exceeds a critical shear stress. The amount of material re-suspended depends upon the grain size, the degree of consolidation and the nature of the particles. A critical shear stress parameter of 0.045 was used in this study as this is the value of the Shields parameter.

4.2 RESULTS OF THE DISPERSION MODELLING SIMULATIONS

The results of the model simulations were saved every 12 hours over the 21 day simulation period. The information saved included the net deposition on the seabed and the suspended sediment concentration in the water column. The results of the simulations are shown in terms of the deposition footprint on the seabed.

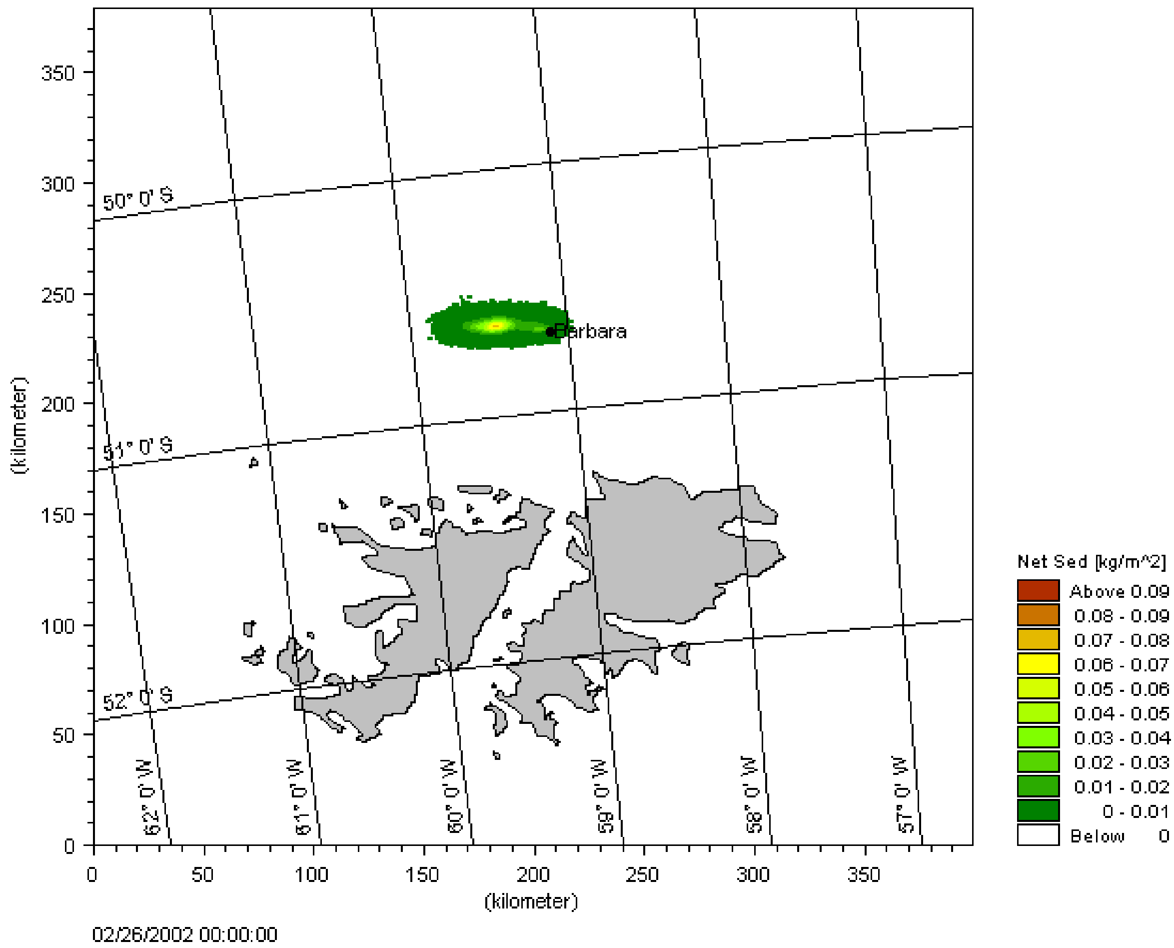

Figure 19: Drill cuttings sedimentation pattern after 21 days

It was found that the drill residue deposition varies between the different well locations quite significantly. The well site Barbara has the largest footprint with respect to the drill residue, as it experiences the largest velocities. Due to the large water depth (in excess of 150metre) it takes a significant amount of time for the plume to settle on the seabed, which means, that the material is extremely scattered of a large area. This means that the total amount per m^2 is very small and it needs to be pointed out, that a net sedimentation of $0.05kg/m^2$ is less than one grain size in thickness. This is in the same order of magnitude of the naturally occurring sedimentation due to the prevailing organic and inorganic suspended material in the sea water. Thus while the plumes appear to cover a large area the actual amount on the ground is in reality below the measurable value.

5 SUMMARY AND CONCLUSIONS

A hydrodynamic model was developed to simulate the prevailing tidal and current conditions over the Patagonian shelf in the South Western Atlantic Ocean. The model results were found to validate well against observed data from a number of locations both in terms of tidal rnages and current velocities. In particular the current direction and the presence and magnitude of the Falkland Current could be well represented. It was concluded that the model was adequate for the assessment of oils spill and drill plumes from a number of proposed oil well sites near the Falkland Islands.

Following the validation of the numerical model the output was used to asses a number of oils spill scenarios from five different well sites to the north of the Falkland Islands. The simulation showed that there was a relatively low probability of beaching from any of the sites. Based on the relatively short wind data set it is assumed that there is a probability of 10% p.a. for the relevant wind condition to occur to cause beaching of oil spilled at the start of the event from site Barbara. For site Ruth this is reduced to 4% p.a. and for sites Ernest, Dawn and Alpha this is further reduced to less than 2% p.a.

Finally the plume of the drill cuttings discharged from the rig during the drilling operation was simulated It was found that the drill residue deposition varies between the different well locations quite significantly. The well site Barbara has the largest footprint with respect to the drill residue, as it experiences the largest velocities. Due to the large water depth (in excess of 150metre) it takes a significant amount of time for the plume to settle on the seabed, which means, that the material is extremely scattered of a large area. This means that the total amount per m^2 is very small with less than one grain size in thickness in places. This is in the same order of magnitude of the naturally occurring sedimentation due to the prevailing organic and inorganic suspended material in the sea water. Thus while the plumes appear to cover a large area the actual amount on the ground is in reality below the measurable value.

6 REFERENCES

Andersen, O.B. (1995). Global ocean tides from ERS1 and TOPEX / POSEIDON altimetry. Geophys. Reserach, 100(C12), 25,249-225,259.

Andersen, O.B., Woodworth P.L. and Flather R.A. (1995). Intercomparison of recent ocean tidal models. Geophys. Research, Vol. 100 (C12), 25,261-25,282.

Glosrioso, P.D., Flather R.A. 1995: A barotropic Model of the currents off SE South America; Journal of Geophysical Research Vol. 100 (C7) Pages 13,427-13,440

Upton, J., Shaw C.J. 2002: An overview of the oceanography and meteorology of the Falkland Islands; Aquatic Conservation: Marine & Freshwater Ecosystems Vol. 12 Pages 15-25

APPENDIX A: HYDRODYNAMIC MODEL CALIBRATION

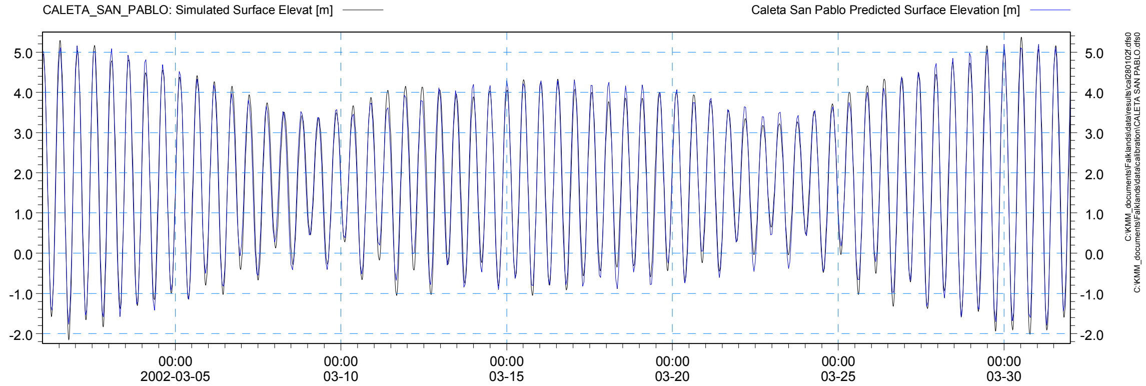

Figure 20: Comparison between simulated and predicted surface elevation at Caleta San Pablo

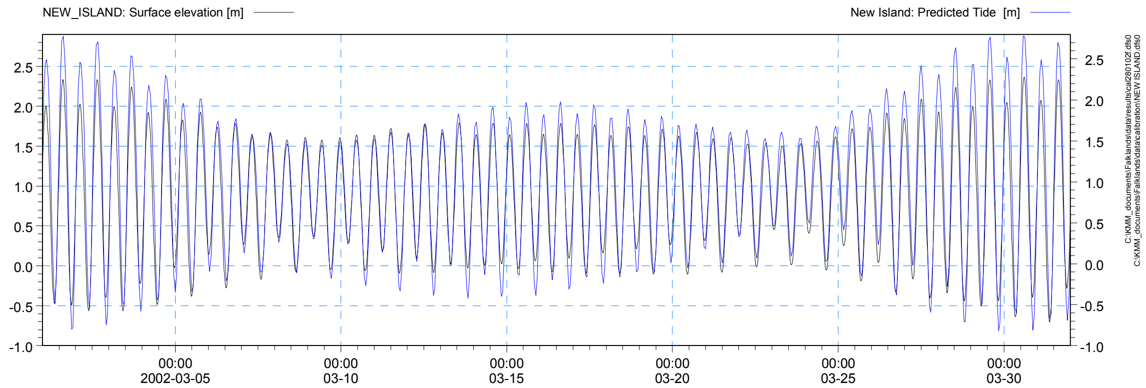

Figure 21: Comparison between simulated and predicted surface elevation at New Island

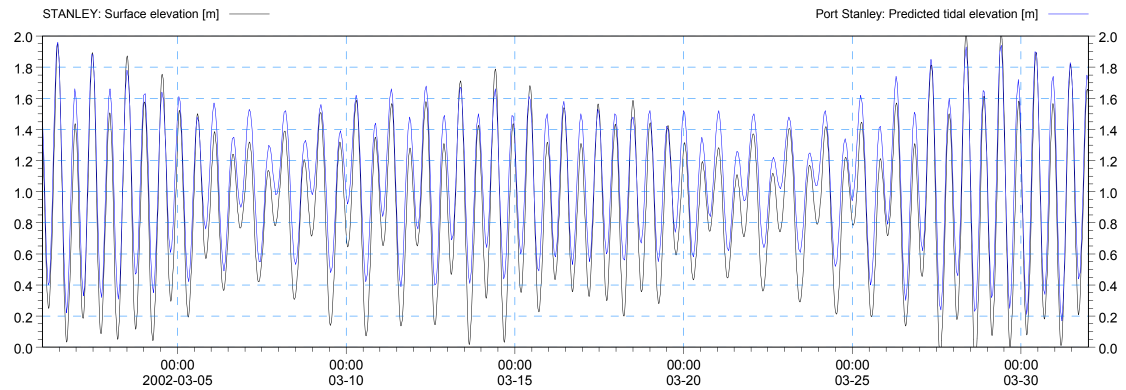

Figure 22: Comparison between simulated and predicted surface elevation at Port Stanley

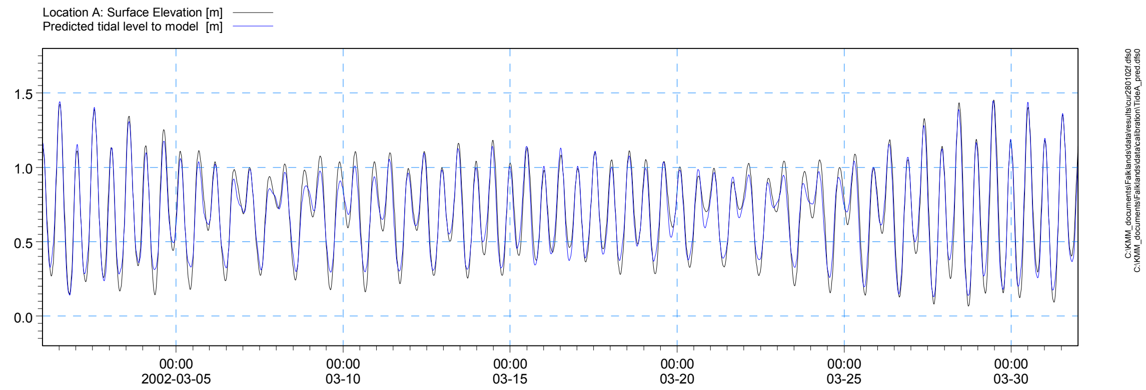

Figure 23: Comparison between simulated and predicted surface elevation at Location A

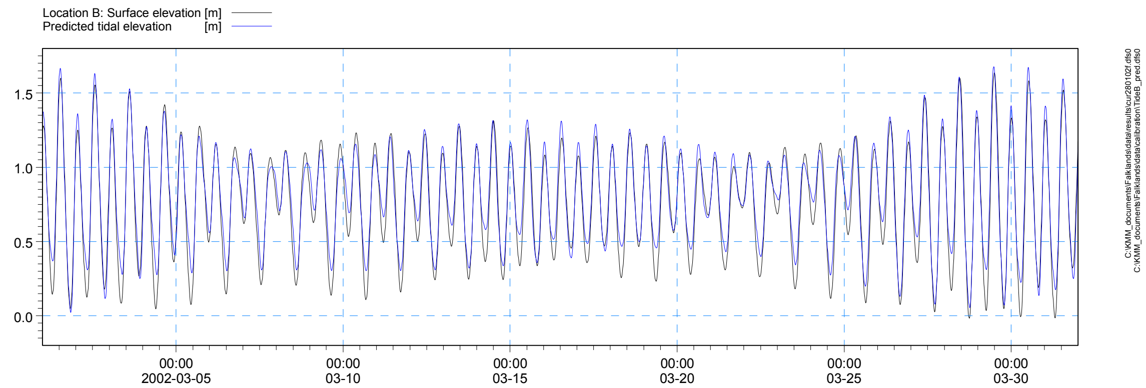

Figure 24: Comparison between simulated and predicted surface elevation at LocationB

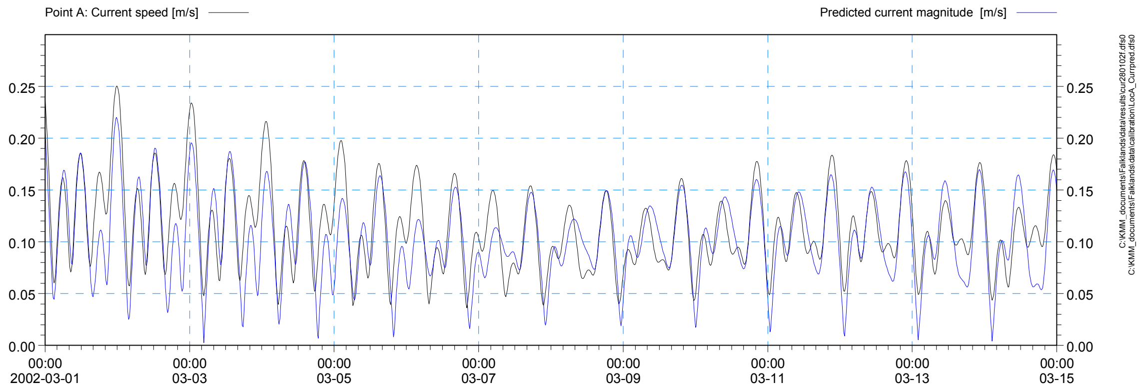

Figure 25: Comparison between simulated and predicted current magnitude at Location A

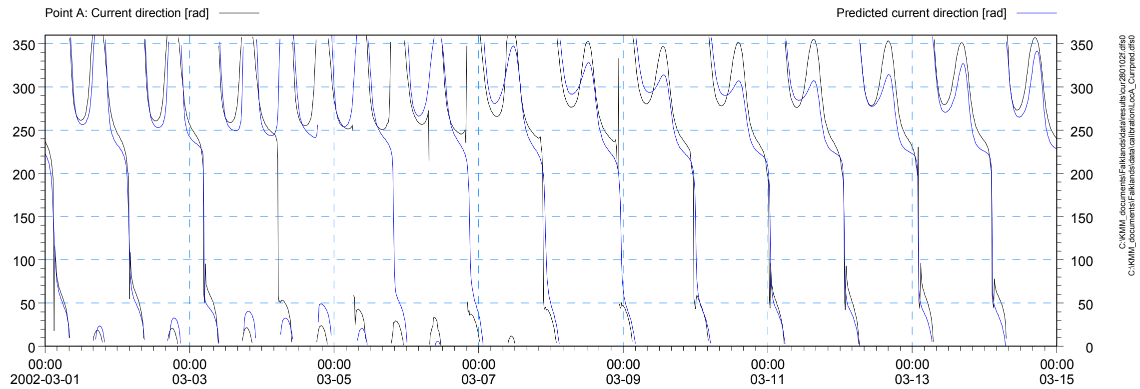

Figure 26: Comparison between simulated and predicted current direction at Location A

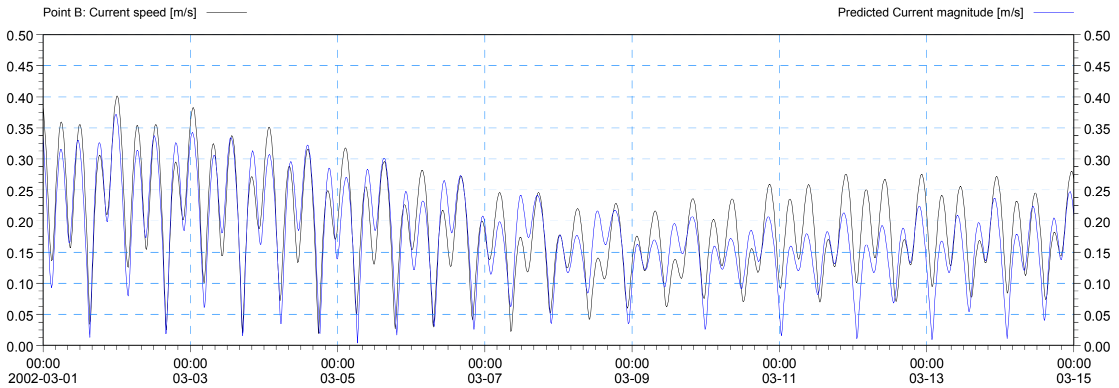

Figure 27: Comparison between simulated and predicted current magnitude at Location B

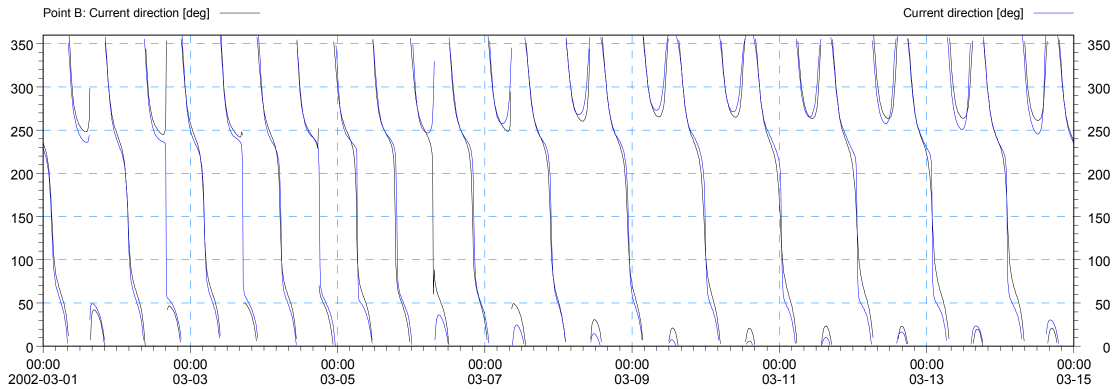

Figure 28: Comparison between simulated and predicted current direction at Location B

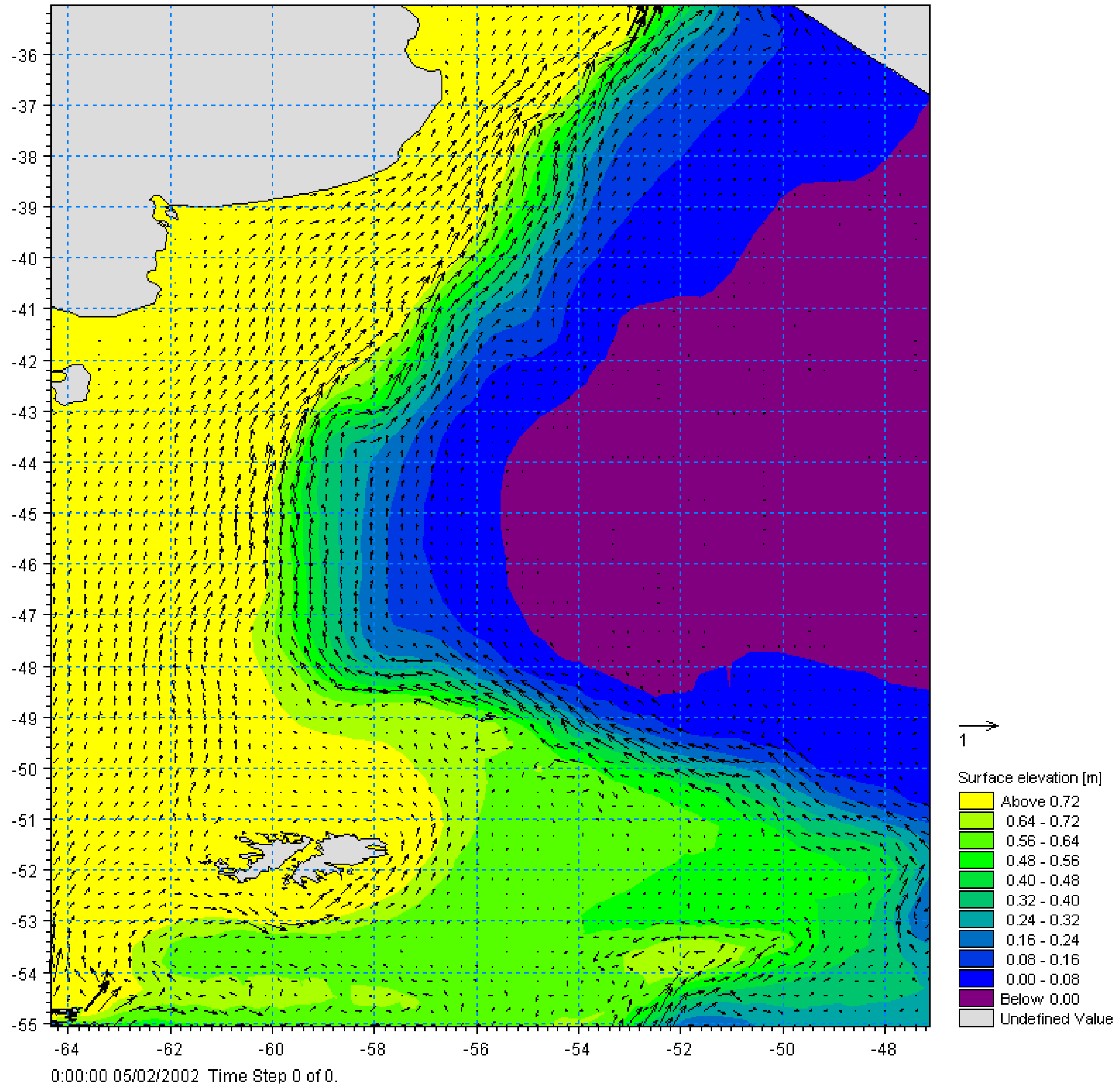

Figure 29: Residual current flow and mean sea level for one month (05 Feb to 05 Mar 2002) without atmospheric influence

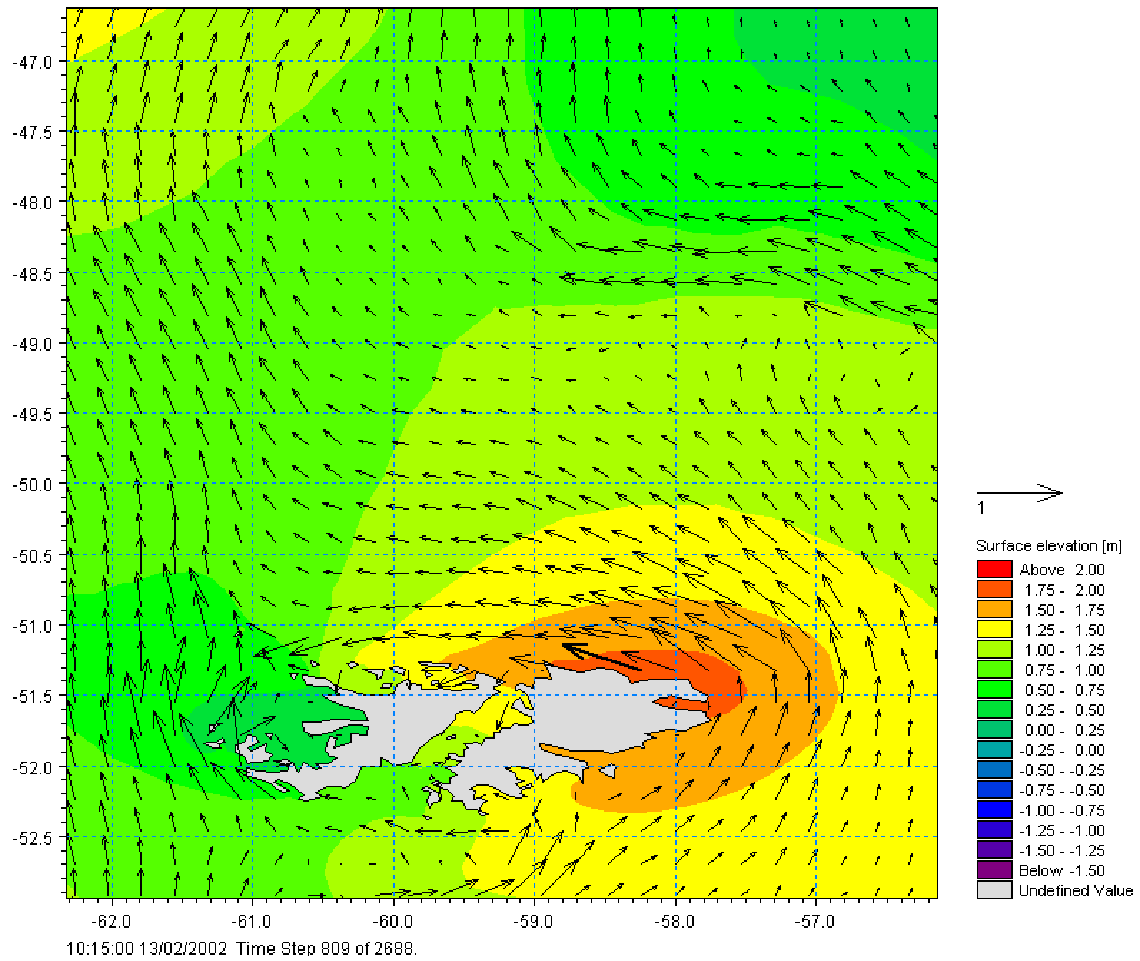

Figure 30: Instantaneous surface elevation and currents at High Water (MHWS) at Port Stanley

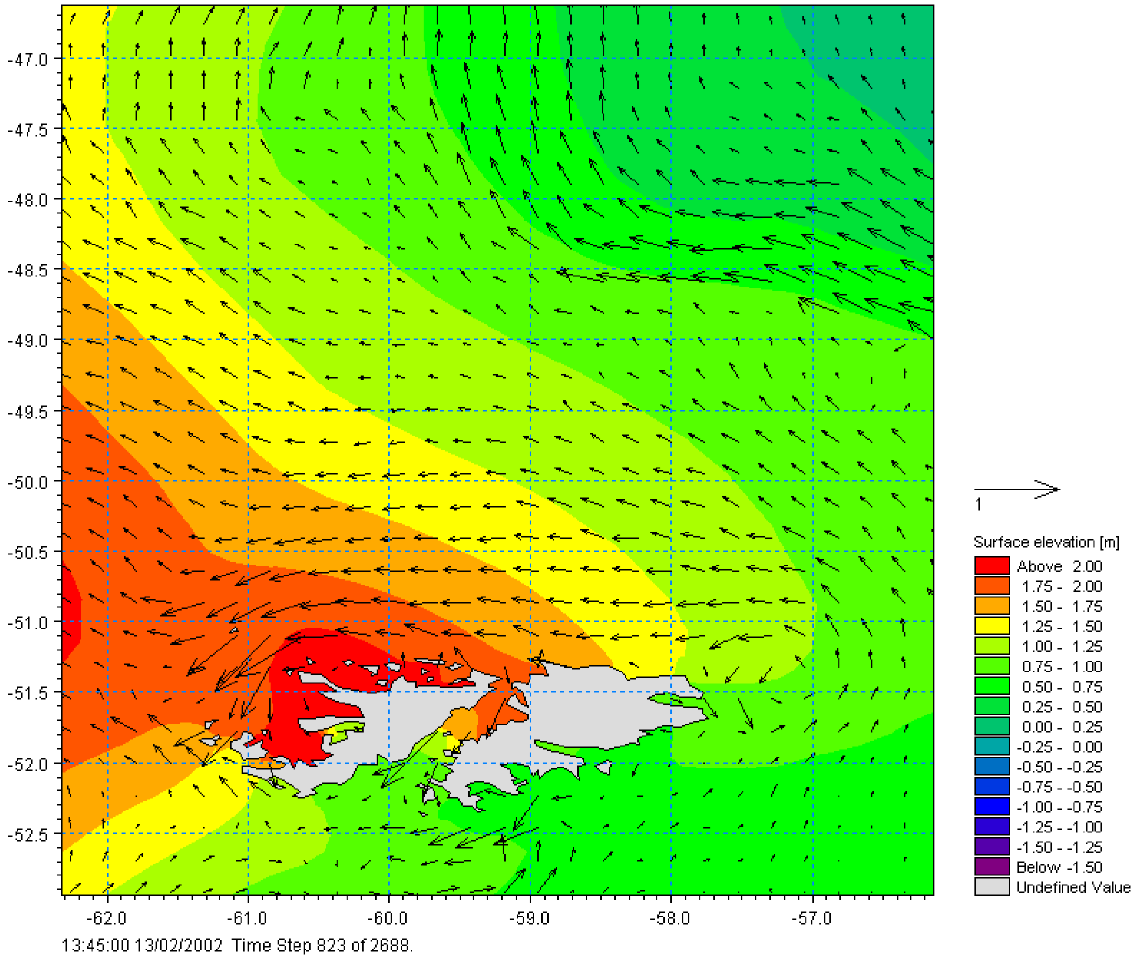

Figure 31: Instantaneous surface elevation and currents at Mid Tide (MHWS) at Port Stanley

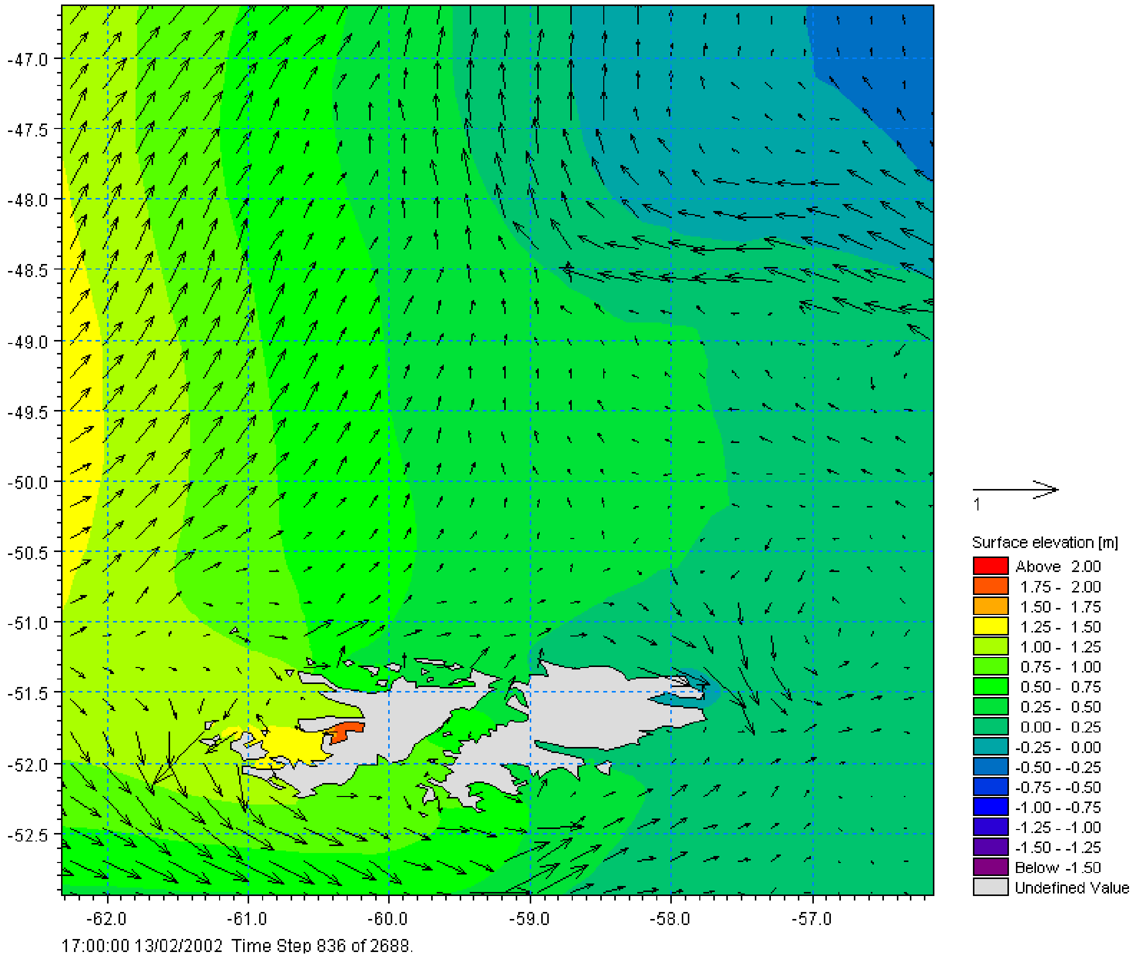

Figure 32: Instantaneous surface elevation and currents at Low Water (MHWS) at Port Stanley

APPENDIX B: OIL SPILL ANALYSIS

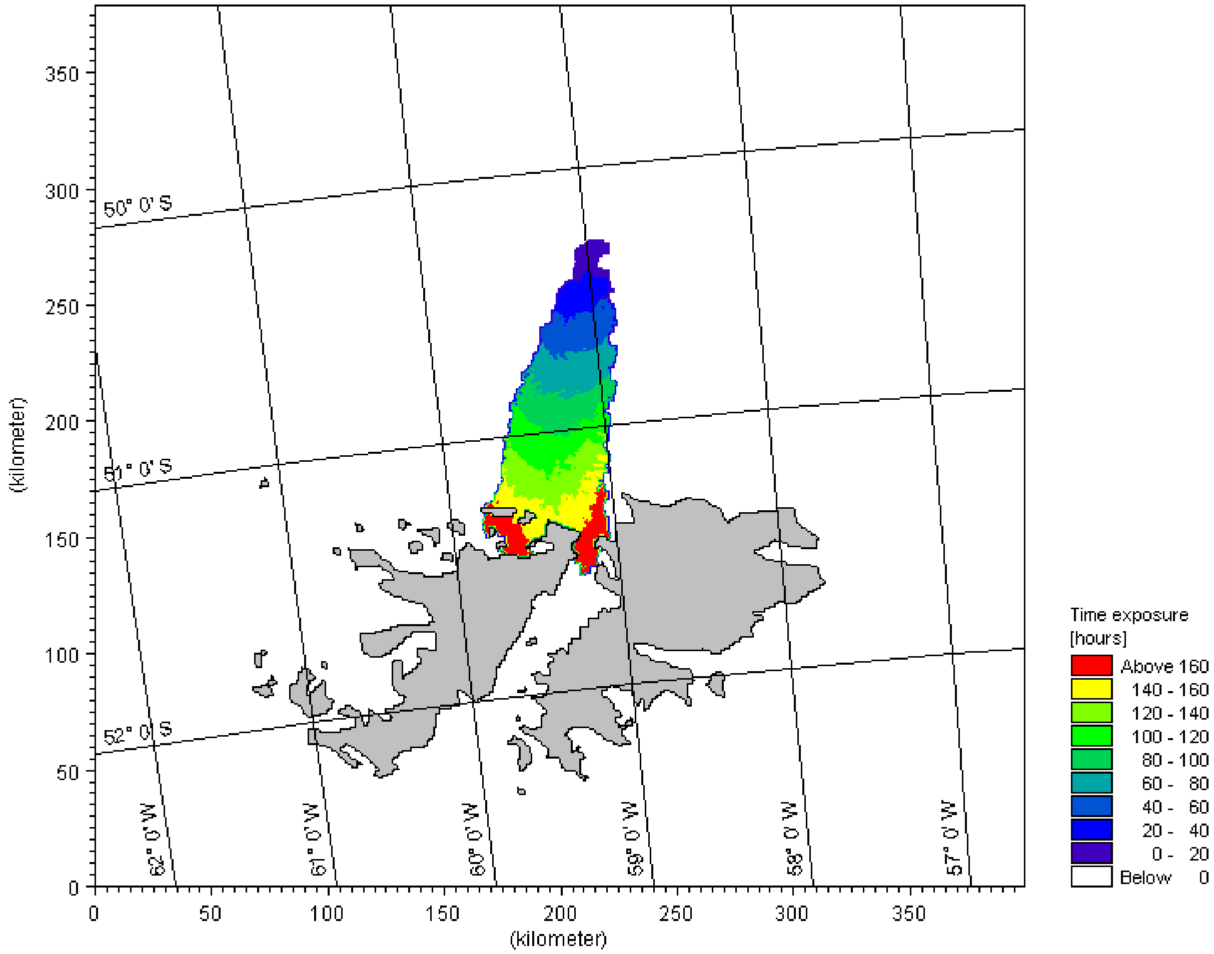

Figure 33: Exposure to oil following spill from site Ernest with wind 10m/s from 15° after 8 days

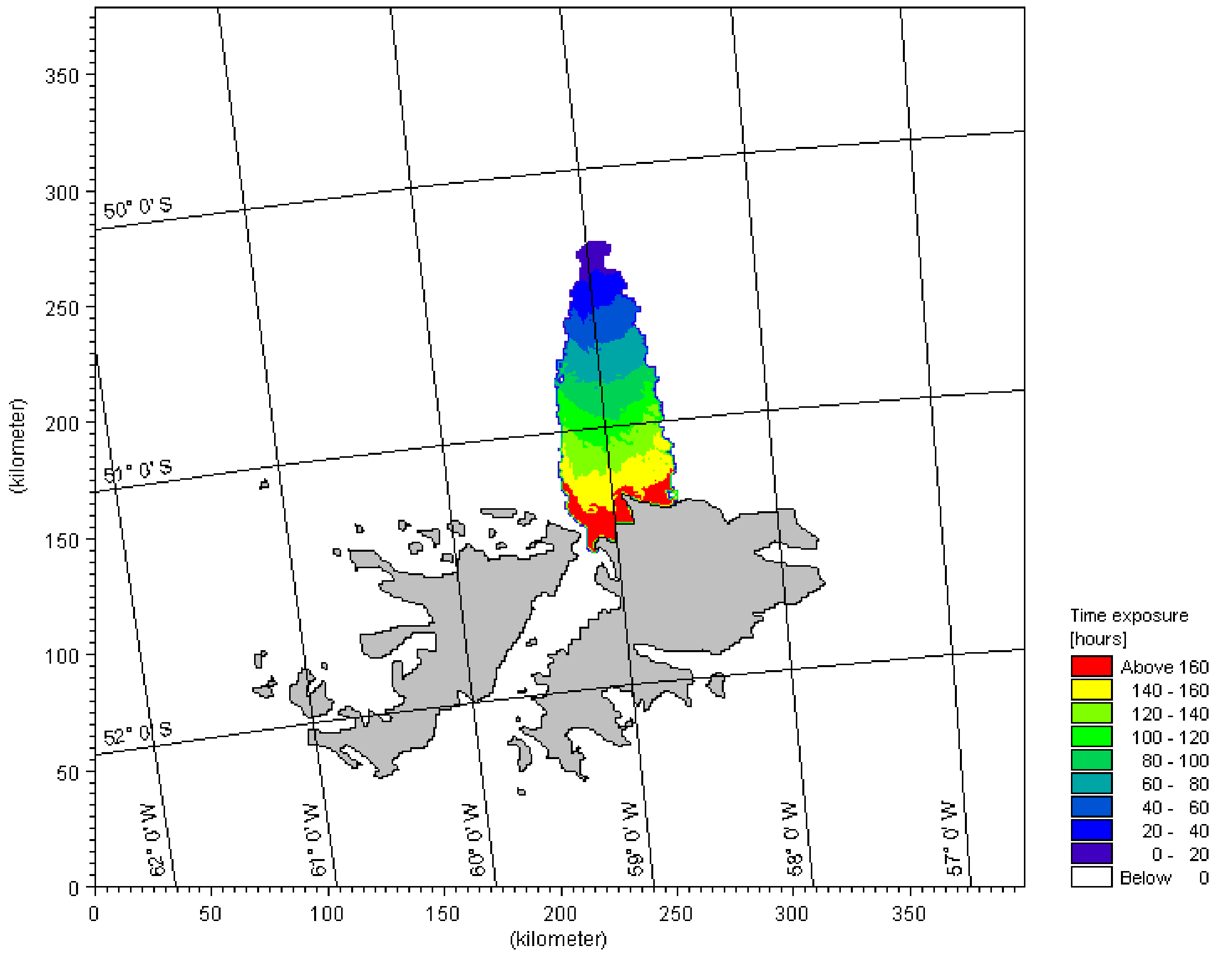

Figure 34: Exposure to oil following spill from site Ernest with wind 10m/s from N after 8 days

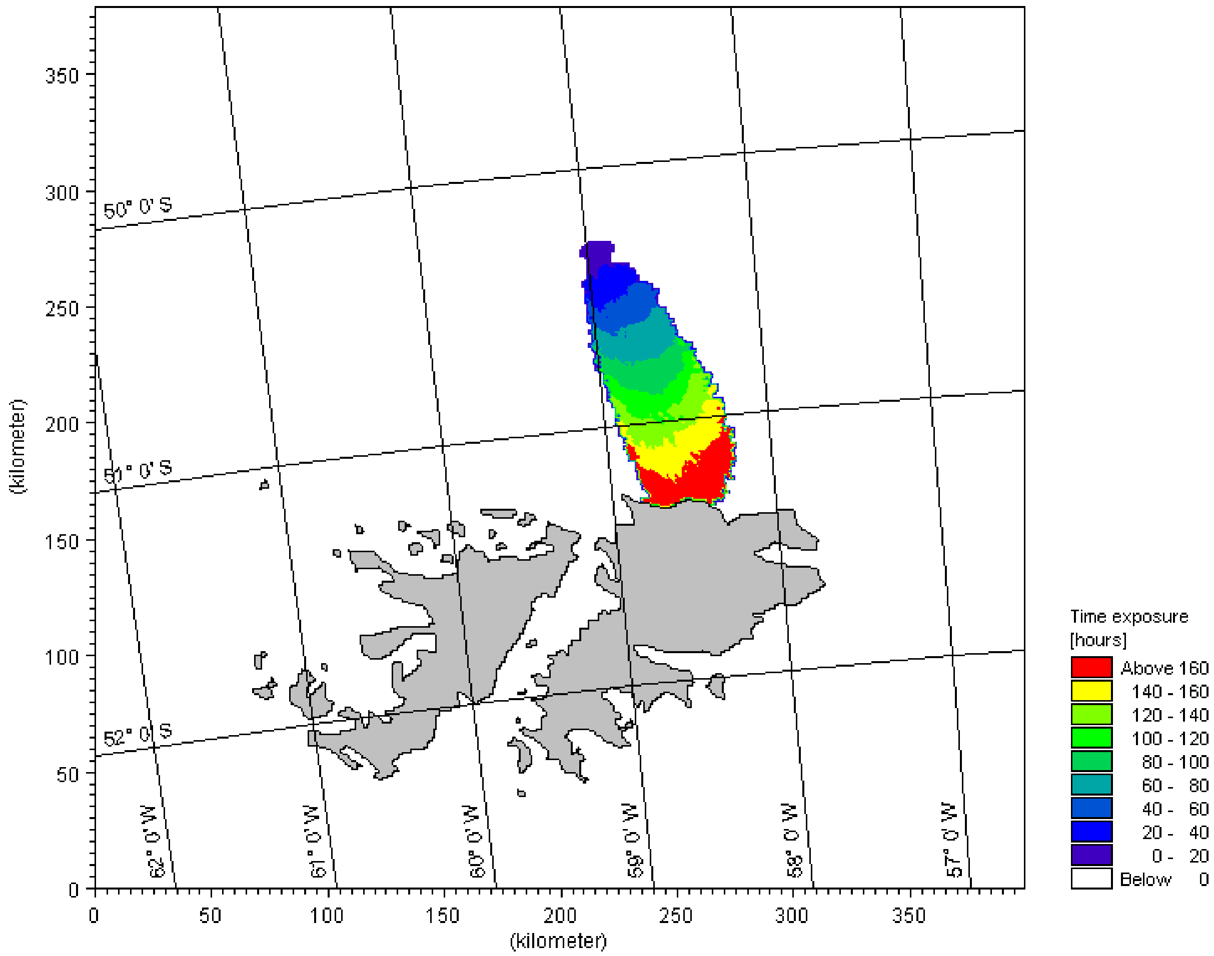

Figure 35: Exposure to oil following spill from site Ernest with wind 10m/s from 345° after 8 days

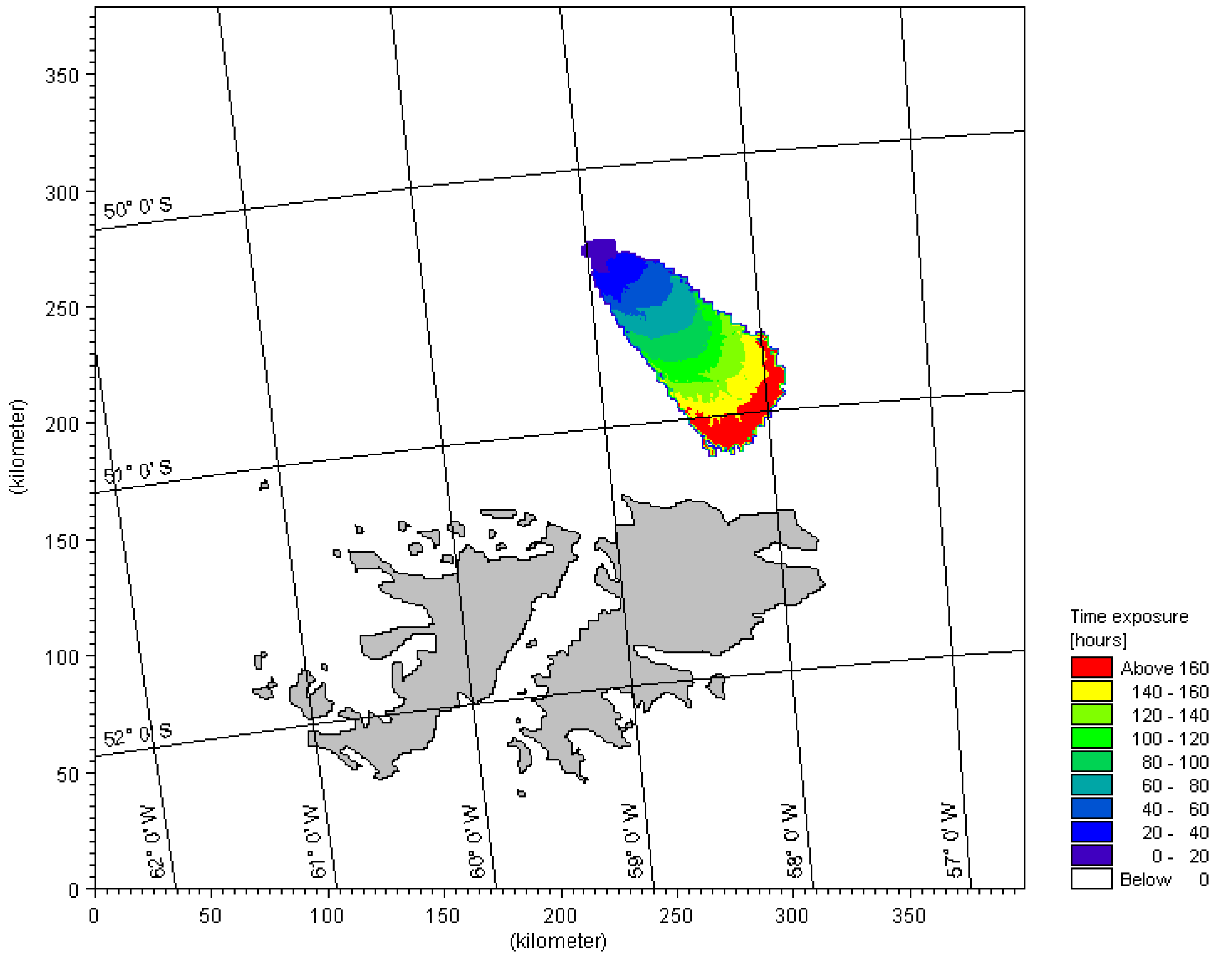

Figure 36: Exposure to oil following spill from site Ernest with wind 10m/s from 330° after 8 days

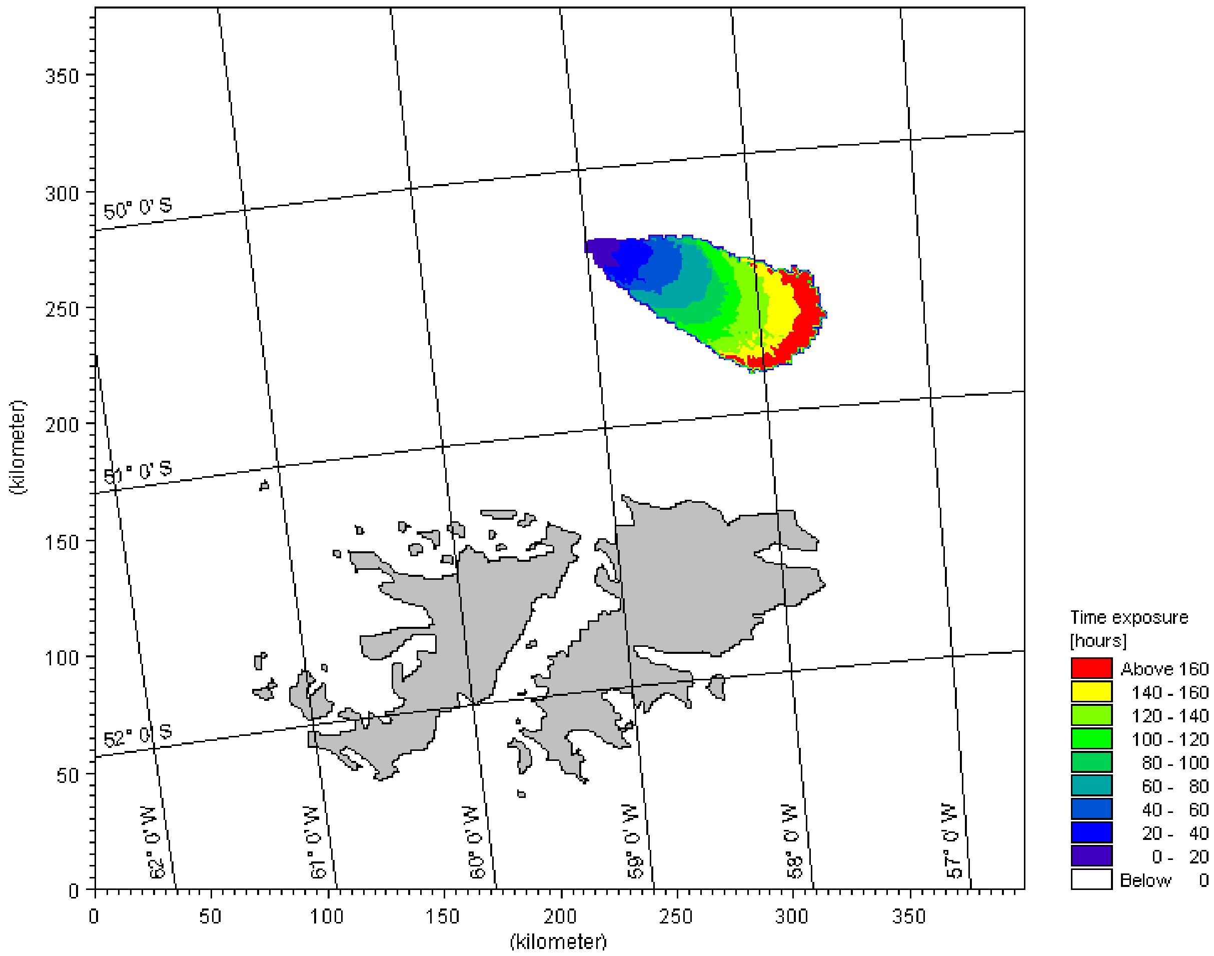

Figure 37: Exposure to oil following spill from site Ernest with wind 10m/s from 315° after 8 days

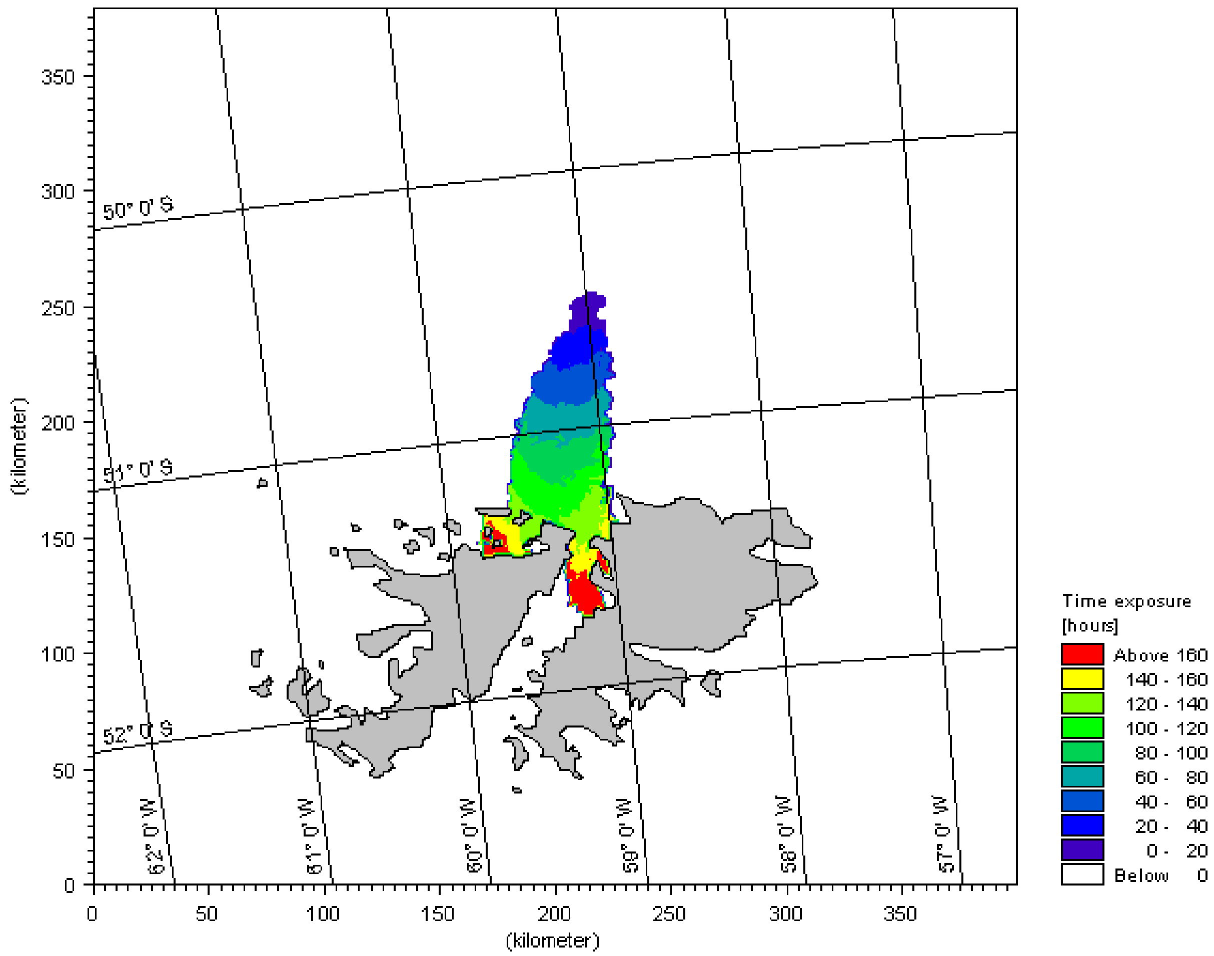

Figure 38: Exposure to oil following spill from site Ruth with wind 10m/s from 15° after 8 days

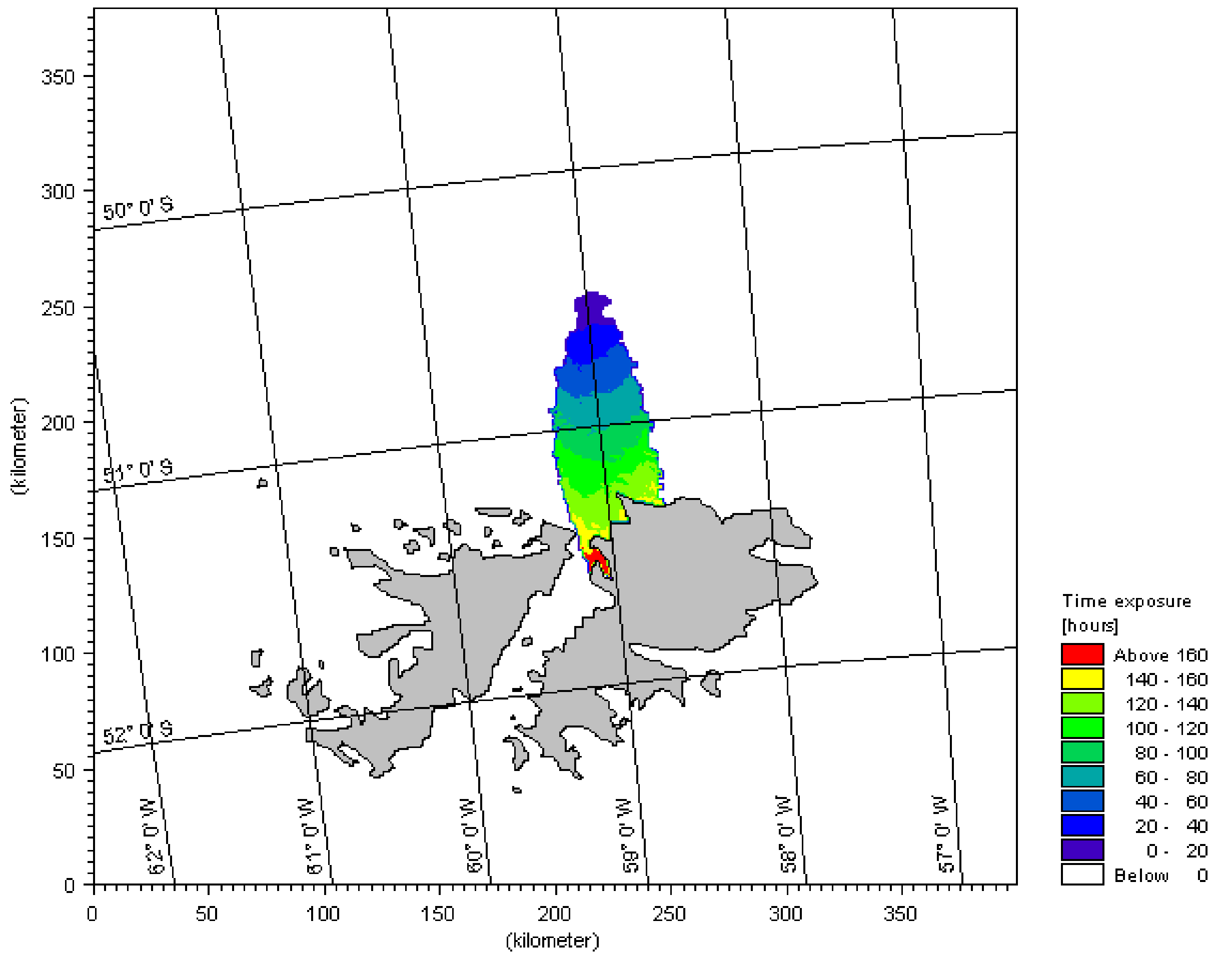

Figure 39: Exposure to oil following spill from site Ruth with wind 10m/s from N after 8 days

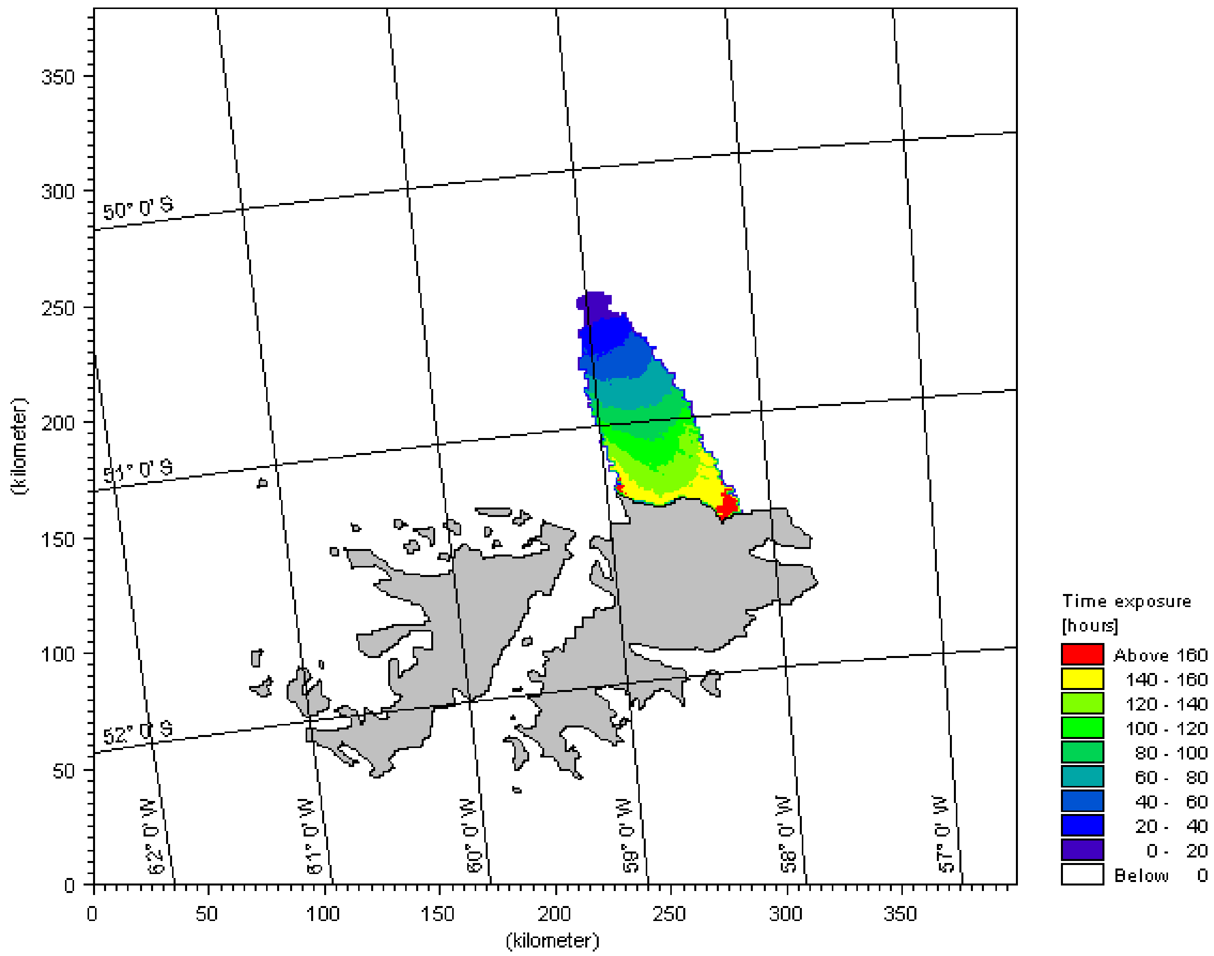

Figure 40: Exposure to oil following spill from site Ruth with wind 10m/s from 345° after 8 days

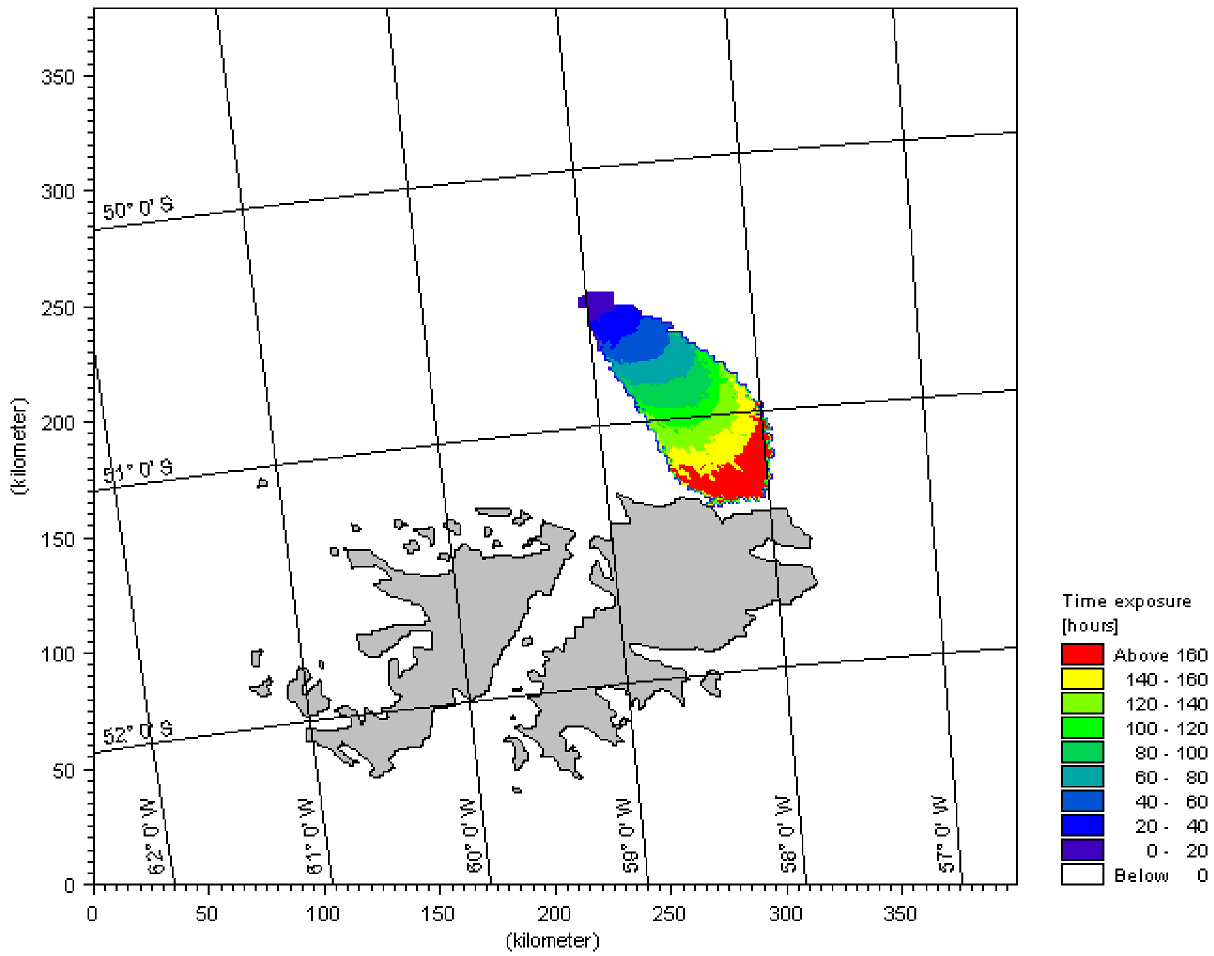

Figure 41: Exposure to oil following spill from site Ruth with wind 10m/s from 330° after 8 days

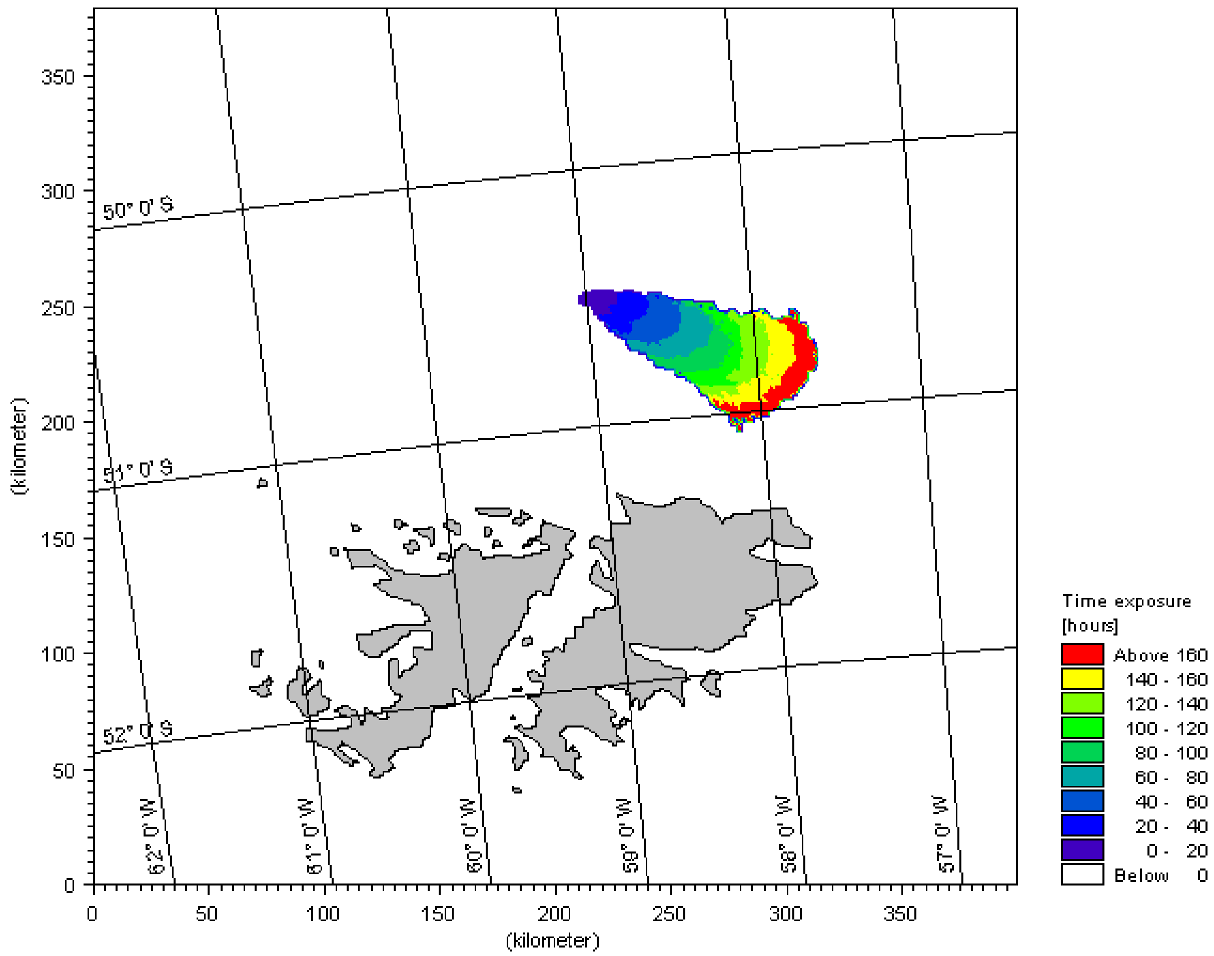

Figure 42: Exposure to oil following spill from site Ruth with wind 10m/s from 315° after 8 days

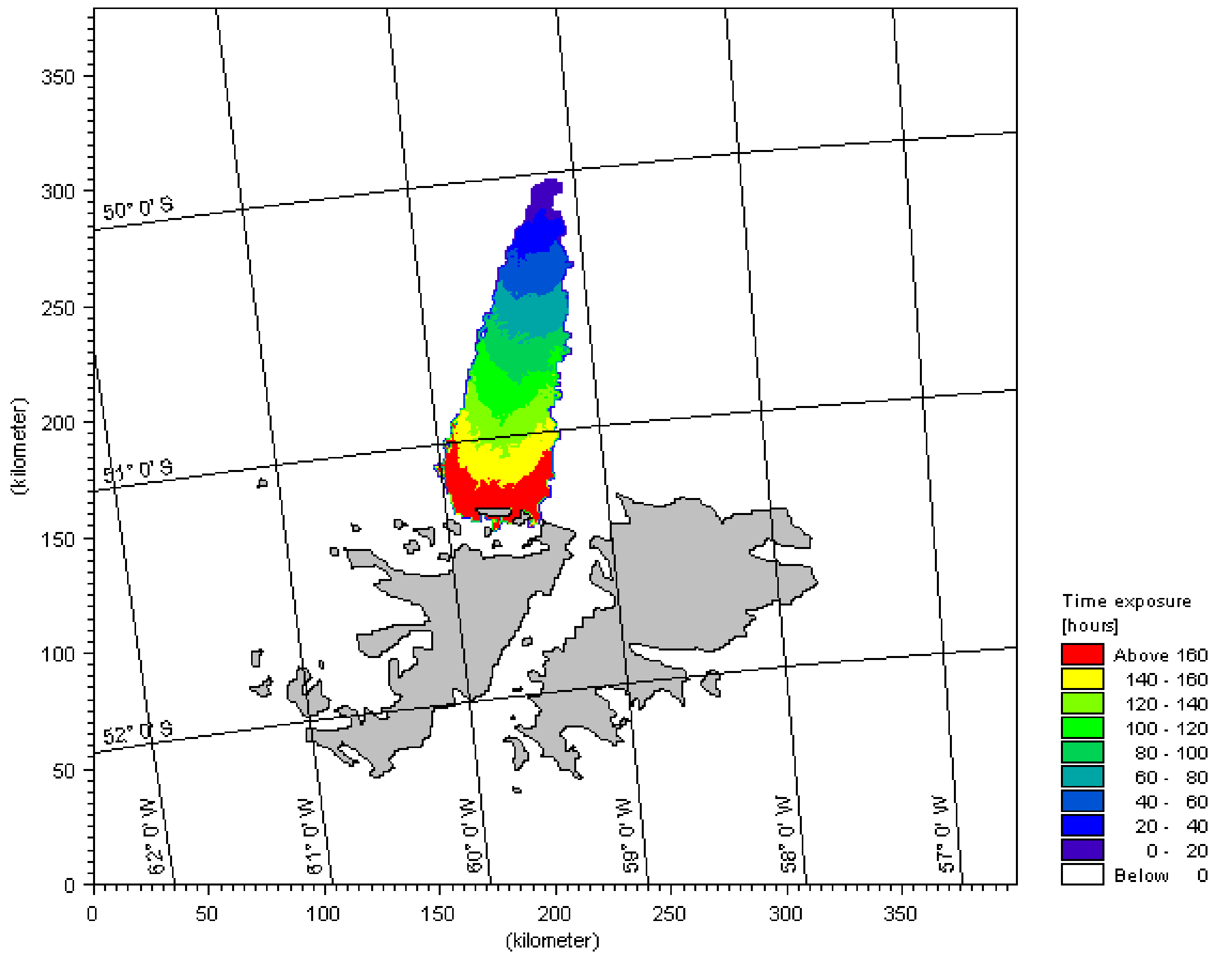

Figure 43: Exposure to oil following spill from site Dawn with wind 10m/s from 15° after 8 days

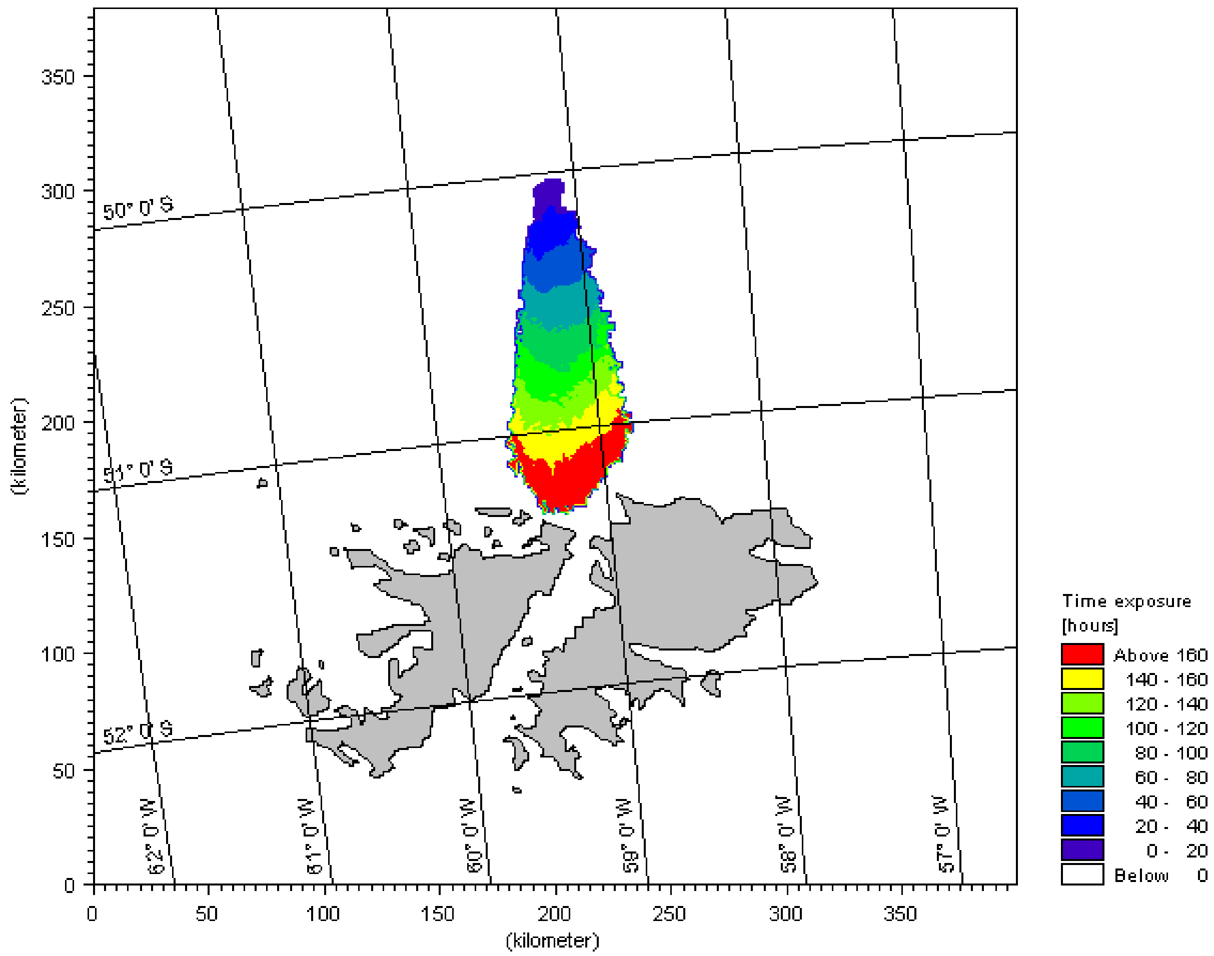

Figure 44: Exposure to oil following spill from site Dawn with wind 10m/s from N after 8 days

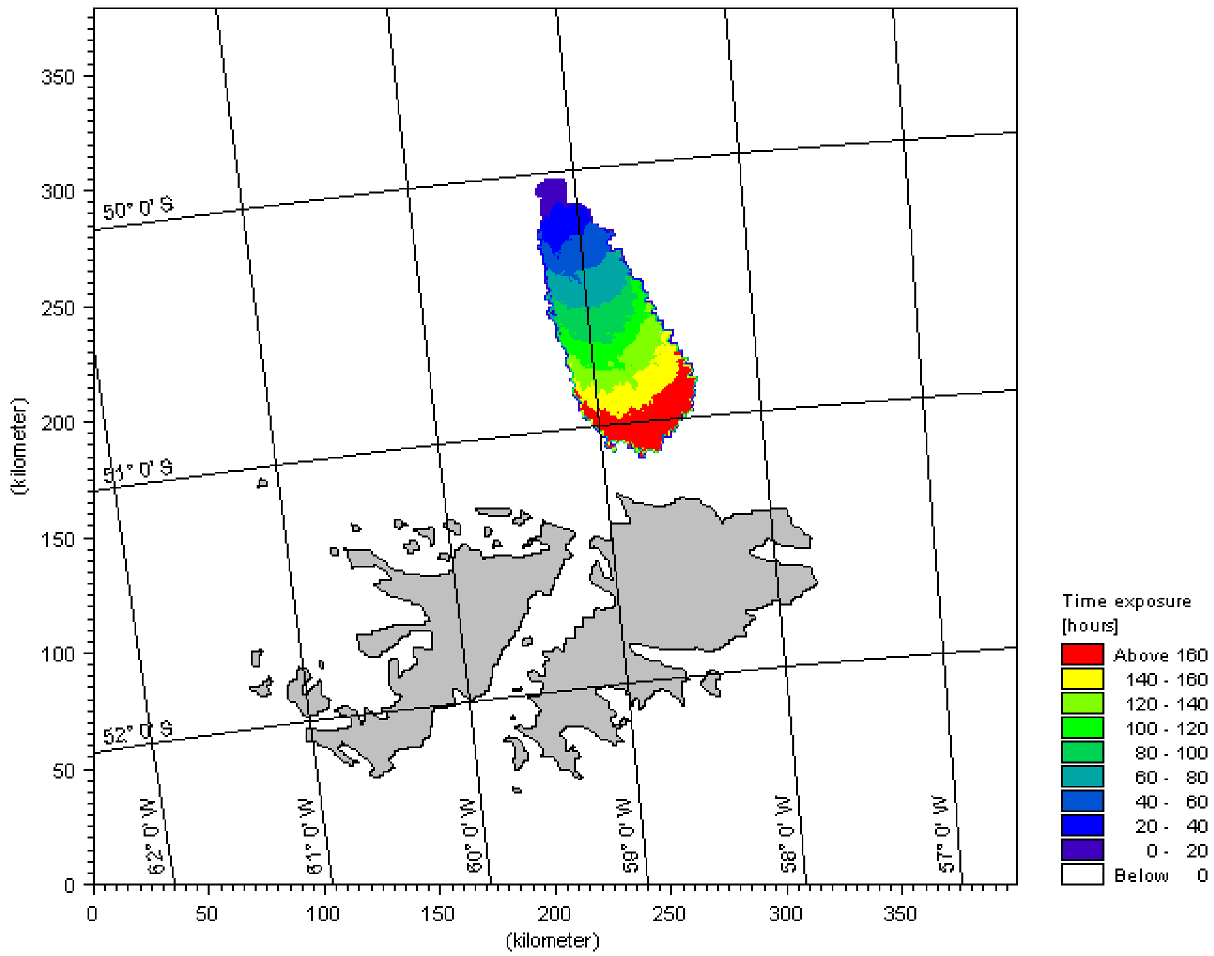

Figure 45: Exposure to oil following spill from site Dawn with wind 10m/s from 345° after 8 days

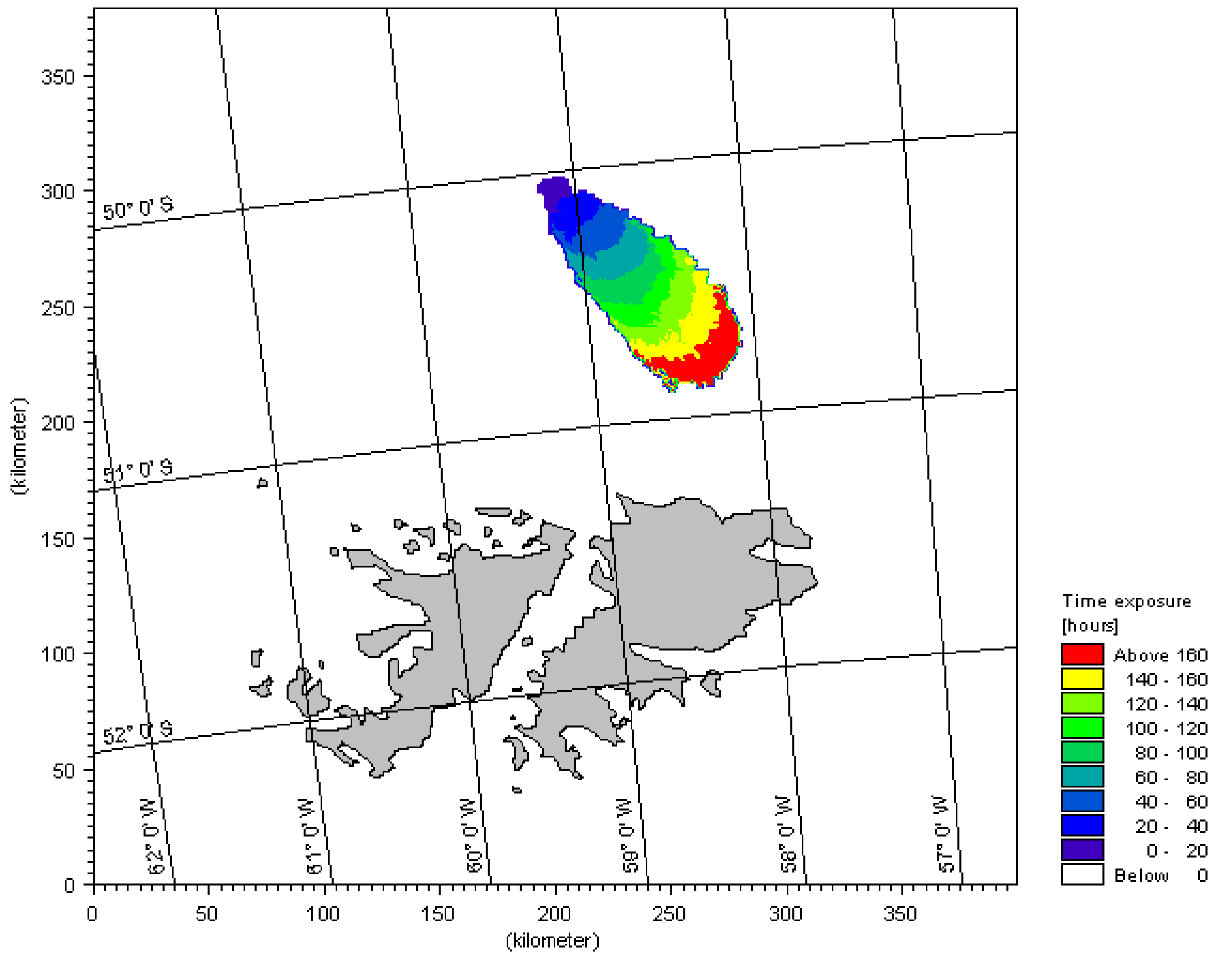

Figure 46: Exposure to oil following spill from site Dawn with wind 10m/s from 330° after 8 days

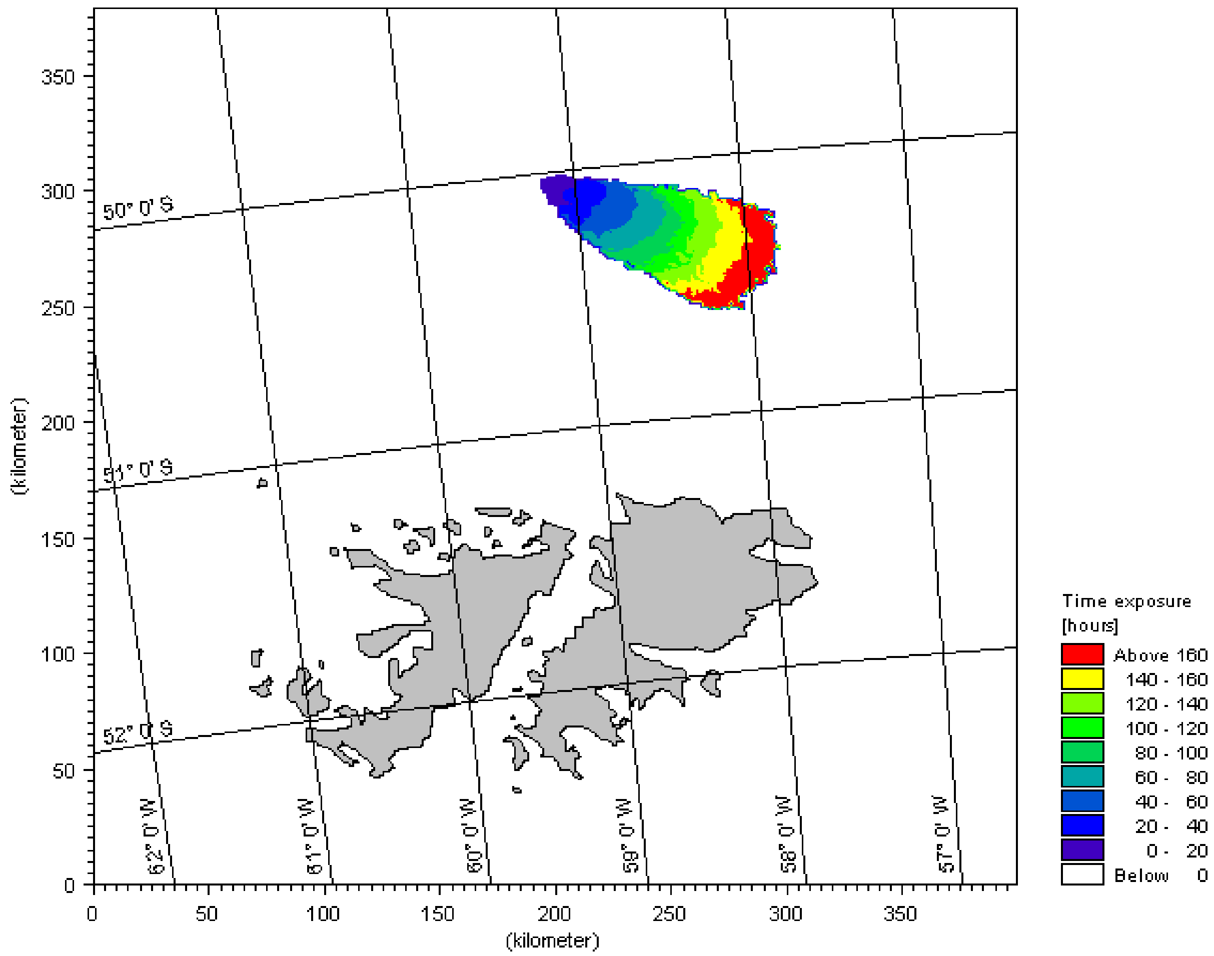

Figure 47: Exposure to oil following spill from site Dawn with wind 10m/s from 315° after 8 days

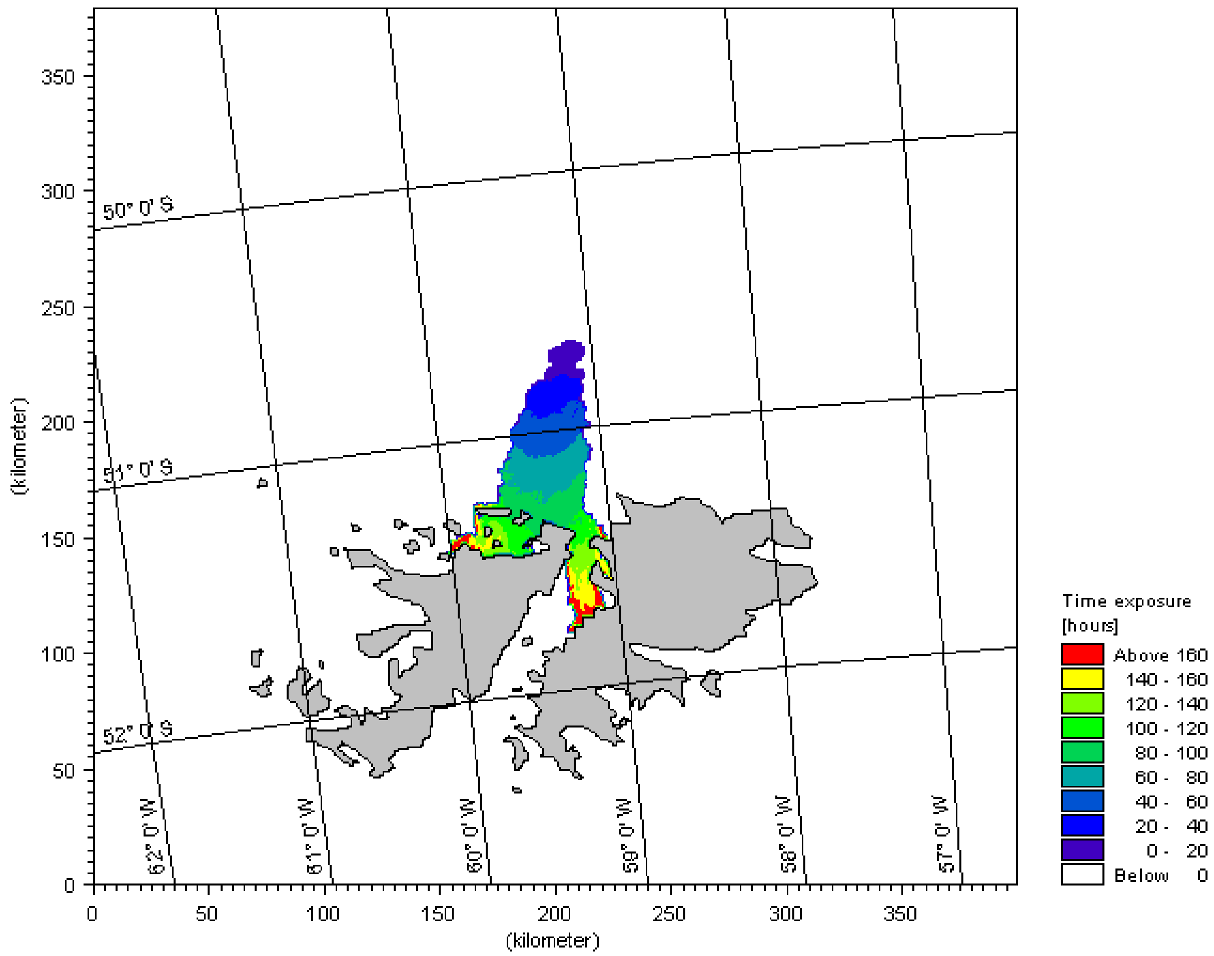

Figure 48: Exposure to oil following spill from site Barbara with wind 10m/s from 15° after 8 days

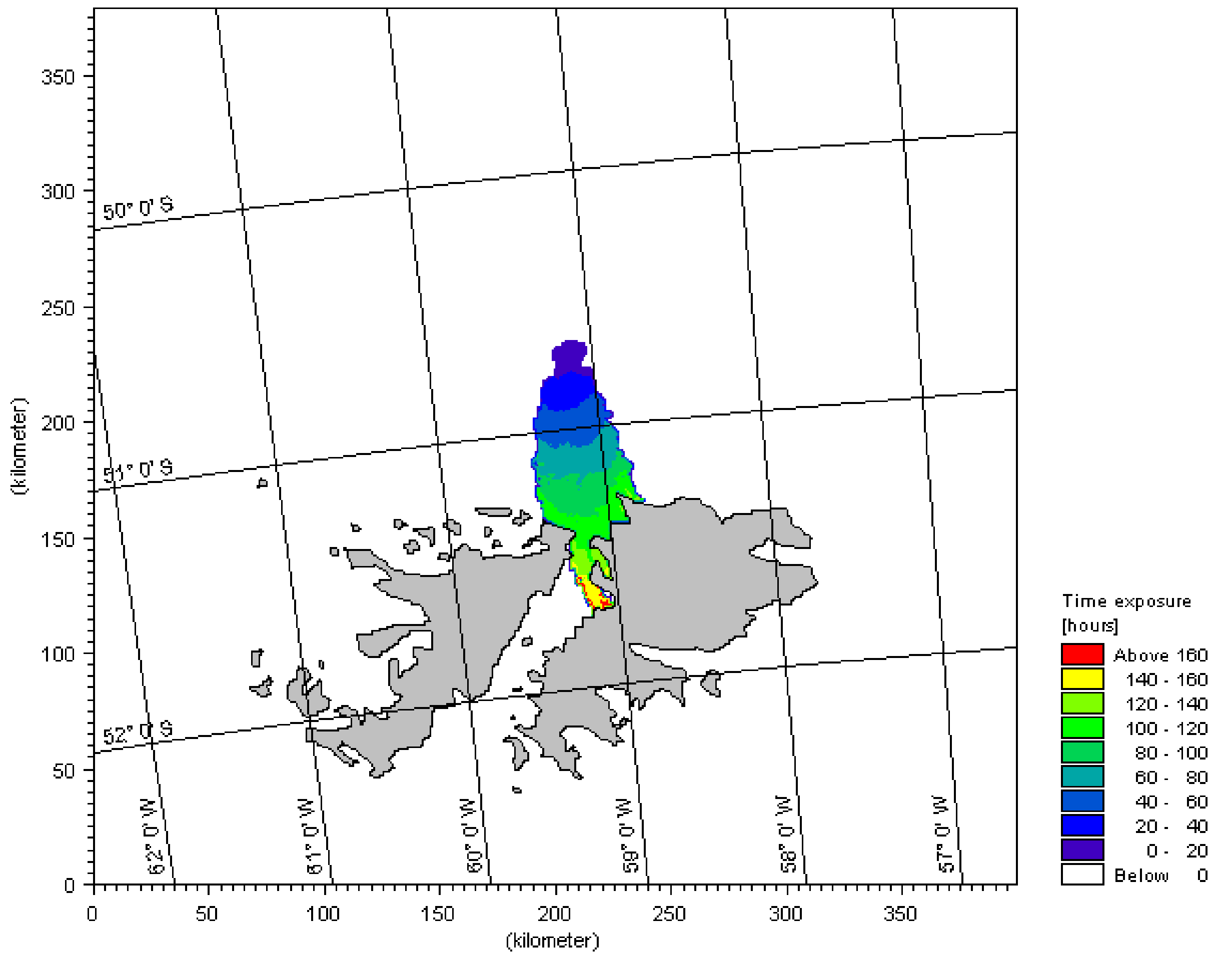

Figure 49: Exposure to oil following spill from site Barbara with wind 10m/s from N after 8 days

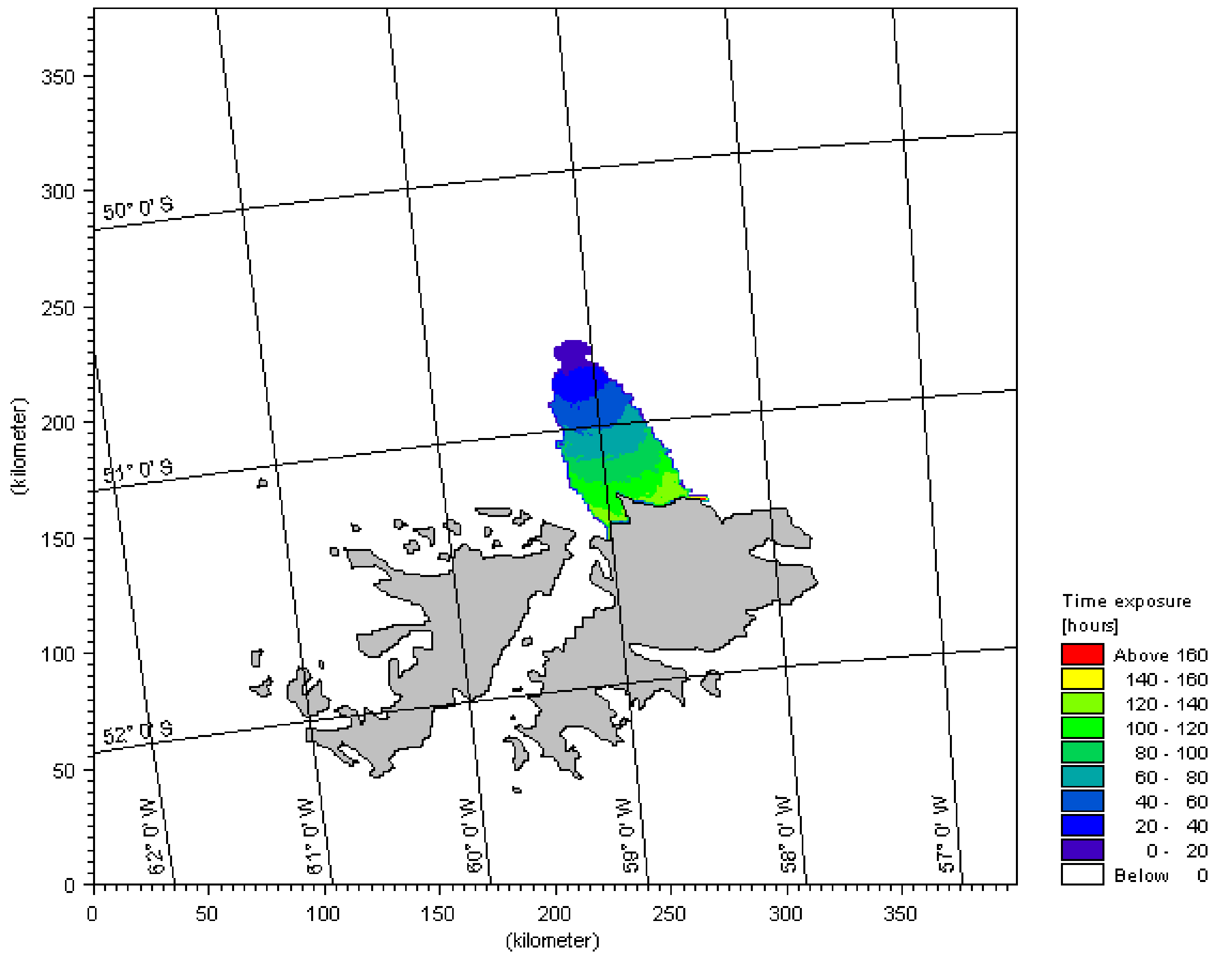

Figure 50: Exposure to oil following spill from site Barbara with wind 10m/s from 345° after 8 days

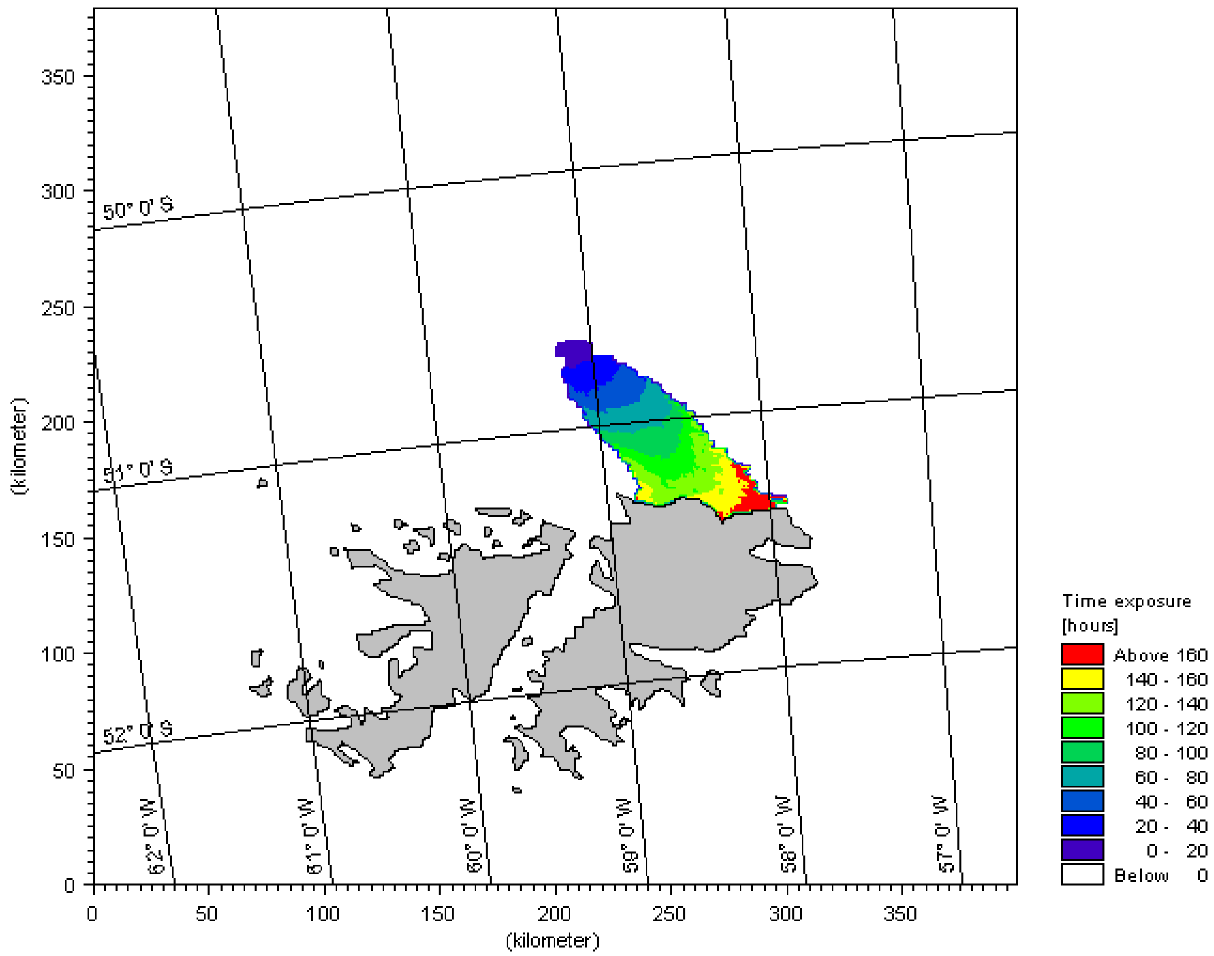

Figure 51: Exposure to oil following spill from site Barbara with wind 10m/s from 330° after 8 days

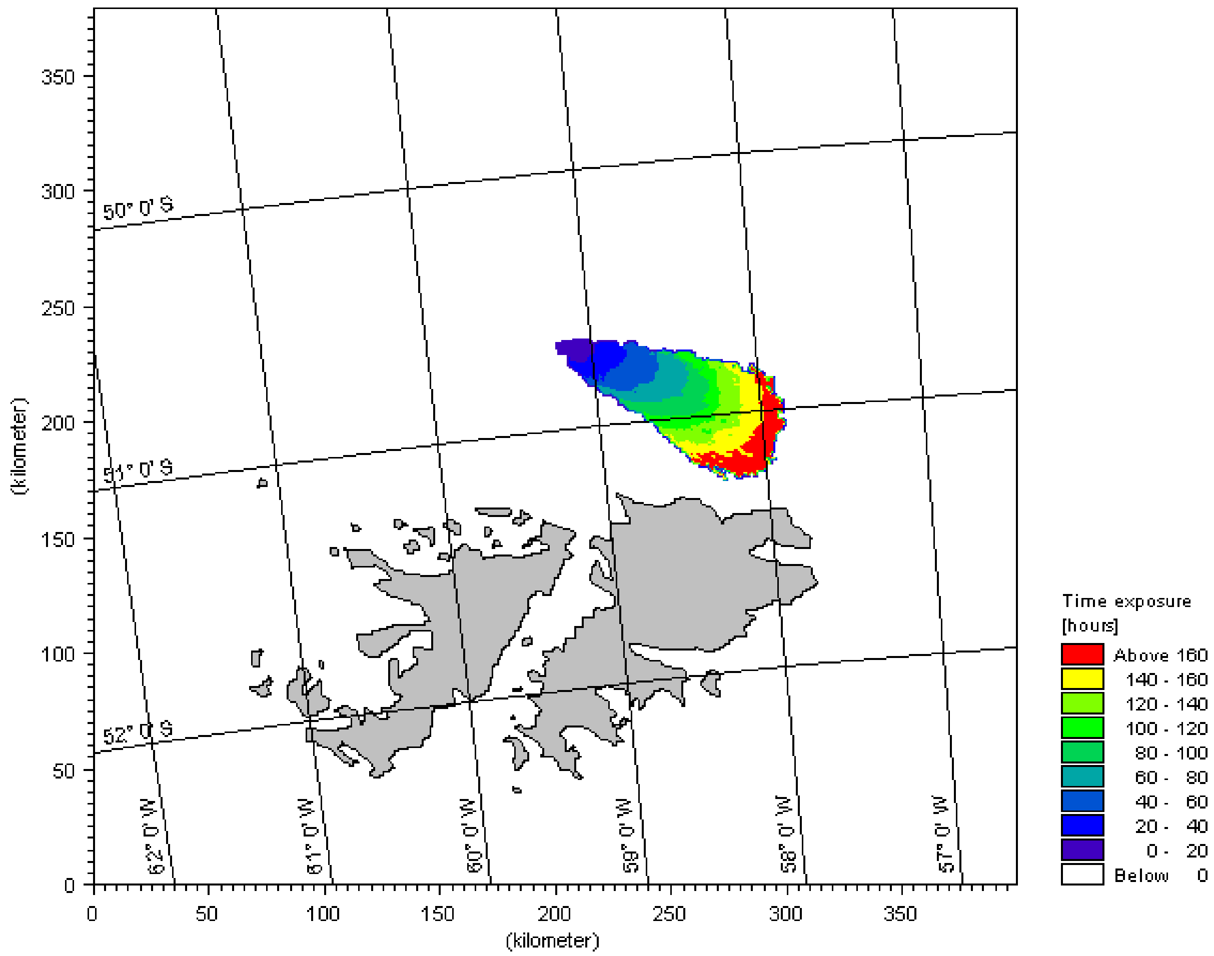

Figure 52: Exposure to oil following spill from site Barbara with wind 10m/s from 315° after 8 days

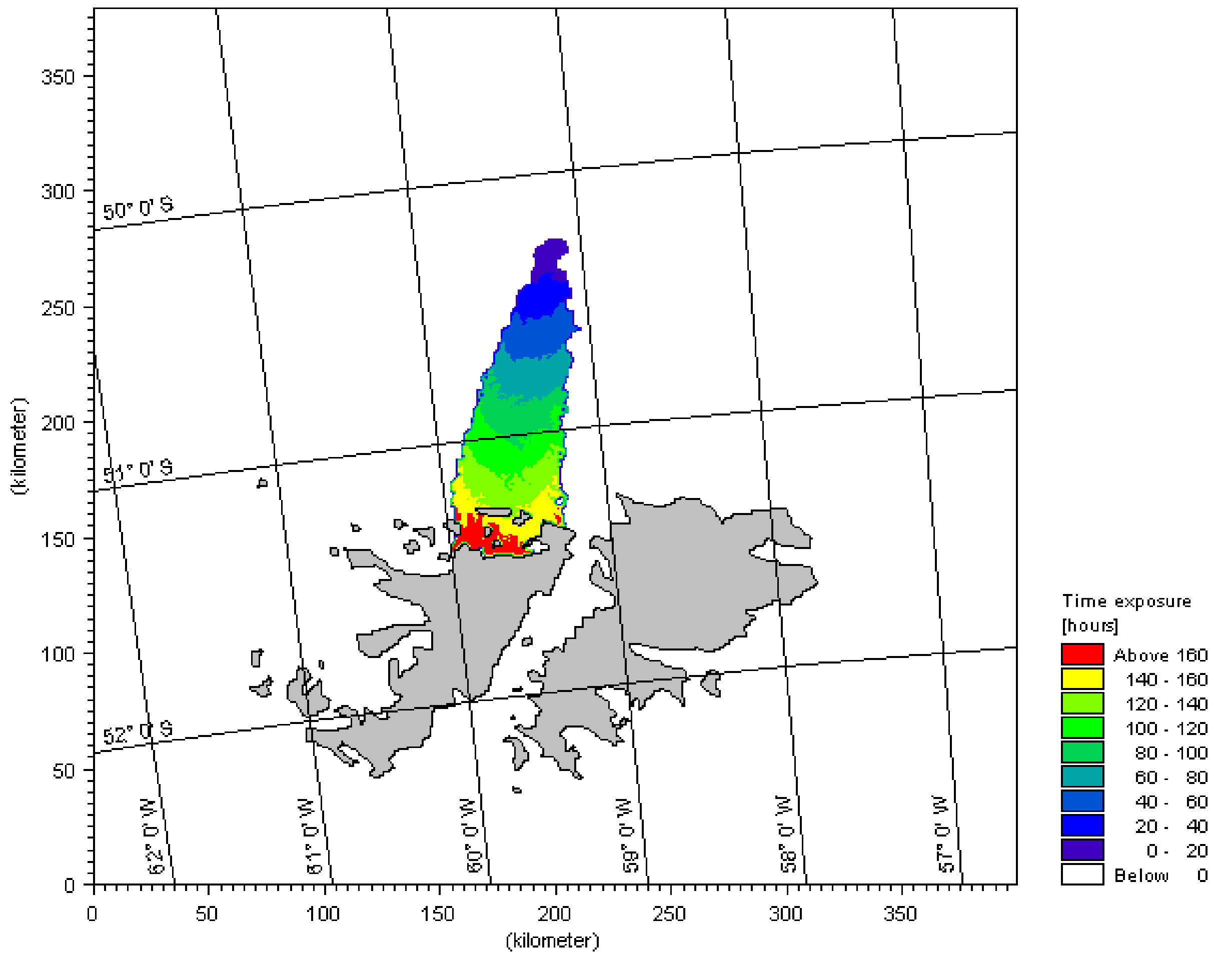

Figure 53: Exposure to oil following spill from site Alpha with wind 10m/s from 15° after 8 days

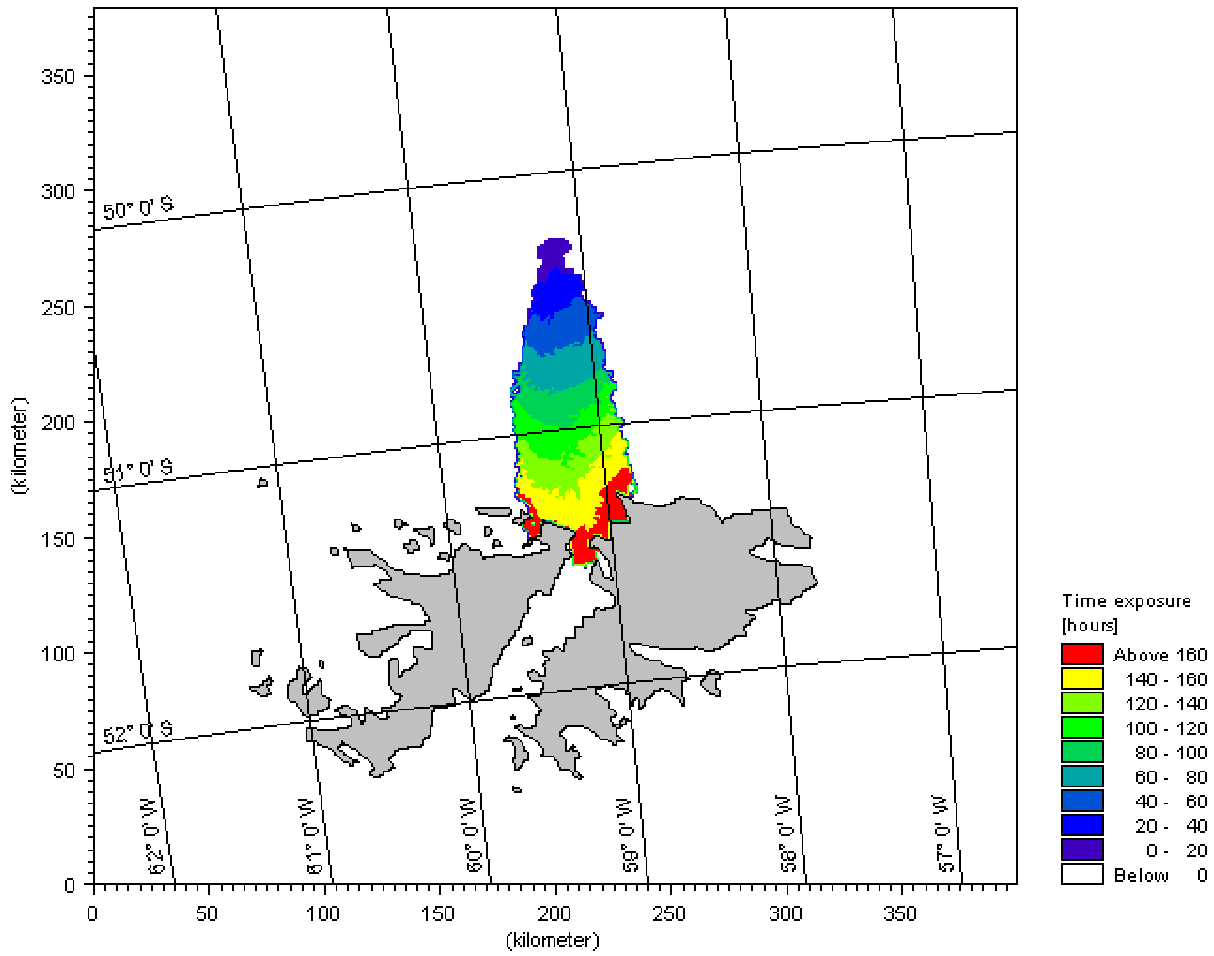

Figure 54: Exposure to oil following spill from site Alpha with wind 10m/s from N after 8 days

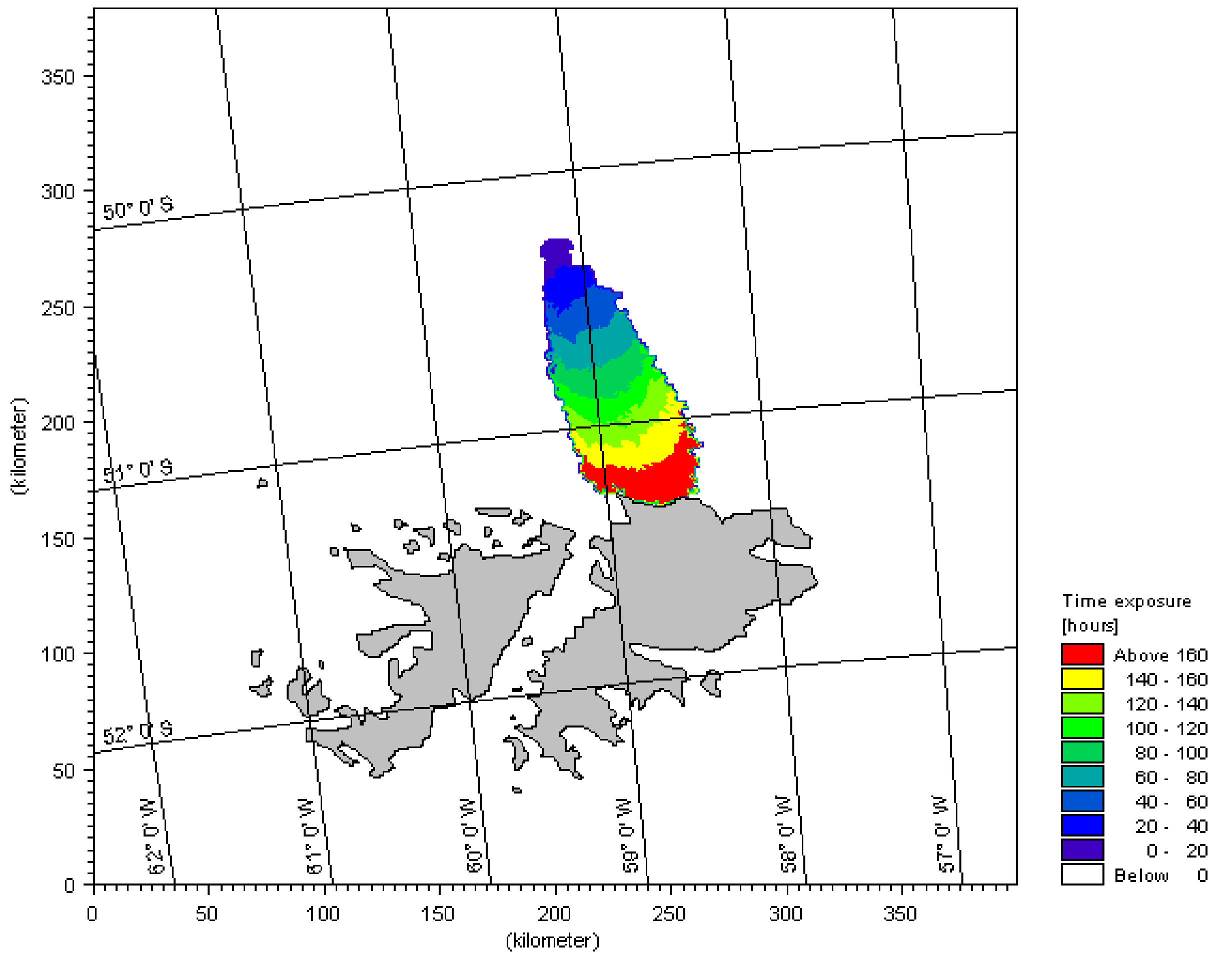

Figure 55: Exposure to oil following spill from site Alpha with wind 10m/s from 345° after 8 days

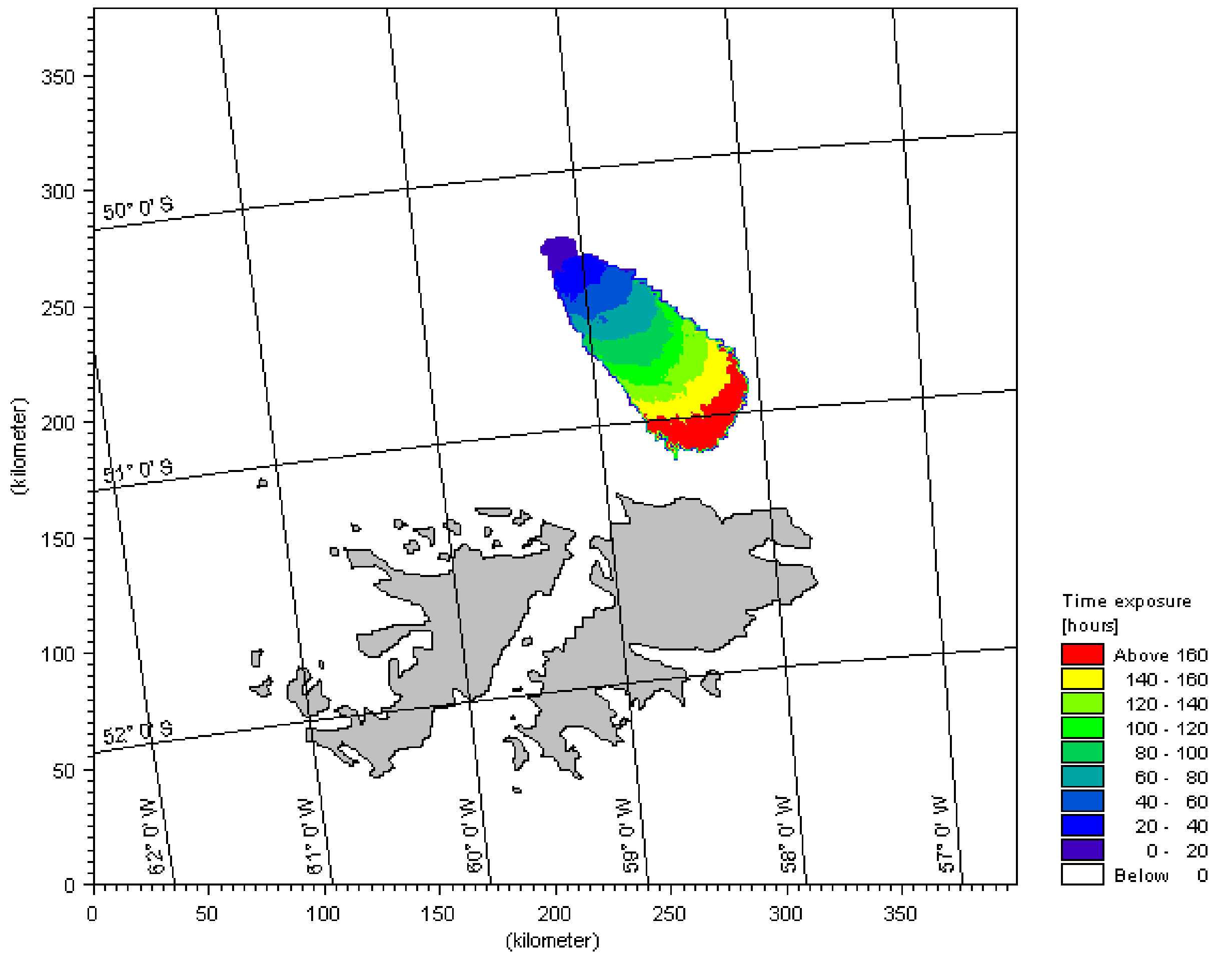

Figure 56: Exposure to oil following spill from site Alpha with wind 10m/s from 330° after 8 days

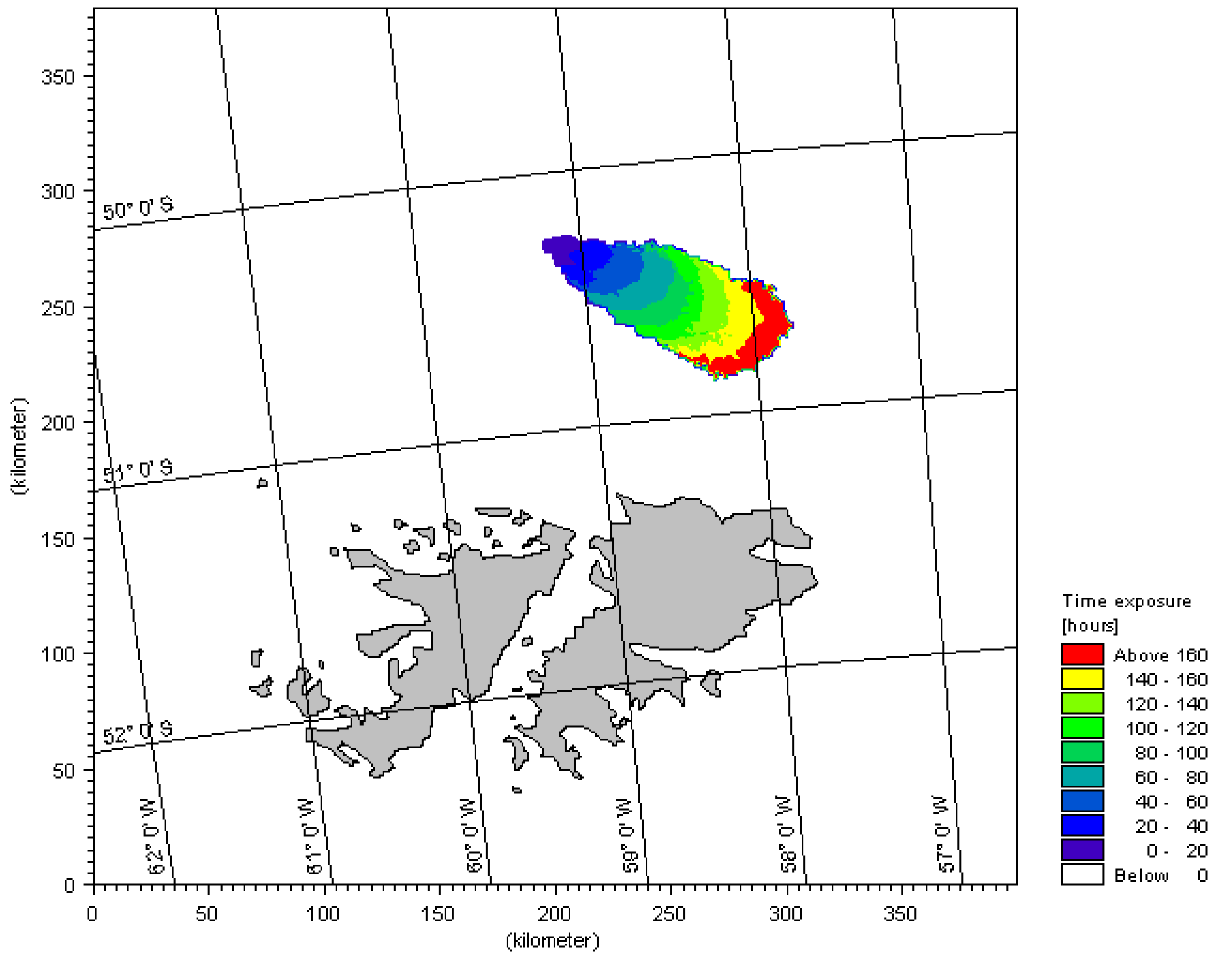

Figure 57: Exposure to oil following spill from site Alpha with wind 10m/s from 315° after 8 days

APPENDIX C: DRILL CUTTINGS PLUME AND DEPOSITION

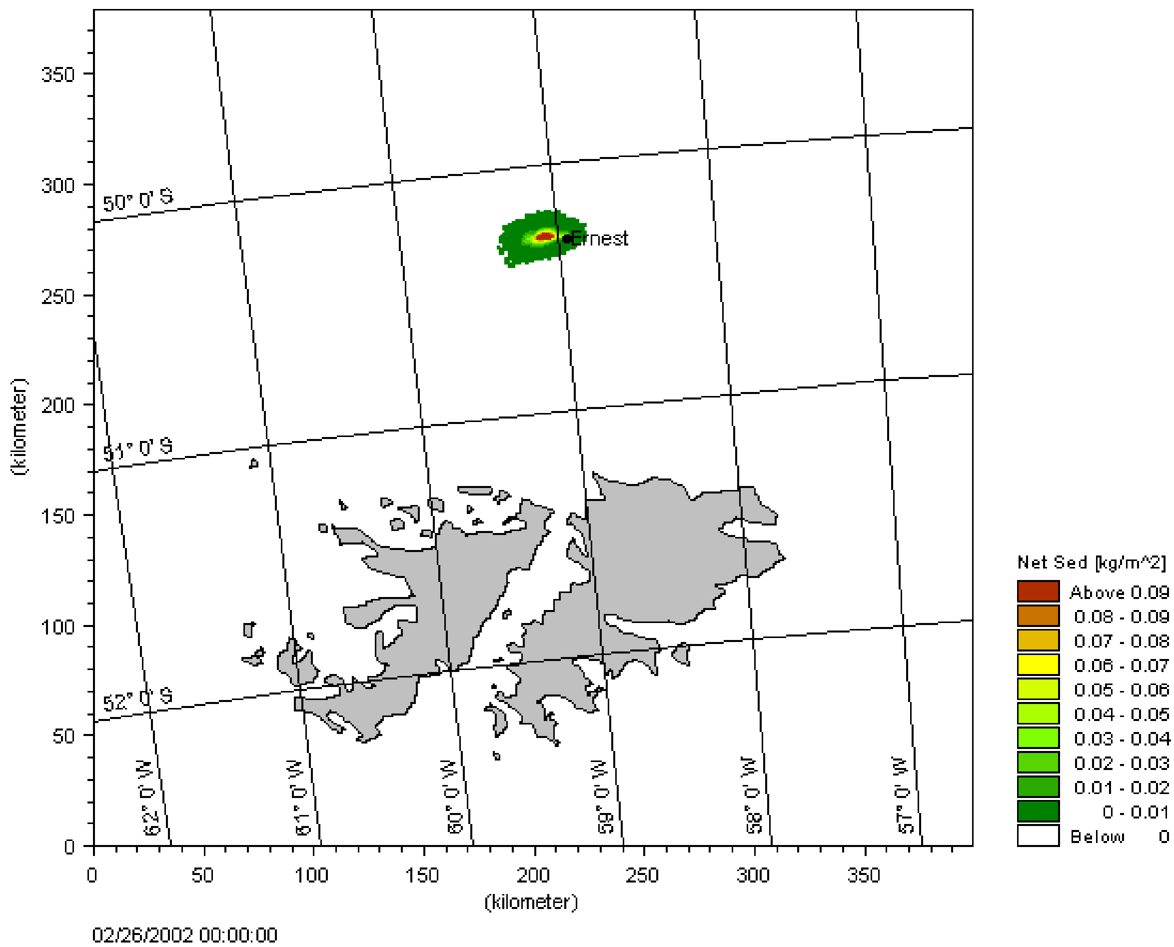

Figure 58: Deposition footprint of drill residue for well site Ernest

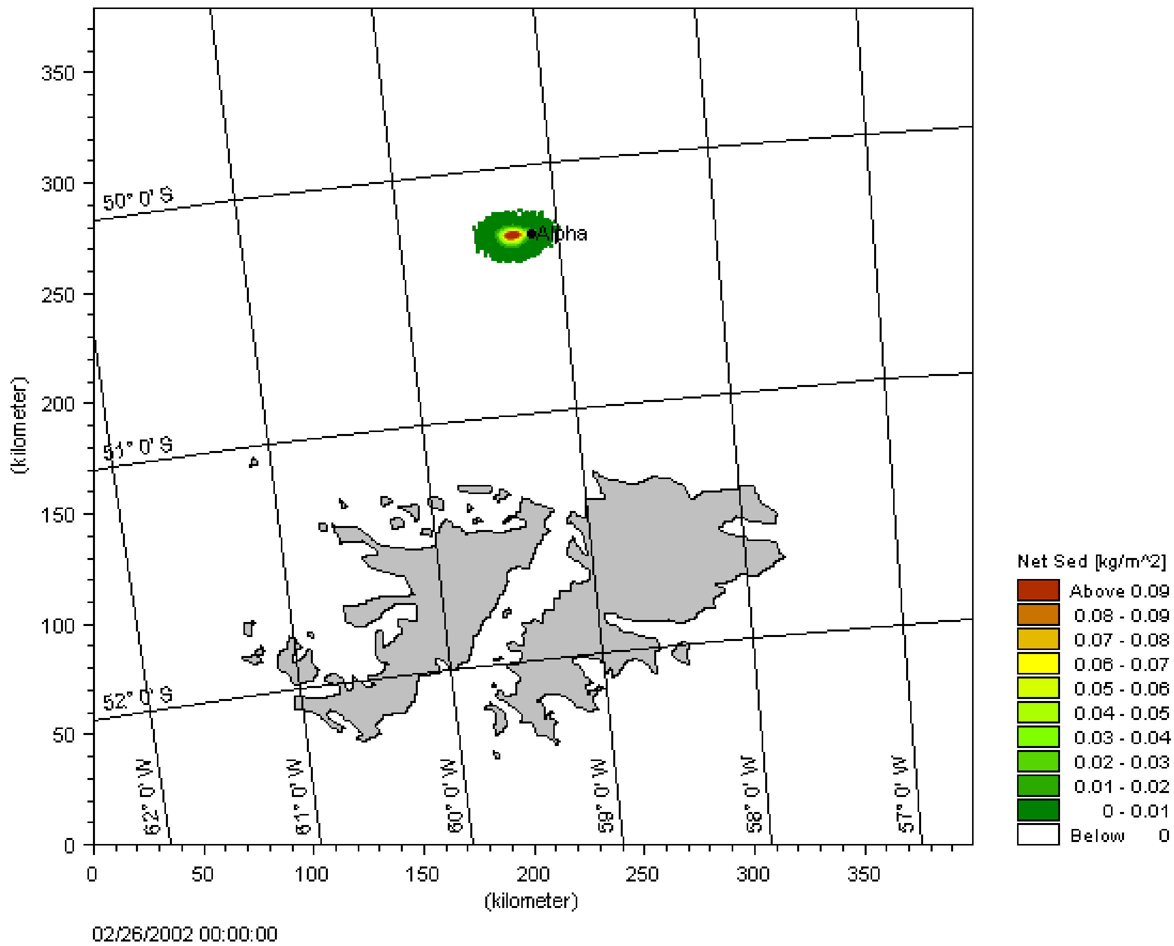

Figure 59: Deposition footprint of drill residue for well site Alpha

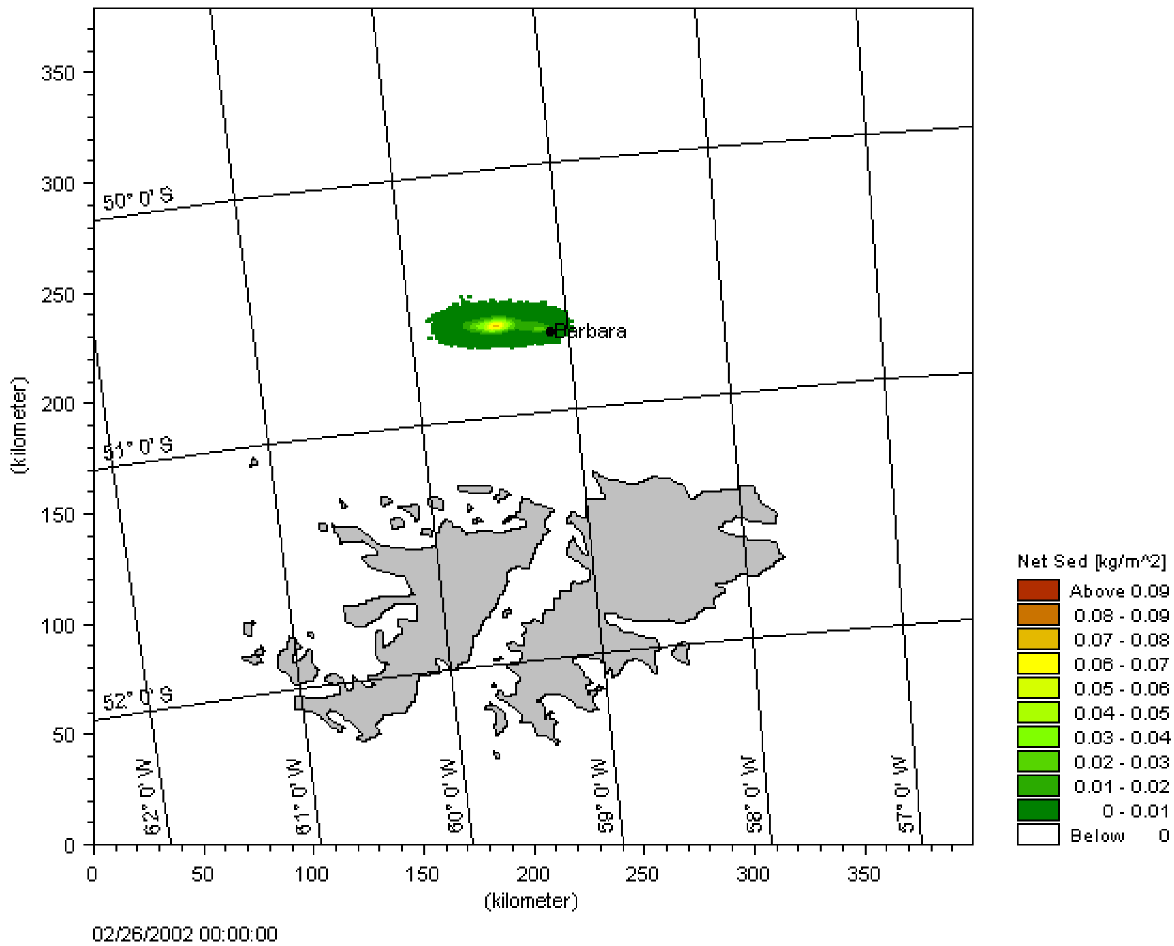

Figure 60: Deposition footprint of drill residue for well site Barbara

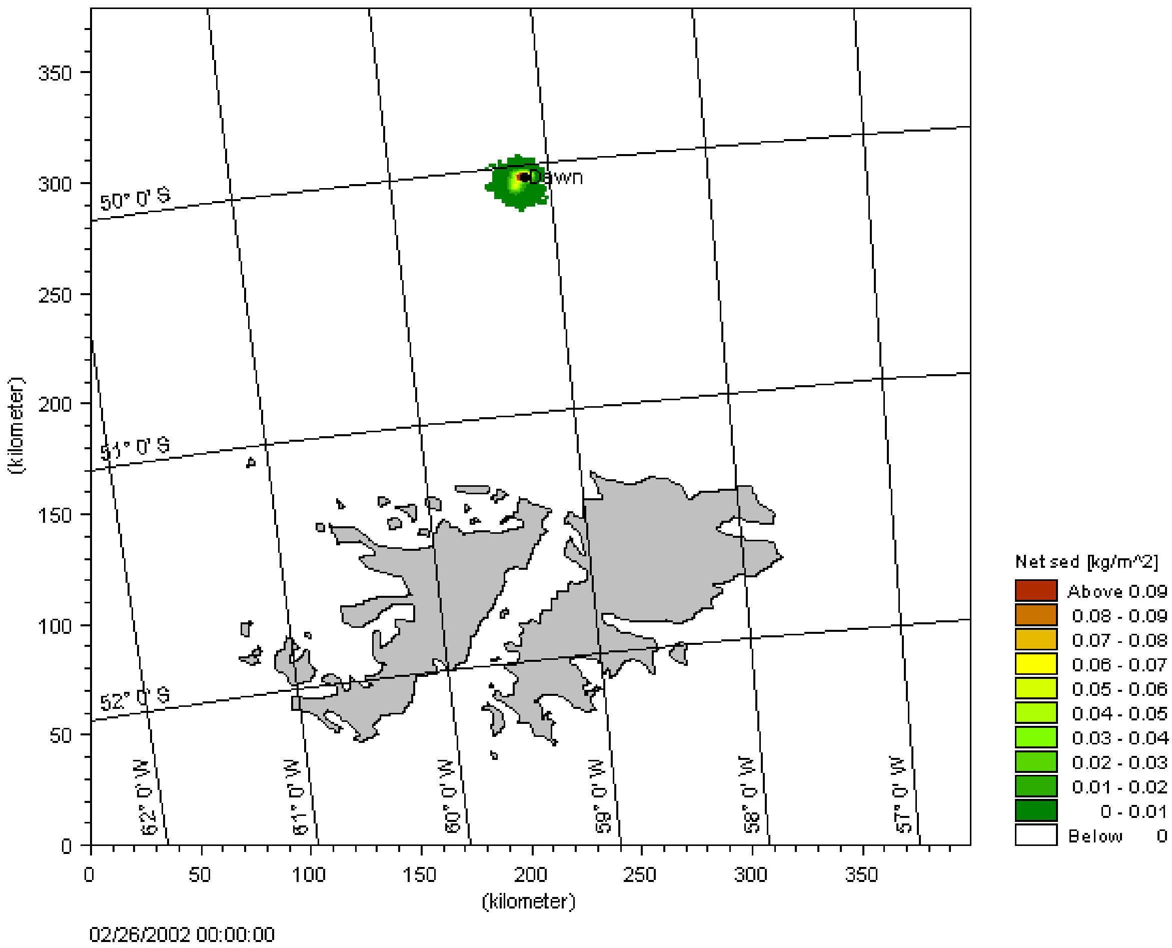

Figure 61: Deposition footprint of drill residue for well site Dawn

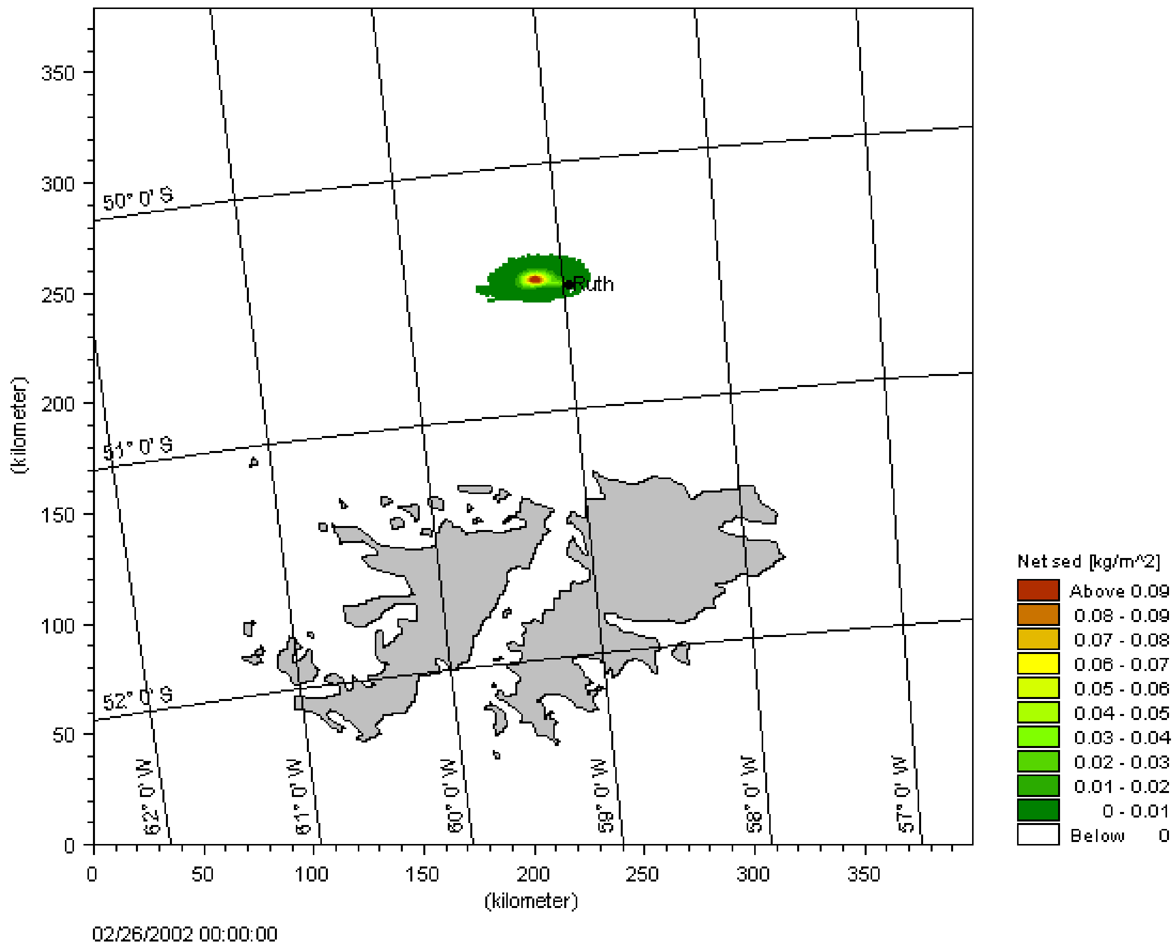

Figure 62: Deposition footprint of drill residue for well site Ruth

Falklands Island Oil Exploration

Oil Spill Analysis and Drill Plume Modelling

DOCUMENT CONTROL SHEET

Client	RPS Group / Energy					
Project Title	Falklands Island Oil Exploration Oil Spill Analysis and Drill Plume Modelling					
Document Title	Oil Spill Analysis and Drill Plume Modelling					
Document No.	IBE0114/R02/BE					
This Document Comprises	DCS	TOC	Text	List of Tables	List of Figures	No. of Appendices
	1	1	63	1	1	3

Rev.	Status	Author(s)	Reviewed By	Approved By	Office of Origin	Issue Date
1	Draft	BE	AKB	AKB	Belfast	July 08

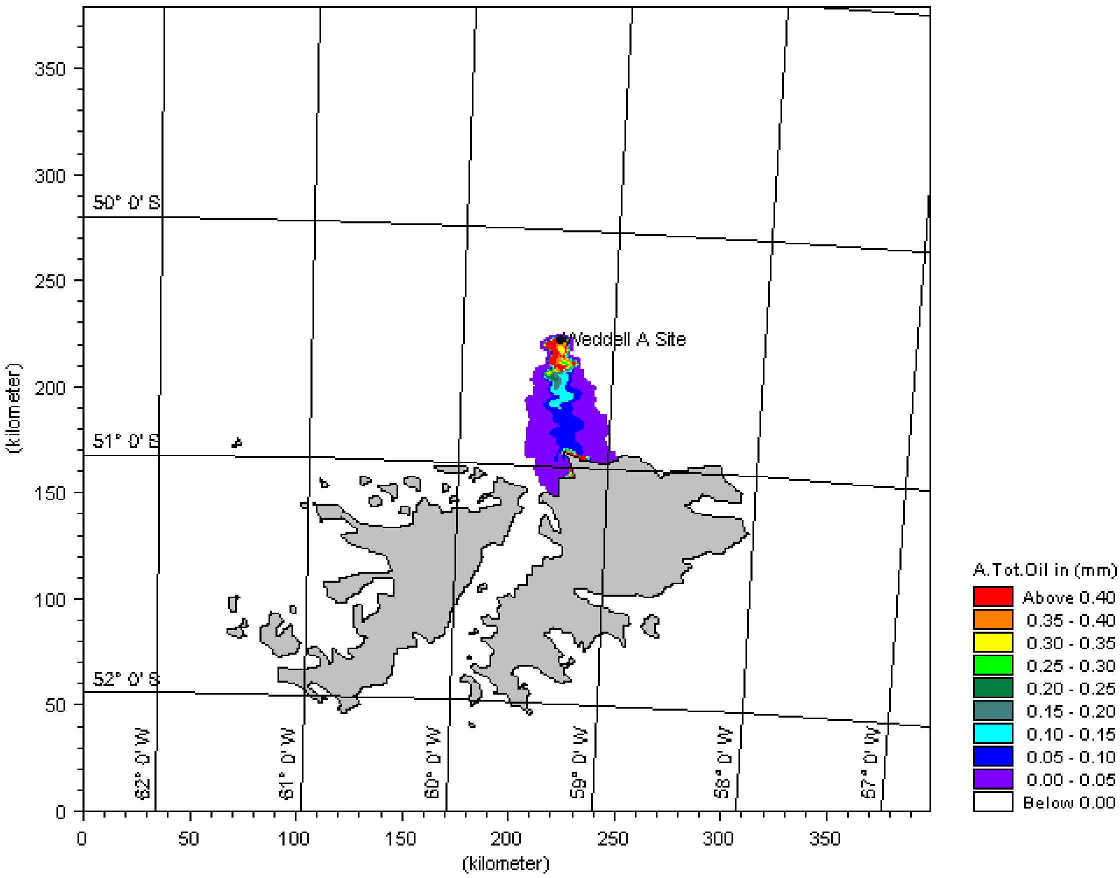

Figure 1: Maximum oil slick thickness during 8 day simulation following spill from site Weddell A with wind 10m/s from 0°

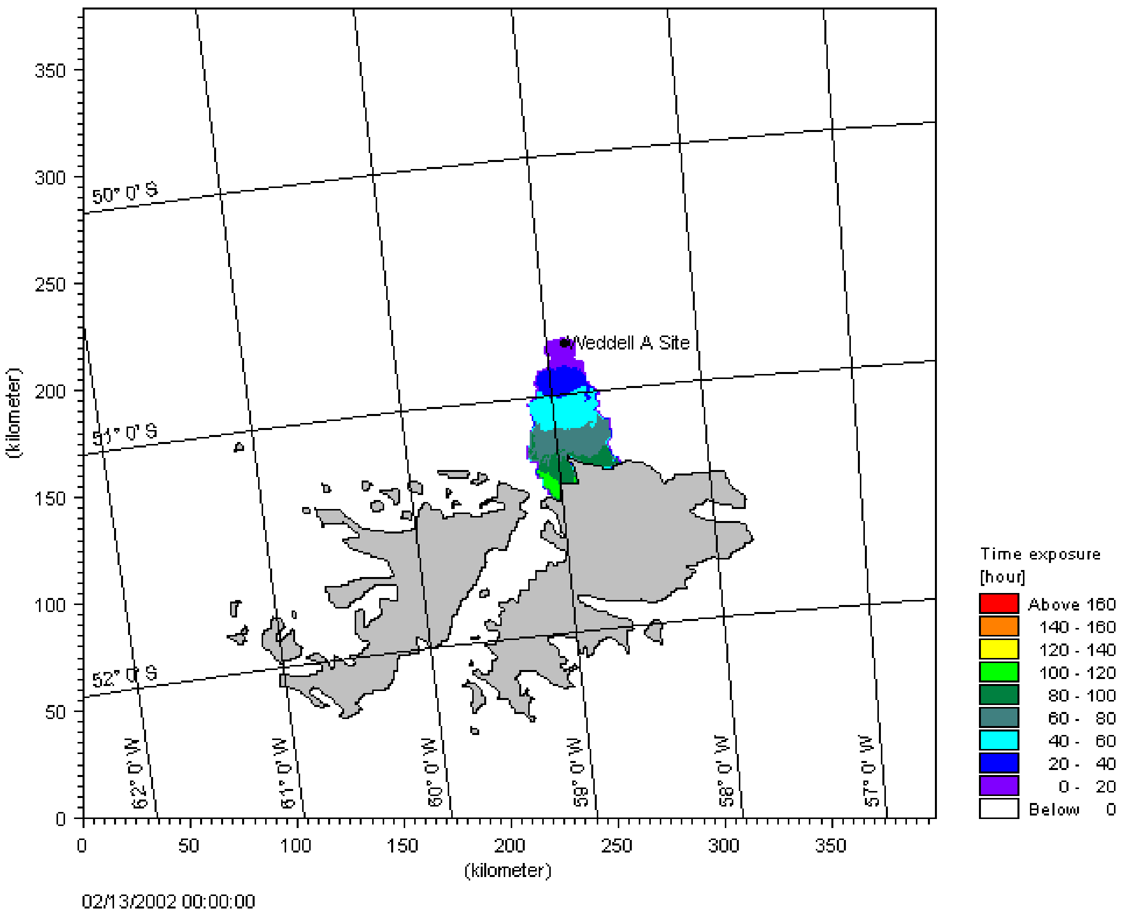

Figure 2: Exposure to oil following spill from site Weddell A with wind 10m/s from 0° after 8 days

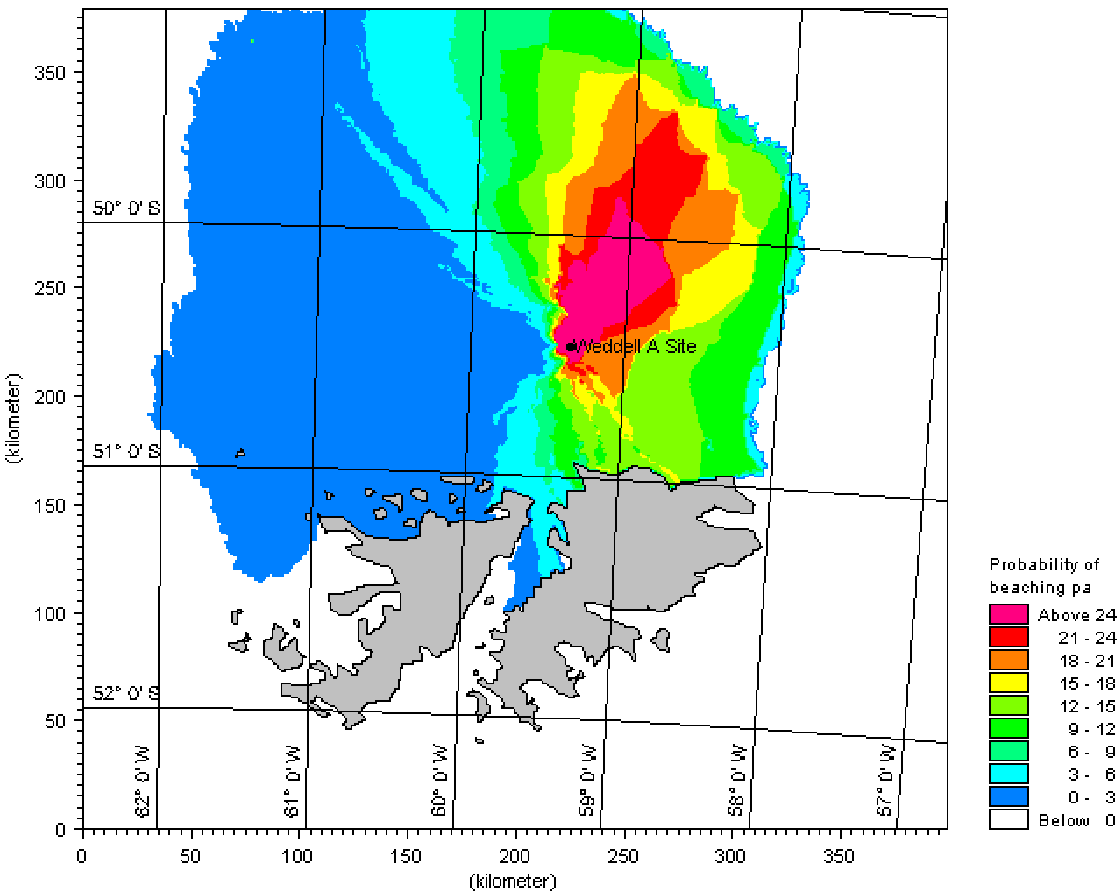

Figure 3: Probability of oil exposure during 8 day simulation following spill from site Weddell A with average annual wind climate

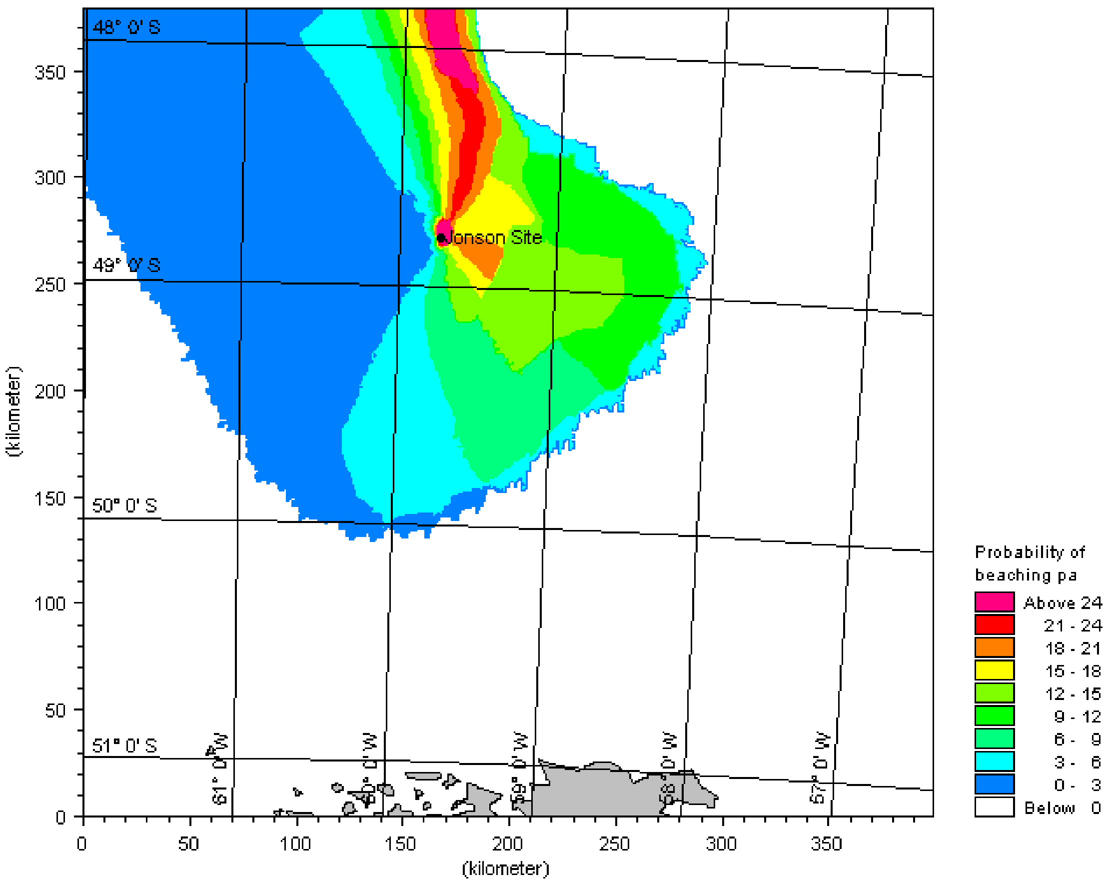

Figure 4: Probability of oil exposure during 8 day simulation following spill from site Johnson with average annual wind climate

Figure 1-4 provide details from the oil spill modelling for the two sites. Figure 1 and 2 show the oil spill scenario after release of oil over a 6 hour period on day one with continuous wind for the following 8 days from the NE sector. As is shown this will lead to an oil spill moving towards the Falkland Islands. Figure 1 shows the maximum oils slick thickness anticipated at any stage during and following the release, Figure 2 provide the exposure in hours. It can be seen that the oil slick is significantly affected by the current around northern part of the Falklands, which leads to a spreading of the oil. As can be seen there is a small chance of beaching under wind conditions with persistent wind from the northerly sector for the Weddell A location. However on day 8 the slick thickness has significantly reduced to less than 50 microns on average at which stage it is expected to have separated into individual slicks of variable size. For the Johnson Site any beaching of oil on the Falkland islands within an 8 day period is extremely unlikely.

Figure 3 and 4 provide the likelihood of exposure in the event of spillage. In essence the likelihood of exposure to oil in the event of spillage at the oil well site is for example less than 3% per annum in the areas marked in blue. The probabilities are based on average annual wind climate conditions based on 11 years of wind climate data, the above assumes that the wind would persist for at least 8 days within one 10° sector. It is found that Johnson is significantly influenced by the Falkland current, which follows the edge of the continental shelf.

Table 1 below provides an overview of the scenarios which would lead to beaching and an estimate of the total amount found ashore after 6 days of cessation of discharge.

Table 1: Total Oil Beached after 6 days (m^3)

Wind Direction	Weddell A
10º	4827.34
N	4390.02
350º	4740.72
340º	4751.65
330º	815.00
320º	0.00

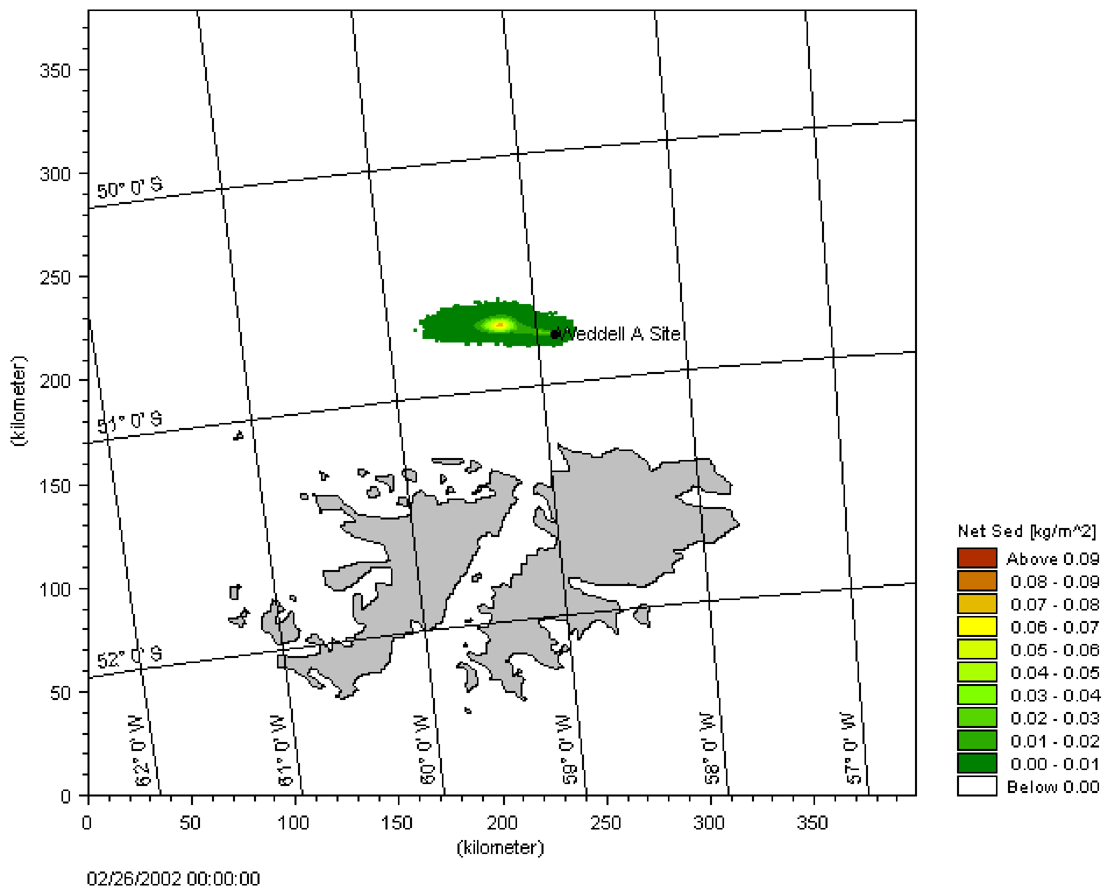

Figure 5: Drill cuttings sedimentation pattern after 21 days at Weddell A

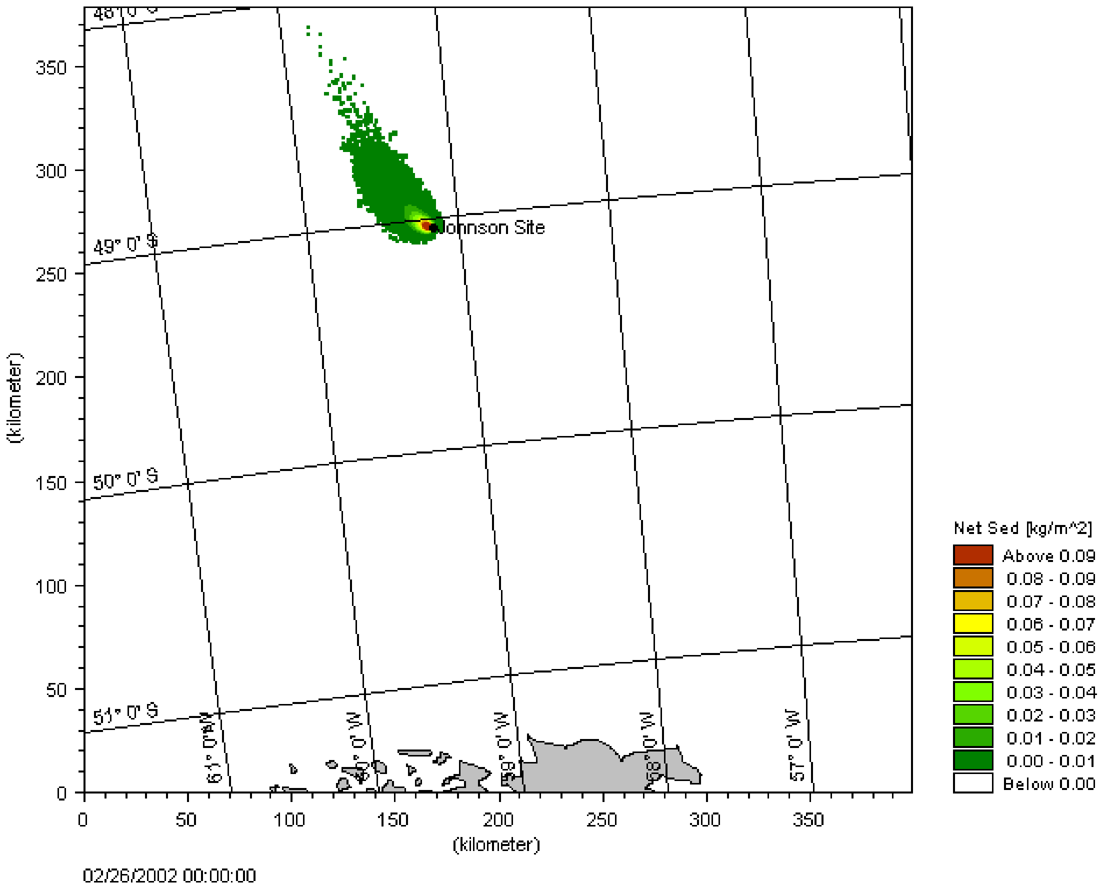

Figure 6: Drill cuttings sedimentation pattern after 21 days at Johnson Well

The drill cuttings simulations have been carried out in the same way as the simulations shown in the report published summer 2008, please use for reference and relevant text.

APPENDIX III BENTHIC ENVIRONMENTAL SURVEY

Desire Petroleum PLC

Rockhopper Exploration PLC

& Arcardia Petroleum Limited

REGIONAL BENTHIC ENVIRONMENTAL SURVEY OF THE SOUHERN NORTH FALKLANDS BASIN

Version 1 REPORT

Client: **Desire Petroleum PLC**
Rockhopper Exploration PLC
Arcadia Petroleum Ltd

Prepared by:

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Tel: +44 1603 783931 , Mobile Tel: +44 7786 361136
Direct Email: Info@benthicsolution.co.uk

Project Reference: BSL0803.1
Survey Dates: 28.08 to 02.09.2008
Date of Report: 09.02.2008

ABSTRACT

In August and September 2008, Desire Petroleum PLC, Rockhopper Exploration PLC and Arcadia Petroleum Limited commissioned Benthic Solutions Limited, to carry out a field environmental survey over a regional area of the southern North Falklands Basin, encapsulating seven prospect exploration well locations. This included analysis and interpretation of benthic sample data acquired during the field acquisition program. Field operations were undertaken by Benthic Solutions personnel from the South Georgian fisheries patrol vessel (*Pharos SG*) using a large double grab sampler. Benthic sampling was undertaken at a total of 77 stations relating to 7 well sites, 38 near-field stations and 32 regional stations. This document will review a combination of the central well locations and the regional sites to provide background coverage for the whole of the southern North Falklands Basin.

The objectives of this study were as follows:

- To analyse and interpret macrofaunal communities at all stations and provide a regional baseline and context from which to later compare well-specific surveys;

- To analyse and interpret physico-chemical samples at all stations and provide a regional baseline and context from which to later compare well-specific surveys;

- To utilise the above sediment and biological data to delineate potentially environmentally sensitive seabed features within the Prospect Area. In particular, the presence of sensitive habitats such as biogenic reefs (such as *Lophelia* and *Madrepora* corals) and cold water seep communities.

A detailed habitat assessment cannot be carried out without the provision of additional acoustic datasets. However the regional coverage of the data (sediments and biology) indicated a generally homogeneous sandy environment throughout the southern North Falklands Basin. Areas of habitat variability were limited to increased softer sediment in the deeper waters of the continental slope and patches of exposed glacial deposits in the central and south-eastern areas of the survey. Localised bedforms and small scale surface variability may occur in some areas. No species or habitats of conservational importance or considered to be sensitive were observed.

The benthic survey revealed that sediments were generally similar across the whole of the survey area, although small scale variations did occur due to changes in the proportion of fines, through increased sedimentation, gravels, through historical glacial deposits, or the sorting of the medium to fine Holocene sand veneer dominant throughout. Particle size analysis confirmed this variability to range from poorly sorted coarse silt at the deepest sample location to moderately or poorly sorted very fine or medium sand throughout the remainder of the survey area. The mean sediment size of fine sand reduced in size to very fine sand at the edge of the shelf break, or to coarse silt at the deepest station, due to increased deposition with water depth. In addition to the above, further multivariate analysis of the granulometry

also highlighted subtle changes in sand distribution in the southern most part of the survey area.

The macrofaunal analysis revealed a community expected for the Magellan faunal area. Whilst similar to that of the Northern Boreal Region, the fauna is characterised by a very high crustacean diversity, with the amphipod *Urothoe* sp dominant across all of the sampled sites. Univariate parameters indicated consistently moderate to high species richness, diversity and evenness throughout the region, similar or marginally greater than those previously recorded in the North Falklands Basin in 1998. Macrofaunal numbers indicated only weak patterns of geographical distribution across the area predominantly due to subtle sediment changes, although no clear community separations were recorded. Multivariate analyses, equally confirmed a relatively diverse faunal population with a high level of similarity across all stations. Minor variability within the population were generally separated by the presence or dominance of only a handful of key species, including the amphipod Phoxocephaloidea sp.C (eyeless),the polychaete species *Aricidea sp.A* or family cirratulidae. Three of the stations also varied slightly due to the high dominance of the ophiuroid echinoderm *Ophiura cf meridionalis* or the mollusc *Cryptodon falklandica.*

As no strong environmental gradients were recorded within the sediments, generally weak correlations occurred within the macrofaunal community and other environmental variables. The most dominant factors were mean sediment size, the proportion of finer sediments, water depth and total organic matter. Overall, however, there was insufficient variability within the habitats recorded to clearly separate out the biological communities recorded by the survey.

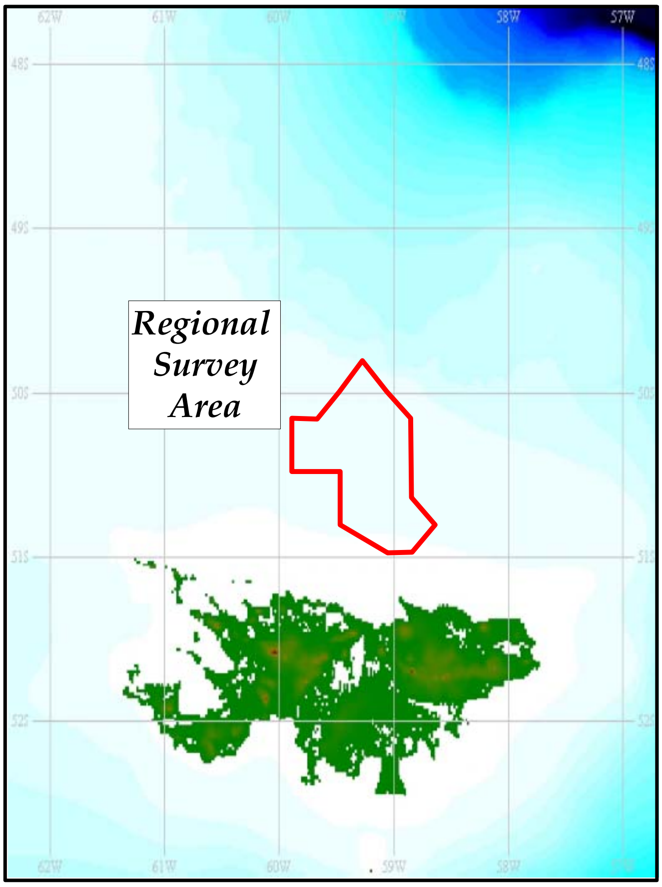
For this preliminary regional assessment the level of analysis has concentrated on the key separation of groups in order to identify trends within the biological community with that of the physical habitats. Further analysis of this material will continue as further data, acquired at individual well prospects, is evaluated and a more definitive species list produced.

Overall, no environmentally sensitive species or habitats considered to be of conservational value were recorded during the regional survey operations.

Chemical analysis, that of heavy & trace metals, organic carbon and sediment hydrocarbons (TPH, aliphatics and polycyclic aromatic hydrocarbons), all showed typically low to very low background concentrations expected for this water depth, sediment type and area. As with sediment particle parameters, the proportion of many parameters did indicate subtle patterns of distributions relative to the proportion of finer sediments or mean particle size. Generally speaking, slightly higher levels of most organic and metals parameters were associated with areas of increased fines, reduced sorting or lower mean particle size, although overall levels remained very low. These have been associated with seabed currents reworking the substrates and either winnowing of fines, or reduced deposition of finer sediments at these locations.

Neither macrofaunal nor physico-chemical analysis revealed any background contamination within the sediments analysed for this study.

LOCATION MAP



CONTENTS

ABSTRACT	**2**
LOCATION MAP	**5**
CONTENTS	**6**
LIST OF FIGURES	**7**
LIST OF TABLES	**8**
1. SCOPE OF WORK	**8**
1.1 Introduction	**8**
1.2 Benthic Survey Strategy	**9**
1.3 Survey Protocol	**10**
2. FIELD OPERATIONS	**12**
2.1 Benthic Environmental Sampling	**12**
2.2 Glossary of Abbreviations	**17**
2.3 Survey Geodesy	**17**
3. SAMPLE ANALYSES	**19**
3.1. Particle Size Distribution (Benthic Solutions Limited)	**19**
3.2. Total Carbon and Nitrogen (TES Bretby)	**22**
3.3. Hydrocarbons Concentrations (TPH & Aliphatics -TES Bretby)	**22**
3.3.1. General Precautions	22
3.3.2. Extraction Procedure for Hydrocarbons	23
3.3.3. Column fractionation for Aliphatic Fractions	23
3.3.4. Quality Control Samples	23
3.3.5. Hydrocarbon Analysis	23
3.3.6. Calibration and Calculation	24
3.4. Heavy & Trace Metal Concentrations (TES Bretby)	**24**
3.4.1. Sample Digestion Procedure	25
3.4.2. Analytical Methodology	26
3.5. Faunal Analysis	**26**
3.5.1. Data Standardisation and Analyses	27
3.6. Environmental Data Presentation using Contouring Software	**29**
3.7. Data Comparisons and Historical Datasets	**30**
4. DISCUSSION	**31**
4.1. Regional Bathymetry and sediment Types	**32**
4.2. Particle Size Distribution	**34**
4.3. Total Organic Matter, Organic Carbon, Carbonates and REDOX	**42**
4.4. Sediment Hydrocarbons	**48**
4.4.1. Total Petroleum Hydrocarbons	48
4.4.2. Saturate Alkanes	48
4.4.3. Polycyclic Aromatic Hydrocarbons	61
4.5. Heavy and Trace Metal Concentrations	**687**
4.6. Macrofaunal Analysis	**82**
4.6.1. Infaunal Trends	86
4.6.2. Univariate Parameters	89
4.6.3. Multivariate Analyses	96
4.6.4. Environmental Variables	101
4.6.5. Summary of Macrofaunal Results	101

4.9.6. Epifaunal Results 102

5. BIBLIOGRAPHY 103

APPENDIX I: PARTICLE SIZE DISTRIBUTION I

APPENDIX II: GC-FID TRACES (SATURATES) III

APPENDIX III: POLYCYLIC AROMATIC HYDROCARBONS IIIII

APPENDIX IV: SAMPLING LOG SHEETS IV

APPENDIX V: MACROFAUNAL SPECIES LISTS V

APPENDIX VI: SAMPLE PHOTOGRAPHS VI

APPENDIX VII: PEARSON'S MULTIVARIATE CORRELATIONS VII

APPENDIX IX: SERVICE WARRANTY IX

LIST OF FIGURES

Figure 2.1. Benthic Sample Locations
Figure 2.2. Survey Operations in the Southern North Falklands Basin
Figure 4.1. Regional Bathymetry of the survey area showing the location of historical survey sites and the current regional survey area
Figure 4.2. Sediment Concretion Recorded in 240m, Tranche F (Gardline 1998f)

Figure 4.3. Particle Size Analysis – Mean Particle Size (mm)
Figure 4.4. Particle Size Analysis – Mean Particle Size (Phi)
Figure 4.5. Particle Size Analysis – Percentage of Fines (<63µm)
Figure 4.6. Particle Size Analysis – Percentage of Coarse (>2mm)
Figure 4.7. Photograph of Coarse Gravels Recorded at Station G6
Figure 4.8. Dendrogram of Regional Sediment Similarity
Figure 4.9. Particle Size Distribution of Regional Sediment Similarities
Figure 4.10. Particle Size Analysis – Total Organic Matter (% LOI)
Figure 4.11. Particle Size Analysis – Total Organic Carbon
Figure 4.12. Particle Size Analysis – Total Carbonates
Figure 4.13. Hydrocarbons – Total Oils (TPH; ng/g)
Figure 4.14. Hydrocarbons – Total N-Alkanes (Saturates; ng/g)
Figure 4.15. Example Gas Chromatograms for Saturate Hydrocarbons Analysis for the Central and Northern Area of the Regional Survey (Stations G10 and G1)
Figure 4.16. Hydrocarbons – Carbon Preference Index (Saturates; ng/g)
Figure 4.17. Hydrocarbons – Petrgenic/Biogenic Ratio (nC_{10-20}/nC_{21-37})
Figure 4.18. Hydrocarbons – Total 2-6 Ring Polycyclic Aromatic Hydrocarbons
Figure 4.19. Heavy & Trace Metals – Total Barium (mg/kg)
Figure 4.20. Heavy & Trace Metals – Total Strontium (mg/kg)
Figure 4.21. Heavy & Trace Metals – Total Aluminium (mg/kg)
Figure 4.22. Heavy & Trace Metals – Total Chromium (mg/kg)
Figure 4.23. Heavy & Trace Metals – Total Copper (mg/kg)

Figure 4.24. Heavy & Trace Metals – Total Lead (mg/kg)
Figure 4.25. Heavy & Trace Metals – Total Nickel (mg/kg)
Figure 4.26. Heavy & Trace Metals – Total Vanadium (mg/kg)
Figure 4.27. Heavy & Trace Metals – Total Zinc (mg/kg)
Figure 4.28. Proportion of Individual Abundance by Main Group and Replicate
Figure 4.29. Proportion of Individual Abundance by Main Group and Station
Figure 4.30. The dominant polychaete Aricidea spA.
Figure 4.31. The larger of two species of *Serolis sp***.**
Figure 4.32. The dominant crustacean *Urothoe sp.*
Figure 4.33. The bivalve *Cuspideria sp.*
Figure 4.34. Macrofauna - Number of Individuals (Abundance per 0.2m^2)
Figure 4.35. Macrofauna - Number of Species (Richness per 0.2m^2)
Figure 4.36. Macrofauna – Shannon-Weiner Diversity (H(s))
Figure 4.37. Macrofauna – Simpson's Index
Figure 4.38. Dendrogram of Macrofaunal Replicates
Figure 4.39. Dendrogram of Macrofaunal Stations
Figure 4.40. MDS Ordination Plot by Station
Figure 4.41. Geographical Separation of Derived Biological Clusters

LIST OF TABLES

Table 1.1. Proposed Well Locations in the Southern North Falklands Basin
Table 1.2. Proposed Infield and Regional Sample Locations
Table 2.1. Chronological Sequence of Field Operations for the Regional Benthic Environmental Survey, Southern North Falklands Basin
Table 2.2. Actual Sampling Locations
Table 3.1. Phi & Sieve Apertures with Wentworth Classifications
Table 3.2. Sorting Classifications
Table 3.3. Skewness Classifications
Table 3.4. Kurtosis Classifications
Table 3.5. Heavy Metals - Mean Detection Limits (MDL)
Table 3.6. Summary of ICP Setup Parameters
Table 3.7. Element Selection Criteria using ICP
Table 3.8. Primary and Univariate Parameter Calculations
Table 3.9. Inference from MDS Stress Values
Table 3.10. Historical Datasets used for Comparison in the Block Area
Table 4.1. Summary of Surface Particle Size Distribution
Table 4.2. Summary of Moisture and Organic Compounds
Table 4.3. Summary Hydrocarbons Concentrations
Table 4.4. Total Aliphatic Concentrations
Table 4.5. Polycyclic Hydrocarons Concentartions
Table 4.6. Total Heavy & Trace Metal Concentrations
Table 4.7. Overall Species Ranking (Top 15 Species)
Table 4.8. Univariate Faunal Parameters (for 0.2m^2 station)
Table 4.9. SIMPER Resulst Showing the Top Five Characterising Species

1. SCOPE OF WORK

1.1. Introduction

Environmental survey data in and around the proposed licensing areas of PL23, 24, I and L are limited. Previous drilling activities in 1998 commissioned by the Falklands Operator Sharing Agreement (FOSA), in Tranches to the north of the current survey area underwent benthic assessments prior to drilling in order to increase the knowledge on benthic habitats. This site specific benthic survey work was carried out in conjunction with the acoustic site-survey activities undertaken at each site to assess shallow gas hazard potential. The strategy of the benthic survey works was to acquire a cruciform template of grab samples taken at 12 stations immediately surrounding each of the wells, orientated along the line of dominant current flow. Furthermore, 1 to 2 additional control stations were taken within a 5km proximity to the well covering in-field seabed variability between neighbouring well locations. A total of 7 wells and an additional 11 control sites were surveyed in total, with one of the wells (Amerada Hess "Little Blue A") revisited to assess post drill effects from the drilling related discharges. All survey data were acquired using a 0.1m^2 Day grab, and later processed for their macro-invertebrate populations (from two replicates), or a standard suite of physico-chemical parameters. All analytical analysis was carried out in the United Kingdom.

The geophysical surveys indicated the presence of a number of trench and trough features produced from iceberg keel scars during the last glaciation. However, the number and severity of these scars reduced in shallower waters and all but disappeared in water depths less than 250m. The benthic sampling undertaken at each of the 7 wells indicated that each site indicated a predominantly homogeneous seabed, dominated by a surface drape from pelagic sedimentation. Whilst the sediment type may have altered slightly from well to well, localised biological communities remained relatively consistent.

By combining the datasets acquired at each of the individual well sites and the infield control locations, the sample results were shown to exhibit a general trend with decreasing water depth. Whilst the deeper sites in 400-500m showed a sandy silt and a small proportion of glacial gravels, sites sampled in the shallower waters (ca. 250m) indicated a more consistent fine sands with notably lower silts and almost no gravels. Both the macro-invertebrate populations and the chemical concentrations recorded reflected these sediment changes. Overall, the biological diversity of the sediments was relatively high, falling into the range previously recorded for this biogeographic region dominated by the nutrient rich waters of the Falklands Current (Bastida *et al.*, 1992). Nevertheless, no unusual or protected habitats were recorded.

One of the historical well sites (Amerada Hess "Little Blue A") was re-surveyed to assess the impacts from drilling related discharges at the site (i.e. water based muds and cuttings). The survey concluded that there was no faunistic evidence to suggest that the area was polluted. Whilst most physico-chemical sediment parameters had increased slightly since drilling, these did not fall outside the range indicative of uncontaminated sediments for the area. The report concluded that drilling activity had had little if any impact on the fauna at the site.

An earlier study by Bastida *et al* (1992), surveying benthic macro-invertebrate assemblages over the wider continental shelf, found the sediments between 49ºS to 55ºS to be quite variable. A further, small qualitative epifaunal trawl survey undertaken in 1994 by the Falkland Islands Fisheries Department at the shelf break (203-232 m) north of the current area, also suggested a degree of spatial heterogeneity of sediment and a greater diversity in the benthic habitat in shallower waters to the south of the main current. Consequently, it is difficult to predict the patchiness or variation in sediments within the proposed prospects area. Given the trend seen in the earlier 1998 studies, however, the sediment types are likely to be sandy and lack significant fines.

1.2. Benthic Survey Strategy

There are six (6) proposed well prospects (7 locations) requiring benthic survey data in 2008. These are summarised in Table 1.1 below.

Table 1.1. Proposed Well Locations in the Southern North Falklands Basin Program

Operator	Well Name	Latitude*	Longitude*	Easting**	Northing**
Desire	Alpha	-59.16474722	-50.27475000	559518	4430487
	Barbara	-59.11369167	-50.68093333	562617	4385281
	Dawn	-59.14657500	-50.04726667	561102	4455765
	Ruth	-58.96326111	-50.46968611	573573	4408632
Rockhopper	Ernest	-50.30480702	-58.94369236	575222	4426945
	Weddell A	-50.78791283	-58.87842083	579058	4373160
	Weddell B	-50.77597275	-58.87126010	579583	4374480

**** WGS84 Spheroid and Datum***
*** The projection used for grid was UTM zone 21 , 60° West.*

Earlier benthic surveys by Gardline Environmental on behalf of the Falklands Operators Sharing Agreement (FOSA), were based upon a generic cruciform template system routinely used offshore for the Oil & Gas Industry in the North Sea at the time. A review of the 1998 surveys showed that most of the survey areas indicated homogeneous localised habitats with consistent sediment and biological parameters, although inter-field variations were recorded in the physico-chemistry and associated biological communities with decreasing depth and proximity to the shelf break. The geophysical datasets, also acquired at the time, showed consistent and relatively benign survey areas dominated by sedimentation, with the greater variance exhibited in the deeper waters where historical glacial activities had created some sediment changes through iceberg keel scarring and patches of gravel deposits. No sensitive habitats, or features of conservational importance were recorded (i.e. cold water corals, geological or biogenic reefs, or gas escape features with authigenic structures).

For the current development, several survey strategies were considered including a repeated site specific template (as per FOSA 1998 works) for each of the 6 wells and a multi-disciplinary survey approach using an intelligent sampling and ground truthing of detailed acoustic assessments. However, given the number of wells and the separation of these sites over what is thought to be a relatively homogenous seabed area, a benthic program of both near field and a regional grid combined to provide both site-specific information but a regional context, was selected as the most pragmatic and appropriate strategy for this survey.

1.3. Survey Protocol

As little is known of the regional sediment variations within the proposed development area north of the Falklands, the scope of work was based on a pragmatic approach with sites based on either a medium or large scale grid, in support of a few localised well-specific stations. Overall, the number of samples acquired and processed was 77 as follows (Table 1.2):

- Three near-field stations for each prospects, at the proposed well centre and 250m up and down current (NW-SE) of the centre to cover a maximum dispersion areas for drill cuttings;
- A further four medium grid samples at a 1.5km radius (NE, NW, SE, SW), to cover a possible anchor pattern area and/or to allow for some movement for the well position.
- Where two alternative well locations were likely (Weddell), near-field locations were combined and expanded to cover the two potential well stations, 250m downstream, and 6 medium grid samples completely enclosing the prospect area.
- Thirty two regional stations positioned at approximately 15km spacing interlinking the 6 proposed prospect areas and covering the remainder of the surrounding blocks;

For each locations a total of four (4) $0.1m^2$ sample replicates were acquired and processed for the following determinants.

- Sediment characteristics (photograph and description)
- Oxidative Reductive Potential (ORP or REDOX potential)
- Triplicate macrofaunal samples processed over 500µm using a *Wilson* Autosiever. Two of the three replicates processed in the laboratory.
- Full Particle size distribution;
- Total organic matter, Total organic carbon and carbonates;
- Total petroleum hydrocarbons (TPH) by GC-FID;
- Saturate hydrocarbons (nC_{10} – nC_{35}) by GC-FID;
- Polycyclic aromatic hydrocarbons (2-6 ring & alkyl derivatives);
- Heavy & trace metals (double acid digest Aqua Regia and HF for Ba, Cd, Cr, As, Cu, Ni, Zn, V, Pb, Al, Fe and Hg).

All analysis was carried out to a high standard so as to be comparable with earlier datasets in the Falklands, and that of similar studies in the Northeast Atlantic and the North Sea.

Table 1.2. ***Proposed Infield and Regional Sample Locations***

Name	Easting	Northing	Latitude	Longitude
Alpha	559518	4430487	-50.27475	-59.16475
A1	559341	4430664	-50.27318	-59.16726
A2	559695	4430310	-50.27632	-59.16223
A3	558457	4431548	-50.26531	-59.17980
A4	560579	4431548	-50.26510	-59.15003
A5	560579	4429426	-50.28418	-59.14969
A6	558457	4429426	-50.28440	-59.17947
Barbara	562623	4385590	-50.67815	-59.11366
B1	562446	4385767	-50.67658	-59.11619
B2	562800	4385413	-50.67973	-59.11112
B3	561562	4386651	-50.66873	-59.12885
B4	563684	4386651	-50.66850	-59.09883
B5	563684	4384529	-50.68758	-59.09846
B6	561562	4384529	-50.68781	-59.12850
Dawn	561102	4455765	-50.04727	-59.14658
D1	560925	4455942	-50.04569	-59.14908
D2	561279	4455588	-50.04884	-59.14408
D3	560041	4456826	-50.03783	-59.16156
D4	562163	4456826	-50.03762	-59.13193
D5	562163	4454704	-50.05670	-59.13159
D6	560041	4454704	-50.05692	-59.16123
Ruth	573573	4408632	-50.46969	-58.96326
R1	573396	4408809	-50.46812	-58.96579
R2	573750	4408455	-50.47125	-58.96073
R3	572512	4409693	-50.46028	-58.97841
R4	574634	4409693	-50.46001	-58.94853
R5	574634	4407571	-50.47909	-58.94810
R6	572512	4407571	-50.47935	-58.97800
Ernest	575222	4426945	-50.30481	-58.94369
E1	575045	4427122	-50.30324	-58.94621
E2	575399	4426768	-50.30637	-58.94117
E3	574161	4428006	-50.29540	-58.95879
E4	576283	4428006	-50.29513	-58.92901
E5	576283	4425884	-50.31421	-58.92859
E6	574161	4425884	-50.31448	-58.95838
Wedell A	579058	4373160	-50.78791	-58.87842
Wedell B	579583	4374480	-50.77597	-58.87126
W1	578881	4373337	-50.78635	-58.88097
W2	577997	4374221	-50.77852	-58.89370

Name	Easting	Northing	Latitude	Longitude
W3	580119	4372099	-50.79731	-58.86314
W4	577997	4372099	-50.79760	-58.89324
W5	579406	4374657	-50.77441	-58.87381
W6	578522	4375541	-50.76658	-58.88653
W7	580644	4375541	-50.76629	-58.85645
W8	580644	4373419	-50.78537	-58.85598
G1	556753	4482600	-49.80637	-59.21127
G2	543000	4461197	-50.00000	-59.40000
G3	542851	4442666	-50.16667	-59.40000
G4	542702	4424135	-50.33333	-59.40000
G5	542552	4405603	-50.50000	-59.40000
G6	542403	4387070	-50.66667	-59.40000
G7	542252	4368537	-50.83333	-59.40000
G8	557333	4461063	-50.00000	-59.20000
G9	557135	4442532	-50.16667	-59.20000
G10	556936	4424001	-50.33333	-59.20000
G11	556736	4405469	-50.50000	-59.20000
G12	556537	4386937	-50.66667	-59.20000
G13	556336	4368404	-50.83333	-59.20000
G14	571666	4460890	-50.00000	-59.00000
G15	571418	4442360	-50.16667	-59.00000
G16	571170	4423829	-50.33333	-59.00000
G17	570920	4405297	-50.50000	-59.00000
G18	570670	4386765	-50.66667	-59.00000
G19	570420	4368232	-50.83333	-59.00000
G20	570169	4349699	-51.00000	-59.00000
G21	585702	4442149	-50.16667	-58.80000
G22	585403	4423618	-50.33333	-58.80000
G23	585104	4405087	-50.50000	-58.80000
G24	584804	4386555	-50.66667	-58.80000
G25	584504	4368023	-50.83333	-58.80000
G26	584202	4349490	-51.00000	-58.80000
G27	598587	4367775	-50.83333	-58.60000
G28	528568	4442762	-50.16667	-59.60000
G29	514284	4442819	-50.16667	-59.80000
G30	514234	4424288	-50.33333	-59.80000
G31	528368	4405698	-50.50000	-59.60000
G32	514184	4405756	-50.50000	-59.80000

Geographical Locations in decimal degrees (WGS84 Spheroid and Datum)
Grid Locations in metres (projection was UTM zone 21 , 60° West).
Well specific locations (outlined in separate reports) are in grey

2. FIELD OPERATIONS

The field environmental survey was undertaken by Benthic Solutions Limited from the South Georgian fisheries patrol vessel *Pharos SG*. The field acquisition was based upon a benthic sampling campaign over a regional area on the northern edge of the Falkland Continental Shelf, located in an area known as Southern North Falklands Basin. The timings for the mobilisation, field survey and demobilisation are summarised in table 2.1.

Table 2.1 Chronological Sequence of Field Operations for the Regional Benthic Environmental Survey, Southern North Falklands Basin

Dates	Activity	Data acquired for this report
21-22.08.2008	Travel	Personnel travel to the Falklands
23-27.08.2008	Standby	Awaiting RAF to ship in survey equipment
28.08.2008	Mobilisation, transit and Sampling	Benthic Samples 2 x Regional Sites
29.08.2008	Sampling	Benthic sampling 7 x Alpha Sites Benthic sampling 7 x Dawn Sites Benthic sampling 6 x Regional Sites
30.08.2008	Sampling and standby for weather	Benthic sampling 7 x Ruth Sites Benthic sampling 7 x Ernest Sites Benthic sampling 7 x Barbara Sites Benthic sampling 2 x regional Sites
31.08.2008	Standby, minor winch problems, then sampling	Benthic sampling 8 x Weddell Sites
01.09.2008	Sampling	Benthic sampling 2 x Weddell Sites Benthic sampling 14 x Regional Sites
02.09.2008	Sampling, transit and demobilisation	Benthic sampling 6 x Regional Sites
02-04.09.2008	Standby	Awaiting RAF flight back to the UK
05-06.09.2008	Travel	Personnel and samples travel back to the UK

2.1 Benthic Environmental Sampling

Benthic samples were acquired using a unique double Van Veen grab sampler designed and built by Benthic Solutions Limited. This devise has two samplers in a single frame and acquires a seabed sample area of 2 x 0.1m^2 on each deployment. Pre-deployment procedures included the cleaning of the inner stainless grab buckets, cable and blocks so that they were generally grease-free. A record of the samplers touch down at deployment depth was monitored by means of cable observations during a drop in tension. Samples were subject to quality control on retrieval and were retained in the following circumstances:

- Water above sample is undisturbed;
- Bucket closure complete allowing no sediment washout;
- Penetration of the grab was sufficient to maintain a seal at the base;
- Sampler was retrieved perfectly upright and has not fouled in any way;
- Sampler access doors had closed properly enclosing the sample;
- No disruption of the sample through striking the side of the vessel;
- Sample was taken within the acceptable target range;
- The sample was acceptable to the principle scientist.

On retrieval, the whole sample was inspected, described and photographed prior to processing. A total of three $0.1m^2$ replicates, were processed onboard using a *Wilson* Auto-siever over a 500µm aperture mesh. Key observations from samples were colour, sediment classification, layering (including RDLs), smell (including the presence of H_2S), obvious fauna and evidence of bioturbation and evidence of anthropogenic debris (e.g. drill cuttings etc., figure 2.2). The remaining sample ($0.1m^2$) was sub-sampled for the following parameters:

- 2 x Surface 1cm scrape for Hydrocarbon analysis (one spare);
- 2 x Surface 1cm sectioned from core tube for heavy & trace metals (one spare);
- 2 x surface 1cm for PSA , TOM & TOC.

All sampling operations were logged both on the deck and within the survey shack were the positioning of the deployment crane was being monitored. All sample containers were labelled with a clear unambiguous information which describes the Well, location, and replicate type.

The preservations of materials were undertaken using standard techniques. All physico-chemical samples were stored in appropriate containers (i.e. glass for hydrocarbons, and plastics for metals and PSA) and immediately frozen and stored (< $-18^{o}C$) for later transportation (frozen) to the laboratory on demobilisation. Faunal samples were fixed and stained in 5% buffered formalin and the vital stain (Rose Bengal) for storage and transportation. This material was later transferred to IMS. All biological samples were double-labelled, with internal tags. On samples that retained minor amounts of clays a small amount of additional di-sodium hexametaphosphate was included within the fixative onboard to induce clay separation during storage.

Sample positions are given in Table 2.1, and plotted in Figure 2.1. Photographs from the field sampling operations are given in figure 2.2 and from the samples in Appendix VI.

Table 2.1 *Actual Sampling Locations*

Sample No.:	Water Depth (m)	Fix #	All Dec* Latitude (S)	All Dec* Longitude (W)	Attempts	Chem	BIO
Regional Locations							
Regional G1	285	63	-49.806267	-59.211700	2	YES	YES
Regional G2	168	159	-50.000083	-59.399850	2	YES	YES
Regional G3	162	158	-50.166825	-59.399717	2	YES	YES
Regional G4	158	155	-50.333392	-59.399792	2	YES	YES
Regional G5	155	172	-50.500017	-59.399617	2	YES	YES
Regional G6	154	178	-50.666733	-59.399967	2	YES	YES
Regional G7	145	181	-50.832950	-59.400042	2	YES	YES
Regional G8	170	59	-50.000125	-59.200650	3	YES	YES
Regional G9	160	39	-50.166650	-59.199317	3	YES	YES
Regional G10	154	19	-50.332717	-59.199867	2	YES	YES
Regional G11	155	173	-50.499958	-59.199875	2	YES	YES
Regional G12	148	177	-50.666683	-59.199925	3	YES	YES
Regional G13	148	182	-50.833117	-59.199442	2	YES	YES
Regional G14	168	64	-50.000033	-58.999500	2	YES	YES
Regional G15	155	67	-50.167058	-59.000042	2	YES	YES
Regional G16	153	91	-50.333175	-58.983400	3	YES	YES
Regional G17	152	111	-50.499950	-59.000167	2	YES	YES
Regional G18	152	13	-50.666175	-58.999442	3	YES	YES
Regional G19	145	187	-50.833333	-58.999883	2	YES	YES
Regional G20	140	185	-51.000250	-58.999417	3	YES	YES
Regional G21	155	84	-50.166983	-58.800567	2	YES	YES
Regional G22	150	88	-50.333208	-58.799800	3	YES	YES
Regional G23	148	152	-50.499933	-58.799858	3	YES	YES
Regional G24	145	151	-50.666633	-58.799942	2	YES	YES
Regional G25	150	189	-50.833283	-58.799767	2	YES	YES
Regional G26	140	12	-50.999783	-58.800200	2	YES	YES
Regional G27	147	193	-50.833375	-58.600108	3	YES	YES
Regional G28	162	162	-50.166742	-59.599708	2	YES	YES
Regional G29	160	163	-50.166617	-59.799850	2	YES	YES
Regional G30	152	166	-50.332825	-59.799650	3	YES	YES
Regional G31	155	170	-50.499625	-59.600483	2	YES	YES
Regional G32	158	167	-50.499892	-59.799908	2	YES	YES
Alpha 0	155	35	-50.274533	-59.164225	2	YES	YES
Barbara 0	150	121	-50.677725	-59.114042	2	YES	YES
Dawn 0	165	48	-50.047250	-59.146892	4	YES	YES
Ernest 0	153	75	-50.304750	-58.943725	2	YES	YES
Ruth 0	150	103	-50.469517	-58.963383	4	YES	YES
Weddell A	150	142	-50.787725	-58.878183	2	YES	YES
Weddell B	150	136	-50.775600	-58.871258	2	YES	YES

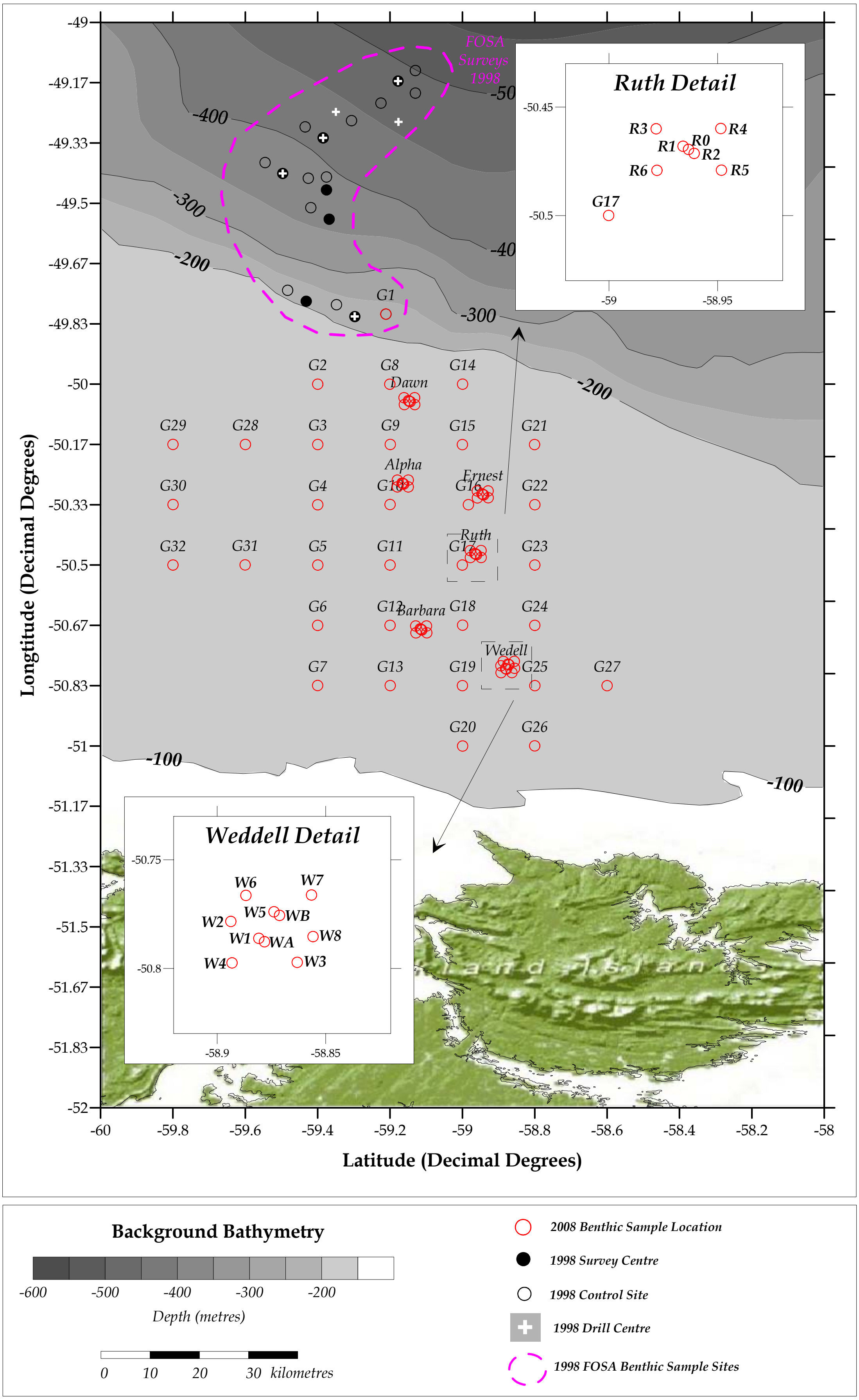
Where Chem = Surface particle size analysis, total organic carbon, carbonates, total organic matter heavy & trace metals, and sediment hydrocarbons. Bio = 3 x 0.1m^2 Macrofaunal replicates sieved above 500µm.
** = WGS84, Datum were WGS84.*

Table 2.1 cont. *Actual Sampling Locations*

Station	Water Depth	Fix #	All Dec * Latitude (S)	All Dec *Longitude (W)	Attempts	Chem	BIO
Potential Well Locations							
Alpha 1	155	29	-50.273483	-59.166667	3	YES	YES
Alpha 2	155	25	-50.276242	-59.162142	2	YES	YES
Alpha 3	157	30	-50.265217	-59.179667	3	YES	YES
Alpha 4	156	33	-50.265150	-59.149600	2	YES	YES
Alpha 5	155	24	-50.284058	-59.149600	2	YES	YES
Alpha 6	155	22	-50.284000	-59.179633	3	YES	YES
Barbara 1	149	119	-50.676242	-59.116642	2	YES	YES
Barbara 2	150	122	-50.679600	-59.112008	2	YES	YES
Barbara 3	150	116	-50.668483	-59.129042	3	YES	YES
Barbara 4	153	113	-50.668458	-59.099233	2	YES	YES
Barbara 5	149	125	-50.687217	-59.098400	3	YES	YES
Barbara 6	147	128	-50.687425	-59.128392	2	YES	YES
Dawn 1	165	52	-50.045425	-59.149050	2	YES	YES
Dawn 2	165	46	-50.048425	-59.144017	4	YES	YES
Dawn 3	167	55	-50.037558	-59.161350	2	YES	YES
Dawn 4	167	58	-50.037517	-59.132158	3	YES	YES
Dawn 5	165	42	-50.056508	-59.131683	2	YES	YES
Dawn 6	160	41	-50.056442	-59.160358	2	YES	YES
Ernest 1	153	73	-50.303092	-58.946092	2	YES	YES
Ernest 2	155	76	-50.306300	-58.941158	2	YES	YES
Ernest 3	151	70	-50.295183	-58.958925	2	YES	YES
Ernest 4	155	68	-50.295175	-58.928917	2	YES	YES
Ernest 5	155	80	-50.314008	-58.928658	4	YES	YES
Ernest 6	152	82	-50.314392	-58.958492	2	YES	YES
Ruth 1	150	104	-50.468067	-58.965917	3	YES	YES
Ruth 2	150	99	-50.471367	-58.960783	2	YES	YES
Ruth 3	150	93	-50.460033	-58.978292	2	YES	YES
Ruth 4	150	110	-50.459908	-58.948508	4	YES	YES
Ruth 5	150	97	-50.479108	-58.948208	2	YES	YES
Ruth 6	150	95	-50.479175	-58.977917	2	YES	YES
Weddell 1	150	139	-50.786167	-58.880800	2	YES	YES
Weddell 2	151	138	-50.778383	-58.893683	2	YES	YES
Weddell 3	153	147	-50.797225	-58.863100	3	YES	YES
Weddell 4	150	149	-50.797467	-58.893125	2	YES	YES
Weddell 5	150	135	-50.773933	-58.873808	2	YES	YES
Weddell 6	150	130	-50.766375	-58.886742	2	YES	YES
Weddell 7	150	133	-50.766200	-58.856525	3	YES	YES
Weddell 8	150	144	-50.785350	-58.855825	2	YES	YES

Where Chem = Surface particle size analysis, total organic carbon, carbonates, total organic matter heavy & trace metals, and sediment hydrocarbons. Bio = 3 x 0.1m² Macrofaunal replicates sieved above 500µm.
** = WGS84, Datum were WGS84.*

Figure 2.1. ***Benthic Sample Locations***



2.2. Glossary of Abbreviations

BSL	Benthic Solutions Limited	ORP	Oxidative Reductive Potential
CPI	Carbon Preference Index	OSPAR	Oslo and Paris Commission
dw	Dry Weight	PAH	Polycyclic Aromatic Hydrocarbons
GC	Gas Chromatography	PPB	Parts Per Billion
GC-FID	Gas Chromatography - Flame Ionisation Detection	PPM	Parts Per Million
ICP-MS	Inductively Coupled Plasma Mass Spectrometry	PRIMER	Plymouth Routines in Multivariate Ecological Research
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry	REDOX	Reductive Oxidative Potential
IMS	Industrial Methylated Spirit	RDL	Redox Discontinuity Layer
LAT	Lowest Astronomical Tide	SD	Standard Deviation
LOI	Loss on Ignition	TOC	Total Organic Carbon
GC-MS	Gas Chromatography Mass Spectrometry	TOM	Total Organic Matter
mg/kg	milligrams per kilogram or PPM	TPH	Total Petroleum Hydrocarbons
MSL	Mean Sea Level	UCM	Unresolved Complex Mixture
ng/g	nanograms per gram or PPB	UKOOA	United Kingdom Offshore Operators Association
nMDS	Non-Metric Multidimensional Scaling	µg.g-1	micrograms per gram or PPM
NPD	Naphalene, Phenanthrene, Anthracene and Dibenziothene	WAS	Wilson Auto-Siever

2.3. Survey Geodesy

The geodetic parameters used were as follows: -

Spheroid	:	WGS 84
Datum	:	WGS 84

Figure 2.2 Survey Operations at the Proposed Fiachra Well (Eire 11/20-A)

(A) Deployment of the unique Benthic Solutions Double Grab (0.2m). Personnel all wear safety lines. (B) Benthic samples were processed by Wilson Autosiever over 500µm. (C) Decapods *Peltarion spinosulum* found in one sample. (D) Example grab samples taken at Regional Station G1. (E) Sieved G1 inset. (F) Sub-sampling from the recovered grab. (G) Two species of Isopod *Serolis sp* were recorded overall.

3. SAMPLE ANALYSES

The recovered benthic samples were sorted and correctly stored prior to demobilisation and transportation of the material to the correct laboratory. All physico-chemical samples were immediately frozen on recovery and hand–carried back to the UK, to be returned to a laboratory freezer within 48hours. This material was analysed at the following laboratories with all remaining material held at Benthic Solutions for back-up:

- Benthic Solutions Limited: Particle size & macrofaunal analysis.
- TES Bretby: Chemical analysis

A summary of the analytical methodologies applied for this study are as follows:

3.1. Particle Size Distribution (Benthic Solutions Limited)

The samples recovered from each site were analysed by Benthic Solutions Limited. The complete sub-sample was dried and passed through stainless steel sieves with mesh apertures of 8000, 4000, 2000µm with a nesting receiver. In most cases almost the entire sample would pass through the sieve stack, but any material retained on the sieve, such as small shells and shell fragments and stones were removed, weighed and recorded.

The sediment particle size distributions below 2000µm were determined using a Malvern Mastersizer 2000 particle sizer according to Standard Operating Procedures (SOP). The results obtained by a sizer have been previously validated by comparison with independent assessment by wet sieving (Hart, 1996). The range of sieve sizes, together with their Wentworth classifications, is given in Table 3.1.

The separate assessments of the fractions above and below 2000µm were combined using a computer programme. This followed a manual input of the dry sieve results for fractions 16-8mm, 8-4mm and 4-2mm and sub-2mm fractions and the electronic data captured by the Mastersizer below 2000µm.

This method defines the particle size distributions in terms of phi mean, fraction percentages (i.e. coarse sediments, sands and fines), sorting (mixture of sediment sizes) and skewness (weighting of sediment fractions above and below the mean sediment size; Folk 1954).

Graphic Mean (M) - a very valuable measure of average particle size in phi units (Folk & Ward, 1957).

$$M = \frac{\text{ø}16 + \text{ø}50 + \text{ø}84}{3}$$

where *M = The graphic mean particle size in phi*
ø = the phi size of the 16th, 50th and 84th percentile of the sample

Table 3.1 *Phi and Sieve Apertures with Wentworth Classifications*

<table>
<tr><th>Aperture in microns</th><th>Aperture in Phi Unit</th><th colspan="2">Sediment Description</th></tr>
<tr><td>2000</td><td>-1</td><td>Granule</td><td rowspan="3">Gravel</td></tr>
<tr><td>1400</td><td>-0.5</td><td rowspan="2">Very Coarse Sand</td></tr>
<tr><td>1000</td><td>0</td></tr>
<tr><td>710</td><td>0.5</td><td rowspan="2">Coarse Sand</td><td rowspan="8">Sands</td></tr>
<tr><td>500</td><td>1</td></tr>
<tr><td>355</td><td>1.5</td><td rowspan="2">Medium Sand</td></tr>
<tr><td>250</td><td>2</td></tr>
<tr><td>180</td><td>2.5</td><td rowspan="2">Fine Sand</td></tr>
<tr><td>125</td><td>3</td></tr>
<tr><td>90</td><td>3.5</td><td rowspan="2">Very Fine Sand</td></tr>
<tr><td>63</td><td>4</td></tr>
<tr><td>44</td><td>4.5</td><td rowspan="2">Coarse Silt</td><td rowspan="8">Fines (Silts)</td></tr>
<tr><td>31.5</td><td>5</td></tr>
<tr><td>22</td><td>5.5</td><td rowspan="2">Medium Silt</td></tr>
<tr><td>15.6</td><td>6</td></tr>
<tr><td>11</td><td>6.5</td><td rowspan="2">Fine Silt</td></tr>
<tr><td>7.8</td><td>7</td></tr>
<tr><td>5.5</td><td>7.5</td><td rowspan="2">Very Fine Silt</td></tr>
<tr><td>3.9</td><td>8</td></tr>
<tr><td>2</td><td>9</td><td rowspan="2">Clay</td><td rowspan="2">Fines (Clays)</td></tr>
<tr><td>1</td><td>10</td></tr>
</table>

Sorting (D) – the inclusive graphic standard deviation of the sample is a measure of the degree of sorting (Table 3.2).

$$D = \frac{\text{ø}84 + \text{ø}16}{4} + \frac{\text{ø}95 + \text{ø}5}{6.6}$$

where *D = the inclusive graphic standard deviation*
ø = the phi size of the 84th, 16th, 95th and 5th percentile of the sample

Table 3.2 ***Sorting Classifications***

Sorting Coefficient (Graphical Standard Deviation)	Sorting Classifications
0.00 < 0.35	Very well sorted
0.35 < 0.50	Well sorted
0.50 < 0.71	Moderately well sorted
0.71 < 1.00	Moderately sorted
1.00 < 2.00	Poorly sorted
2.00 < 4.00	Very poorly sorted
4.00 +	Extremely poorly sorted

Skewness (S) – the degree of asymmetry of a frequency or cumulative curve (Table 3.3).

$$S = \frac{\o 84 + \o 16 - (\o 50)}{2(\o 84 - \o 16)} + \frac{\o 95 + \o 5 - 2(\o 50)}{2(\o 95 - \o 5)}$$

where *S = the skewness of the sample*
ø = the phi size of the 84th, 16th, 50th, 95th and 5th percentile of the sample

Table 3.3 ***Skewness Classifications***

Skewness Coefficient	Mathematical Skewness	Graphical Skewness
+1.00 > +0.30	Strongly positive	Strongly coarse skewed
+0.30 > +0.10	Positive	Coarse skewed
+0.10 > -0.10	Near symmetrical	Symmetrical
-0.10 > -0.30	Negative	Fine skewed
-0.30 > -1.00	Strongly negative	Strongly fine skewed

Graphic Kurtosis (K) – The degree of peakedness or departure from the 'normal' frequency or cumulative curve (Table 3.4).

$$S = \frac{\o 95 - \o 5}{2.44(\o 75 - \o 25)}$$

where *K = Kurtosis*
ø = the phi size of the 95th, 5th, 75th and 25th percentile of the sample

Table 3.4 *Kurtosis Classifications*

Kurtosis Coefficient	Kurtosis Classification	Graphical meaning
0.41 < 0.67	Very Platykurtic	Flat-peaked; the ends are better sorted than the centre
0.67 < 0.90	Platykurtic	
0.90 < 1.10	Mesokurtic	Normal; bell shaped curve
1.11 < 1.50	Leptokurtic	Curves are excessively peaked; the centre is better sorted than the ends.
1.50 < 3.00	Very Leptokurtic	
3.00 +	Extremely Leptokurtic	

3.2. Total Carbon and Nitrogen (TES Bretby)

The sample is dried at approximately 40°C (on a hot plate first, if required) in a vacuum oven, then ground with a pestle and mortar avoiding contamination. An Agate set was available for small sample sizes. The sample should then pass through a 150µm sieve and 1g of sample was added to a pre-weighed 100ml beaker (weighed to at least 3 decimal places, preferably 5).

A known mass of the sample burnt in oxygen. The combustion gases are passed over suitable reagents to assure complete oxidation and removal of undesirable by-products such as sulphur, phosphorus and halogen gases. The oxides of nitrogen are converted to molecular nitrogen and residual oxygen is removed in the reduction tube. The concentrations of carbon dioxide, water vapour and nitrogen gas are measured by thermal conductivity cells. The instrument uses the concentration of these gases together with the sample weight to give a direct readout of the percentages of carbon, hydrogen and nitrogen.

3.3. Hydrocarbon Concentrations (Total Petroleum Hydrocarbons and Aliphatics - TES Bretby)

This method details the solvent extraction of sediment samples to quantify the toluene equivalent organic contaminants present and to prepare samples for further analysis by Gas Chromatography (GC) and GC-Mass Spectroscopy (GC-MS).

3.3.1. General Precautions

High purity solvents, free from PAH contamination, were selected for use. Solvent purity was checked by evaporating an appropriate volume down to 1ml and analysing by GC for general hydrocarbons, and specifically the target n-alkanes and aromatics. All glassware and extraction sundries were cleaned prior to use by thorough rinsing with hydrocarbon-free deionised water followed by two rinses with methylene chloride.

3.3.2. Extraction Procedure for Hydrocarbons

Approximately 200g of wet sample was homogenised and air dried at room temperature. 30±0.1g of air dried sample was spiked with a surrogate standard solution containing the following components: aliphatics - heptamethylnonane, 1 chlorooctadecane and squalane; aromatics - naphthalene-d8, anthracene-d10 and pyrene-d10; and soxhlet extracted using methylene chloride/acetone (90:10) for 12 hours. Copper powder was added to the boiler flask to remove elemental sulphur.

3.3.3. Column fractionation for Aliphatic Fractions

The 1ml aliquot was solvent exchanged into 1ml of cyclohexane and then transferred to a flash chromatography column containing approximately 10g of silica gel (Aldrich Grade 923 100-200 mesh activated overnight at 200°C). The aliphatic compounds were eluted with 25ml of n-pentane reduced down to 1ml using the TurboVap.

3.3.4. Quality Control Samples

The following quality control samples were prepared with the batches of sediment samples:

i A method blank comprising 30±0.1g of baked anhydrous sodium sulphate treated as a sample.

ii A blank spike consisting of 30g baked sodium sulphate spiked with 5µl of PAH EPA16 (100µg/ml) and 10µl of Florida mix (50µg/ml) and treated as a sample.

iii A sample duplicate - any one sample from the job, dependent upon available sample mass, to perform in duplicate.

iv A solvent blank prepared by taking: sediments = 200ml of 90:10 HPLC DCM / acetone and reducing to 2ml final volume.

3.3.5. Hydrocarbon Analysis

Analysis of total hydrocarbon and n-alkanes was performed by gas chromatography flame ionisation detection (GC-FID). The instrument and operating conditions employed are given below.

Instrument	HP6890 dual flame ionisation detectors
Column (capillary for both methods)	RH-5 MS 30m, 0.32mm ID, 0.25µm film thickness
Carrier Gas	Hydrogen (constant flow 6 ml/min)
Injector	HP6890 auto-injector, splitless injection
Temperature Program	45°C initial hold for 2 minutes. 45-300°C @ 10°C/min hold for 4 minutes @ 300°C. 300-325°C at 20°C/min with final hold for 4 minutes @ 325°C.
Detector (FID) / Source (MS) temperature	50°C (FID)

3.3.6. Calibration and Calculation

This method relies upon the quantification of target analytes relative to surrogate internal standards. This means that the response of any target analyte is compared to the response obtained for the internal standard that in practice will have been recovered from the matrix at <100%. The analytical data are therefore corrected for recovery. The concentrations of target analytes were calculated by comparison to the nearest eluting internal standard. For n-alkanes the response relative to the internal standard was assumed to be 1.

The mean detection limits used for the sediment total hydrocarbons and n-alkanes were:

- n-alkanes 1ng.g^{-1} (ppb)
- Total Hydrocarbon 1µg.g^{-1} (ppm)

3.4. Heavy & Trace Metal Concentrations (TES Bretby)

Sediment samples were homogenised and a 50g portion was air dried at room temperature. Each sample was then ground down to a fine powder (<100µm) by hand using a mortar and pestle. A clean blank sand sample was hand ground prior to preparation of the field samples to identify the presence of any trace metals in the system.

3.4.1. Sample Digestion Procedure

Easily Leachable (Aqua Regia) Extraction.

Approximately 1g of the sediment was accurately weighed out and transferred to a beaker and wet with approximately 20ml of distilled water. Hydrochloric acid (6ml) and nitric acid (2ml or each) were added and the covered sample left to digest for 4 hours in a steam bath.

After digestion, the sample was filtered through a Whatman 542 filter paper into a 100ml standard flask. The watch glass and beaker were rinsed thoroughly, transferring the washings to the filter paper. The filter paper was rinsed until the volume was approximately 90ml. The filter paper and acid insoluble residue was allowed to air dry for 48 hours, before being mixed to prevent removal of the surface layer of filter paper and a 0.2g aliquot removed for the Hydrofluoric (HF) extraction, below. The filtrate was then analysed by inductively coupled plasma optical emission spectrometry (ICPOES) and inductively coupled plasma – mass spectrometry (ICP-MS). The mean detection limits are given in Table 3.5.

Hydrofluoric (HF)/Boric Acid Extraction.

The 0.2g aliquot of the acid residue, remaining after the Aqua Regia digestion, was accurately weighed out and placed in a PTFE bottle. Hydrofluoric (HF) acid (2.5ml) was added and the bottle placed in an oven at 105±5°C for approximately 30 minutes. The bottle was then allowed to air cool and 60ml of 4% boric acid added. The contents were mixed thoroughly and placed in a polypropylene flask and made up to 100ml. The sample was then analysed by ICPOES. The mean detection limits are given in Table 3.5.

Table 3.5 ***Heavy Metals - Mean Detection Limits (MDL)***

Analyte	Unit	MDL	
		AR	HF
Ni	$\mu g.g^{-1}$	1	0.5
V	$\mu g.g^{-1}$	1	2
Al	$\mu g.g^{-1}$	10	4
Zn	$\mu g.g^{-1}$	5	3
Fe	$\mu g.g^{-1}$	5	6
Cu	$\mu g.g^{-1}$	1	0.5
Ba	$\mu g.g^{-1}$	5	1
Cr	$\mu g.g^{-1}$	1	0.5
As	$\mu g.g^{-1}$	1	0.5
Cd	$\mu g.g^{-1}$	1	0.1
Pb	$\mu g.g^{-1}$	1	0.5
Sr		10	3
Hg	$\mu g.g^{-1}$	0.01	0.1

ICPMS ICPOES

3.4.2. Analytical Methodology

Table 3.6. Summary of ICP Setup Parameters

ICP Settings	Optical Emission Spectrometry (ICPOES)	Mass Spectrometry (ICP-MS)
RF Power	650W	1300W
RF Matching	-	2V
Sample Depth	-	6.5mm
Carrier Gas	Ar 30 psi	1.28 l/min
Plasma Gas	Ar 34 psi	-
Coolant Gas	Ar 25 psi	-
Calibration	1ml = 10mg spectroscopic solutions dilution matrix matched with the appropriate acid(s) and an initial 5 point calibration performed at the emission wavelengths shown below.	1 ml = 10mg spectroscopic solution dilution. Seven standards at the atomic masses shown below. Direct comparison to the internal standard scandium (45), yttrium (89) and terbium (159).

ICP Instrument Performance was set up as per Table 3.6 for the two analytical techniques. Individual element selection was based upon Table 3.7.

Table 3.7. Element Selection Criteria using ICP

Element	ICPOES (nano metre)	ICP-MS (atomic mass)
As	189.04	75
Ba	233.53	-
Cd	226.50	111
Cr	267.72	52
Pb	220.35	208
Hg	-	80
Ni	231.60	60
V	290.88	51
Zn	213.86	66

3.5. Faunal Analysis

All macrofaunal determination was carried out using laboratories operated by Benthic Solutions Limited (previously DRM Associates). The senior taxonomist was involved with previous macrofaunal identification undertaken for the FOSA surveys in 1998, and the Fisheries Inshore EIA in 2000. Benthic sediment samples were thoroughly washed with freshwater on a 500µm sieve to remove traces of formalin, placed in gridded, white trays and then hand sorted by eye followed by binocular microscope to remove all fauna. Sorted organisms were preserved in 70% Industrial Methylated Spirit (IMS) and 5% glycerol. Where possible, all organisms were identified to species level according appropriate keys for the region. This includes specialist patagonian material obtained from German cruises carried out in the 1970's. Colonial and encrusting organisms were recorded by presence alone and where colonies could be identified as a single example these were also recorded, although these data have been removed from the analyses of the material. The presence of anthropogenic components were also recorded where relevant.

Benthic Solutions is committed to total quality control from the start of a project to its completion. All samples taken or received by the company were given a unique identification number. All analytical methods were carried out according to recognised standards for marine analyses. All taxonomic staff are fully qualified to post-doctorate level. Documentation is maintained that indicates the stage of analysis that each sample has reached. A full reference collection of all specimens has been retained for further clarification of putative species groups where/if required. BSL is a participant in the NMBAQC quality assurance scheme.

Digital datasets are kept for all sites in the form of excel spreadsheets (by sample and by station) on BSL's archive computer. This system is duplicated onto a second archive drive in case of electronic failure. These data will be stored in this way for a minimum of 3 years, or transferred to storage disk (data CD or DVD).

All taxa were distinguished to species level and identified to at least family level where possible, although as little is known of about the area, many of the species were separated putatively. Whilst some of the groups were only partially separated in this document, ongoing analysis with further site-specific well sites will increase our knowledge of the area and a more definitive faunal matrix will be provided at a later point in time. Nomenclature for species names were allocated either when identity was confirmed, allocated as "cf." when apparently identifying to a known species but confirmation was not possible (for example, incomplete specimens or descriptions), or allocated as "aff." when close to but distinct from a described species. The terms "indet." refers to being unable to identify to a lower taxon and "juv" as a juvenile to that species, genus or family. Species lists for 39 stations (78 samples (2 replicates per station)), together with univariate parameters for both sample replicates and stations, are given within Appendix V.

3.5.1 Data Standardisation and Analyses

In accordance to OSPAR Commission (2004) guidelines, all species falling into juvenile, colonial, planktonic of meiofaunal taxa are excluded from the full analyses within the dataset (this is discussed further within the text of section 4.6). This helps to reduce the variability of data undertaken during different periods within the year, or where minor changes may occur or where some groups may only be included in a non-quantitative fashion, such as presence/absence. Certain taxa, such as the Nematodes, normally associated with meiofauna, were included where individuals greater than 10mm were recorded. The following primary and univariate parameters were calculated for each all data by stations and sample (Table 3.8).

Table 3.8. ***Primary and Univariate Parameter Calculations***

Variable	Parameter	Formula	Description
Total Species	S	Number of species recorded	Species richness
Total Individuals	N	Number of individuals recorded	Sample abundance
Shannon-Weiner Index	H(s)	$H(s) = -\sum_{i=1}^{s} (Pi)(\log_2 Pi)$ where s = number of species & Pi = proportion of total sample belonging to *i*th species.	Diversity: using both richness and equitability, recorded in log 2.
Simpsons Dominance	1-Lambda	$Lambda = \sum \left(\frac{ni(ni-1)}{N(N-1)} \right)$ where ni = number of individuals in the *i*th species & N = total number of individuals	Evenness, related to dominance of most common species (simpson 1949)
Pielou's Equitability	J	$J = \frac{H(s)}{(\log S)}$ where s = number of species & H(s) = Shannon-Weiner diversity index.	Evenness or distribution between species (Pielou, 1969)
Margalefs Richness	D_{Mg}	$D_{Mg} = \frac{(S-1)}{(\log N)}$ where s = number of species & N = number of individuals.	Richness derived from number of species and total number of individuals (Clifford & Stevenson, 1975)

In addition to univariate methods of analysis, data for both sample replicates and stations were analysed using multivariate techniques. These serve to reduce complex species-site data to a form that is visually interpretable. A multivariate analyses was based on transformed data (double square root) to detect any improved relationships when effects of dominance were reduced. The basis for multivariate analyses was based upon the software PRIMER (Plymouth Routines In Multivariate Ecological Research).

Similarity Matrices and Hierarchical Agglomerative Clustering

A similarity matrix is used to compare every individual sample replicate and/or stations with each other. The coefficient used in this process is based upon Bray Curtis (Bray & Curtis, 1957), considered to be the most suitable for community data. These are subsequently assigned into groups of replicates and/or stations according to their level of similarity and clustered together based upon a Group Average Method into a dendrogram of similarity.

Non-Metric Multidimensional Scaling (MDS): MDS is currently widely used in the analysis of spatial and temporal change in benthic communities (e.g. Warwick & Clarke, 1991). The recorded observations from data were exposed to computation of triangular matrices of similarities between all pairs of samples. The similarity of every pair of sites was computed using the Bray-Curtis index on transformed data. Clustering was by a hierarchical agglomerative method using group average sorting, and the results are presented as a dendrogram and as a two-dimensional ordination plot. The degree of distortion involved in producing an ordination gives an indication of the adequacy of the nMDS representation and is recorded as a stress value as outline in Table 3.9.

Table 3.9. Inference from MDS Stress Values

nMDS Stress	Adequacy of Representation for Two-Dimensional Plot
≤0.05	Excellent representation with no prospect of misinterpretation.
>0.05 to 0.1	Good ordination with no real prospect of a misleading interpretation.
>0.1 to 0.2	Potentially useful 2-d plot, though for values at the upper end of this range too much reliance should not be placed on plot detail; superimposition of clusters should be undertaken to verify conclusions.
>0.2 to 0.3	Ordination should be treated with scepticism. Clusters may be superimposed to verify conclusions, but ordinations with stress values >2.5 should be discarded. A 3-d ordination may be more appropriate.
>0.3	Ordination is unreliable with points close to being arbitrarily placed in the 2-d plot. A 3-d ordination should be examined.

SIMPER: the MDS clustering program is used to analyse differences between sites. SIMPER enables those species responsible for differences to be identified by examining the contribution of individual species to the similarity measure. As all sites grouped within a single cluster, this program was subsequently not used.

3.6. Environmental Data Presentation using Contouring Software

To aid in the interpretation and presentation of the environmental information acquired for this report, both hydrographic and environmental variables were processed using contouring and 3D surface mapping software (Surfer v8). This software allows a digital terrain model (DTM), or grid, to be interpolated from irregularly spaced geographical information (XYZ data). When large quantities of data are used (such as in swathe bathymetry), the level of interpolation is limited only to small spaces in between the data points. However, when processing environmental variables only 39 stations were sampled and analysed during the benthic survey. In this instance a diagrammatic circle of a 0.04 decimal degrees diameter has been used to colour illustrate the parameter level at each relevant site. It should be remembered that this is done for presentation purposes only and that these data values are "not representative" for the whole of the geographical area covered by the circle.

3.7. Data Comparisons and Historical Datasets

During the interpretation, data comparisons have been made to previous survey data from the Falkland Operators Sharing Agreement (FOSA) and survey carried in 1998 in the North Falklands basin. Sources used in this comparison are outlined below in Table 3.10:

Table 3.10. Historical Datasets used for Comparison in the Survey Area

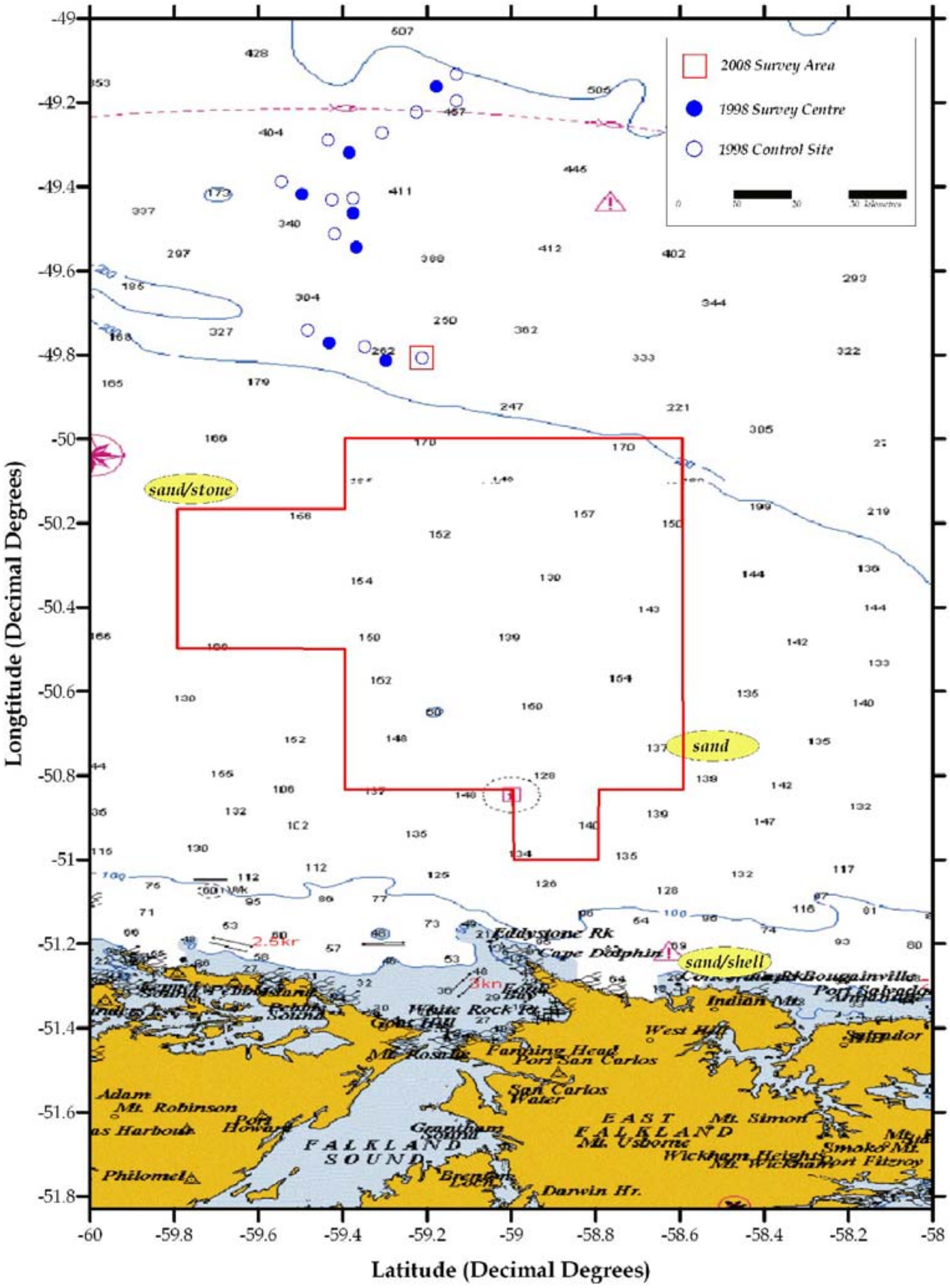
Source and Year	Contractor	Region and Comment
AFEN 1996-2000	NOC	Northeast Atlantic from 100-2000 metres water depth. Three cruises.
Gardline 1998a-h	Gardline	A total of 7 baselne surveys and 1 repeated post-drill survey at sites in the North Falklands Basin

Other referenced data will be based on standard North Sea and Northeast Atlantic levels as published by mean and 95th percentile values for background sediments (UKOOA, 2001).

4. DISCUSSION

A summary of the regional conditions is given below. This is taken from a general review of the marine environment north of the Falklands, and in particular the area at the edge of the Falklands Plateau and the southern flank of the North Falklands Basin which was subject to previous survey activities during the 1998 drilling campaign (Gardline 1998a-h and Fugro 1998). These data were further supplemented by observations acquired during the current sampling campaign and the processing of 2D seismic lines for water depths at 4 of the proposed 6 survey prospects (RPS, 2008).

Figure 4.1. Regional Bathymetry of the survey area showing the location of historical survey sites and the current regional survey area



4.1. Regional Bathymetry and Sediment Types

The Falkland Islands are situated on an area known as the Falklands Plateau, separated to the north from the Argentine Basin by the Falklands Escarpment. The general bathymetry of the North Falkland Basin indicates a gently sloping gradient with contours oriented along a northwest-southeast direction (Figure 4.1). The proposed survey area lies on the northern edge of the Falklands Plateau, close to the shallow shelf break dropping into the North Falklands Basin. Whilst the gradient of the seabed is expected to be very gradual within the survey area, localised small-scale bathymetric features such as hummocks, channels and low level bedforms might be encountered within the area. Furthermore, area that indicated coarser sediment deposits may also exhibit some minor relief associated with these features.

Observations made during the previous geophysical and environmental surveys to the north of the current area (Tranches A, B, C and F) indicated water depths ranging from 220 to 500m. Detailed multibeam acquisition indicated the presence of numerous poorly preserved iceberg keel scars showing homogeneous sediment infill. Other complex topographic features observed were a series of depressions (generally with a maximum depth of up to 4m) and an east-west trending trough or channels of unknown origin; commonly up to 1.5km wide and up to 210km in length. Furthermore, a number of hard sonar contacts were also identified, although the absence of any notable relief suggested that these were patches of glacial debris, such as glacial gravels and partially buried boulders.

The Falklands Plateau is characterised by a layer of fine to medium sand, which may be up to 2m thick (Bastida et al, 1992). Some areas are known to have a high percentage of gravel comprising either small pebbles or bioclasts with both gravels and sedimentary concretions recorded in the earlier baseline surveys in the North Falklands Basin (Figure 4.2, Gardline 1998f). The prevalence of hard-bottom areas is not accurately known due to the difficulties in sampling. Although originally reported to be scarce, it is believed these areas may have been under reported (Bastida et al, 1992 and Munro, 2004).

Figure 4.2.

Sediment Concretion Recorded in 240m, Tranche F (Gardline 1998f)

Historical benthic sampling programs have been undertaken on a regional scale throughout the Argentine continental shelf (i.e. FFS *Walter Herwig* cruise in 1978) including the seas around the Falkland Islands (Bastida *et al*, 1992). However, the methods and aims of such projects have sometimes been very limited. The latter study showed the sediment to be quite variable with a high percentage of bioclasts and in general a small percentage of carbonates between 49ºS to 55ºS. A later qualitative study of the shelf break (203-232 m) looked at the larger epifauna using Rockhopper trawl (Falkland Islands Fisheries Department 1994). This indicated a degree of spatial heterogeneity within both sediment and community type for this area, showing biological characteristics from both soft and hard grounds during the survey.

Detailed benthic sampling in this region has been limited to a number of benthic baseline surveys carried out by Gardline Surveys in 1998. Undertaken in Tranches A, B, C, D and F, a total of 332 samples were obtained at 7 locations from water depths ranging from 220 to 500m. Whilst all sites were deeper than that of the current prospect area, changes in sediment type gave a good indication of changing sediment dynamics progressively upslope towards the North Falklands Plateau; the site of the current study. Furthermore, the fine sandy sediments and occasional concretion encountered at the shallowest of the 1998 sites in 220m (Tranche F) was expected to be indicative of some sediments across the continental shelf. For continuity, one of the 1998 reference sites was repeated during the current sampling campaign. Previous data from the 1998 studies will be used periodically throughout this report for comparative purposes.

In addition to the benthic communities, an appreciation of the habitats recorded on the Falklands Plateau is also important, in particular those that may be considered to be of conservational importance. Legislation into the protection of certain marine habitats has altered dramatically in recent years and now constitutes a very central aspect to any environmental assessment for offshore developments. The previous acoustic and benthic sampling activities in the North Falklands Basin did not identify any sensitive habitats, although their presence cannot be entirely ruled out for the region. Habitats of environmental importance that might be encountered in Falkland Island waters are as follows:

- Coldwater seep communities often associated with active pock marks (escaping gases and fluids);
- Chemosynthetic structures associated with methane derived authigenic carbonates with active gas seeps;
- Biogenic reefs associated with coldwater corals (*Lophelia* and *Madrepora*), octocorals, demosponges, mollusc beds (*Modiolus*) or polychaete concretions (*Sabelleria);*
- Rocky reefs (seamounts and volcanic outcrops) which may have an affect on current circulation and provide a hard substrate in an otherwise soft sediment environment.

Evidence from previous acoustic surveying have failed to identified any of the above features although a prevalence of infilled iceberg keel scars, often linked with pockets of shallow gas and the existence of pock marks, was recorded in the deeper waters off the plateau. The seafloor was also shown to have significant pitting, although further sonar interpretation did not highlight pock mark activity as an area of concern.

4.2 Particle Size Distribution

Analytical results of all the processed samples, along with observations made within the field indicated that the seabed within the regional survey area showed only slight variability in sediment distributions relative to location on the Falklands Plateau. Overall mean particle sizes varied from poorly sorted coarse silt at the deepest sample locations (ca. 285m, station G1) to moderately or poorly sorted very fine or medium sand throughout the remainder of the survey area (Figure 4.3). The distribution of mean sediment size of fine sand remained relatively constant over the central part of the survey area (156µm, SD 44µm), but reduced in size to very fine sand (<113µm) at stations G8, G14 and Dawn at the edge of the shelf break. This is expected to be a natural decrease in sediment particle size with increasing water depth from 153m in the central area to ~285m at the deepest station (G1). A logarithmic scale of the median particle size (i.e. that of the central size, Figure 4.4), further reflects this subtle reduction in particle size towards the shelf edge and down slope. Here, median sediments also ranged from fine sand in the central area, falling through very fine sands on the shelf edge to coarse silt at the deeper G1 station.

By separating out the proportion of fine sediments (i.e. depositional sediments of silts and clays below 63µm; Figure 4.5), the data showed that the reasons for the fall in sediment size is only partially due to an increase in the proportion of fines. The overall proportion of sediment fines varied from 7.3 to 25.4% over the main area (mean 17.5%, SD 6.6%), and 50.5% at station G1 down slope. The latter is indicative of increased hemi-pelagic sedimentation with depth.

The proportion of coarser sediments (i.e. that of gravels above 2mm ; Figure 4.6) was quite variable remaining unrecorded at 7 out of the 39 regional sites, and recording a maximum of 10.8% at stations G30. Proportionally, the area revealed a rather mixed distribution of coarser sediments, although these sampled data only partially reflects the nature of the seabed due to the existence of some material not included in the analytical process due to size. Fine gravels and occasional pebbles were recorded at a number of the stations, but these coarser sediments were often covered by a veneer of mobile Holocene sands or constituted oversized gravel components too large for sub-sampling and subsequent analysis. Consequently, the analytical effort on a small surface samples did always reflect the presence or absence of gravels from a regional location. An example of this is stations G6 (pictured in Figure 4.7). Here there was a clear presence of large gravel components (pebbles and possible a cobble) yet the analysis of the surface sediments showed only a minor gravel component of 0.36% in the sample. Ultimately, particle size analysis of the coarser fractions will only take into account the finer gravel components with a bias away from coarser mixed sediments at some stations. Field observations and photographs of the samples (Appendix VI) showed that this may have occurred on stations G1, G6, G11 and Ruth within the regional program.

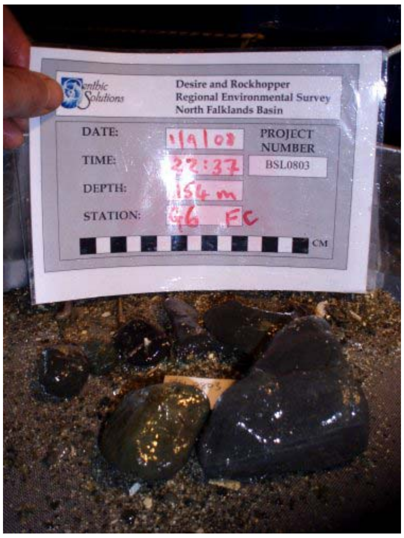
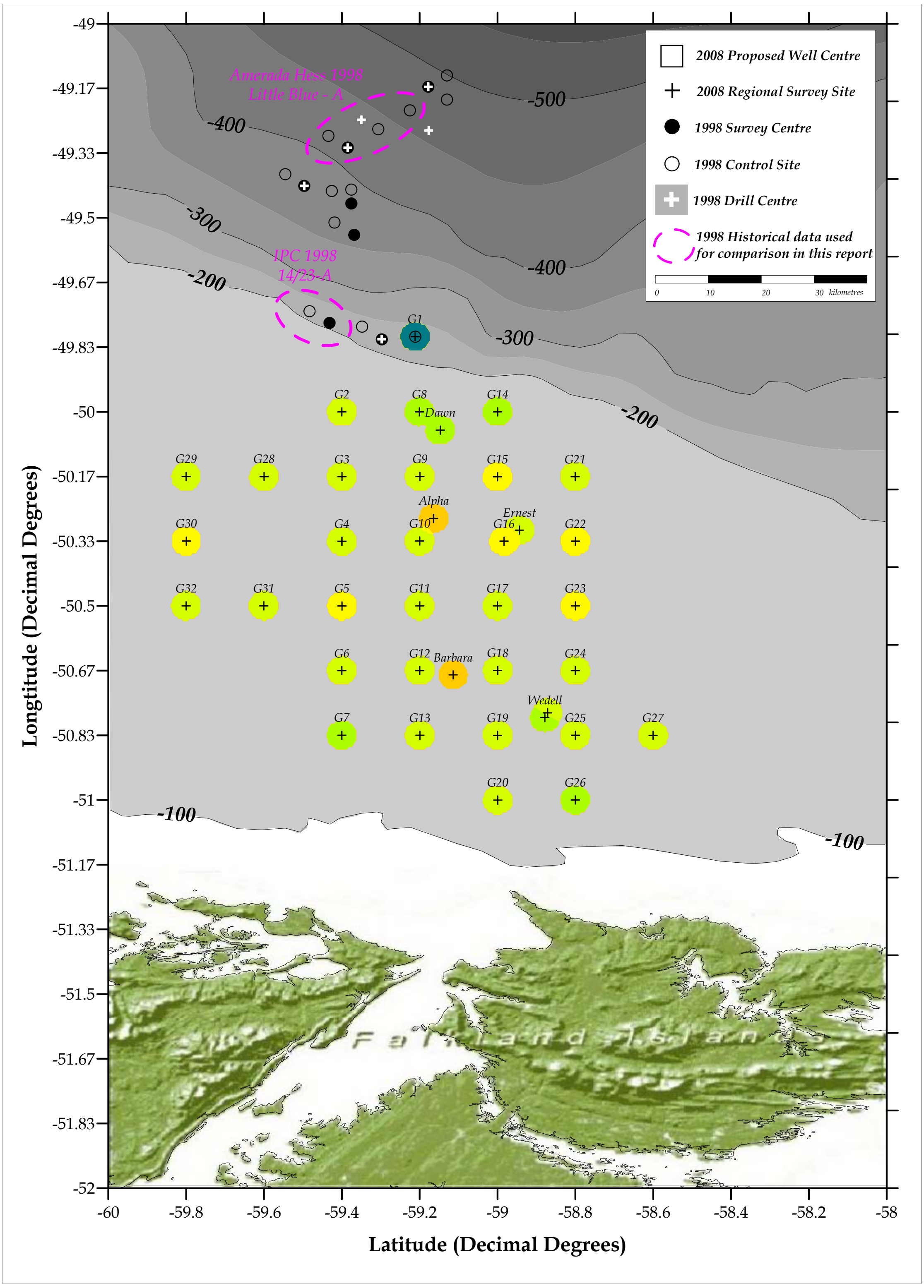


Figure 4.7 Photograph of Coarse Gravels Recorded at Station G6

Table 4.1. *Summary of Surface Particle Size Distribution*

Station	Mean Size		Sorting	Skewness	Kurtosis	% Fines	% Sands	% Gravel
	µm	Phi						
Regional G1	42.4	4.56	1.70	0.48	0.97	50.5%	49.5%	0.0%
Regional G2	128.5	2.96	1.30	-0.02	1.14	19.0%	80.8%	0.2%
Regional G3	133.3	2.91	1.28	0.26	1.30	17.5%	82.4%	0.1%
Regional G4	136.1	2.88	1.27	0.16	1.59	14.5%	85.0%	0.5%
Regional G5	193.8	2.37	1.40	0.34	1.57	13.3%	85.9%	0.8%
Regional G6	140.0	2.84	1.40	0.38	1.52	17.2%	82.4%	0.4%
Regional G7	123.2	3.02	1.42	0.28	1.45	19.2%	79.9%	0.9%
Regional G8	99.1	3.33	1.10	0.17	1.55	21.2%	78.7%	0.1%
Regional G9	157.0	2.67	1.30	0.25	1.07	15.7%	84.1%	0.2%
Regional G10	157.7	2.66	1.35	0.36	1.38	15.7%	84.0%	0.3%
Regional G11	172.6	2.53	1.88	0.08	1.79	16.4%	78.1%	5.5%
Regional G12	173.6	2.53	1.73	0.43	1.21	18.8%	79.3%	1.8%
Regional G13	139.0	2.85	1.41	0.17	1.50	16.4%	82.7%	0.9%
Regional G14	113.0	3.15	1.10	0.13	1.45	17.3%	82.7%	0.0%
Regional G15	195.8	2.35	1.32	0.30	1.04	12.9%	86.0%	1.1%
Regional G16	199.3	2.33	1.52	0.36	1.20	14.6%	84.5%	0.9%
Regional G17	163.7	2.61	1.40	0.42	1.56	15.6%	84.2%	0.3%
Regional G18	154.2	2.70	1.74	0.31	1.41	18.6%	78.2%	3.2%
Regional G19	151.0	2.73	1.75	0.14	1.19	19.6%	79.6%	0.9%
Regional G20	127.6	2.97	0.98	0.23	1.86	9.0%	90.6%	0.4%
Regional G21	168.8	2.57	1.45	0.18	1.04	15.7%	84.0%	0.3%
Regional G22	195.6	2.35	1.59	0.41	1.08	16.2%	83.2%	0.6%
Regional G23	181.0	2.47	1.53	0.41	1.29	16.1%	83.6%	0.3%
Regional G24	176.4	2.50	1.48	0.42	1.36	15.7%	84.1%	0.1%
Regional G25	143.0	2.81	2.13	-0.05	1.83	20.5%	71.1%	8.5%
Regional G26	117.3	3.09	0.90	0.32	1.97	9.5%	90.5%	0.0%
Regional G27	146.4	2.77	1.29	0.22	1.46	13.9%	86.1%	0.0%
Regional G28	144.5	2.79	1.34	0.16	1.27	16.3%	83.4%	0.4%
Regional G29	142.1	2.82	1.59	0.25	1.17	20.6%	78.9%	0.6%
Regional G30	182.1	2.46	2.73	0.12	1.08	25.4%	63.8%	10.8%
Regional G31	170.3	2.55	1.61	0.47	1.40	17.9%	82.1%	0.0%
Regional G32	141.7	2.82	1.66	0.46	1.21	21.1%	78.8%	0.1%
Alpha 0	277.5	1.85	1.17	0.19	1.54	7.3%	90.1%	2.6%
Barbara 0	296.1	1.76	1.04	0.31	1.73	7.7%	92.0%	0.3%
Dawn 0	98.7	3.34	1.08	0.12	1.54	21.2%	78.8%	0.0%
Ernest 0	178.9	2.48	1.49	0.36	1.21	15.8%	84.0%	0.2%
Ruth 0	194.5	2.36	1.48	0.41	1.43	14.7%	85.2%	0.1%
Weddell A	116.4	3.10	1.47	0.42	1.48	19.8%	80.2%	0.0%
Weddell B	132.3	2.92	1.55	0.25	1.38	19.6%	79.1%	1.3%
Survey Mean	**156.5**	**2.74**	**1.46**	**0.27**	**1.39**	**17.4%**	**81.5%**	**1.1%**
Survey St Dev	**44.5**	**0.45**	**0.33**	**0.13**	**0.24**	**6.6%**	**7.3%**	**2.3%**
Gardline 1998d mean	**84.0**	**3.58**	**1.18**	**0.26**	**1.64**	**26.2%**	**73.8%**	**0.0%**
Gardline 1998a Mean	**35.2**	**4.84**	**2.09**	**0.15**	**1.15**	**66.9%**	**32.2%**	**0.9%**

Figure 4.3. Particle Size Analysis – Mean Particle Size (mm)



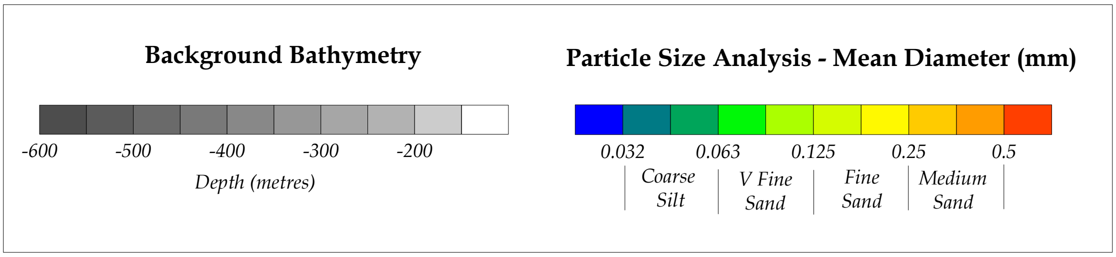


Figure 4.4. Particle Size Analysis – Median Particle Size (Phi)

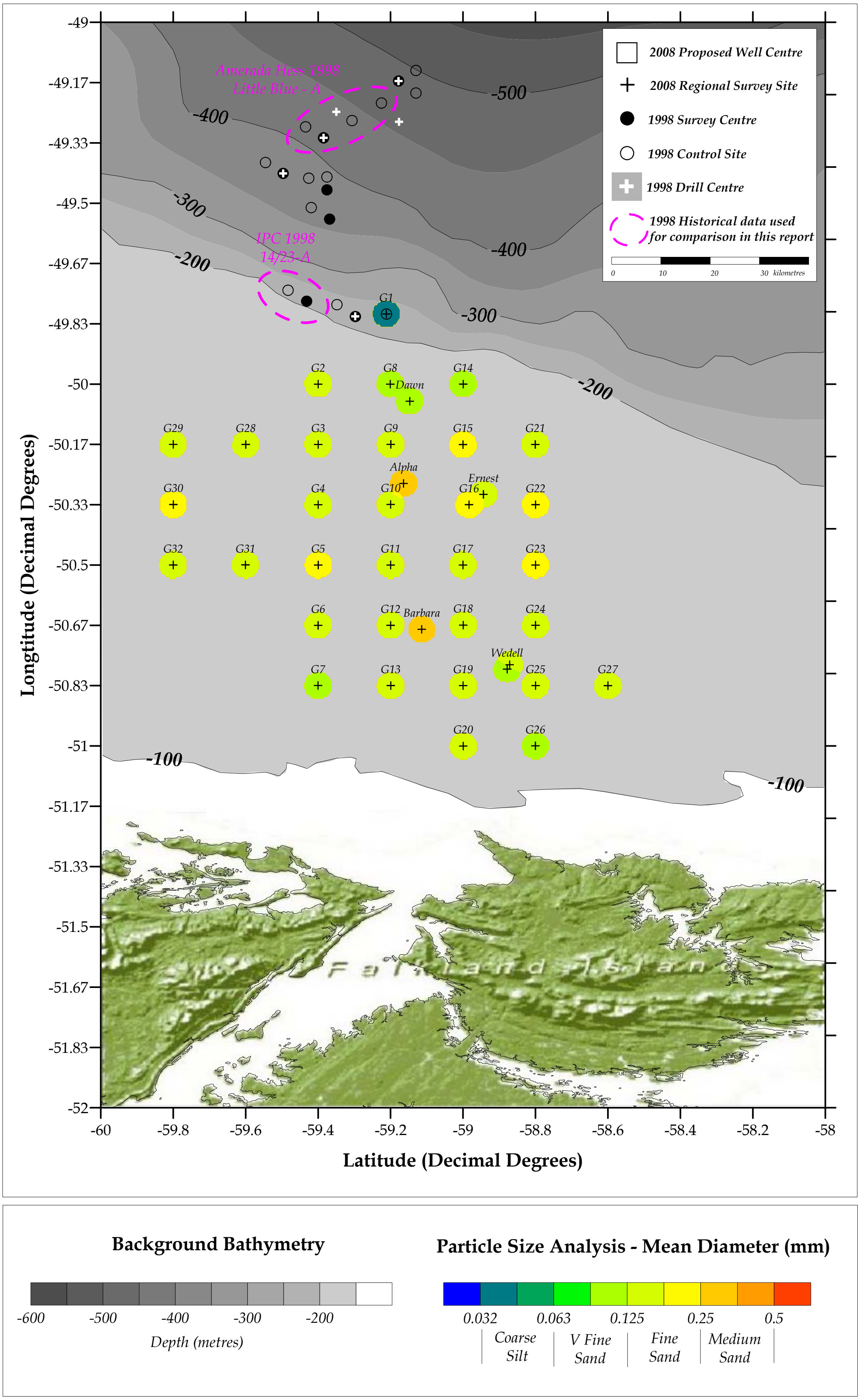
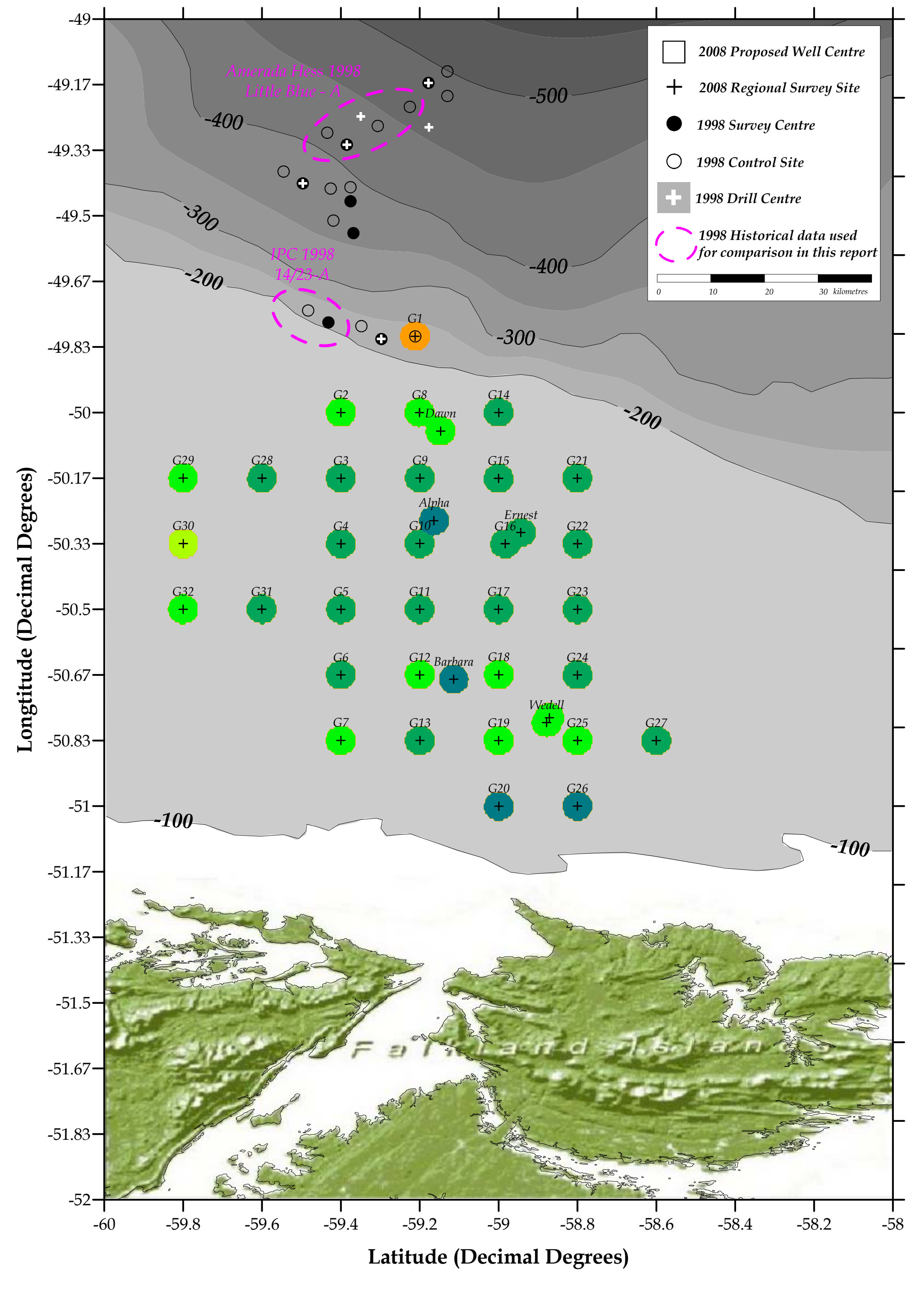


Figure 4.5. Particle Size Analysis – Percentage of Fines (<63µm)



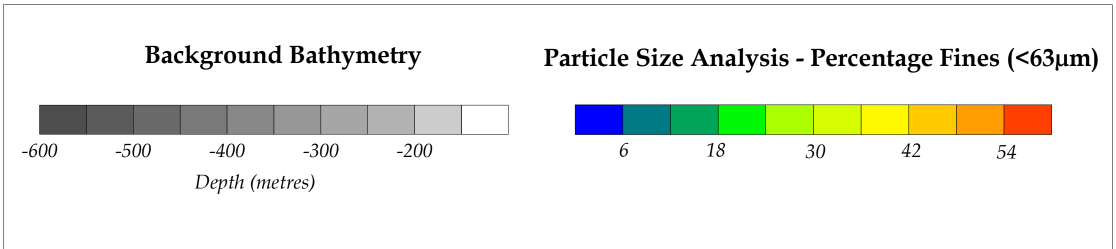
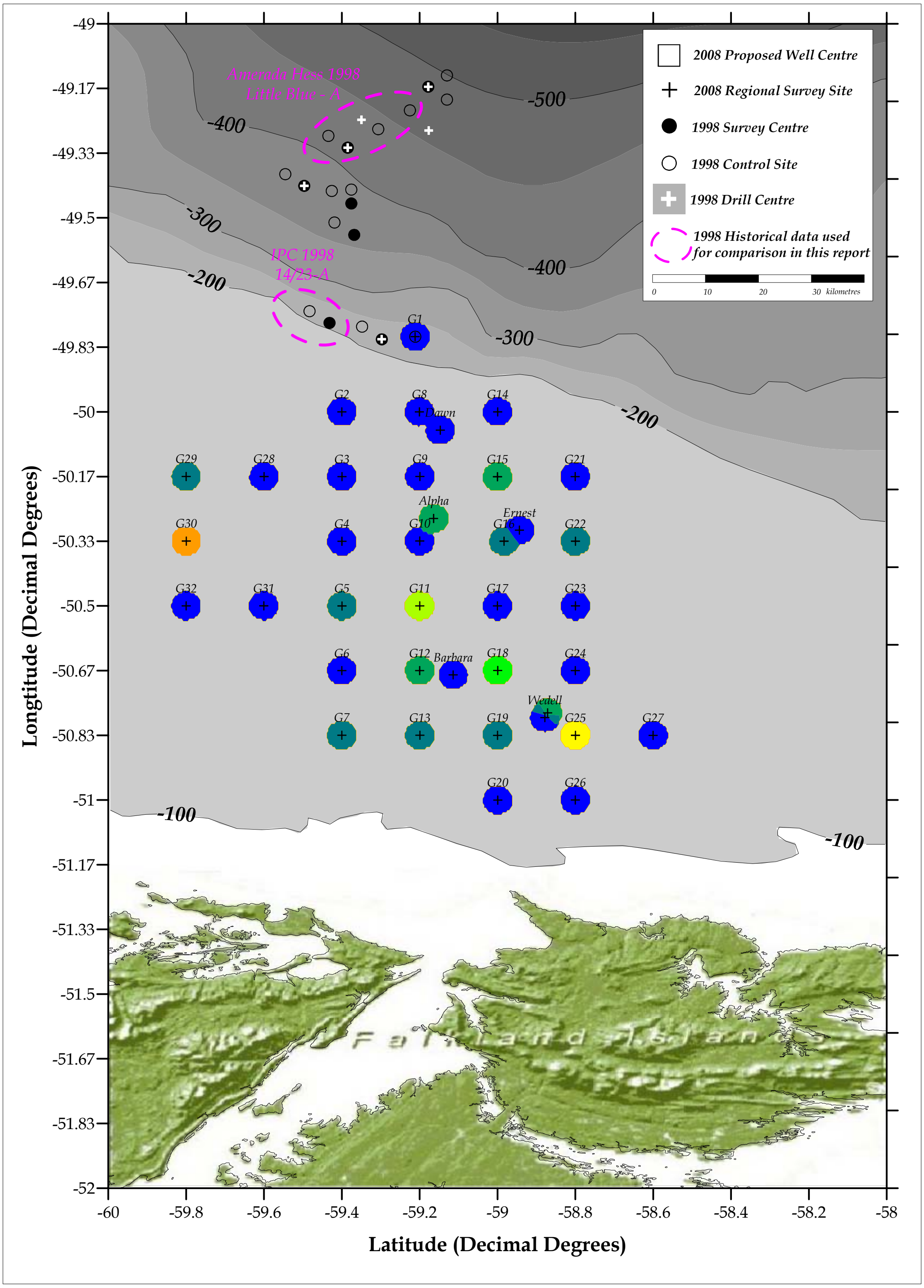
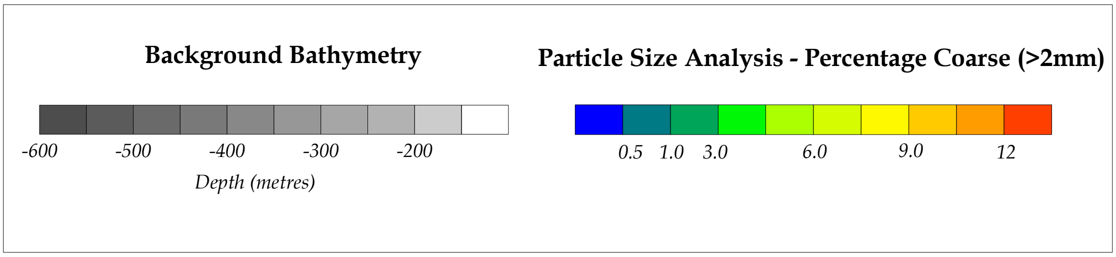


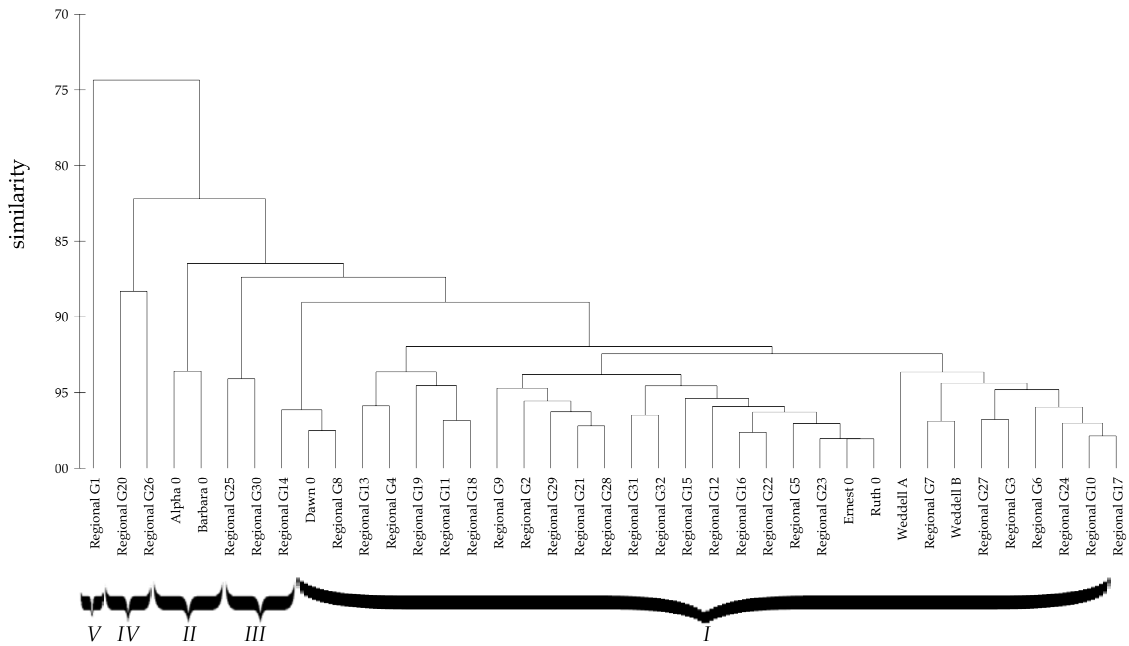
Figure 4.6. Particle Size Analysis – Percentage of Coarse (>2mm)





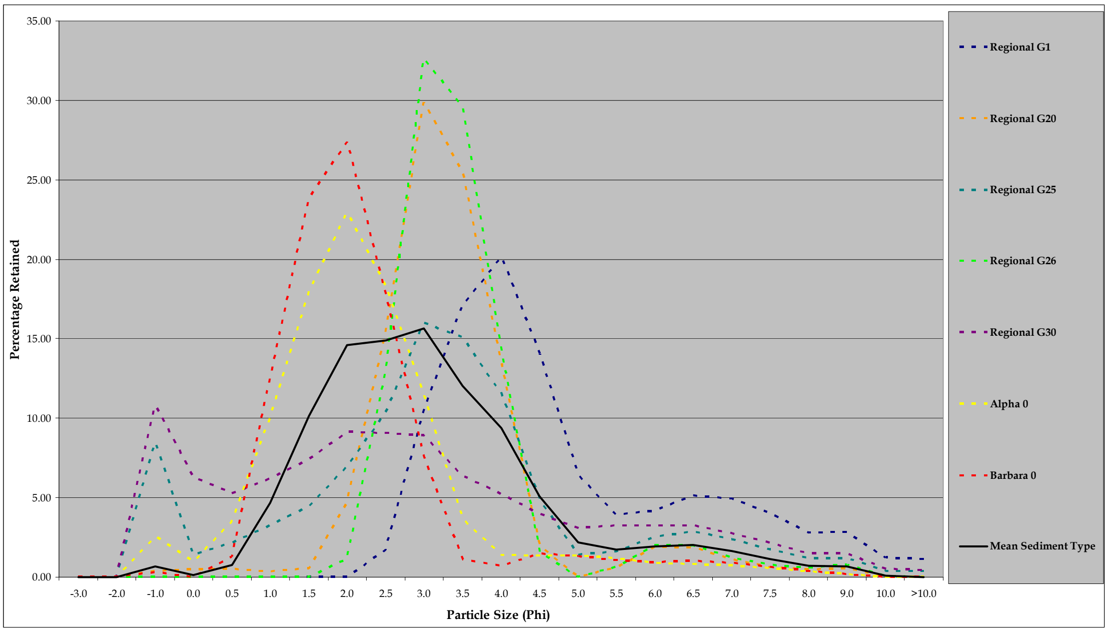
Further to the proportion of sediments at the extremes of the distribution (i.e. gravels and fines), all samples were broken down into size classes at half phi intervals and compared to each other using a multivariate analysis to identify similarities between sediment types across the survey area. Multivariate analyses were undertaken using the Plymouth Routines in Multivariate Ecological Research (PRIMER). Data for the percentage composition within each size class were clustered into a similarity matrix using the Euclidean distance similarity measure and presented as a dendrogram (Figure 4.8). These data separate the sediments into 5 clusters. These are described further below and presented as size class distributions for Figure 4.9.

Figure 4.8. Dendrogram of Regional Sediment Similarity



The dominant particle size distribution (cluster I) was exhibited at 32 of the 37 stations sampled for the regional survey program, clustering at a 89% similarity. The mean distribution for all of these sites (presented as a black line in Figure 4.9) exhibits a broad sand distribution of 4 phi sizes centralised on fine sand, with a small but significant proportion of silts and clays (at around 15%) and minor admixture of gravel (<1%). Three small clusters separate from this mean and were represented by two stations each. Cluster II, represented by stations Alpha and Barbara, and Cluster III, represented by stations G25 and G30, showed similarities in excess of 94%, even though both sets of sites were disparate geographically. The distribution for Cluster II indicated that a relatively small sand distribution of 3 size classes around medium sand and less than 8% fines, whilst Cluster III showed very poor sorting and greater than 8% coarser sediments. Cluster IV was represented by stations G20 and G26 and was 88% similar. These sites are found together in the shallowest part in the south of the survey area. Sediments here were dominated by a small sand distribution centred around very fine sand with over 20% fines. The final Cluster V, represented by only a single site (stations G1), was only 75% similar to other sediments and was clearly dominated by fines (as >50%), with a broad sand distribution centralised on very fine sand to coarse silts. This station represents the deepest location and is indicative of increased hemi-pelagic sedimentation away from the continental slope.

Figure 4.9. Particle Size Distribution of Regional Sediment Similarities



Overall, stations are classified as sandy MUD for G1, SAND for stations G20, G26, Alpha and Barbara and muddy SAND for all other stations under the modified Folk classification scheme (Appendix I).

These results are in accordance with the regional description provided by the earlier benthic survey works carried out in the North Falklands Basin, or from the earlier studies on this part of the continental shelf (Bastida et al, 1992). All of the regional sites, with the exception of the stations G1 were sampled in shallower waters on the main part of the continental shelf where mobile Holocene sands dominate. Off the shelf break a slow increase in depth is accompanied by an increase in the deposition fines, so that historical survey data from the IPC A site (Gardline 1998d) and the Amerada Hess Little Blue A site (Gardline 1998a), located west and north of the G1 location gave either lesser or greater concentrations of sediment fines, respectively (Table 4.1).

Subtle variations in both mean particle size, along with the proportions of the different size classes has resulted in a slight gradient within the parameters which statistically correlate with a large number of other environmental factors including metals, total PAHs and allkanes and water depth. Also affected are several univariate macrofaunal parameters often at the 99.9% confidence level (Pearsons' P<0.001). Many of these correlations will be an artefact of auto-correlation against key parameters, with the mean & median particle sizes, %fines and sorting coefficient being the most dominant.

4.3. Total Organic Matter, Organic Carbon, Carbonates and Redox Potential

Total organic matter (TOM) was measured as a percentage of the total sample weight, and represents the combustible constituent within the sediments Table 4.2 and Figure 4.10. TOM is made up from a mixture of different organic materials, but is predominantly naphthenic materials (such as carboxylic acids and humic substances) which play an important role within the benthic community as a potential food source to deposit feeding organisms. This has led to the suggestion that variation in benthic communities is, in part, caused by the availability of organic materials (Snelgrove & Butman, 1994). Furthermore, organic matter is also an important scavenger of other chemical components, such as heavy metals and some hydrocarbon compounds (McDougall, 2000). Overall, the proportion of total organic matter by loss on ignition (LOI) is generally considered to be a coarse indicator in sediments as it is subject to errors such as over-estimation of organic content, due to loss of non-organic substances on ignition (i.e. volatile oxides and carbonates, and the bodies of living organisms).

The level of total organic matter was slightly variable (ranging from 0.77 to 2.69) between stations, but consistently remained low throughout the study area (mean 1.7, SD 0.4). Spatially, the samples showed a mixed distribution (Figure 4.10), but did show a slight enhancement for station G1 at the deepest site. Statistically, TOM did not correlate with water depth, but rather the particle size, and in particular, the proportion of fines ($P<0.001$). As organic matter is predominantly related to the rate of sedimentation (detrital rain), low concentration are expected to be found in mobile sandier areas where surface sediment indicate some mobility and reduced %fines, common over much of the regional survey area. The overall level was very low when compared to previous studies in this region. Examples to the north of the main area but west and north of the G1 location, indicate slightly elevated levels of 9.3 and 13.6%, respectively. It is uncertain why these previous values were so high, but may have been caused by recently deposited detritus following a plankton bloom, or down to a slightly higher temperature during the ignition technique in the laboratory (previously undertaken by Geochem). Comparisons with values from other continental margins, such as the Atlantic Frontier Environmental Network in the Northeast Atlantic, gave mean percentage of 1.3%, similar to that of the current study.

In addition to total organic matter, the sediment were also analysed for total organic carbon (TOC) and the proportion of inorganic carbon (i.e. carbonates, Table 4.2 and Figure 4.11 and 4.12, respectively). The mean values had respective proportions of 0.46 and 0.56%, respectively. TOC was not previously analysed in the North Falklands Basin, but generally made up around 28% of the organics present with no pattern of distribution. Mean TOC levels for the Northeast Atlantic Margin was 0.79% (AFEN, 2000). Carbonates were previously recorded in the Falklands in 1998, with percentages averaging at 1.8 and 5.7% for the two survey areas west and north of the G1 station. As with TOM, these proportions are notably higher than the current study without explanation, although the 1998 works did identify a calcareous bryozoan as responsible for the high proportion of carbonates in some of the sites previously surveyed.

The sediment on the continental shelf are too shallow for the natural formation of calcareous oozes by the deposition of detrial skeletal material from the water column (foraminifera and coccolithophores). The current study does show a slight pattern of distribution with slightly higher concentrations recorded in the southern, shallower part of the survey area.

Field measurement of the oxygenation reduction potential (ORP) of the surface sediments was carried out at both 1 and 5 cm depths directly from the grab samples onboard. Although generally considered to be only a coarse indication of sediment oxygen, these results show strongly positive voltages synonymous with well oxygenated sediments. This would reflect low microbial activity within the sediments and support the low organic concentrations recorded at each of the sites. As the ORP values remained well above 0mV at all sites for the lower depth, it can be summised that the redox discontinuity layer (RDL; or the point where free oxygen disappears) was deeper than the 5cm depth measured at all of the sites. These values are marginally higher (more oxygenated) than those recorded during the previous surveys in 1998. This is to be expected given the higher proportion of sands observed.

Weak correlations were recorded between TOC and most of the key sediment characteristics, with the highest significances found with median particle sizes or the proportion of medium sands (Pearson's $P<0.001$). Total carbonates only correlated with the phi 0.5 (i.e. coarse sand; $P<0.001$).

Table 4.2. *Summary of Moisture and Organic Components*

Station	Moisture Content %	Total Organic Matter %	Total Organic Carbon (%)	Total Carbonates (%)	Proportion TOC (%)	Redox Potential (mV)	
						1cm	5cm
Regional G1	30.3	2.69	0.6	0.47	22.3	407	362
Regional G2	20.6	1.76	0.5	0.12	28.4	425	402
Regional G3	20.6	1.91	0.45	0.22	23.6	385	362
Regional G4	21.4	1.72	0.47	0.46	27.3	382	360
Regional G5	19.3	1.17	0.38	0.52	32.5	422	392
Regional G6	22.5	1.57	0.58	0.63	36.9	423	405
Regional G7	24.3	1.79	0.57	1.05	31.8	417	327
Regional G8	23.7	2.07	0.63	0.08	30.4	397	386
Regional G9	18.3	1.66	0.36	0.14	21.7	305	327
Regional G10	20.4	1.45	0.31	0.31	21.4	451	442
Regional G11	20.7	1.65	0.5	0.6	30.3	409	367
Regional G12	21	1.7	0.44	0.72	25.9	407	355
Regional G13	25.5	1.88	0.48	0.8	25.5	425	389
Regional G14	22.5	1.64	0.39	0.13	23.8	267	272
Regional G15	18.8	1.22	0.35	0.29	28.7	338	325
Regional G16	16.8	1.17	0.27	0.54	23.1	399	367
Regional G17	19.3	1.47	0.33	0.37	22.4	431	391
Regional G18	23	1.79	0.51	0.67	28.5	462	440
Regional G19	24.4	2.08	0.56	1.56	26.9	505	408
Regional G20	28.5	1.85	0.48	1.37	25.9	450	407
Regional G21	19.1	1.36	0.29	1.53	21.3	401	361
Regional G22	17	1.2	0.34	1.4	28.3	371	341
Regional G23	18.7	1.39	0.26	0.36	18.7	375	319
Regional G24	16.5	1.53	0.32	0.54	20.9	449	405
Regional G25	26.8	1.17	0.64	0.93	54.7	452	409
Regional G26	27	1.67	0.45	0.75	26.9	380	406
Regional G27	22.5	1.87	0.4	0.38	21.4	428	390
Regional G28	21.3	1.75	0.44	0.18	25.1	423	375
Regional G29	19.9	1.63	0.52	0.35	31.9	420	402
Regional G30	20.2	2.17	0.76	0.97	35.0	408	352
Regional G31	21.7	1.53	0.7	0.2	45.8	417	377
Regional G32	21.3	1.22	0.28	0.44	23.0	417	387
Alpha 0	16.9	0.77	0.38	0.3	49.4	379	333
Barbara 0	20	1.85	0.5	0.7	27.0	424	349
Dawn 0	25.5	2.25	0.59	0.18	26.2	368	360
Ernest 0	17.8	1.33	0.23	0.59	17.3	409	369
Ruth 0	18.2	1.36	0.5	0.2	36.8	399	340
Weddell A	26.7	2.64	0.49	0.28	18.6	444	414
Weddell B	23.9	1.82	0.54	0.49	29.7	459	408
Survey Mean	**21.6**	**1.66**	**0.46**	**0.56**	**28.1**	**408**	**373**
Survey StDev	**3.4**	**0.39**	**0.13**	**0.39**	**8.0**	**42**	**35**
Gardline 1998d	**27.8**	**9.3**	**-**	**1.8**	**-**	**328**	**256**
Gardline 1998a Mean	**-**	**13.8**	**-**	**5.7**	**-**	**250**	**181**

Figure 4.10. Particle Size Analysis – Total Organic Matter (Percentage LOI)

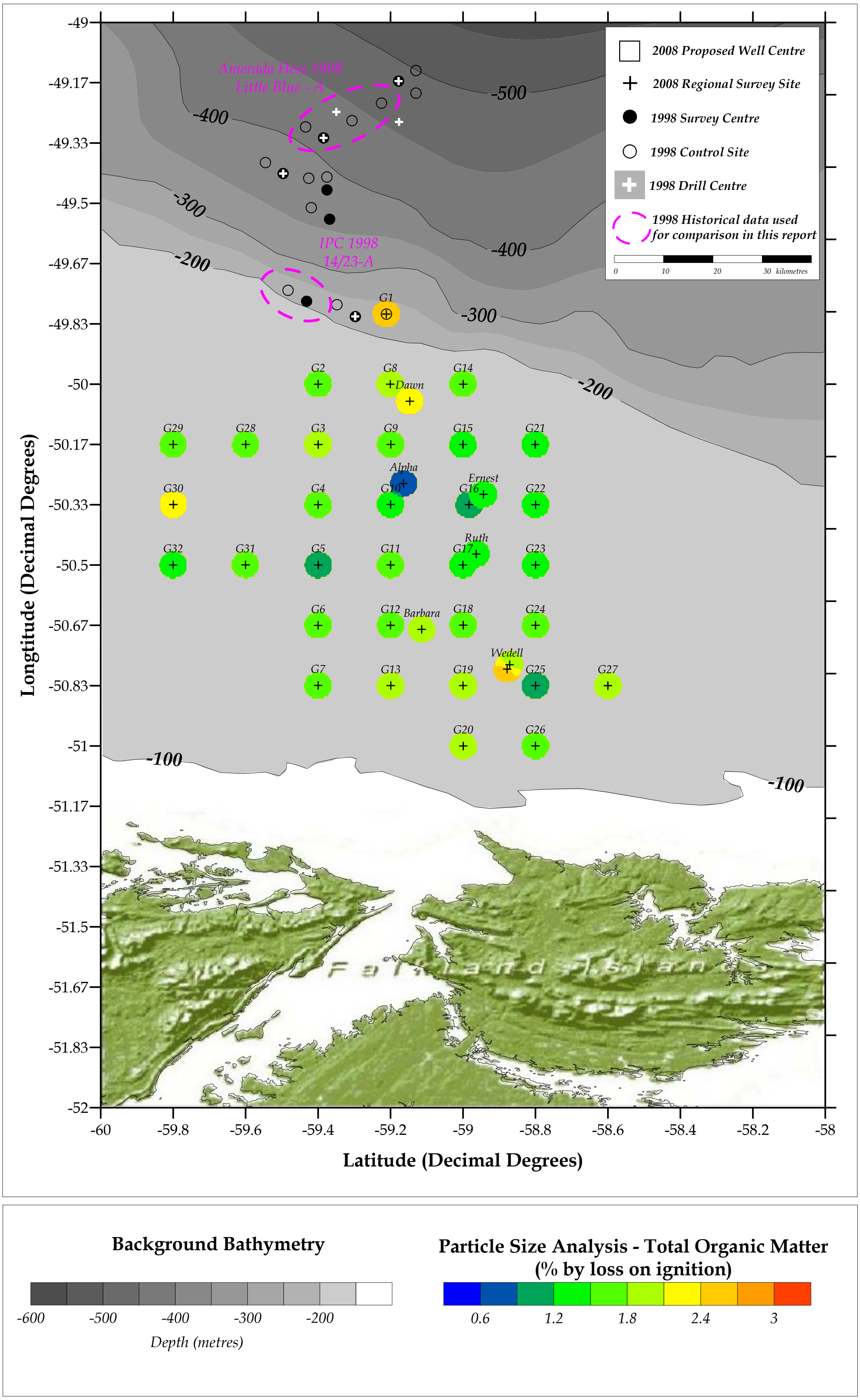


Figure 4.11. *Particle Size Analysis – Total Organic Carbon*

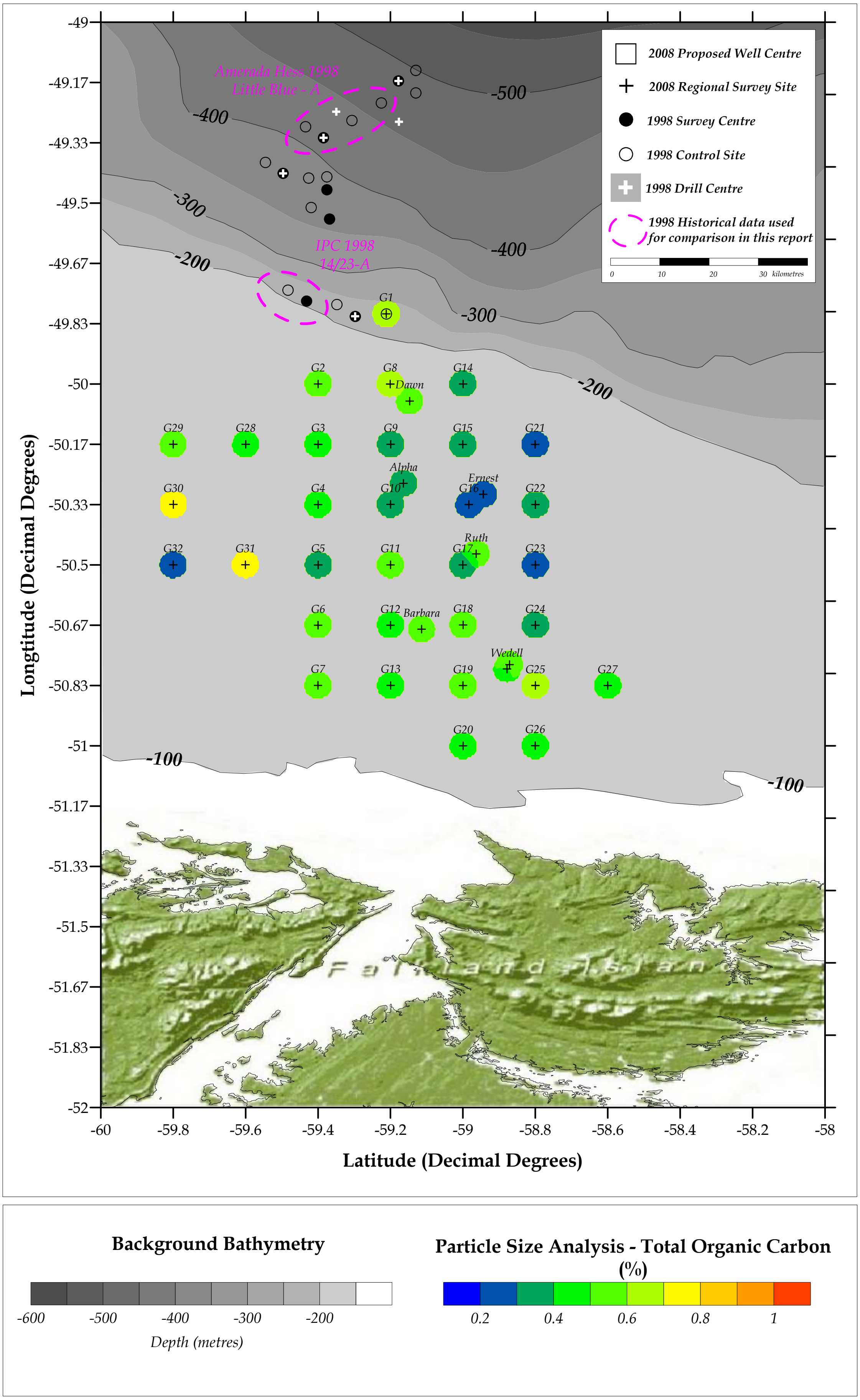
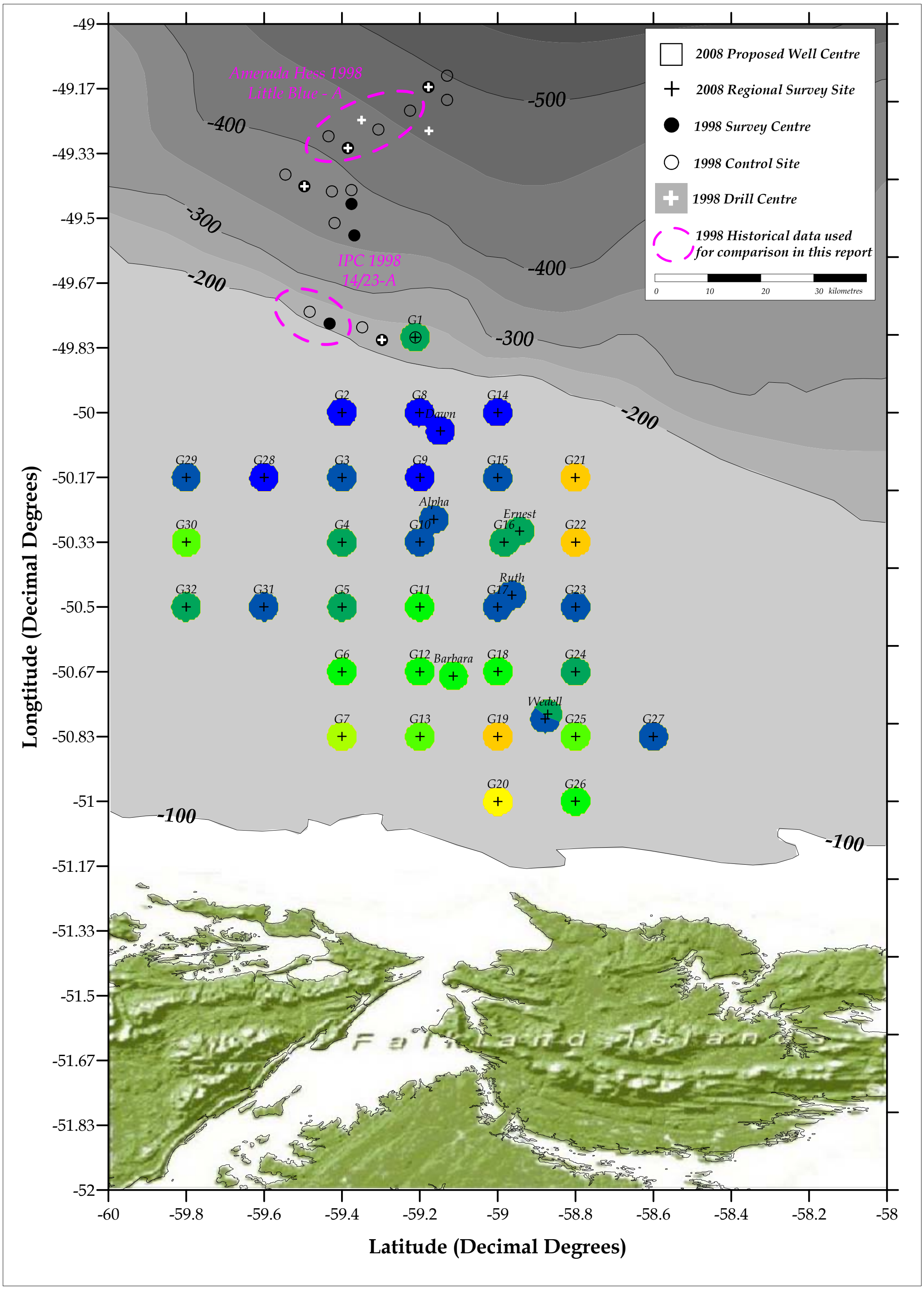
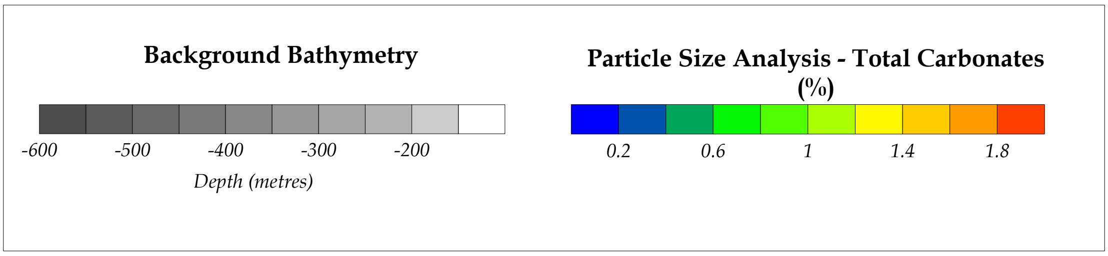


Figure 4.12. *Particle Size Analysis – Total Carbonates*





4.4. Sediment Hydrocarbons

4.4.1. Total Petroleum Hydrocarbons

Results for hydrocarbon analysis are summarised and tabulated as total hydrocarbon concentrations, total n-alkane and homologue ratios in Table 4.3, with individual alkanes (nC_{10}-nC_{37}) listed in Table 4.4. The analytical gas chromatogrammes, example given in Figure 4.15 (Appendix II) and show the aliphatic hydrocarbon traces for each station, labelled with every fourth n-alkane, the isoprenoid hydrocarbon, Pristane (IP18) and the internal standards hepta-methylnonane (A), 1-chlorooctadecane (B) and squalane (C).

The total petroleum hydrocarbon (TPH) concentrations of the sediments, measured by integration of all non-polarised components within the GC trace, showed moderate level background concentrations at all sites sampled ranging from 1.2 to 8.1µg.g^{-1} (ppm, Table 4.3 & Figure 4.13). The mean for the whole survey area was 4.3µg.g^{-1} (SD 1.4). These are moderately high, given the remote nature of the survey, relating closely to the range expected for uncontaminated sediments in the North Sea (ca. 8µg.g^{-1} UKOOA, 2001) or higher than a similar area in the Northeast Atlantic (ca. 2.9µg.g^{-1} AFEN 2000). Comparative results for the previous survey in the North Falklands Basin, showed a much lower concentration 1.16 and 0.13 µg.g^{-1} for sites west and North of the G1 location, but a similar respective concentration of 7.7 and 2.0 µg.g^{-1} for the total organic extractables recorded at the same time. This suggested that a notable proportion of the sediments in 1998 were made up from significant concentrations of polarised materials, thought to be of planktonic detritus origin, with a clear elevation of this material recorded in the shallower sites surveyed at that time. It is unclear why similarly high levels have been recorded in the total oils fraction in the current study.

The levels total oils showed no notable pattern of distribution, although this parameter did statistically correlate with the mean and median particle sizes and, in particular, % fines and all of the finer fractions below phi 6 (fine silts, $P<0.001$). This has been interpreted as a function of hydrodynamics and increased sedimentation, with the proportion of oils associated with the retention of detritus along with finer sediments at certain sites. Therefore, the highest oil concentrations were generally associated with sites with the higher fines (i.e. G1 and G25).

The mean level of unresolved compounds was generally very high constituting between 92 and 97% of the total oils recorded within the survey area. This component is likely to represent complex organic materials that are ubiquitous within this region of the south Atlantic and are present through a range of predominantly natural autochthonous marine biogenic sources.

4.4.2. Saturate Alkanes

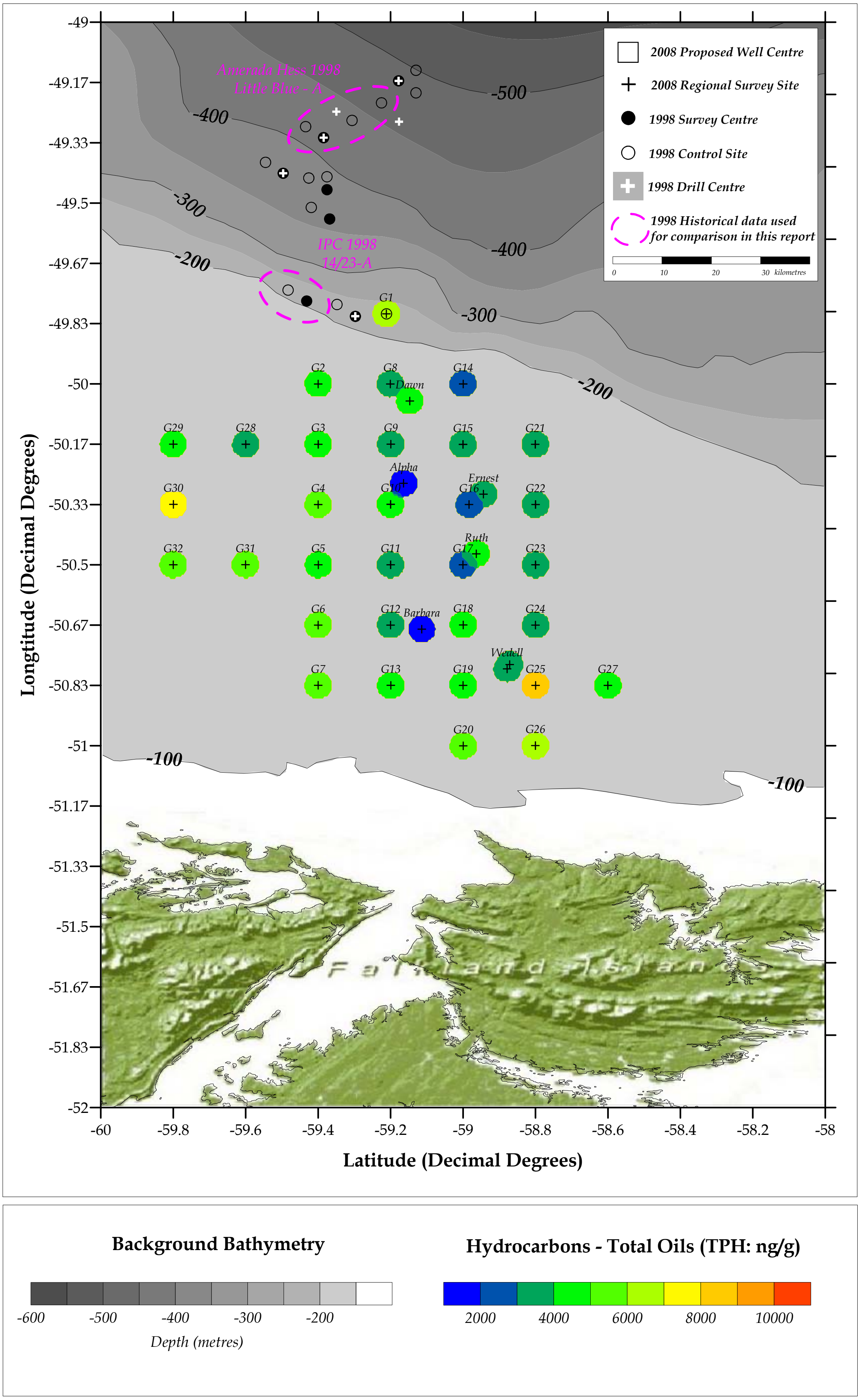
All of the sample stations were analysed for n-alkanes using gas chromatography with flame ionisation detection (GC-FID). The results are summarised in Table 4.3 and individually listed in Table 4.4, which gives a breakdown of consecutive n-alkane content from nC_{10} through to nC_{37}, together with the isoprenoid hydrocarbons Pristane (Pr) and Phytane (Ph).

Table 4.3. *Summary Hydrocarbon Concentrations*

Station	TPH ($ng.g^{-1}$)	Total n-alkanes ($ng.g^{-1}$)	Carbon Preference Index	Pristane/ phytane Ratio	P/B ratio	Alkane proportion	Total PAHs ($ng.g^{-1}$)	NPD PAHs ($ng.g^{-1}$)
Regional G1	6314	327.9	2.49	4.30	0.15	5.19%	16.5	12.55
Regional G2	4275	179.3	1.29	NC	0.15	4.19%	ND	ND
Regional G3	4296	203.0	1.55	NC	0.17	4.73%	ND	ND
Regional G4	5224	208.8	1.85	NC	0.12	4.00%	ND	ND
Regional G5	4128	155.7	2.14	NC	0.16	3.77%	ND	ND
Regional G6	5124	218.6	2.08	NC	0.14	4.27%	ND	ND
Regional G7	5840	252.0	2.73	NC	0.10	4.31%	1.06	1.06
Regional G8	3830	185.7	1.47	NC	0.15	4.85%	ND	ND
Regional G9	3537	171.2	1.64	NC	0.14	4.84%	ND	ND
Regional G10	4288	215.5	1.74	NC	0.13	5.03%	ND	ND
Regional G11	3728	221.8	2.05	1.03	0.17	5.95%	ND	ND
Regional G12	3909	231.7	2.17	NC	0.12	5.93%	ND	ND
Regional G13	4990	247.2	2.05	0.49	0.16	4.95%	ND	ND
Regional G14	2508	198.4	1.45	0.50	0.15	7.91%	ND	ND
Regional G15	3516	184.1	1.45	0.58	0.19	5.24%	ND	ND
Regional G16	2554	154.2	1.67	0.78	0.16	6.04%	ND	ND
Regional G17	2369	146.5	1.41	NC	0.19	6.18%	ND	ND
Regional G18	4518	265.6	1.66	0.29	0.13	5.88%	ND	ND
Regional G19	4878	240.0	2.00	1.58	0.14	4.92%	1.04	1.04
Regional G20	5363	298.0	1.55	NC	0.31	5.56%	ND	ND
Regional G21	3974	218.1	1.70	0.57	0.14	5.49%	ND	ND
Regional G22	3965	180.6	1.79	0.55	0.14	4.55%	ND	ND
Regional G23	3025	206.1	1.72	NC	0.13	6.81%	ND	ND
Regional G24	3644	198.8	2.12	1.38	0.22	5.46%	ND	ND
Regional G25	8097	302.3	2.54	0.96	0.18	3.73%	ND	ND
Regional G26	6579	214.4	2.23	1.07	0.21	3.26%	ND	ND
Regional G27	4184	166.9	1.83	0.81	0.21	3.99%	ND	ND
Regional G28	3859	206.8	1.65	0.64	0.16	5.36%	ND	ND
Regional G29	4278	184.1	1.62	1.03	0.18	4.30%	ND	ND
Regional G30	7616	323.2	1.99	0.52	0.11	4.24%	1.28	1.28
Regional G31	5481	210.7	2.49	NC	0.12	3.85%	1.06	1.06
Regional G32	5850	221.3	2.19	NC	0.11	3.78%	ND	ND
Alpha 0	1227	82.8	1.95	NC	0.13	6.75%	ND	ND
Barbara 0	1333	93.8	2.07	1.00	0.21	7.04%	ND	ND
Dawn 0	4573	235.5	1.25	NC	0.14	5.15%	1.0	1.0
Ernest 0	3213	175.3	1.41	1.13	0.18	5.46%	ND	ND
Ruth 0	4485	224.7	1.59	0.41	0.15	5.01%	ND	ND
Weddell A	3307	179.8	2.30	1.70	0.15	5.44%	ND	ND
Weddell B	3793	189.4	2.48	0.90	0.15	4.99%	ND	ND
Survey Mean	**4299**	**208.2**	**1.88**	**1.01**	**0.16**	**5.1%**	**0.6**	**0.5**
Survey StDev	**1447**	**51.7**	**0.38**	**0.82**	**0.04**	**1.0%**	**2.6**	**2.0**
Gardline 1998d Mean	**7713**	**198.9**	**2.04**	**0.07**	**0.36**	**23.1/2.9***	**90.3**	**27.0**
Gardline 1998a Mean	**1989**	**15.4**	**1.08**	**NC**	**0.15**	**13.4/2.8***	**60.4**	**18.7**

NC = Not calculated (insufficient data)
ND = Not detected
** proportion relative to total organic extractables*

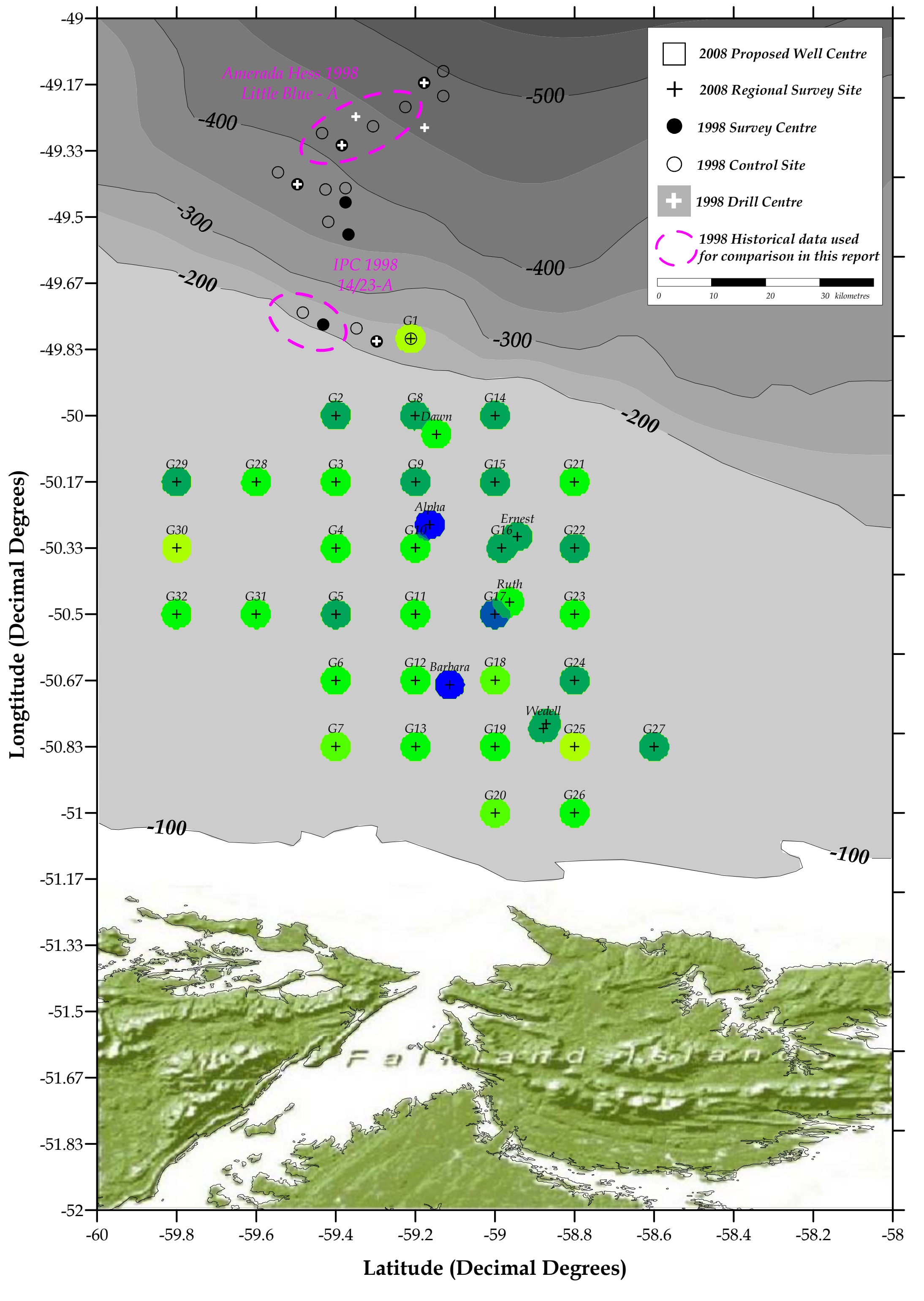
Figure 4.13. Hydrocarbons – Total Oils (TPH; ng/g)



Unlike the proportion of total oils, the total n-alkane concentrations were very low ranging from 82.7 to 327.9ng.g^{-1} (mean 208, SD 51.7; Figure 4.14). However, like total oils there was no clearly defined pattern of distribution, although statistically, alkanes correlated closely with sediment parameters in particular mean size, % fines and each of the individual size classes below phi 5.5 (coarse silt; $P<0.001$). The levels of alkanes were very similar to those recorded during the 1998 survey to the west of G1, mean of 198 ng.g^{-1} but notably higher than those of the deeper waters to the north, mean 15.4 ng.g^{-1}. The overall concentration of alkanes consistently made up around 5% of the total oils recovered, compared to around 23% for the two previous studies, equivalent to around 2.8% of the total organic extractables.

On inspection of the individual gas chromatograms (Figure 4.15 and Appendix II) all stations indicated similar forms with little or no trends seen, other than those of natural background alkanes recorded in sediments of this type and region. This gave a consistent pattern within the range nC_{25} to nC_{36}, with higher concentrations being evident for the odd numbered alkanes. This distribution is consistent with the presence of terrestrial derived n-alkanes from the wax cuticles of higher plants, which typically comprise the long-chain, odd carbon number n-alkanes (nC_{25-33}) (Eglinton *et al.*, 1962), whereas marine organisms (phyto- and zooplankton) preferentially synthesize short-chain, odd carbon number (nC_{15-21}) (Blumer *et al*,, 1971). Terrestrial matter is often evident in marine sediments, particularly inshore sediments, although it has also been observed from samples in remote areas like the northeast Atlantic Margin (McDougall, 2000), having entered the marine environment through run-off and aeolian processes from adjacent land masses. GC traces also indicated some slightly elevated concentrations of heavy weight compounds just outside the quantifiable range of the instrument (ca. nC_{38}+). A GC trace taken from the earlier environmental survey is also displayed inset. Although the analytical ranges and graph axes differ slightly a relatively large envelope of unresolved complex mixtures can be seen at a lower range than that of the current study. This was recorded at all of the shallower 1998 sites (Blocks 14/19 and 14/23 and 24) and may have related to a natural seasonal effect.

Figure 4.14. Hydrocarbons – Total N-Alkanes (Saturates; ng/g)



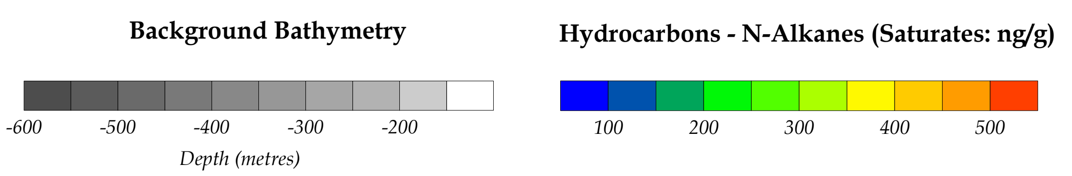
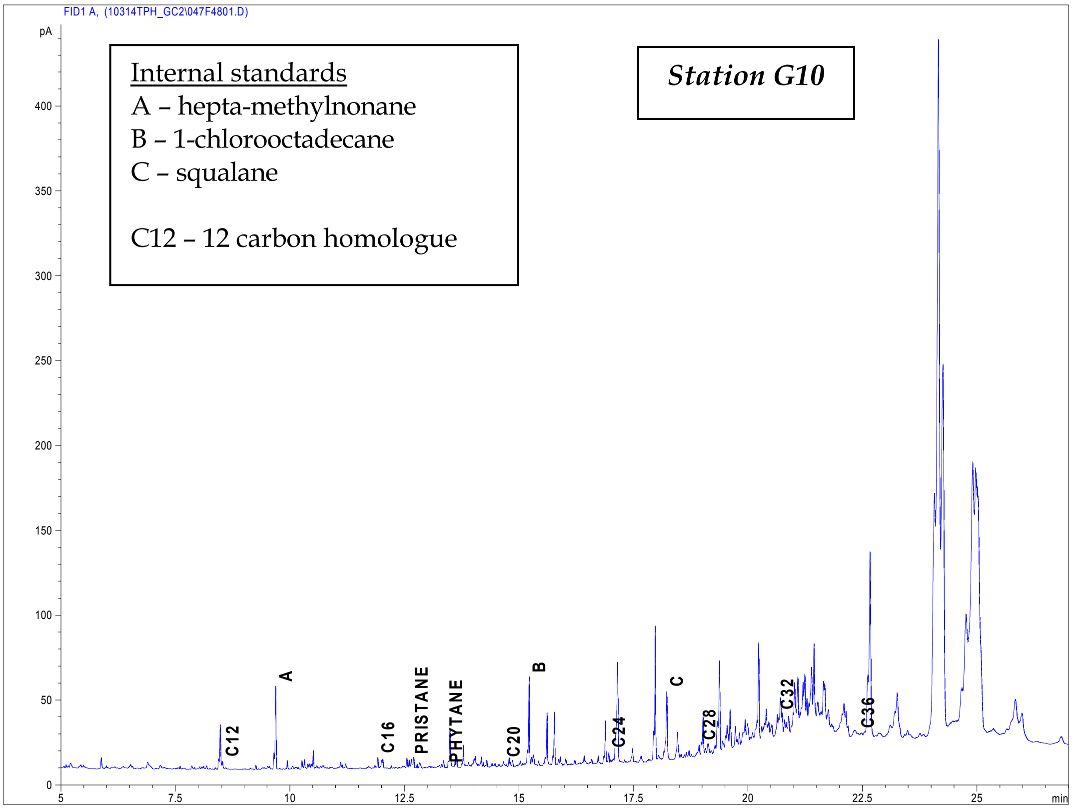
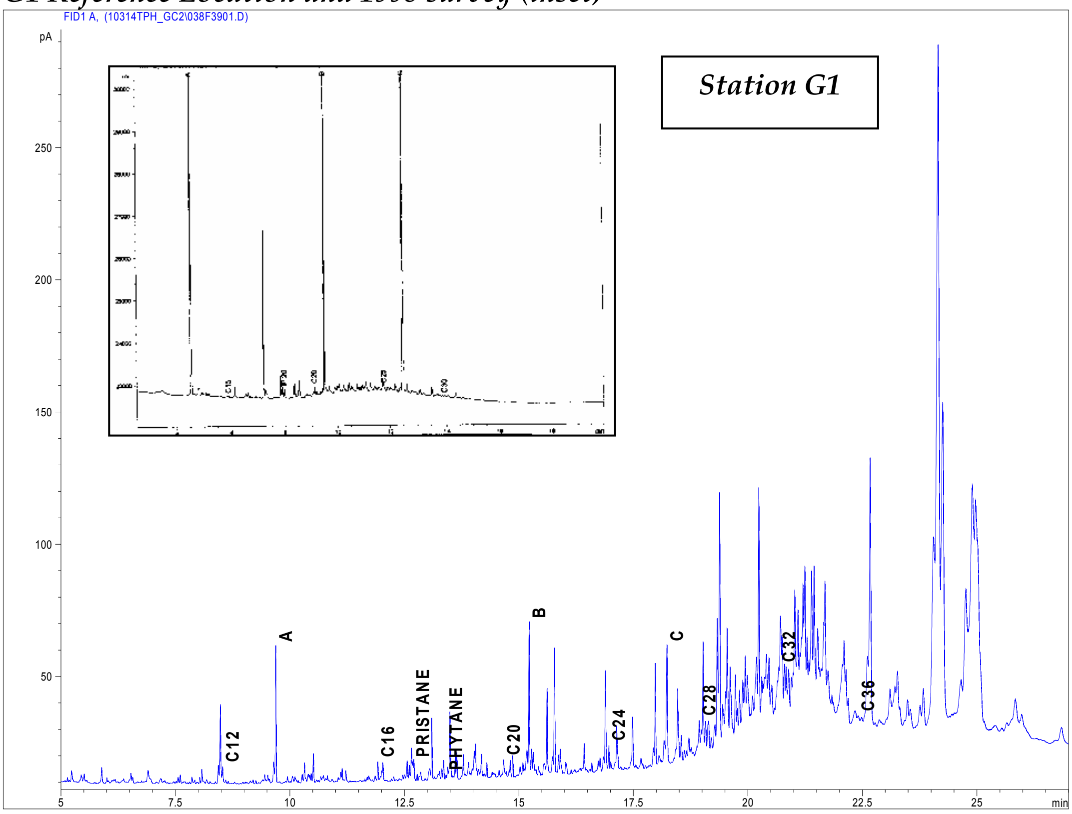


Figure 4.15. Example Gas Chromatograms for Saturate Hydrocarbons Analysis for the Central and Northern Area of the Regional Survey (Stations G10 and G1)



G1 Reference Location and 1998 survey (inset)



A closer inspection of the different proportions of n-alkanes recorded can sometimes identify trends within the data or the source from which the different organic components derive. Even though the overall level of saturates is extremely low, the following ratios were also calculated and assessed:

Carbon Preference Index (CPI):

The carbon preference index (CPI), is associated with the preference of biogenic n-alkanes (i.e. that of a preference for odd-carbon numbered homologues, particularly around nC_{27}-nC_{33}; Sleeter *et al.*, 1980), derived from fatty acids, alcohols, esters and land plant waxes. The CPI was calculated for all sites and ranged from 1.25 to 2.73 (mean 1.88; Figure 4.16). This is a consistent dominance by biogenic, and in particular, terrestrial aliphatics and compares favourably with the closest site surveyed in 1998 (mean 2.04) or that of the Northeast Atlantic margin of 1.47 (AFEN 2000). The figure indicates a relatively clear pattern of distribution relating to the edge of the continental shelf. This correlated weakly with the proportion of fines and the sorting coefficient, suggesting that sediments with less reworking had slightly higher influences from terrestrial alkane deposits.

The carbon preference index is calculated as follows;

$$CPI = \frac{\text{odd homologues } (nC_{11} \text{ to } nC_{35})}{\text{even homologues } (nC_{10} \text{ to } nC_{34})}$$

Petrogenic/Biogenic or (P/B) Ratio:

$$\text{P/B Ratio} = \frac{P = \text{sum of } nC_{10} \text{ to } nC_{20}}{B = \text{sum of } nC_{21} \text{ to } nC_{35}}$$

The P/B ratio compares the lighter, more petrogenic aliphatics with the heavier, and more biogenic aliphatics. Results were calculated for all stations showing a consistently low, biogenic ratio ranging from 0.10 to 0.31 (Mean, 0.16; figure 4.16) with a slight elevation in petrogenic influence in the southern part of the survey area. Previous surveys in the region showed mean P/B ratios of 0.36, to the west and 0.15 in deeper water to the north. All are notably lower than similar sediment samples in the Northeast Atlantic (mean 0.73, AFEN 2000), and were indicative of natural biogenic origins.

The Pristane/Phytane Ratio

Pristane and phytane are both isoprenoidal alkanes commonly found as constituents within crude oils. However, in biogenic environments, only pristane is found with phytane generally absent or only present at low levels in uncontaminated natural systems (Blumer and Snyder, 1965). A presence of both isoprenoids at similar levels is typically taken as an indication of petroleum contamination.

The Pristane/phytane ratio could not be calculated for 22 out of the 39 regional stations due to the extremely low levels of these isoprenoids recorded. The remaining stations indicated variable ratios ranging from 0.3 to 4.3 (mean 1.0). This would indicate an inconclusive results of mixed origin, although it should be noted that Pristane/Phytane ratio can often be difficult to interpret due to its erratic nature and should be used mainly to substantiate other interpretations. The use of the ratio in interpretative discourse is open to criticism, mainly owing to the natural occurrence of phytane in some older sediments and the confusing variation of sedimentary pristane induced by the variability of phytoplankton numbers (Blumer & Synder, 1965).

Figure 4.16. Hydrocarbons – Carbon Preference Index (Saturates; ng/g)

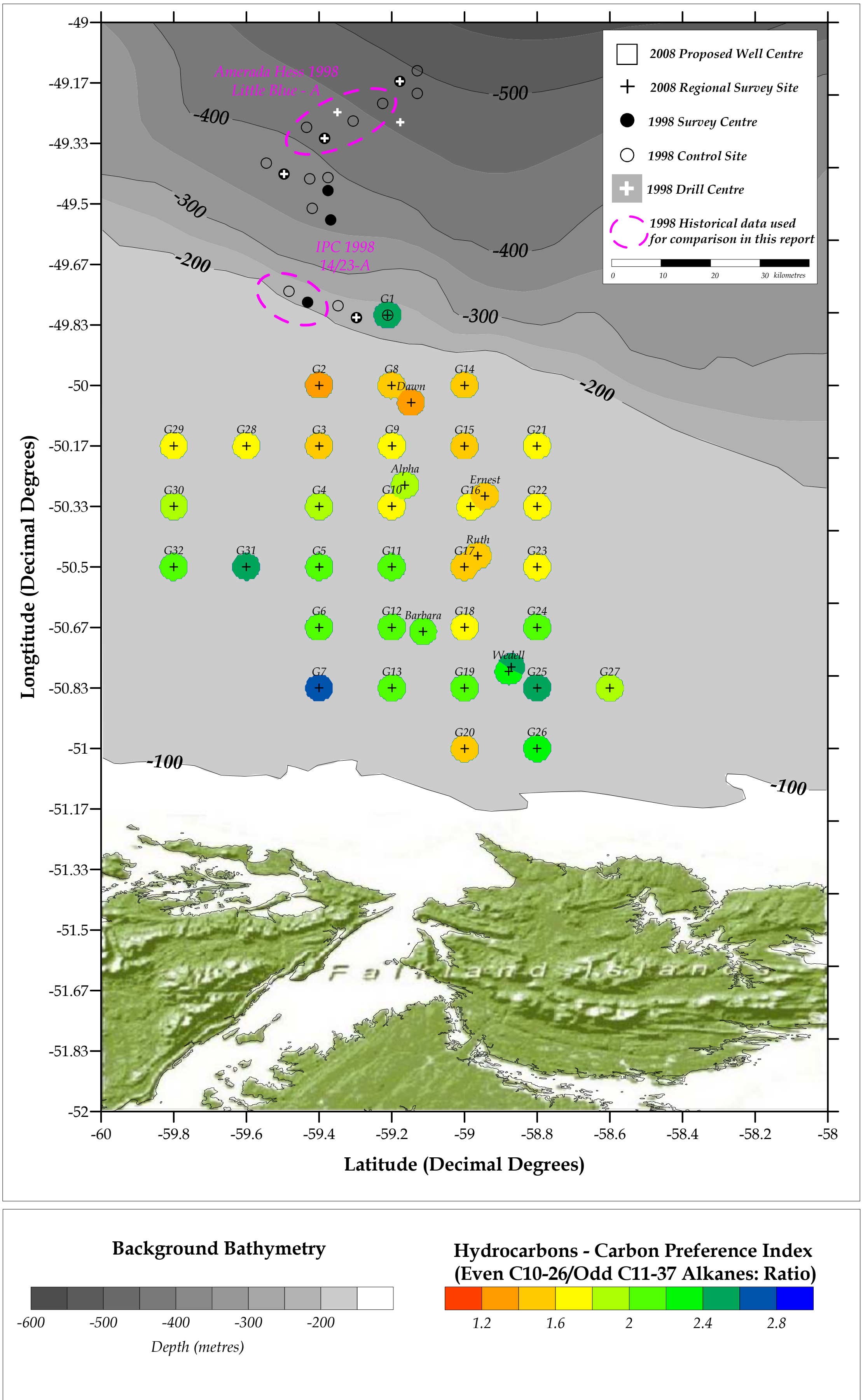


Figure 4.17. ***Hydrocarbons – Petrgenic/Biogenic Ratio (nC_{10-20}/nC_{21-37})***

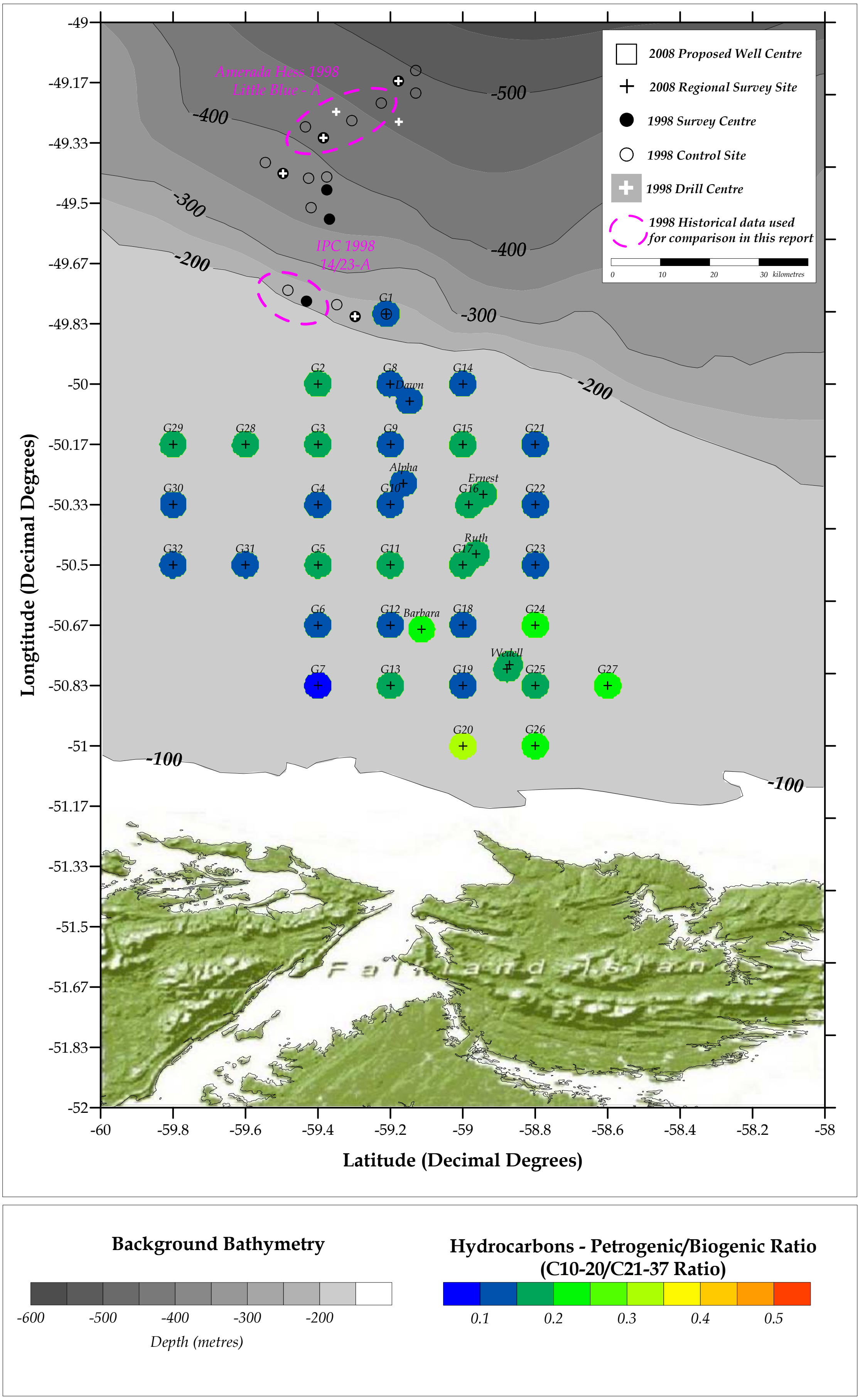


Table 4.4. *Total Aliphatic Concentrations (ng.g^{-1})*

Station	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
nC10	2.3	1.1	1.3	1.5	1.1	1.2	1.3	1.5	1.8	1.4
nC11	1.8	<1	<1	<1	<1	<1	<1	1.0	<1	<1
nC12	3.0	1.7	1.5	2.4	1.5	1.4	1.6	1.3	1.7	1.4
nC13	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC14	4.4	3.4	3.6	4.1	2.8	2.9	3.3	3.4	3.7	3.9
nC15	1.2	2.2	1.0	2.1	3.5	3.3	3.4	1.1	1.2	1.9
nC16	5.5	2.9	12.3	3.7	3.2	7.9	3.0	5.4	3.1	5.0
nC17	10.6	5.6	3.7	3.4	4.2	4.2	4.8	5.3	3.9	5.2
pristane	5.3	1.3	<1	<1	1.1	1.0	1.8	1.5	<1	1.4
nC18	5.2	2.7	2.2	2.1	2.1	2.6	2.7	2.2	2.2	3.7
phytane	1.2	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC19	2.6	1.6	1.4	1.4	1.3	1.2	<1	1.0	1.0	1.4
nC20	5.2	2.4	2.5	2.5	1.8	1.9	2.3	1.7	2.5	1.7
nC21	4.7	2.2	2.0	2.6	2.0	2.6	3.3	2.4	1.6	1.9
nC22	4.0	1.2	2.1	1.4	<1	2.3	1.9	1.1	1.3	1.8
nC23	7.3	2.3	3.5	2.5	2.2	3.3	4.2	1.9	1.7	2.3
nC24	6.5	2.8	2.4	4.0	3.1	8.5	3.7	5.0	2.9	5.4
nC25	17.0	5.4	8.1	12.9	6.4	9.9	9.9	6.5	6.6	7.5
nC26	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC27	27.4	11.0	24.4	15.3	13.2	23.3	26.2	17.6	13.1	17.8
nC28	7.5	4.7	5.7	4.5	3.3	5.9	5.8	3.7	2.4	5.8
nC29	70.6	27.7	31.2	34.7	28.3	41.3	53.8	28.9	28.1	39.6
nC30	10.9	5.5	6.1	7.5	4.8	8.2	8.3	6.1	4.4	6.1
nC31	64.4	30.2	33.7	41.5	31.8	42.9	55.2	30.5	32.3	42.1
nC32	1.5	2.5	1.6	3.4	<1	1.6	5.9	1.4	<1	5.4
nC33	26.3	12.9	14.4	19.2	13.2	15.8	23.7	14.5	16.9	17.1
nC34	37.8	47.4	38.3	36.2	20.8	26.6	27.7	39.6	33.4	37.0
nC35	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC36	<1	<1	<1	<1	5.1	<1	<1	2.7	5.4	<1
nC37	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Oil	**6314**	**4275**	**4296**	**5224**	**4128**	**5124**	**5840**	**3830**	**3537**	**4288**
Total n alkanes	**327.9**	**179.3**	**203.0**	**208.8**	**155.7**	**218.6**	**252.0**	**185.7**	**171.2**	**215.5**

Table 4.4. cont. *Total Aliphatic Concentrations (ng.g-1)*

Station	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20
nC10	1.1	1.6	1.8	1.8	1.7	1.2	2.0	1.8	1.9	<1
nC11	<1	1.0	1.2	<1	1.0	<1	<1	<1	<1	1.4
nC12	2.5	1.6	2.2	1.9	2.3	2.1	2.1	2.4	2.5	2.3
nC13	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC14	4.4	4.0	4.2	4.8	5.1	3.9	5.1	5.1	4.6	3.6
nC15	3.2	1.5	2.9	<1	1.5	<1	<1	2.5	2.5	3.2
nC16	4.0	2.7	3.5	4.2	3.6	2.6	3.3	6.0	3.1	39.2
nC17	3.6	3.4	3.8	3.4	4.1	3.3	2.0	3.3	3.5	4.7
pristane	1.6	<1	1.8	1.3	1.7	1.3	<1	1.5	1.8	1.5
nC18	3.8	3.6	4.8	3.7	4.1	3.2	3.8	4.5	3.9	4.7
phytane	1.6	1.5	3.6	2.6	3.0	1.6	1.4	5.0	1.2	<1
nC19	4.1	1.1	1.5	1.3	<1	1.9	<1	<1	2.2	3.0
nC20	6.0	3.8	7.7	4.0	5.5	3.1	4.7	5.6	4.9	7.9
nC21	4.5	3.2	4.9	4.9	3.9	3.9	2.4	4.3	5.1	5.1
nC22	1.4	1.7	1.8	1.9	1.5	1.1	2.1	1.6	1.6	2.4
nC23	3.1	3.7	5.2	2.8	2.9	2.1	1.6	4.9	3.2	2.9
nC24	5.0	3.7	3.8	4.4	3.0	2.2	2.2	6.9	3.5	1.4
nC25	12.2	10.1	10.9	9.9	6.7	9.3	4.1	7.5	7.8	14.5
nC26	1.9	<1	<1	<1	<1	<1	1.4	<1	<1	2.7
nC27	11.6	12.6	12.9	11.2	7.4	7.2	6.1	16.5	14.8	52.2
nC28	4.2	5.4	6.7	6.7	6.2	4.5	3.6	7.6	4.4	12.2
nC29	40.9	53.7	49.0	34.8	33.3	26.5	27.1	51.1	47.1	42.4
nC30	8.5	9.3	8.9	8.7	6.0	5.2	5.1	9.2	7.6	11.6
nC31	46.2	48.2	52.9	33.2	32.9	27.9	29.8	55.1	50.8	39.3
nC32	1.6	3.6	5.2	3.6	4.5	2.7	2.7	2.7	6.5	6.3
nC33	19.6	19.9	20.9	16.0	15.1	14.2	12.4	20.4	22.9	12.6
nC34	28.6	27.1	28.8	35.2	31.7	22.6	22.8	39.4	28.2	14.9
nC35	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC36	<1	5.0	1.6	<1	<1	3.4	<1	7.2	7.4	7.6
nC37	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Oil	**3728**	**3909**	**4990**	**2508**	**3516**	**2554**	**2369**	**4518**	**4878**	**5363**
Total n alkanes	**221.8**	**231.7**	**247.2**	**198.4**	**184.1**	**154.2**	**146.5**	**265.6**	**240.0**	**298.0**

Table 4.4. cont. *Total Aliphatic Concentrations (ng.g^{-1})*

Station	G21	G22	G23	G24	G25	G26	G27	G28	G29	G30
nC10	2.6	2.8	1.6	1.3	<1	1.2	1.3	<1	<1	<1
nC11	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC12	1.1	<1	1.3	2.2	2.9	2.5	1.7	1.7	1.6	2.2
nC13	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC14	2.5	2.8	3.7	3.2	3.4	5.2	3.0	4.1	4.1	3.1
nC15	<1	<1	1.5	2.4	1.5	4.5	1.8	1.9	1.9	5.2
nC16	2.3	2.5	4.4	3.6	3.8	3.5	3.0	2.9	3.2	3.5
nC17	4.8	3.8	4.8	5.8	7.8	6.8	4.9	5.2	4.2	5.0
pristane	2.1	1.4	<1	2.1	3.1	2.9	1.5	1.2	1.7	1.4
nC18	5.1	3.3	2.8	8.9	14.6	5.3	3.9	3.4	4.5	4.2
phytane	3.7	2.4	1.2	1.5	3.2	2.7	1.8	1.9	1.6	2.7
nC19	2.8	2.7	1.1	5.2	7.8	2.5	3.4	4.1	4.4	2.6
nC20	5.1	4.5	2.9	3.4	4.7	6.1	5.5	5.0	4.6	5.6
nC21	4.6	4.2	2.9	6.3	11.9	10.5	6.0	5.4	5.1	6.0
nC22	1.3	1.5	2.5	1.2	3.5	2.2	1.5	<1	1.5	4.7
nC23	6.4	4.1	5.5	5.7	9.4	4.3	3.2	2.8	2.9	4.1
nC24	3.4	3.3	5.5	4.1	3.2	3.9	3.5	2.9	3.3	4.1
nC25	10.1	6.6	8.8	10.1	16.0	13.9	7.3	5.8	7.8	10.2
nC26	<1	<1	<1	<1	2.2	<1	<1	<1	<1	<1
nC27	12.6	10.6	15.3	14.0	23.9	16.7	12.1	12.1	10.7	22.9
nC28	5.4	4.8	8.7	5.4	13.8	8.6	2.9	3.3	5.0	6.8
nC29	40.0	35.1	37.2	34.9	56.5	38.4	28.5	34.5	30.4	63.2
nC30	5.7	4.8	6.0	6.2	5.7	6.4	5.3	6.2	6.5	10.2
nC31	38.8	36.8	36.4	36.9	65.8	36.2	28.9	38.4	33.3	70.6
nC32	3.8	3.1	3.4	1.0	1.4	2.0	1.5	<1	<1	2.8
nC33	17.0	12.0	16.8	13.7	16.4	14.3	11.9	18.4	12.9	25.2
nC34	42.6	31.3	31.2	23.4	26.1	18.1	23.6	48.5	36.1	61.2
nC35	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC36	<1	<1	1.6	<1	<1	1.5	2.3	<1	<1	<1
nC37	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Oil	**3974**	**3965**	**3025**	**3644**	**8097**	**6579**	**4184**	**3859**	**4278**	**7616**
Total n alkanes	**218.1**	**180.6**	**206.1**	**198.8**	**302.3**	**214.4**	**166.9**	**206.8**	**184.1**	**323.2**

Table 4.4. cont *Total Aliphatic Concentrations (ng.g-1)*

Station	G31	G32	Dawn	Ruth	Alpha	Barbara	Ernest	Wedell A	Wedell A
nC10	1.5	1.3	2.2	2.4	<1	<1	2.9	<1	1.1
nC11	<1	<1	1.1	<1	<1	<1	<1	<1	<1
nC12	1.7	1.7	2.4	3.8	<1	1.8	3.0	<1	<1
nC13	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC14	2.9	3.9	4.7	4.5	2.0	2.4	3.5	2.9	2.4
nC15	3.6	2.7	2.1	<1	<1	<1	<1	2.0	1.3
nC16	2.8	2.5	6.2	3.5	2.1	2.2	4.2	2.4	2.3
nC17	4.0	4.7	3.2	3.8	1.5	2.0	2.8	4.2	3.0
pristane	1.2	<1	1.1	1.4	<1	1.1	1.3	2.6	2.0
nC18	2.7	2.2	2.8	4.4	2.1	2.4	4.6	4.8	3.0
phytane	<1	<1	<1	3.4	<1	1.2	1.2	1.5	2.2
nC19	<1	1.2	<1	1.7	<1	3.4	3.0	1.9	7.1
nC20	2.7	2.5	3.6	5.7	1.4	2.3	2.8	5.3	4.6
nC21	2.4	2.6	2.7	4.6	1.3	2.1	3.7	2.6	3.8
nC22	1.4	1.8	1.5	1.6	<1	<1	1.1	<1	<1
nC23	3.0	4.5	2.7	4.9	<1	1.7	2.9	4.0	2.5
nC24	3.9	3.7	5.5	3.7	1.8	2.7	3.2	3.0	5.4
nC25	8.8	8.8	9.7	8.3	5.5	4.6	5.0	5.9	5.4
nC26	<1	<1	1.7	<1	<1	<1	1.2	<1	<1
nC27	16.8	16.7	15.0	11.7	6.6	7.6	7.8	12.1	13.3
nC28	4.1	8.6	11.5	6.3	3.0	2.9	5.7	5.3	4.0
nC29	44.1	45.3	42.5	43.0	15.8	16.6	31.3	39.5	41.8
nC30	6.8	8.5	7.2	5.9	3.3	3.0	5.0	5.2	5.5
nC31	47.4	46.6	37.2	44.5	17.0	18.7	32.5	41.7	45.8
nC32	<1	2.5	4.8	3.0	1.3	1.2	3.4	2.8	1.1
nC33	20.3	18.8	14.7	15.5	7.0	6.6	13.7	11.4	11.1
nC34	30.0	30.1	50.6	40.2	10.9	9.6	32.3	22.9	25.0
nC35	<1	<1	<1	<1	<1	<1	<1	<1	<1
nC36	<1	<1	<1	1.6	<1	<1	<1	<1	<1
nC37	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Oil	**5481**	**5850**	**4573**	**4485**	**1227**	**1333**	**3213**	**3307**	**3793**
Total n alkanes	**210.7**	**221.3**	**235.5**	**224.7**	**82.8**	**93.8**	**175.3**	**179.8**	**189.4**

4.4.3. Polycyclic Aromatic Hydrocarbons (PAH)

Quantitative polycyclic aromatic hydrocarbons were analysed at each station using Gas Chromatography-Mass Spectrometry (GC-MS). Results of the single ion current (SIC) analyses are summarised in Table 4.3, and detailed in Table 4.5, showing concentrations for both parent compounds and their alkyl derivatives. A summary of PAH distributions are given in Appendix III.

Total PAH concentrations were exceptionally low remaining undetected at all but 6 of the 39 regional sites surveyed. These remaining stations had a maximum concentration of 16.5ng.g^{-1} (Figure 4.18). Given such low levels, it is difficult to separate out any pattern of distribution, however stations G1, in deeper water and showing a significantly greater proportion of fines indicated the highest total PAH concentration, approximately twelve times higher than any other level measured on the continental shelf.

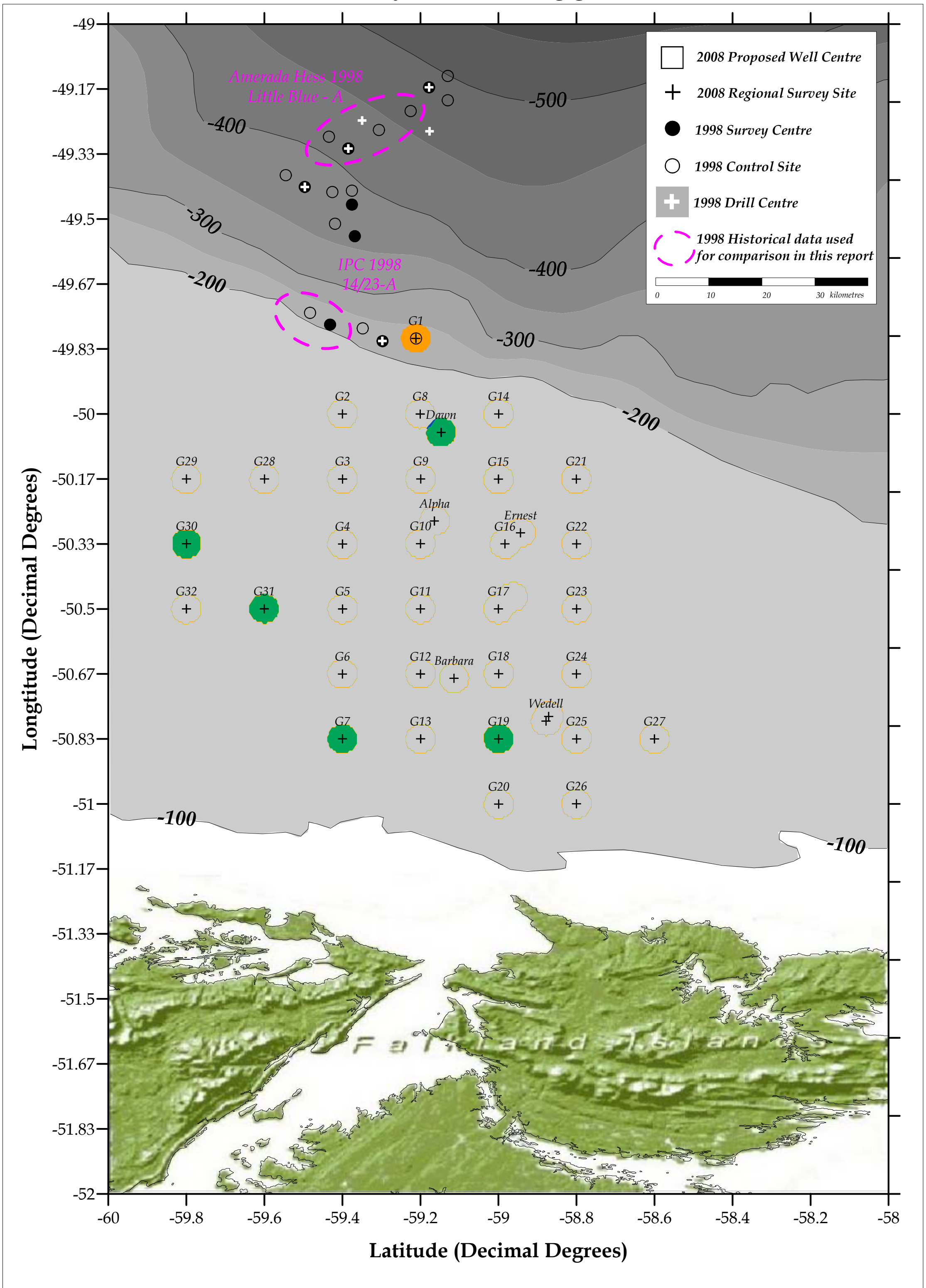
Polyaromatic hydrocarbons and their alkyl derivatives have been recorded in a wide range of marine sediments (Laflamme & Hites, 1978) with the majority of compounds produced from what is thought to be pyrolytic sources. These are the combustion of organic material such as forest fires (Youngblood & Blumer, 1975), the burning of fossil fuels and, in the case of offshore oilfields, flare stacks, etc. The resulting PAHs, rich in the heavier weight 4-6 ring aromatics, are normally transported to the sediments via atmospheric fallout or river runoff. Another PAH source is petroleum hydrocarbon, often associated with localised drilling activities. These are rich in the lighter, more volatile 2 and 3 ring PAHs (NPD; naphthalene (128), phenanthrene, anthracene (178) and dibenzothiophene (DBT) with their alkyl derivatives).

The NPD fraction represented all PAHs recorded at 5 out of the 6 stations where aromatics were recorded. This would ordinarily identify the dominance of petrogenic hydrocarbons within these sediments, but this is not thought to be the case for these data. The use of NPD ratios to signify aromatic origin is primarily based on sediments were there is a significant ubiquitous baseline of pyrolytic source. The exceptionally low levels of total PAHs would suggest an absence of such a baseline thereby rendering a 2 and 3 ring weight comparison obsolete. This would suggest that natural pyrolytic sources of PAHs to the sediment are extremely rare in this part of the south Atlantic. Assuming that most PAHs are transported to the sediments via aeolian (wind blown) followed by particle flocculation and settling to the seabed, the sandy substrate, wind direction and the absence of any significant land mass that might produce smoke from incomplete combustion are limited. Prevailing winds are from the southwest and the main current is from the south, where the only landmasses are the Falkland Islands and Tierra del Fuego, where fires are rare and the Antarctic continent.

Another proportional check for PAHs would be a comparison of the parent compounds over their substituted alkyl derivatives. Again, results are inconclusive due to the low concentrations recorded.

In 1998, higher concentration, although still low overall, were recorded west and north of the current study. The mean concentrations were 90.3 and 60.4ng.g^{-1}. As all stations were off the continental shelf in sediments which indicated a significantly high proportion of fine sediments, a slightly higher background for PAHs at these sites was to be expected.

Figure 4.18. Hydrocarbons – Total 2-6 Ring Polycyclic Aromatic Hydrocarbons (ng/g)



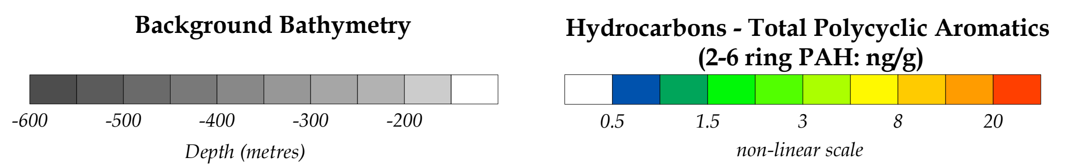


Table 4.5. ***Polycyclic Aromatic Hydrocarbon Concentrations***

(Single Ion Currents, $ng.g^{-1}$)

Station	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Naphthalene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Naphthalenes	1.07	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Naphthalenes	1.82	<1	<1	<1	<1	<1	1.06	<1	<1	<1
C3 Naphthalenes	1.49	<1	<1	<1	<1	<1	<1	<1	<1	<1
C4 Naphthalenes	1.36	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Naphthalenes	**5.74**	**0**	**0**	**0**	**0**	**0**	**1.06**	**0**	**0**	**0**
Phenanthrene / Anthracene	1.55	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 178	2.07	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 178	1.8	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 178	1.39	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 178	**6.81**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Dibenzthiophene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Dibenzthiophenes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fluoranthene / pyrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 202	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzanthracene / chrysene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 228	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 228	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 228	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzfluoranthenes / benzopyrenes	1.11	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 252	2.84	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 252	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 252	**3.95**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Aranthanthrenes / indeno- pyrene / benzperylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 276	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 276	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 276	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Sum of all fractions	**16.5**	**nc**	**nc**	**nc**	**nc**	**nc**	**1.06**	**nc**	**nc**	**nc**
Sum of NPD fraction	**12.55**	**nc**	**nc**	**nc**	**nc**	**nc**	**1.06**	**nc**	**nc**	**nc**

nc = not calculated

Table 4.5. cont. ***Polycyclic Aromatic Hydrocarbon Concentrations (Single Ion Currents, ng.g⁻¹)***

Station	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20
Naphthalene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	1.04	<1
C3 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C4 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Naphthalenes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1.04**	**0**
Phenanthrene / Anthracene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 178	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 178	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 178	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 178	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Dibenzthiophene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Dibenzthiophenes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fluoranthene / pyrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 202	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzanthracene / chrysene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 228	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 228	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 228	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzfluoranthenes / benzopyrenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 252	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 252	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 252	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Aranthanthrenes / indeno- pyrene / benzperylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 276	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 276	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 276	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Sum of all fractions	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**1.04**	**nc**
Sum of NPD fraction	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**1.04**	**nc**

nc = not calculated

Table 4.5. cont. Polycyclic Aromatic Hydrocarbon Concentrations

(Single Ion Currents, ng.g^{-1})

Station	G21	G22	G23	G24	G25	G26	G27	G28	G29	G30
Naphthalene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.28
C3 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C4 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Naphthalenes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1.28**
Phenanthrene / Anthracene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 178	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 178	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 178	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 178	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Dibenzthiophene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Dibenzthiophenes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fluoranthene / pyrene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 202	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 202	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzanthracene / chrysene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 228	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 228	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 228	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzfluoranthenes / benzopyrenes	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 252	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 252	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 252	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Aranthanthrenes / indeno- pyrene / benzperylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 276	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 276	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 276	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Sum of all fractions	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**1.28**
Sum of NPD fraction	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**nc**	**1.28**

nc = not calculated

Table 4.5. CONT. Polycyclic Aromatic Hydrocarbon Concentrations

(Single Ion Currents, $ng.g^{-1}$)

Station	G31	G32	Alpha	Dawn	Ruth	Barbara	Ernest	Wedell A	Wedell B
Naphthalene	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Naphthalenes	1.06	<1	<1	1	<1	<1	<1	<1	<1
C3 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
C4 Naphthalenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Naphthalenes	**1.06**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
Phenanthrene / Anthracene	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 178	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 178	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 178	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 178	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Dibenzthiophene	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 Dibenzthiophenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum Dibenzthiophenes	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fluoranthene / pyrene	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 202	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 202	<1	<1	<1	<1	<1	<1	<1	<1	<1
C3 202	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 202	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzanthracene / chrysene	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 228	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 228	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 228	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Benzfluoranthenes / benzopyrenes	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 252	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 252	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 252	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Aranthanthrenes / indeno- pyrene / benzperylene	<1	<1	<1	<1	<1	<1	<1	<1	<1
C1 276	<1	<1	<1	<1	<1	<1	<1	<1	<1
C2 276	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum 276	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Sum of all fractions	**1.06**	**nc**	**nc**	**1**	**nc**	**nc**	**nc**	**nc**	**nc**
Sum of NPD fraction	**1.06**	**nc**	**nc**	**1**	**nc**	**nc**	**nc**	**nc**	**nc**

nc = not calculated

4.5. Heavy and Trace Metal Concentrations

Results for heavy and trace metal analysis are given in Table 4.6. All of the heavy and trace metals analysed (Al, Ba, Sr, As, Fe, Cd, Cr, Cu, Hg, Ni, Pb, V and Zn), with the exception of mercury (Hg), underwent a double aqua regia followed by a hydrofluoric (HF) digestion and extraction, to provide a sub-digestion values (sometimes reported as "bioavailable") in addition to total sediment metals.

The question of biolavailability of metals to marine organisms is a complex one, as sediment granulometry and the interface between waters and sediment all affect the bioavailability and subsequently toxicity. Therefore, even if a metal is found in higher concentrations it does not necessarily follow that this will have a detrimental effect on the environment, if present in an insoluble state. Historically, several extraction techniques have been applied to metal analysis in the past, with the most common applying to an HF/perchloric extraction for total metals, and a weaker nitric or aqua regia extraction for bioavailable metals. The latter techniques have shown close correlation to metal burdens in the tissues of benthic organisms (Luoma and Davies, 1983; Bryan and Langston, 1992). However the overall extent to which a particular digests reflects bioavailability is still not fully understood. Sometime the concentrations of some metals, like barium, typically recorded in areas where previous drilling activities have occurred, are so high that full dissolution cannot be guaranteed even with hydrofluoric acid digestions, necessitating a further fusion technique. This was not required for the baseline sediments on this study.

Historically, it is important to establish baseline levels for several heavy and trace metals where found in elevated concentrations within drilling fluids or produced waters discharged by Oil & Gas installations, both through intentional additives (such as metal based salts and organo-metallic compounds in the fluids) as well as impurities within the mud systems. Metals most characterised by offshore contamination to the sediments are barium, chromium, lead and zinc (Neff, 2005), although these may vary greatly dependant upon the constituents used.

Barium remains the most abundant metal found in drilling related discharges due to its use as a weighting agent within the drilling mud program in the form of barite ($BaSO_4$). Consequently, it is often used as an indicator to the effects of drilling related discharges. For this baseline survey, natural barium levels remained relatively low and constant throughout the area ranging from $120\mu g.g^{-1}$ to $364\mu g.g^{-1}$ (mean $285\mu g.g^{-1}$), with slightly lower concentrations recorded in the centre of the regional area (Figure 4.19). As drilling related discharges have not occurred in the vicinity of this survey, these values reflect the natural variation relative to the sediment changes at these locations, the majority of which (83-97%) remaining insoluble and unavailable to the marine fauna. As barium is generally considered as non-toxic in the insoluble sulphate form (Gerrard et al, 1999), this metals is rarely of toxicological concern. Statistically, the barium correlated strongly with many other mineral or crustal metals, such as aluminium and strontium, as well as autocorrelation with others. Bariums also showed a significant correlations with sediment parameters such as mean particle size, % sands, and in particular sediment classes between phi 1 and 3.5 (medium to very fine sands; generally $P<0.001$). Previous total barium levels of 289 and $382mg.kg^{-1,}$ were recorded in 1998 west and north of the G1 location, respectively.

Strontium is a similar metal also often associated with drilling related discharges. This metal showed a clear pattern of distribution relating to elevated levels inshore (Figure 4.20). Overall levels ranged from 109 to 293 $mg.kg^{-1}$ (mean 194 $mg.kg^{-1}$).

Another crustal metal Aluminium (which is often used for normalisation of metals to reflect natural changes in sediments; Figure 4.21), indicated significant variability (from 13.0 to 57.1 $mg.g^{-1}$ and mean 35.2 $mg.g^{-1}$) with a marginally lower concentration to the east of the survey area. Aluminium correlated weakly with the mean particle size and in particular, negatively with phi 1 to 2 (medium sand) size classes (Pearson's $P<0.01$). Previous aluminium levels were marginally higher with an average of 71.1 and 52.8 $mg.g^{-1,}$ recorded in 1998 west and north of the G1 location, respectively.

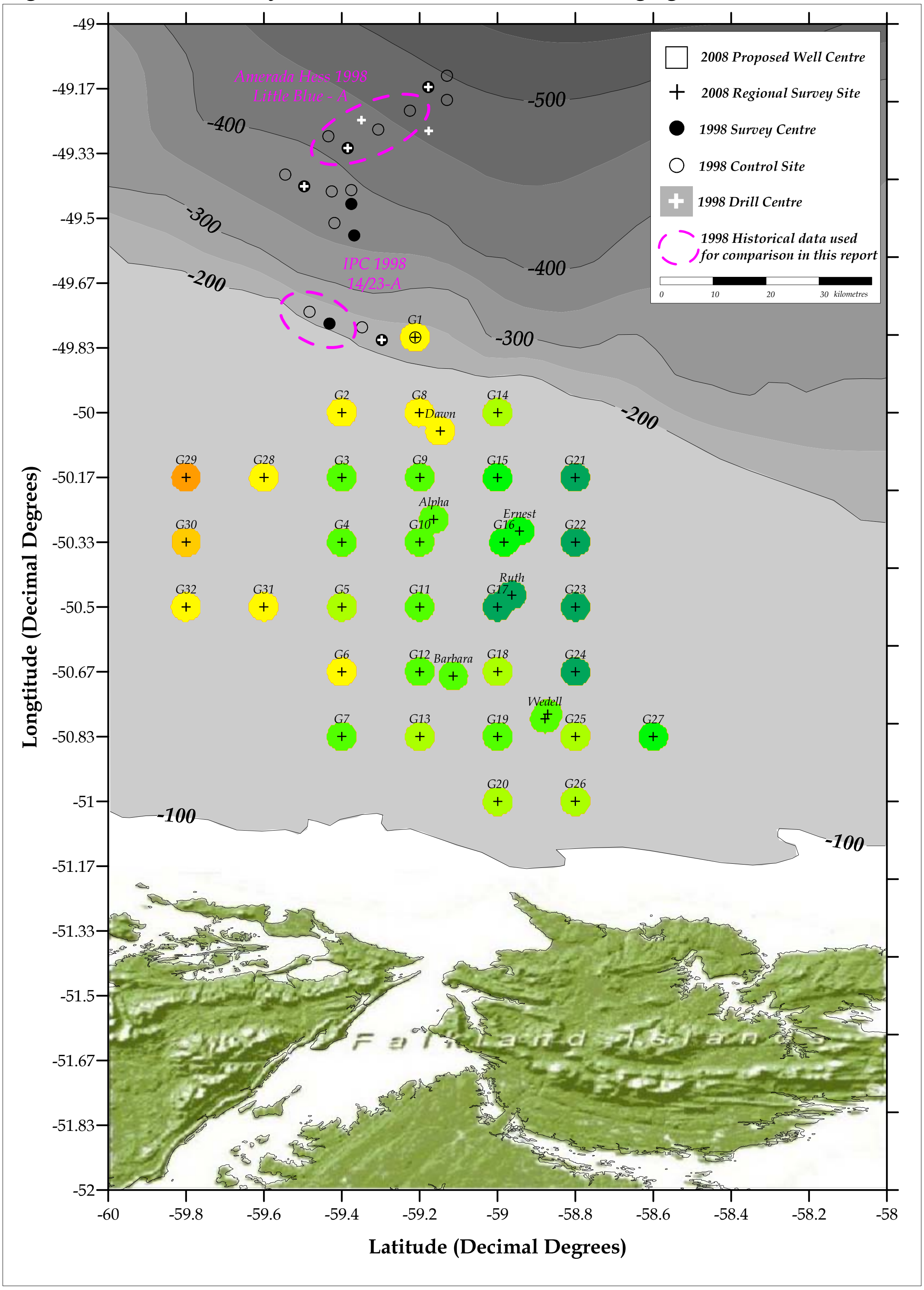
All of the remaining metals analysed show generally low level concentrations expected for an uncontaminated offshore environment. When comparing the key elements with those of the OSPAR background reference concentrations (BRCs) values, the seven key metals cadmium, chromium, copper, mercury, nickel, lead and zinc all gave concentrations below OSPAR BRCs with the exception of cadmium which was marginally elevated (examples Figures 4.22 -4.27). There remains some debate as to toxicity of cadmium to marine and terrestrial organisms. Some papers describe cadmium as "very toxic" (Muniz et al 2004), whilst others consider this metals to have no negative effects (McLeese et al, 1987). Other attempts to quantify the critical level of cadmium toxification were carried out by Buchman (1999) and suggested 'probable effect level' of around 4.2$mg.kg^{-1}$. The highest concentration of cadmium was recorded at stations G1, at 0.7$mg.kg^{-1}$.

Of the other metals analysed, iron (Fe) gave variable levels ranging from 7.5 to 46.9 $mg.g^{-1}$. This is an important metal as it is often associated with other elements, such as Arsenic (As) to which they adsorb (2 to 8$\mu g.g^{-1}$). Vanadium (V) levels remained low and consistent (mean 28.9mg.kg-1; Figure 4.26). Vanadium is often associated with the oil and gas industry as s it is present in relatively high concentrations in most crude oils (Khalaf et al, 1982). Most vanadium enters seawater in suspension or colloidal form, passing quickly out of the water column and into silt deposition (Cole et al, 1999).

As a double digestion was carried out on the metals for the current study, only the total metals can be compared to those previously recorded in the North Falklands Basin in 1998. Overall, the metals aluminium (Al), barium (Ba) , cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), vanadium (V) and zinc (Zn) were all below the previously recorded levels. Only lead (Pb) gave a higher value (mean 5.8$mg.kg^{-1}$, Figure 4.24) as unrecorded (<0.5$mg.kg^{-1}$) during the earlier surveys. This was interpreted as possible matrix masking during the laboratory testing during the earlier study and not a true representation of the sediment concentration at that time.

Many of the metals indicated subtle patterns of distribution as demonstrated in figures 4.19 to 4.27. Statistically most of the metals auto-correlated between themselves, (Pearson's $P<0.01-0.001$), due to the fact that they also related to the major particle size parameters (such as mean sizes and fines). Individual particle size classes separated the metals slightly but were all were enhanced by finer sediments either by negatively correlated with the coarser sand fractions (i.e. matrix metals such as barium, aluminium and iron) or positively correlating with the silts and clays (vanadium) or both (cadmium and strontium). Other key correlations were TOM, PAHs and n-alkanes, although these were only on selected metals and expected to represent a link back to sediment parameters. Overall variations in metals are a function of the naturally variability of sediments rather than representing a significant enough gradient to produce a "cause and effect" on other factors.

Figure 4.19. Heavy & Trace Metals – Total Barium (mg/kg)



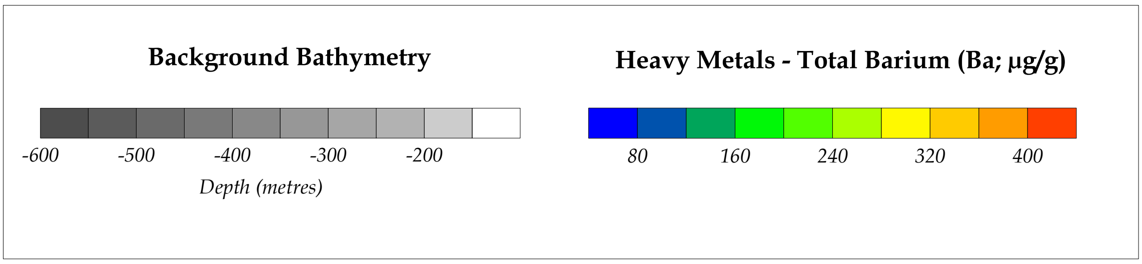


Figure 4.20. *Heavy & Trace Metals – Total Strontium (mg/kg)*

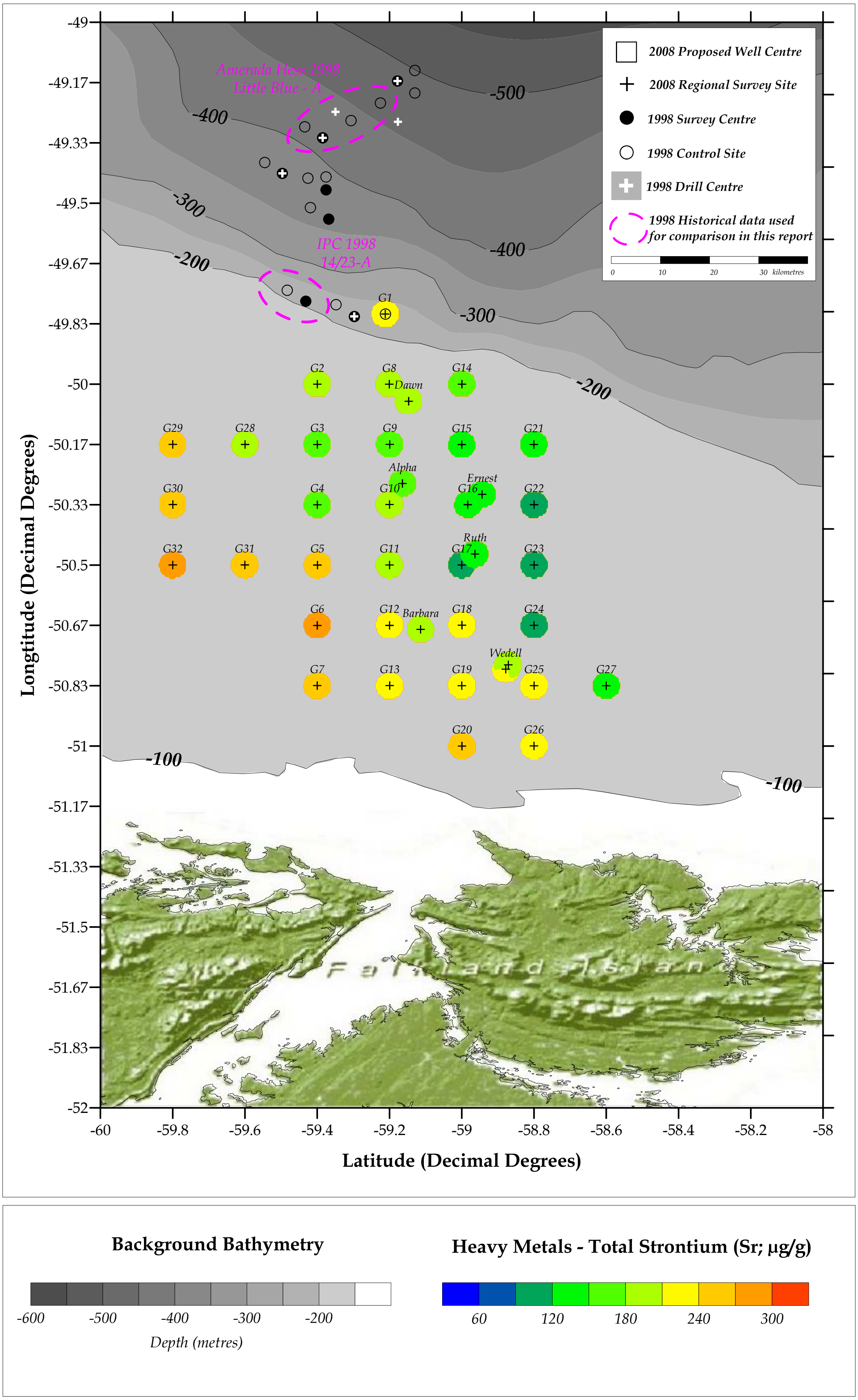
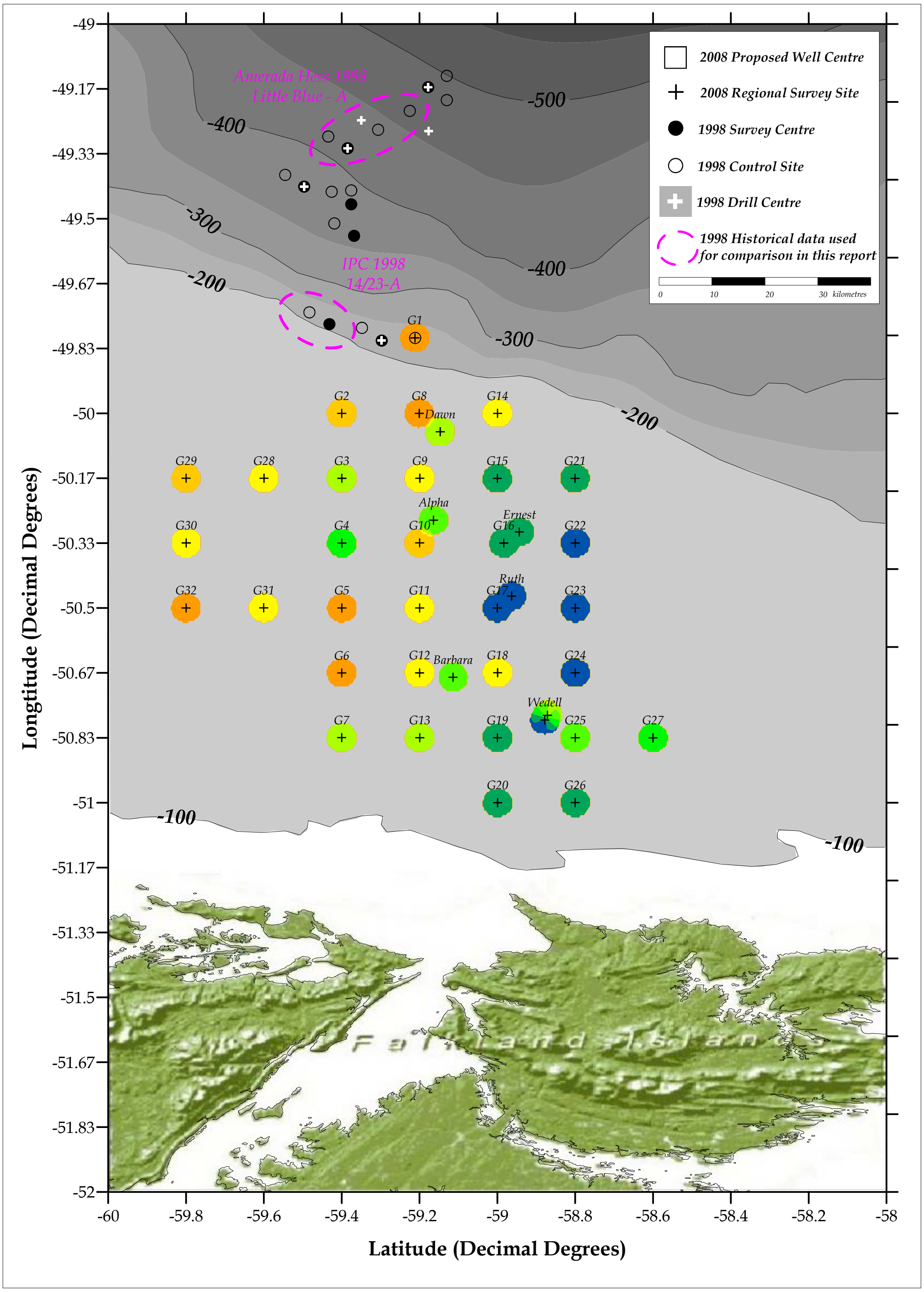


Figure 4.21. *Heavy & Trace Metals – Total Aluminium (mg/kg)*



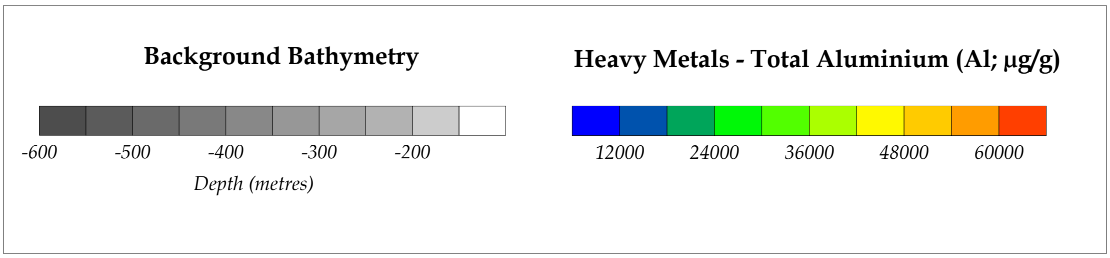
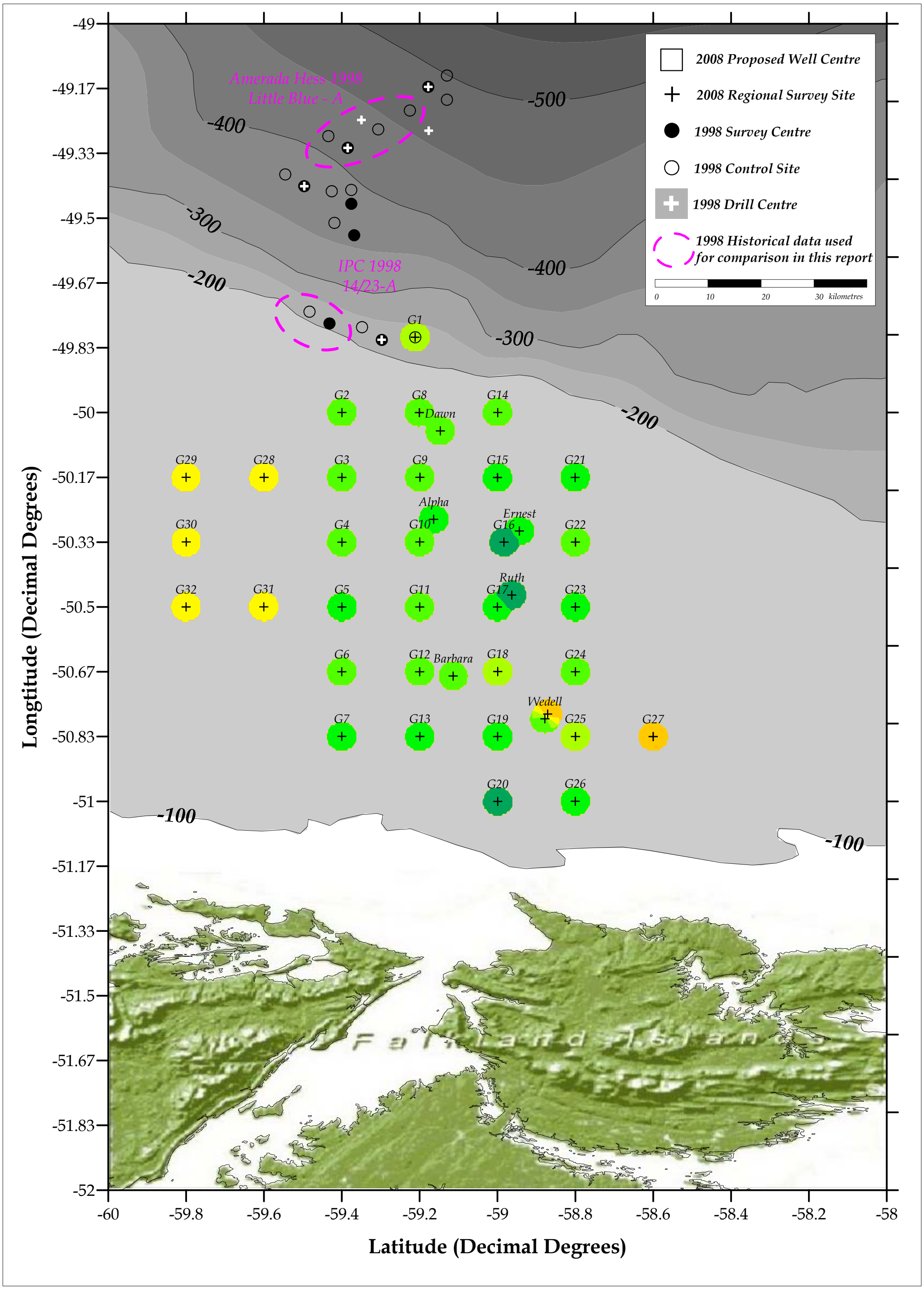


Figure 4.22. *Heavy & Trace Metals – Total Chromium (mg/kg)*



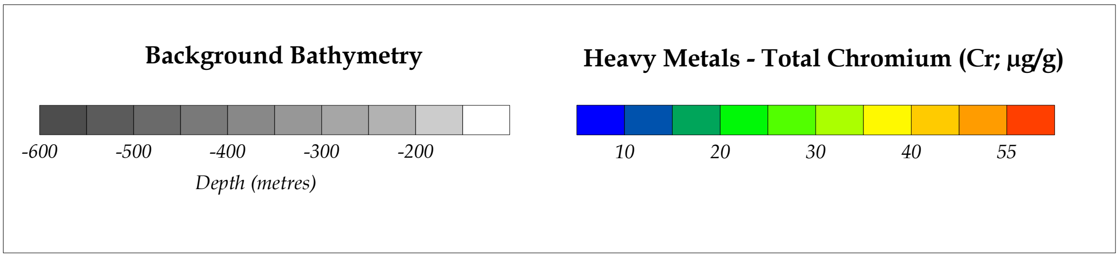


Figure 4.23. *Heavy & Trace Metals – Total Copper (mg/kg)*

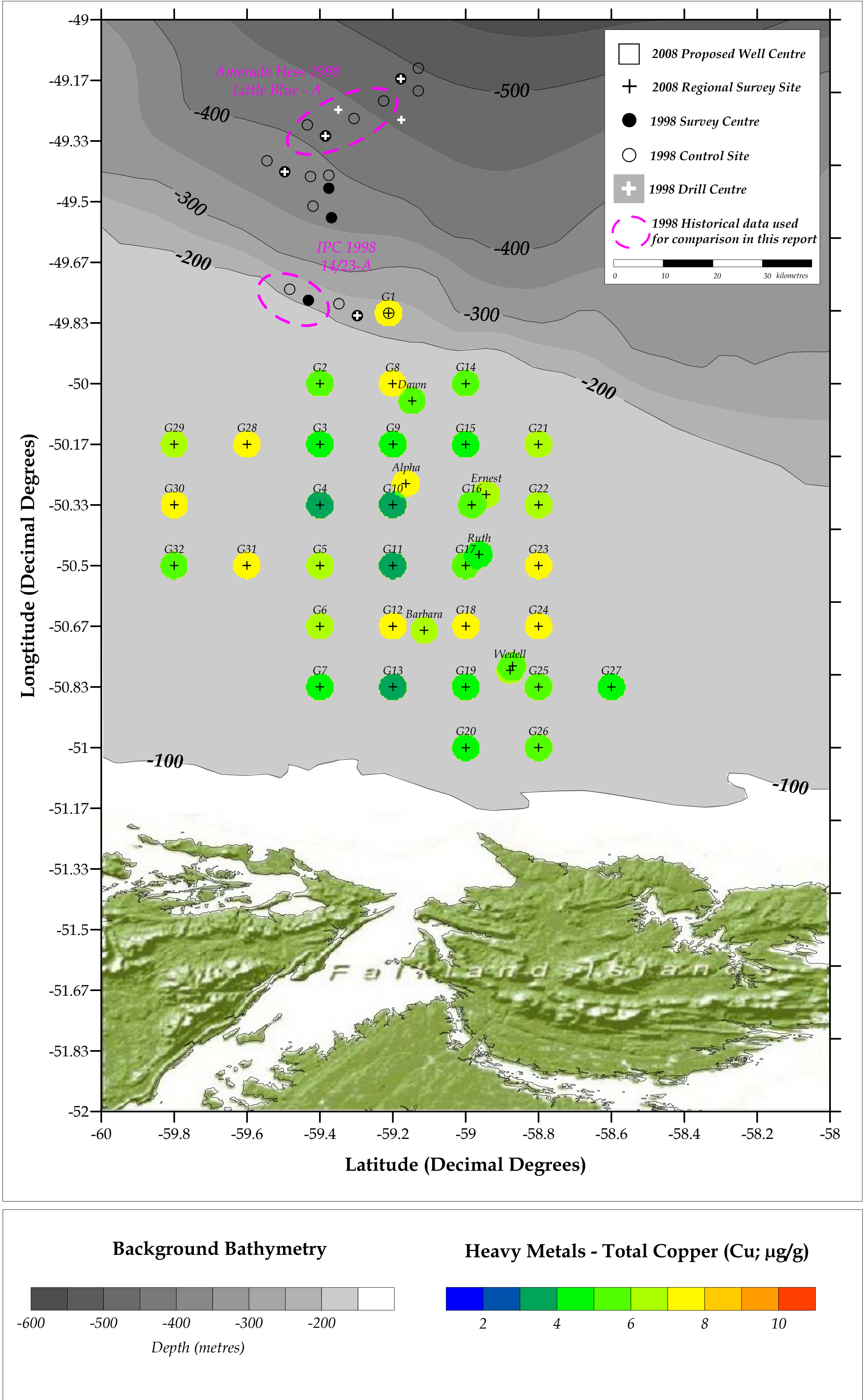
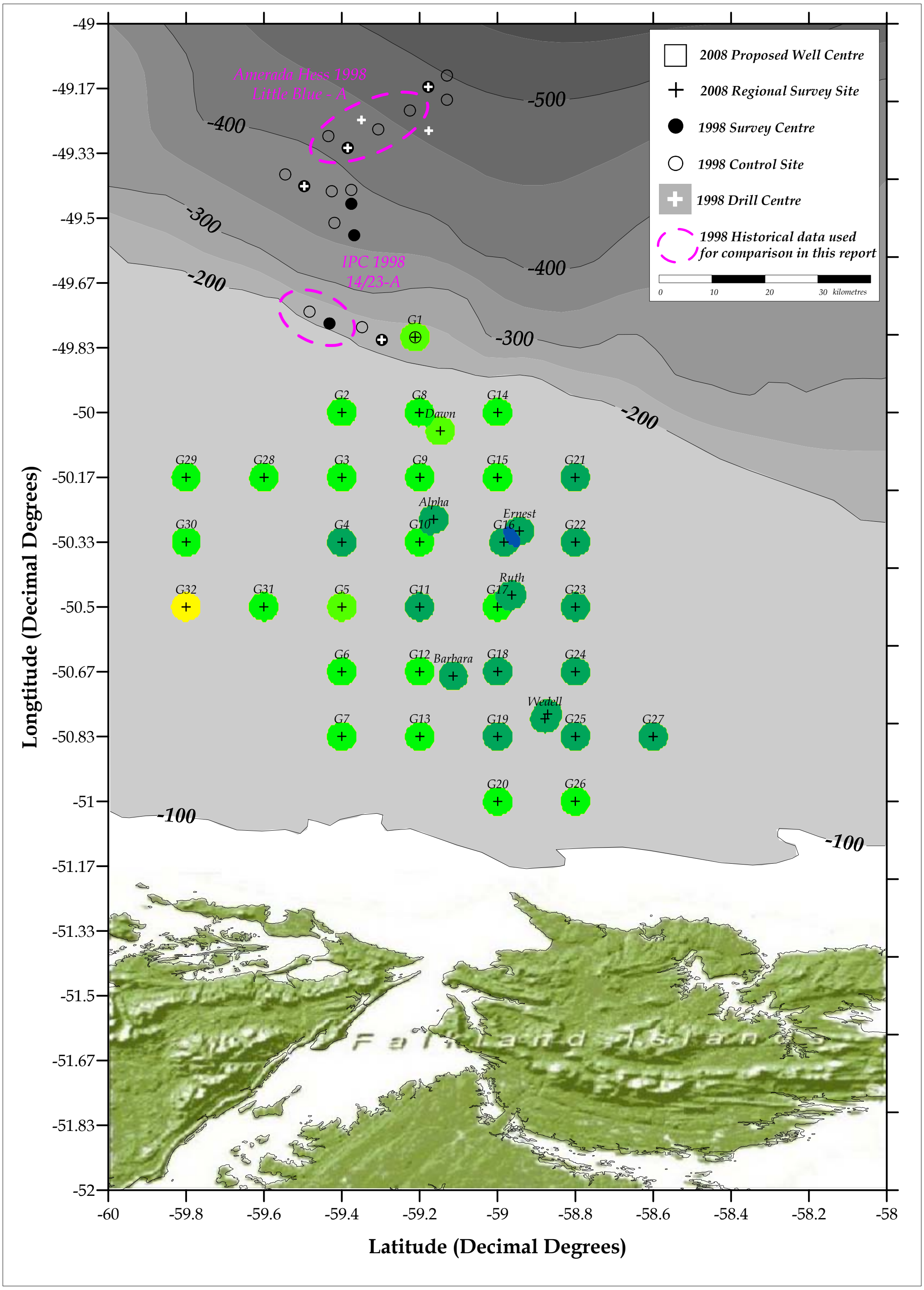


Figure 4.24. *Heavy & Trace Metals – Total Lead (mg/kg)*



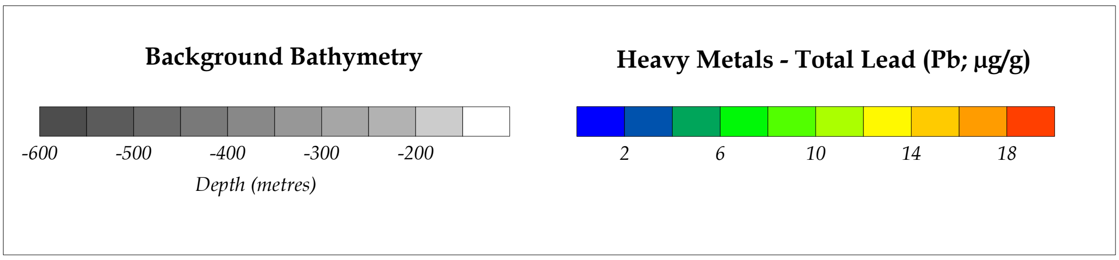
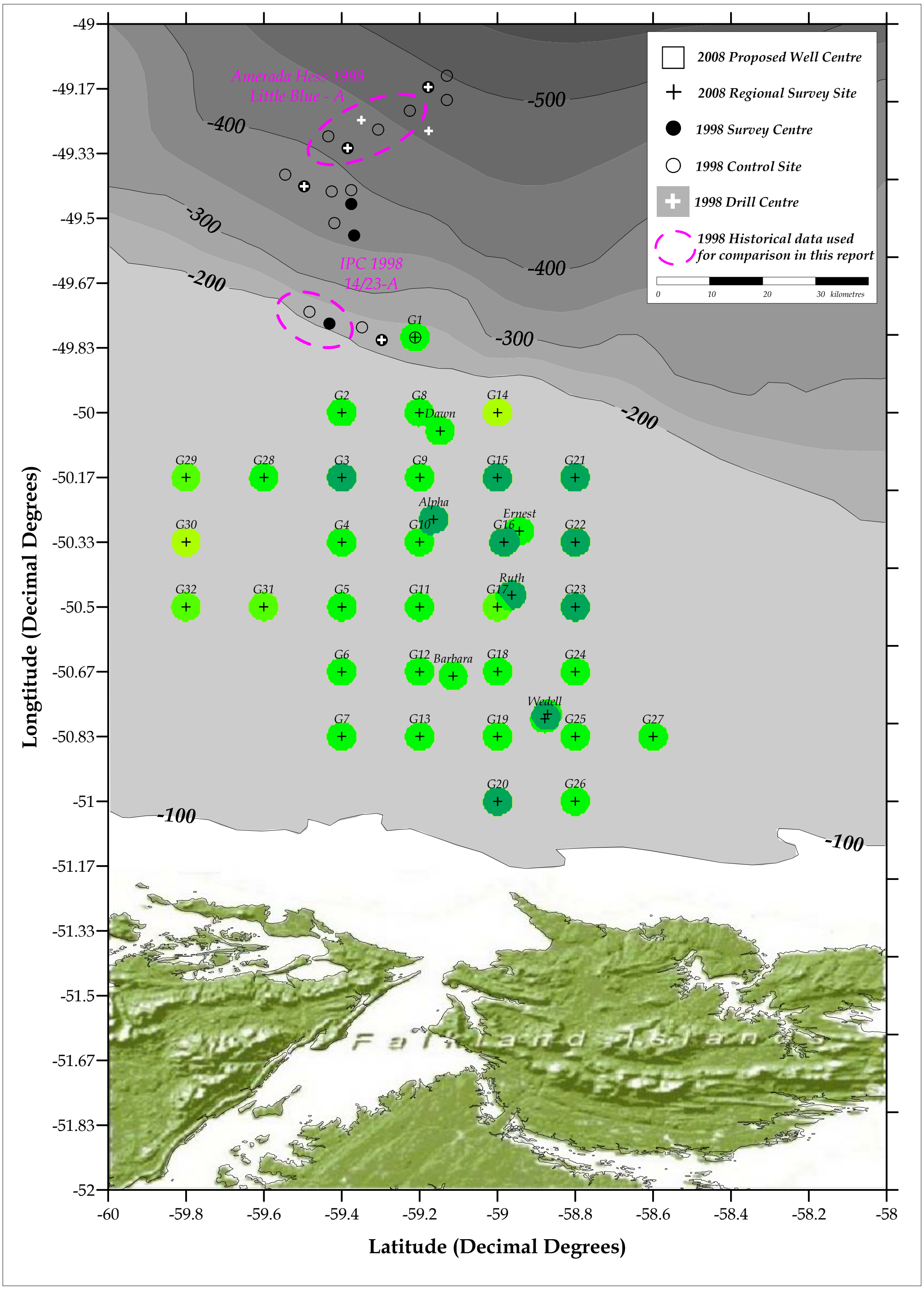


Figure 4.25. Heavy & Trace Metals – Total Nickel (mg/kg)



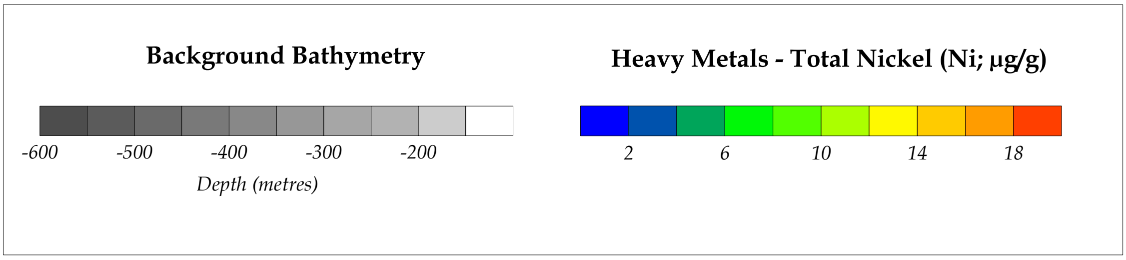
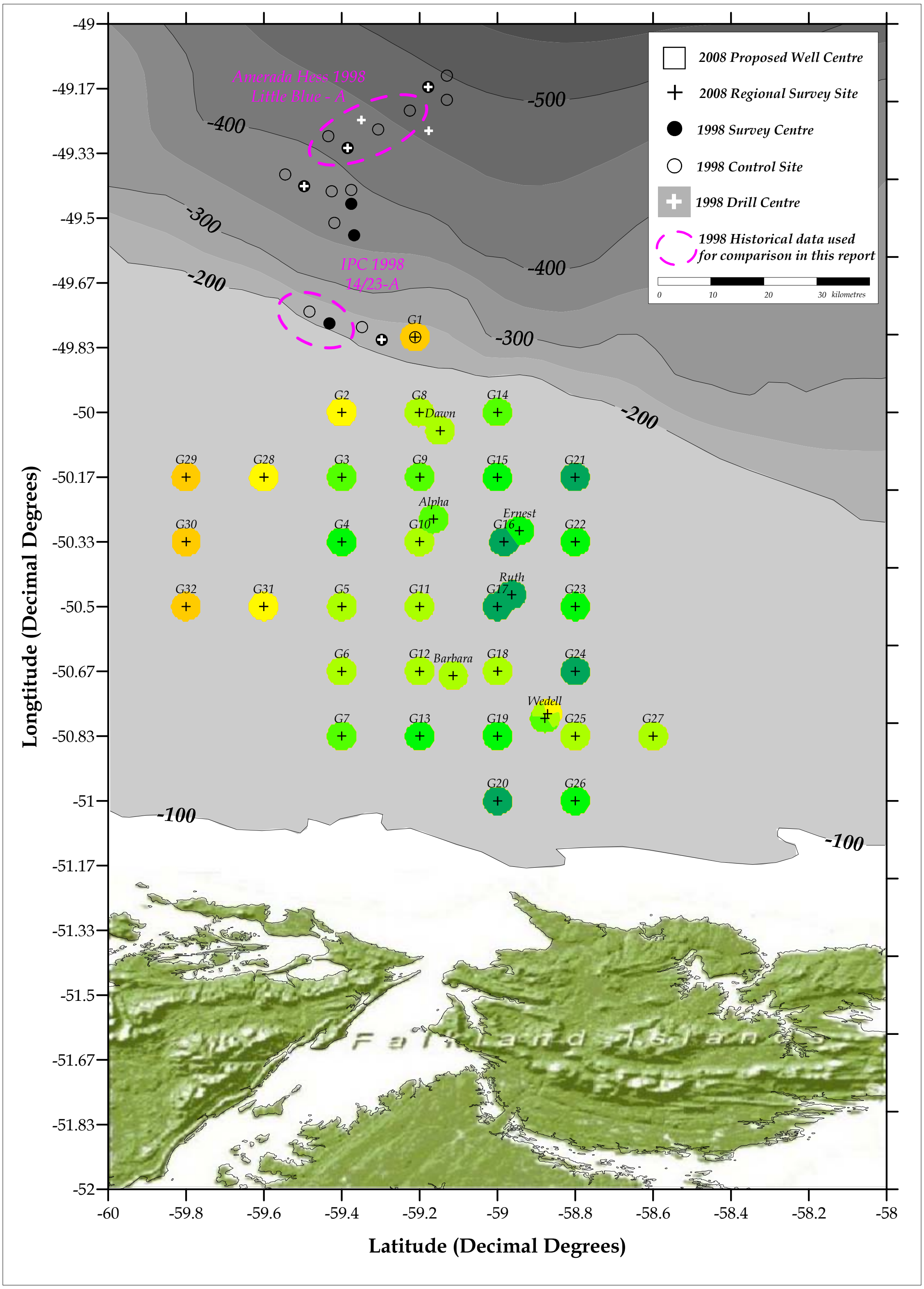


Figure 4.26. *Heavy & Trace Metals – Total Vanadium (mg/kg)*



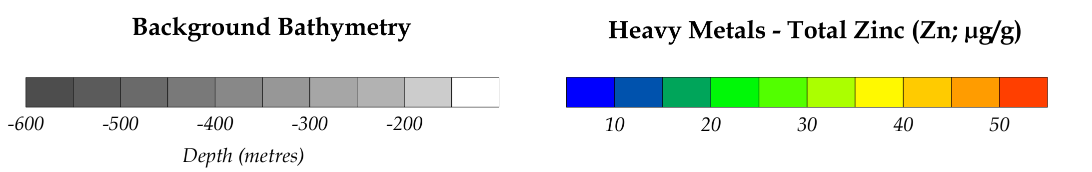


Figure 4.27. Heavy & Trace Metals – Total Zinc (mg/kg)

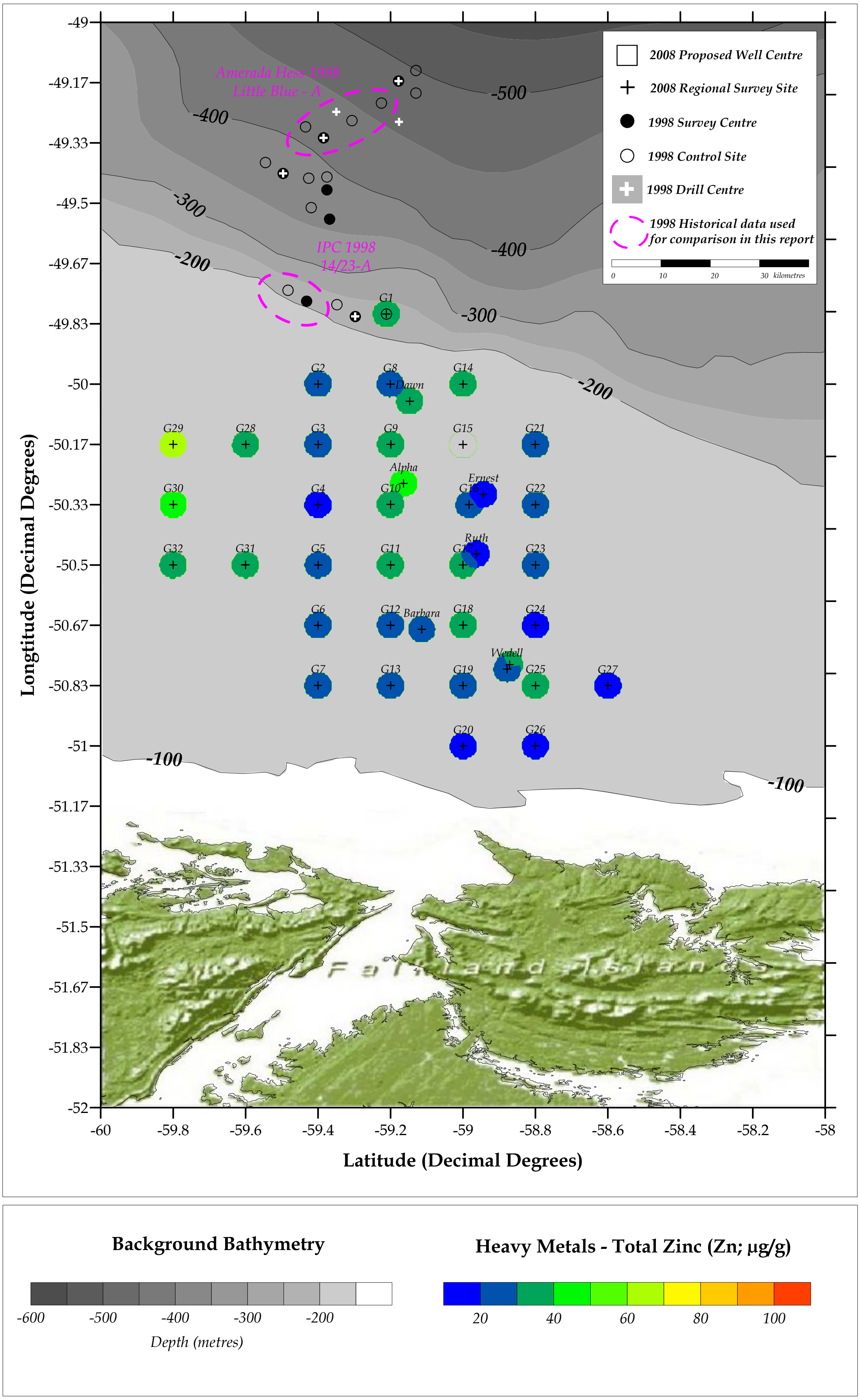


Table 4.6. *Total Heavy & Trace Metal Concentrations (µg.g^{-1} or ppm)*

Station	Arsenic		Barium		Cadmium		Chromium		Copper		Lead		Hg
	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR	
G1	4	3.4	315	36	0.7	<1	30	25.7	8	6.6	9	3.6	0.02
G2	4	3.1	291	16	0.5	<1	28	23.6	5	<5	6	2.2	0.01
G3	3	4	228	26	0.4	<1	27	25.5	4	27.4	6	2.6	0.01
G4	3	2.1	229	8	0.3	<1	26	19.4	3	<5	5	1.7	0.01
G5	4	3.6	273	14	0.3	<1	24	23	6	<5	8	3.8	0.02
G6	4	4.2	284	26	0.3	<1	26	27	6	8.6	6	2.3	0.02
G7	2	1.9	237	10	0.5	<1	20	14.6	4	<5	6	2.3	0.01
G8	4	2.9	298	17	0.5	<1	28	25.3	8	<5	7	2.1	0.02
G9	4	3.5	225	23	0.4	<1	27	22	4	7.3	7	2	0.01
G10	4	3.4	233	15	0.4	<1	29	24.5	3	<5	6	2	0.01
G11	4	3.2	236	24	0.4	<1	26	22.5	3	7.6	5	2.1	0.01
G12	4	4	227	16	0.4	<1	25	23	7	5.4	6	2.2	0.01
G13	3	2.9	251	16	0.4	<1	20	18.2	3	6.4	6	2	0.03
G14	3	2.8	264	15	0.4	<1	25	21.9	5	<5	6	2.2	0.01
G15	2	1.8	177	13	0.1	<1	20	15.2	4	<5	6	2.6	0.01
G16	2	2	161	9	0.2	<1	18	14.7	5	<5	4	2.5	0.01
G17	2	3.2	157	25	0.2	<1	22	21.4	5	11.1	6	2.7	0.01
G18	4	4.1	248	8	0.4	<1	30	24.2	8	8.7	5	3.3	0.01
G19	3	2	209	20	0.4	<1	21	14.2	4	<5	5	2.1	0.01
G20	2	1.6	261	15	0.6	<1	18	13.3	4	<5	6	4.4	0.01
G21	2	1	156	16	0.3	<1	20	10.1	6	<5	4	1.3	<0.01
G22	2	1.4	129	16	0.3	<1	26	11	6	<5	4	1.4	<0.01
G23	2	1.6	142	16	0.3	<1	23	13.6	7	<5	5	1.3	<0.01
G24	7	1.5	120	10	0.6	<1	28	11.4	8	<5	4	1.1	<0.01
G25	4	4	247	17	0.5	<1	31	22.5	5	<5	5	2	0.01
G26	3	2.2	279	16	0.6	<1	22	13.8	5	<5	7	5.4	<0.01
G27	6	4.2	195	14	0.5	<1	41	28	4	5.1	5	1.6	<0.01
G28	4	3.4	291	17	0.5	<1	36	27	7	<5	6	1.9	0.01
G29	5	3.2	364	21	0.5	<1	37	20.2	6	<5	6	1.7	<0.01
G30	6	4.1	347	28	0.5	<1	36	18.8	8	<5	6	1.8	0.01
G31	4	3.3	308	38	0.4	<1	35	23.2	7	<5	6	2.1	<0.01
G32	4	2.8	307	26	0.4	<1	35	22.2	5	<5	13	2.1	<0.01
Alpha 0	3	2.7	216	13	0.3	<1	24	19.4	8	<5	5	1.7	<0.01
Barbara 0	3	3.1	218	18	0.3	<1	27	19	6	5	5	1.9	<0.01
Dawn 0	4	3	303	25	0.6	<1	29	23.1	5	<5	8	2.2	0.03
Ernest 0	2	1.7	169	9	0.3	<1	21	14.2	6	<5	4	1.7	<0.01
Ruth 0	2	1.8	139	24	0.3	<1	17	14.3	4	<5	4	3.7	<0.01
Weddell A	3	3.4	239	32	0.4	<1	26	22.1	6	7.5	5	2.5	0.01
Weddell B	8	8.2	222	23	0.5	<1	46	46.3	5	5.9	5	2.2	0.01
Mean	**3.6**	**3.0**	**235.8**	**18.7**	**0.4**	**<1**	**26.9**	**20.5**	**5.5**	**8.7**	**5.8**	**2.3**	**0.01**
St Dev	**1.4**	**1.2**	**60.7**	**7.4**	**0.1**	**nc**	**6.5**	**6.5**	**1.6**	**5.9**	**1.6**	**0.9**	**nc**
Bioavailable	83.7%		7.9%		nc		76.51		100.0%		39.6		nc
Gardline 1998d	-	-	289.5	-	<0.5	-	35.7	-	3.2	-	<0.5	-	<0.5
Gardline 1998a	-	-	382.6	-	<0.5	-	45.2	-	14.1	-	<0.5	-	1.3
OSPAR BRC	-		-		0.2		60		20		25		0.05

Nc = not calculated
HF = Total metals by hydrofluoric extraction
AR = "bioavailable" metals by aqua regia extraction

Table 4.6. cont. Total Heavy & Trace Metal Concentrations ($\mu g.g^{-1}$ or ppm)

Station	Nickel		Strontium		Vanadium		Zinc		Aluminium		Iron	
	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR	HF	AR
G1	7	9.5	239	101	45	26.3	39	32.7	57100	12400	19900	17900
G2	6	7.4	205	55	36	18.3	27	20.9	53900	7660	15100	11500
G3	5	8.2	167	57	27	16.1	22	15.5	39200	7570	13700	14000
G4	6	5.1	168	58	24	11.8	19	12.9	25700	4820	12600	7920
G5	6	6.2	240	61	32	17.4	26	18.2	55800	6240	15100	9360
G6	6	9.7	275	111	31	19.7	26	20.7	55900	9790	14600	14000
G7	6	8.5	240	121	25	11.1	21	14.7	39900	4730	10700	7140
G8	6	7.8	200	58	32	18.4	26	19	54300	8100	15000	12400
G9	6	7.5	174	60	29	16.1	34	14.8	43500	7180	11800	12000
G10	6	6.6	191	59	34	16.1	33	15.9	48000	6390	12200	9780
G11	7	8.3	209	163	30	17.5	34	15	42900	7670	12300	12700
G12	6	6.9	225	97	33	18.7	29	15.3	45100	6700	16100	12000
G13	6	8	226	115	24	13.8	25	15.4	41400	6250	12400	10200
G14	12	6.3	175	50	28	15.5	30	16.3	44700	7090	14600	11400
G15	5	<5	135	50	20	10.9	5	12	21200	4480	9650	7390
G16	5	<5	129	52	19	9.6	23	10.1	19200	3550	8500	5950
G17	8	7.4	118	58	19	12.3	32	12.5	17400	5350	10600	12000
G18	7	8.1	225	143	33	17.8	32	16.5	43800	4560	17700	7600
G19	6	5.6	234	99	23	11.1	22	12.8	22500	8000	10100	13400
G20	5	8.1	257	175	18	8	18	51	22600	4600	10300	8460
G21	5	<5	121	94	19	6.2	20	11.1	18800	3300	10100	7200
G22	5	<5	109	53	22	6.7	23	9.1	15100	3140	7560	8630
G23	5	<5	119	57	21	6.6	21	9.5	16600	2870	10800	8860
G24	7	<5	109	53	18	6.6	19	8.6	13000	2910	10700	5570
G25	7	7.2	215	110	31	15.4	34	16.2	33100	6750	22000	16000
G26	6	5.3	218	119	22	9.3	19	11.5	23800	4460	12400	10300
G27	6	6.3	145	65	32	14.2	19	13.3	25900	7500	38200	19600
G28	7	7	205	55	38	18.4	37	18.5	44300	7670	18300	12800
G29	8	6.3	266	59	45	14.4	62	16.2	48200	7170	18300	11600
G30	10	6.5	267	96	45	18.3	41	16.2	42100	6680	20900	12000
G31	8	6.1	260	82	39	16.3	32	15	46900	8080	17100	13600
G32	8	6.5	293	82	42	16.5	34	17.5	54600	8170	17300	12200
Alpha 0	5	5.5	169	38	25	13.8	41	12.4	34200	5380	11300	8160
Barbara 0	6	5.5	192	56	33	15.6	27	11.6	34300	6120	18000	10600
Dawn 0	7	7.1	201	60	32	17.5	33	17.8	40200	8620	15400	14000
Ernest 0	6	4.8	144	44	21	9.4	14	13.5	21200	3580	8990	5610
Ruth 0	4	<5	128	51	17	9	15	11.9	17600	4260	8040	7950
Weddell A	6	9	213	102	28	16.6	22	15.3	16100	8190	16000	14000
Weddell B	6	8.6	193	94	36	28.1	32	16.1	36500	11700	46900	30400
Mean	**6.4**	**7.1**	**194.8**	**79.8**	**28.9**	**14.5**	**27.4**	**16.0**	**35297**	**6402**	**15160**	**11440**
St Dev	**1.5**	**1.3**	**51.0**	**33.6**	**8.0**	**5.0**	**9.7**	**7.1**	**13861**	**2246**	**7483**	**4487**
Bioavailable	100.0%		41.0%		50.1%		58.4%		18.1%		87.0%	
Gardline 1998d	**<0.5**	**-**	**-**	**-**	**70.8**	**-**	**28.9**	**-**	**71150**	**-**	**-**	**-**
Gardline 1998a	**15**	**-**	**-**	**-**	**67.0**	**-**	**59.2**	**-**	**52792**	**-**	**-**	**-**
OSPAR BRC	**45**		**-**		**-**		**90**		**-**		**-**	

Nc = not calculated
HF = Total metals by hydrofluoric extraction
AR = "bioavailable" metals by aqua regia extraction

4.6. Macrofaunal Analysis

Macrofaunal analysis was carried out on seventy eight replicates (39 sites) over the regional survey area. The sediments showed a relatively consistent sandy sediment type with subtle variations in additional finer or coarser admixtures relative to the location on the continental shelf, or slope. Particle sizes varied from very poorly to moderately well sorted medium sand to coarse silt. Macrofaunal samples were all processed in the field using a 500µm mesh size. Subsequent macrofaunal taxonomy for this regional report has provided a preliminary assessment of the main taxa recorded across the site. As such, some of the groups have not been fully described and will be expanded once all of the individual well sites have also been completed (discussed later). Of the identified fauna to date, a total of 16,775 individuals/colonies were identified from the 78 samples analysed. Faunal data for each sample are listed in Appendix V, whilst univariate analyses are summarised in Table 4.8. Of the 210 species/groups recorded, 180 were infaunal, consisting of 65 annelids accounting for 47.6% of the total taxa. The molluscs were represented by 25 species (8.5%), the crustaceans by 63 species (35.4%) and the echinoderms by 10 species (4.6%), while all other groups (cnidaria, nemertea, nematoda, platyhelminths, sipuncula, pycnogonida, brachiopoda, enteropneusta and chordata) accounted for the remaining 9.4%, or 17 species. A distribution of the different taxa is presented in Figure 4.28 by station abundance (i.e. number of individuals in each phyla) or Figure 4.29 by station richness (i.e. number of species in each phyla).

With the exception of species that have been intentionally grouped into higher taxonomic levels (e.g. Nematoda, Nemertea etc.), the majority of adult specimens were identified to species level where possible. Some of the complicated polychaete and amphipod species have yet to be fully separated and have been intentionally grouped into a higher taxonomic level. Key families included in this are the polychaetes cirratulida, Paraonida and Maldanida. The crustacea *Aricidea* has also been split into putative species but further separation can be expected. Of the 180 separated taxa/groups used in this report approximately 42 of the specimens were recorded to species (excluding juveniles and fragmented species), along with a further 54 identified to genus/putative species level. This is equivalent to around 56.5% of the taxon or, 69.6% of the total specimens. Species separated into putative species, but only identified to family or order, accounted for a further 17% of taxon, 11% of specimens. Only 8 juvenile species were recorded throughout the survey area (possibly reflecting the winter time of the sampling), of which all were infaunal (3 annelid, 2 crustacea and 3 echinoderms). Juveniles are often excluded from community analyses due to their high mortality prior to reaching maturity and difficulties in distinguishing species of the same genus. Consequently, they tend to induce a recruitment spike at certain times of the year due to rapid settlement and colonisation, but are essentially a ephemeral part of the population masking the underlying trends within the mature adults. Although juvenile numbers were moderately high (680 individuals or 3.9% of the population), these specimens have been excluded from the multivariate analyses.

The previous macrofaunal survey operations in the North Falklands basin in 1998 was acquired over a slightly smaller geographical area, but on sediments covering a larger depth range. Samples were taken from 97 locations and the final faunal matrix indicated a community made up of 328 species. These were separated into 112 annelids (34.2%), 54 molluscs (16.5%), 106 crustacea (32.3%), 28 echinoderms (8.5%) and 28 other (8.5%).

Other macrofaunal groups not included in the multivariate analyses are the foraminerfera, epifaunal species (such as poriphera, hydroidea and bryozoa) and some damaged specimens. Overall, these groups accounted for a further 35 different groups or 15.9% of the community recorded. These have been separated from the main matrix or recorded as presence/ absence and not included in the multivariate analysis. These have been listed separately in Appendix V.

Figure 4.28. Proportion of Individual Abundance by Main Group and Replicate

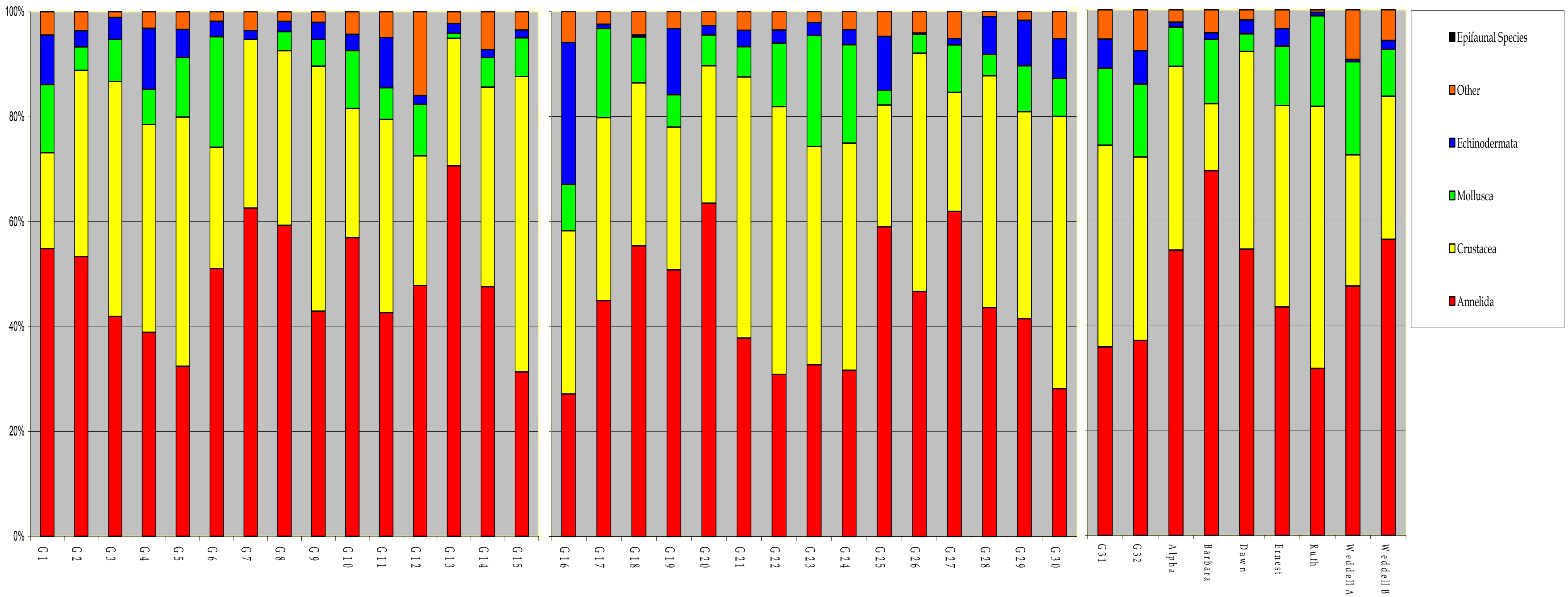
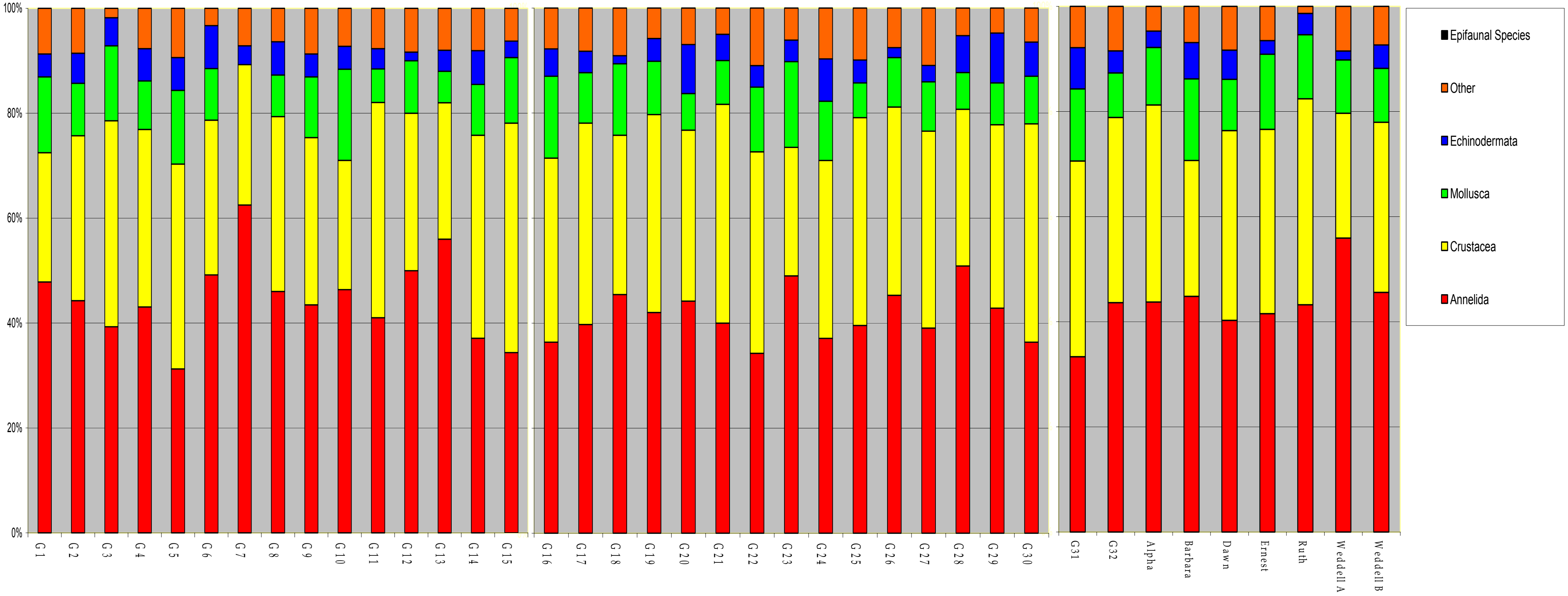


Figure 4.29. Proportion of Individual Abundance by Main Group and Station



4.6.1. Infaunal Trends

The benthic fauna of the Falkland Islands belongs to the Magellan faunal area, made up of the sea areas around the southern part of South America (e.g. of the Coasts of Argentina and Chile, and the subantarctic area to the south). In many aspects it is comparable to the Northern Boreal Region; it is however characterised by a very high diversity within the crustacea, with many groups well represented. For this preliminary regional assessment the level of analysis has concentrated on the key separation of groups in order to identify trends within the biological community with that of the physical habitats over the northern continental shelf. Further analysis of this material is expected to refine a greater number of specimens to species level; although our knowledge of the fauna is much more limited than that of the northern Atlantic and European waters, with the use of specialist taxonomic knowledge to resolve some of the groups and a definite identification and description of hitherto unrecognised species.

The top five dominant species across the regional survey area were, in order, the amphipod *Urothoe* sp, the polychaetes *Aricidea Sp A* (pictured Figure 4.30*), a further* gammarid crustacea Phoxocephaloidea sp.C (eyeless) and the families maldanidae and cirratulidae. However, the distribution of these key species alter slightly on a regional scale. This is explained further during the multivariate analyses (see section 4.6.3).

Table 4.7. Overall Species Ranking (Top 15 Species)

Overall Top 15 Rank	Species/Taxon	Total rank score (out of 80)	Numerical Abundance (16 replicates)	Numerical Ranking
1	*Urothoe sp.*	351	2417	1
2	*Aricidea sp.A*	226	1746	2
3	Phoxocephaloidea sp.C (eyeless)	174	678	4
4	Maldanidae spp	170	782	3
5	Cirratulidae spp.	145	614	5
6	*Cryptodon falklandica*	133	527	7
7	*Ophiura cf meridionalis*	91	564	6
8	Aff Scoloplos sp	82	411	8
9	Paraonoidae spp.	66	301	10
10	*Aricidea sp.B*	65	360	9
11	*Spiophanes cf soederstroemi*	52	261	13
12	Oligochaeta Tubificidae	47	262	12
13	Ampelisca sp. A	46	265	11
14	*Yoldiella / Ledella*	43	164	16
15	*Cyamiomactra falklandica*	40	241	14

A measure of the overall dominance pattern in the sampling area was achieved by ranking the top species per station according to abundance, giving a rank score of 15 to the most abundant species, decreasing to 1 for the fifteenth most abundant species, and summing these scores for all 39 sites to provide an overall dominance score (Eleftheriou & Basford, 1989) for each species. The top 15 species are shown in Table

4.7. This ranking closely matches the numerical ranking for the species overall with only a few of the taxa changing positions numerically with a neighbour. This suggests that the proportion of these species remains relatively consistent across the survey area with clear habitat changes and subsequent sub-communities absent.

Comments relating to individual infaunal groups recorded during the survey are as follows:

Polychaeta: The polychaete fauna contained many cosmopolitan and bipolar species which were morphologically indistinguishable from their northern counterparts. Surveys by the cruise of the *Walther Herwig* on the Patagonian Shelf and the Falkland Islands for example (Hartmann-Schröder 1983) yielded 34 species, of which 31% were cosmopolitan, 15 % subantarctic and Antarctic species, and a further 15% belonged to the Magellan faunal region. The remainder of the species had a circumpolar distribution around the Antarctic continent. Other surveys from German cruises into the subantarctic and Antarctic by Hartmann-Schröder (1986) and Hartmann-Schröder & Rosenfeldt (1989, 1990, 1991& 1992) gave similar results. Further zoogeographical information for the area is contained in Orensanz (1974). Examples of as bipolar or cosmopolitan species, common in the northern hemisophere (including the British Isles) and recorded within the current macrobenthos dataset are as follows. These species show no morphological differences to their northern counterparts, and this list is expected to increase on further review of the results.

- *Levinsenia gracilis*
- *Spiophanes bombyx*
- *Maldane sarsi*
- *Rhodine loveni*
- *Chaetozone setosa*
- *Notomastus latericeus*
- *Ophelina cylindricaudata*
- *Scalibregma inflate*
- *Terebellides stroemi*

Figure 4.30. The dominant polychaete Aricidea spA.

A wide distributions of some polychaete fauna should not be surprising given the often lengthy planktonic life of polychaete larva. There were no obvious differences in the biology of these species nor in those species which share their generic status within the northern boreal region.

Crustacea: The same is not quite true of the crustacean fauna, which is highly diverse especially with regards to the amphipoda and isopoda. Highly characteristic for example is the Isopod *Serolis* (pictured Figure 4.31), which has no northern equivalent. A large number of small specimens were regularly recorded, with two separate species delineated (predominantly separated by size; see Appendix V).

Figure 4.31. The larger of two species of Serolis sp.

Also of interest is the Tanaid *Archaeotanais hirsutus* which was frequently encountered in larger tubes (probably abandoned polychaete tubes?) and in one instance three large adults shared a single tube with more than 15 juveniles; this which may indicate a degree of parental care.

The amphipod *Urothoe* sp. dominated the faunal community as it was recorded at all stations (Figure 4.32). Other prominent crustacea was the gammarid Phoxo-cephaloidea sp.C (eyeless)

Figure 4.32. The dominant crustacean Urothoe sp.

Several amphipod species have been identified. However, the specific naming of currently distinguished morphological types is ongoing. It is unknown what percentage are currently described species and can be named with absolute certainty.

Mollusca: In contrast the molluscan fauna was not well developed. Bivalve specimens, as a rule, were very small and rarely exceeding a couple of m millimetres; similar to that found in much deeper waters of the Atlantic. Two species of the carnivorous bivalve recorded (genus *Cuspidaria*, Figure 4.33), have counterparts in northern hemi-sphere, whilst others do not share more than Family status.

Figure 4.33. The bivalve Cuspideria sp.

A relatively frequent Gastropod is ascribed to the large genera *Skenea/Cyclotrema*; the family status of which is somewhat uncertain

(Skeneidae with genera *Skenea* and *Cyclotrema* or separate families) These two genera groups are very large with a wide distribution, predominantly in deeper waters of the Atlantic.

Echinodermata: The Echinoderms were generally well identified where their size permitted with most specific identities reliable in status. The frequently encountered starfish *Ctenodiscus australis*, a cushion star type, is found in all sizes from a post larval stage as yet without arms to fairly large specimens. The same is applicable to the irregular sea urchin *Abatus cavernosus*, characterized by a deeply furrowed anterior ambulacrum. Of interest is the seven-armed brittle star *Ophiacantha vivipara* which like many antarctic species broods it's young.

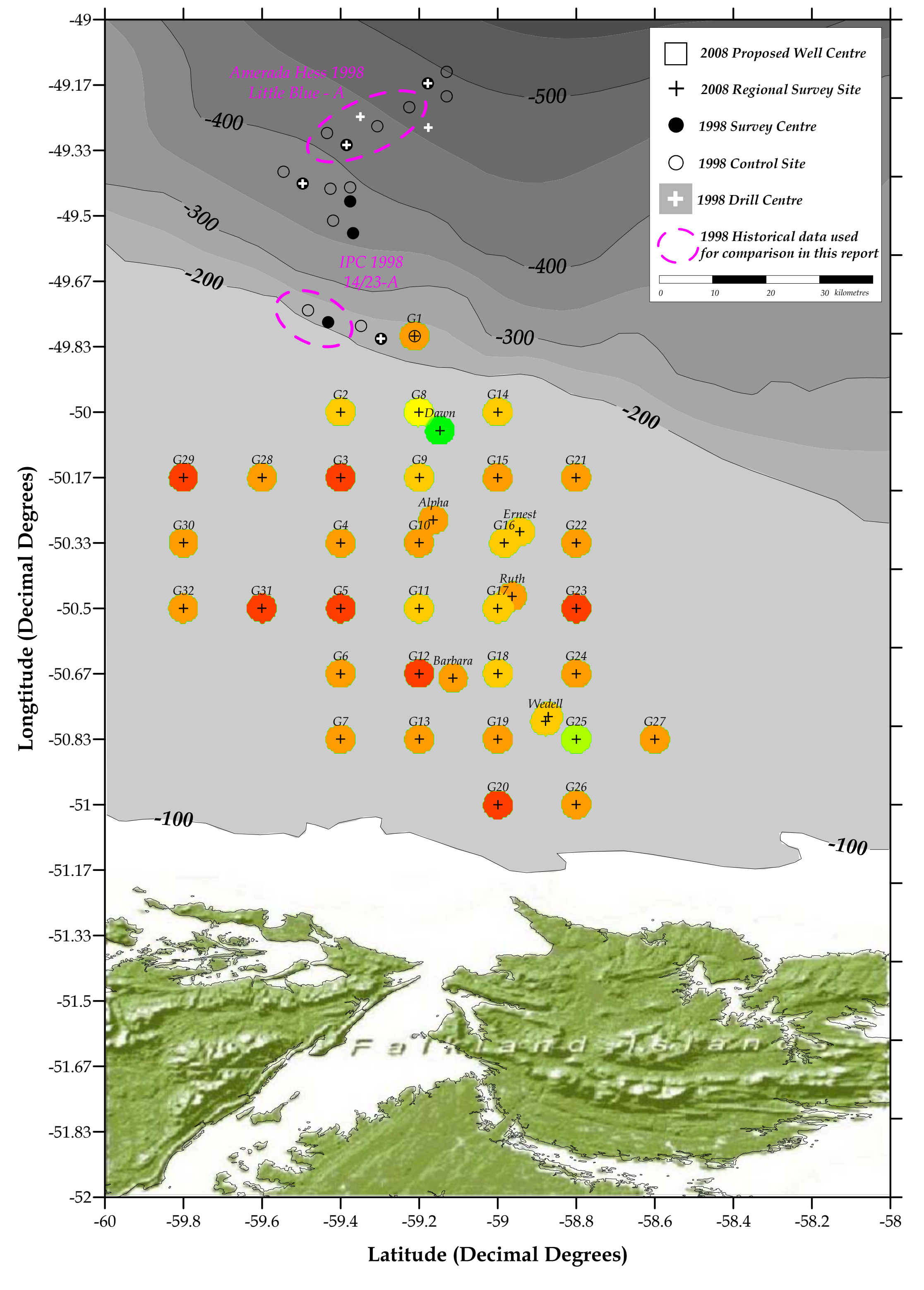
4.6.2. Univariate Parameters

The primary and univariate parameters are listed for individual macrofaunal replicates, together with aggregated stations in Appendix V (by replicates) and Table 4.8 (by stations), respectively. The total number of individuals varied from 20 to 659 per 0.1m^2 (198 to 1099 by station (0.2m^2)) and taxa varied from 20 to 68 per 0.1m^2 (43 to 91 by station (0.2m^2)), with the greatest abundance in taxa and second highest number of individuals recorded in the southeast corner of the survey area (Figures 4.34 and 4.35). No other pattern of distribution was recorded with very little correlation with other sediment parameters. With the exception of a weak correlation between abundance and sorting and a weak negative correlation between richness and skewness, no relationships were recorded. This highlights the essentially homogenous biological habitat across the whole of the survey area.

The Shannon-Weiner diversity values were generally quite high, but variable ranging from 4.2 to 5.4 (mean 4.8, SD 0.3) for all stations. No significant pattern of distribution was recorded (Figure 4.36), although station G1 and sites to the west of the area gave marginally greater diversity, and a small cluster of stations at the shelf break (G8, G9, G14, Dawn and Alpha) a slightly lower diversity. This is due to the fact that statistically, diversity correlated strongly with sorting, % fines and a number of the finer size class below phi 5.5 (coarse silt). The Pielou's Equitability was also quite variable and high ranging from 0.7 to 0.90 (Mean 0.80, SD 0.05), indicating a variable species dominance across the sampling template. Margalef's Index (Species Richness) varied between 7.77 and 13.31 (mean 10.6, SD 1.3), whilst Simpson's evenness ranged from 0.85 to 0.97 (mean 0.93, SD 0.03; Figure 4.37). The latter further highlights the grouping of stations G8, G9, G14, Dawn and Alpha at the shelf break with a generally low evenness at this site. This means that these stations were statistically dominated by only a few species, compared to other sites in the area.

A comparison with two of the North Falklands Basin sites, sampled in 1998, indicated generally similar values for both richness and abundance over the same sample area per station (Gardline 1998d, Table 4.8). The mean abundance per 0.2m^2 varied from 346 to 516 in 1998 a compared to 430 in the present study, whilst richness varied from 52 to 62 in 1998 a compared to 65 in this report. The diversity and evenness of these earlier sites gave marginally lower values (4.58-4.66 and 0.77-0.81) than recorded regionally here (4.81 and 0.93, respectively) highlighting the slightly higher species dominance for the earlier program. Like the current study, the community compositions was well presented by crustacea, in particular the amphipods *Urothoe* and from the family Phoxocephalidae, along with the polychaetes from the genus *Aricidea spp.* and *Onuphis aff.holobranchiata.* All of these species were common in this regional survey, with the amphipod *Urothoe* representing the dominant species at all sites.

Figure 4.34. Macrofauna - Number of Individuals (Abundance per 0.2m²)



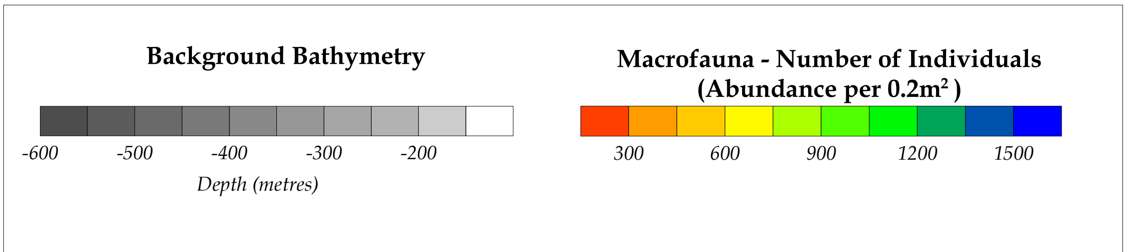
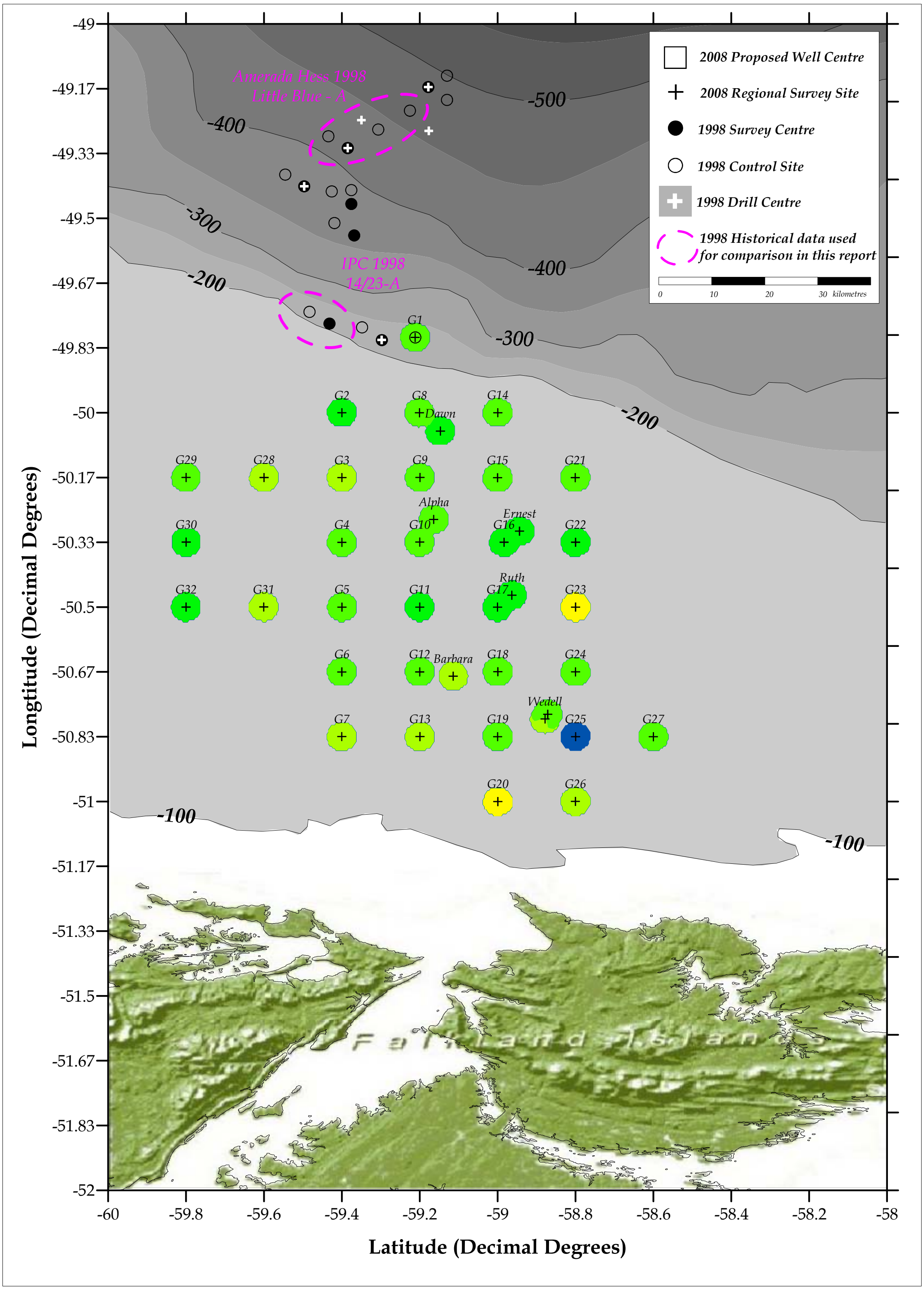


Figure 4.35. *Macrofauna - Number of Species (Richness per 0.2m²)*



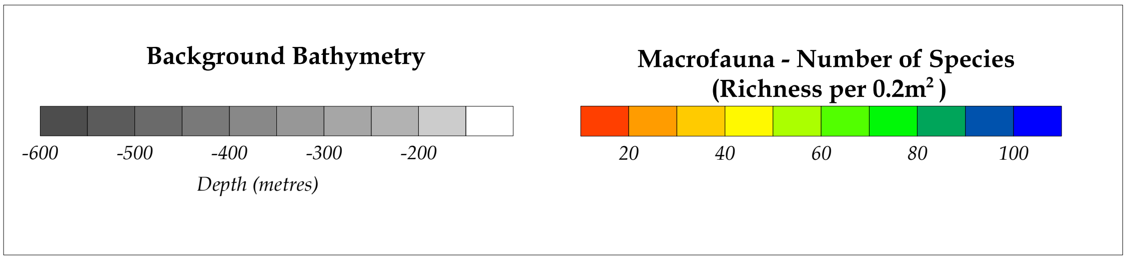
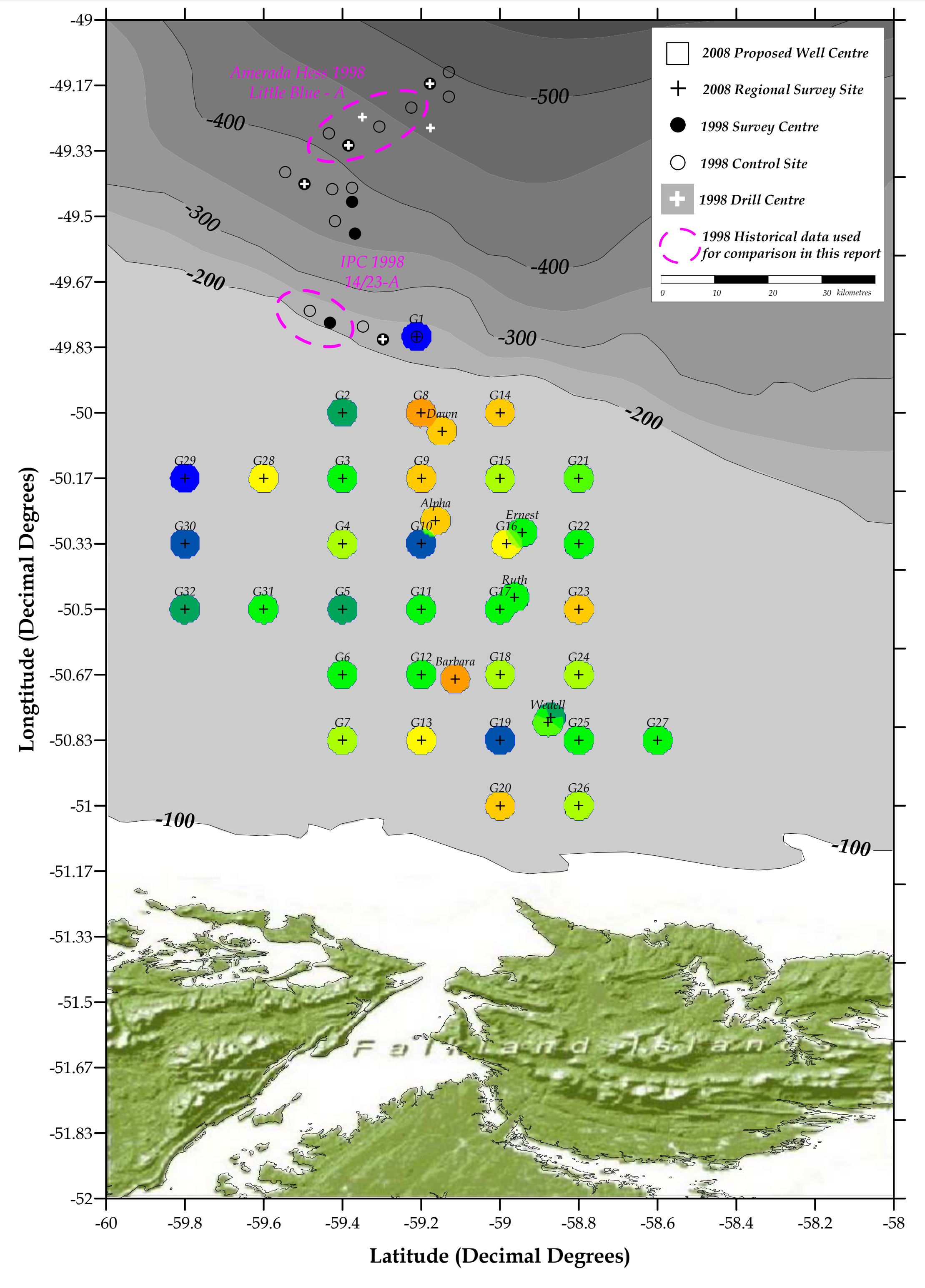


Figure 4.36. *Macrofauna – Shannon-Weiner Diversity (H(s))*



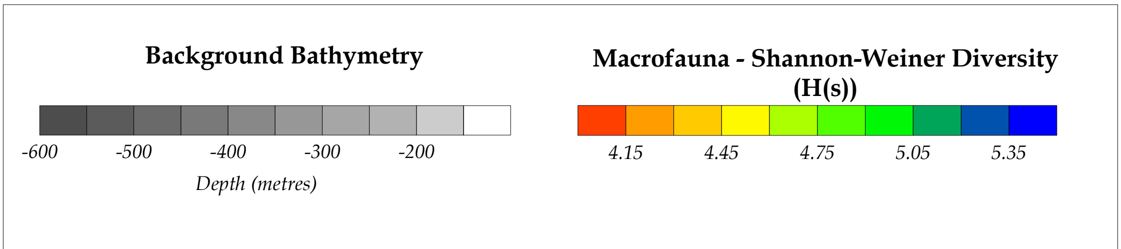


Figure 4.37. *Macrofauna – Simpson's Index*

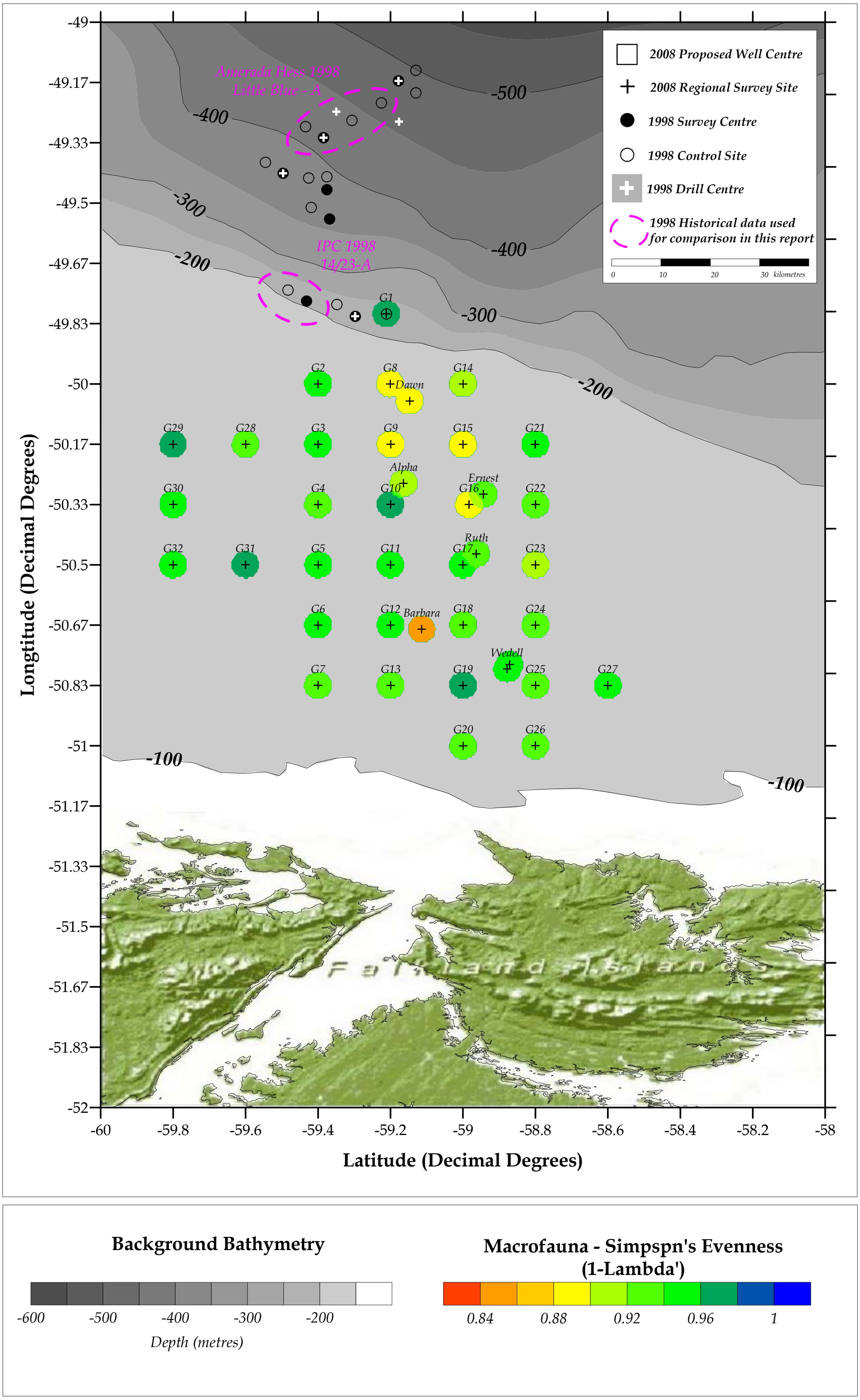


Table 4.8. Univariate Faunal Parameters (0.2m² station)

Station	Number of Species (S)	Number of Individuals (N)	Richness (Margalef)	Evenness (Pielou's Evenness)	Shannon-Wiener Diversity	Simpsons
Regional G1	69	361	11.550	0.879	5.367	0.968
Regional G2	70	583	10.840	0.839	5.145	0.949
Regional G3	56	286	9.724	0.854	4.958	0.952
Regional G4	65	447	10.490	0.767	4.622	0.926
Regional G5	64	299	11.050	0.851	5.107	0.958
Regional G6	61	337	10.310	0.851	5.048	0.955
Regional G7	56	420	9.106	0.805	4.676	0.939
Regional G8	63	715	9.434	0.713	4.261	0.887
Regional G9	69	454	11.110	0.726	4.438	0.895
Regional G10	69	353	11.590	0.853	5.207	0.963
Regional G11	78	532	12.270	0.802	5.042	0.942
Regional G12	60	295	10.370	0.848	5.009	0.951
Regional G13	50	317	8.509	0.799	4.507	0.930
Regional G14	62	586	9.571	0.739	4.397	0.914
Regional G15	64	405	10.490	0.773	4.639	0.897
Regional G16	77	541	12.080	0.721	4.517	0.891
Regional G17	73	494	11.610	0.811	5.018	0.948
Regional G18	66	493	10.480	0.778	4.699	0.933
Regional G19	69	309	11.860	0.854	5.216	0.961
Regional G20	43	222	7.774	0.799	4.337	0.925
Regional G21	60	418	9.776	0.817	4.828	0.944
Regional G22	73	398	12.030	0.805	4.981	0.936
Regional G23	49	284	8.497	0.791	4.441	0.905
Regional G24	62	347	10.430	0.791	4.707	0.923
Regional G25	91	864	13.310	0.764	4.970	0.932
Regional G26	53	392	8.708	0.803	4.600	0.933
Regional G27	64	331	10.860	0.824	4.945	0.952
Regional G28	57	319	9.713	0.784	4.571	0.928
Regional G29	63	241	11.300	0.896	5.357	0.968
Regional G30	77	330	13.110	0.846	5.300	0.952
Regional G31	51	198	9.455	0.882	5.004	0.960
Regional G32	71	361	11.890	0.832	5.117	0.955
Alpha 0	64	429	10.390	0.738	4.428	0.902
Barbara 0	58	392	9.546	0.717	4.200	0.853
Dawn 0	72	1099	10.140	0.697	4.300	0.893
Ernest 0	77	538	12.090	0.798	5.002	0.932
Ruth 0	74	447	11.960	0.794	4.930	0.925
Weddell A	59	457	9.470	0.809	4.757	0.945
Weddell B	68	481	10.850	0.838	5.103	0.956
Survey Mean	**64.8**	**430.1**	**10.609**	**0.802**	**4.814**	**0.933**
Survey StDev	**9.4**	**171.5**	**1.292**	**0.050**	**0.327**	**0.026**
Gardline 1998d	**52.1**	**346**	**-**	**-**	**4.662**	**0.818**
Gardline 1998a	**62**	**516**	**-**	**-**	**4.585**	**0.770**

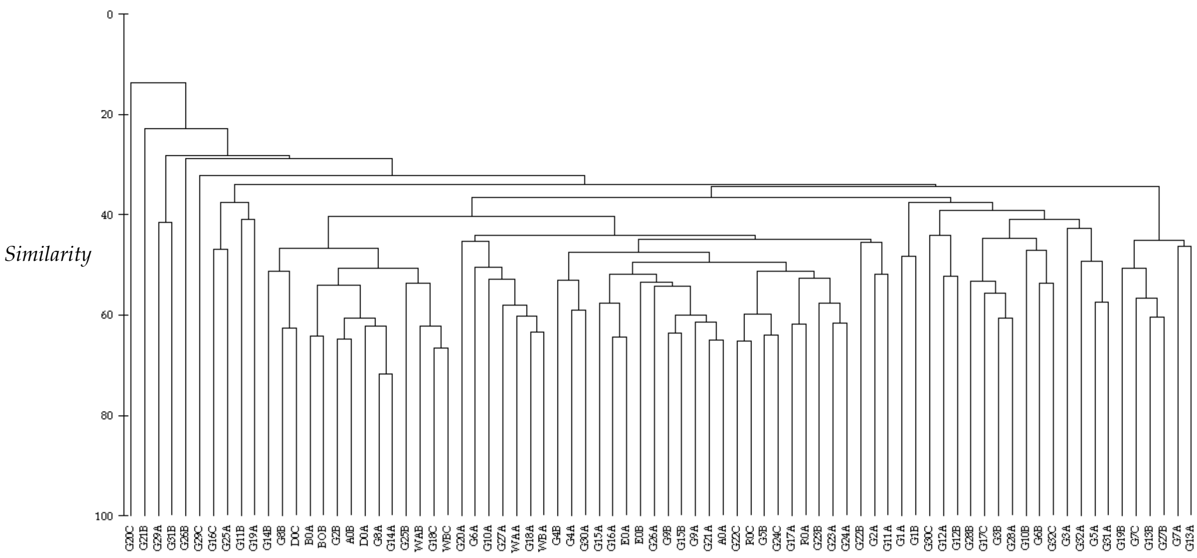
4.6.3. Multivariate Analyses

To provide a more thorough examination of the macrofaunal community, multivariate analyses was performed upon the data for both the replicate and aggregated stations using Plymouth Routines in Multivariate Ecological Research software (PRIMER; Clarke & Warwick 1994) to illustrate data trends. Unlike univariate parameter, multivariate analyses preserve the identity of the different species by assigning a similarity or dissimilarity between the samples. The analyses were undertaken on double square-root transformed data, as these data gave a clearest interpretation.

4.6.3.1. Dendrogram – Group Average Method

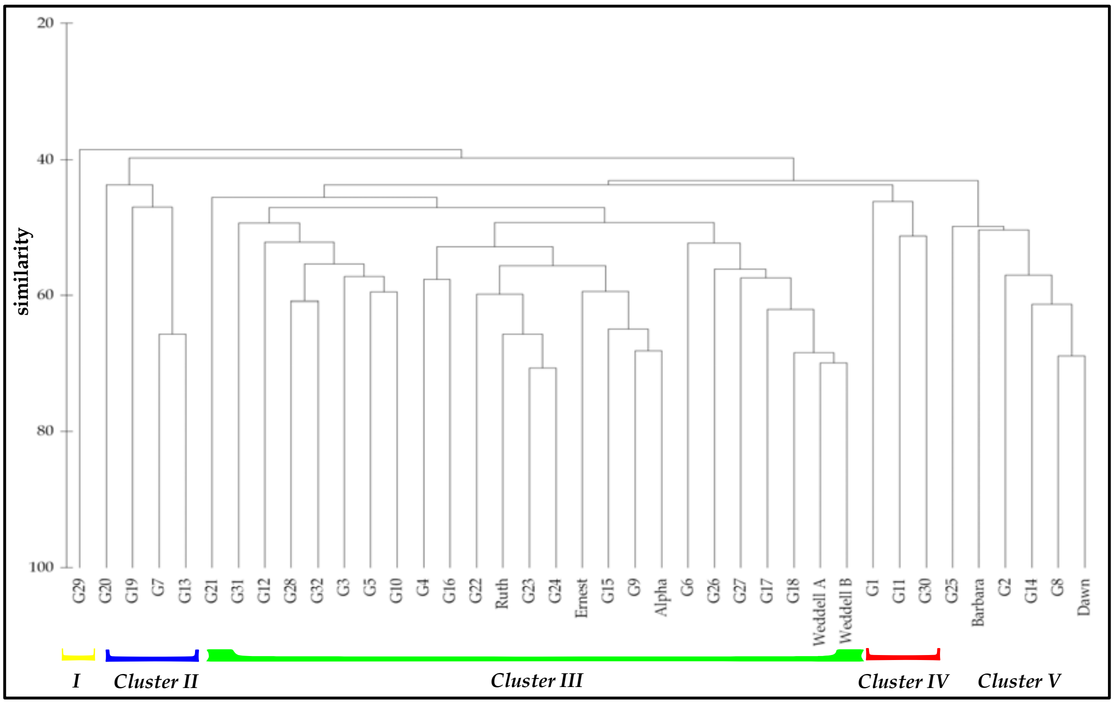
The similarity dendrogram is given for all replicates in Figure 4.38. This diagram shows that intra-station relationships are relatively poor compared to Inter-station variability. Consequently, many of the replicates fail to cluster with other replicates from the same stations, with all replicates generally showing a 45 to 65 similarity. No clear separation of grouped replicates is evident, although the occasional disparate sample separates from the main group at only a 15 to 30% similarity (i.e. replicates G20C, G21B, G29A, G31B and G26B). These data confirm a high intra-station variability.

Figure 4.38. Dendrogram of Macrofaunal Replicates



By combining the replicate dataset, the similarity dendrogram is also given for all stations (Figure 4.39). These differ slightly from that of the replicate analysis in that the larger surface areas show a weak separation of stations into a number of pseudo groups at varying similarities range from 40 to 50%. The inter-station similarity was slightly greater, generally clustering around a 60 to 70% similarity level. The clusters separate into five groups consisting of stations G29 (Cluster I), stations G7, G13, G19 and G20 (Cluster II), stations G1, G11, and G30 (Cluster IV), stations G2, G8, G25, Barbara and Dawn (Cluster V) and all of the remaining 25 sites loosely grouping together (Cluster III).

Figure 4.39. *Dendrogram of Macrofaunal Stations*

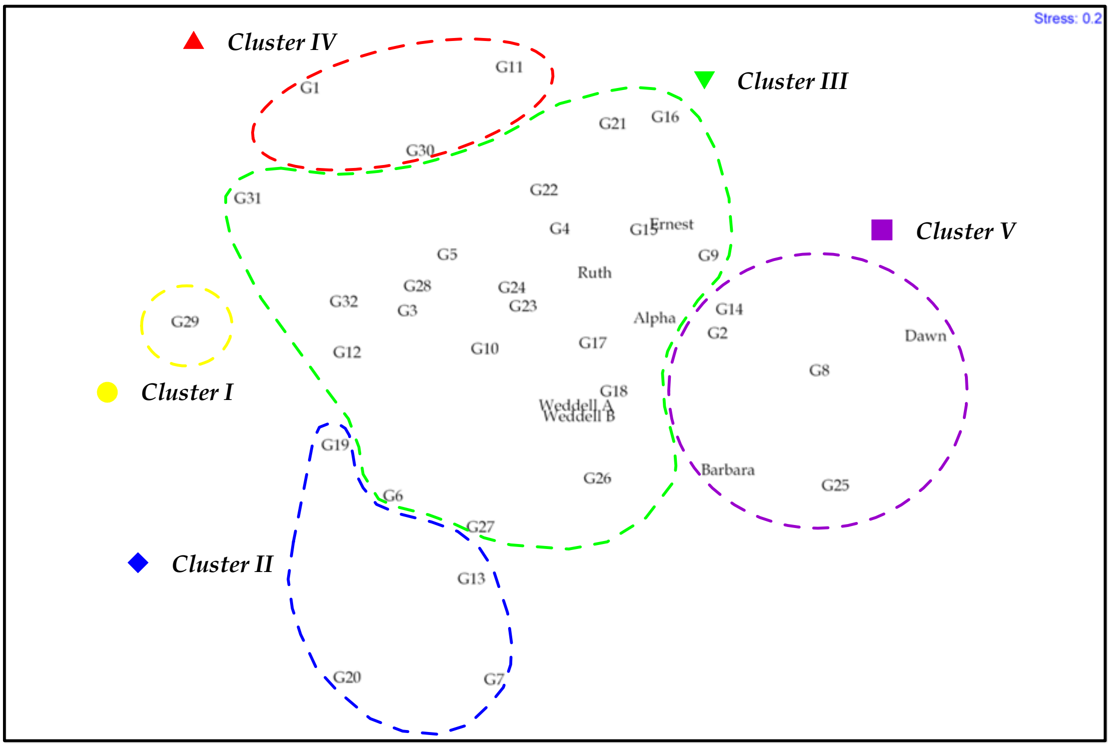


<u>4.6.3.2. MDS Ordination Plot</u>

The above similarities were presented into a 2-dimensional representation where the two axes of similarity, for both replicate and station communities, are shown. This multi-dimensional scaling (MDS) ordination is presented in Figure 4.40 for all 39 stations, with the separation of the 5 clusters represented. It should be noted that none of these groups are distinct or fully removed from the main "cloud"of stations, suggesting a subtle or marginal separation in the dominant species across these sites.

The stress values recorded within the statistical representations was moderately high at 0.2. Consequently, the ordination should be treated as marginal with only low level reliance associated with this representation. This is a result of the high intra station similarity and that the separation of grouped stations are generally weak. Ultimately, these data may be subject to over interpretation and possible miss-representation if not supported by other trends or correlations within the data. From this, it is likely that there are little or no strong environmental factor dictating separation of the biological communities over the regional survey area.

Figure 4.40. ***MDS Ordination Plot by Station***



The separation of the five clusters is one based on subtle community variations related to environmental factors. The locations of the five clusters are shown in Figure 4.41 over the survey area. This shows that the central well area is dominated by the main Cluster III, whilst Cluster IV, which includes the deeper site G1 is dotted throughout the area, and Cluster I (the single station G29), is found at the northwest extremity of the site. Whilst four out of the six Cluster V sites group together along the shelf break, only Cluster II remains within a tight geographical group of their own. Few correlations exist between the MDS axes and other environmental variables, although the axis 1 (vertical axis) tends to correlate with sorting and finer sediment size classes below phi 5 (coarse silt), and axis 2 showed minor correlations with sediment moisture content and the proportion of coarser sand fractions ($P<0.01$).

Using SIMPER, a summary of the top five species (in rank order) responsible for the separation of the Clusters is given in Table 4.9. The similarity contribution is also presented. Grouped similarities are all relatively weak clustering at only 44 to 54% similarity. All stations have the amphipod crustacean *Urothoe sp*. as the dominant or second most dominant species, whilst a second amphipod Phoxocephaloidea sp.C (eyeless) was also present in clusters with the exception of Cluster II. Similarly the cirratulidae polychaete was in all clusters except Cluster IV, and *Aricidea sp.A,* was only absent in Cluster II and IV. Clusters III and V showed the same top five species but in as different order of dominance. Only Cluster IV showed an echinoderm (ophiuroid *Ophiura cf meridionalis)* or a mollusc (*Cryptodon falklandica)* in the top 5 five dominant species.

Figure 4.36. Geographical Separation of Derived Biological Clusters

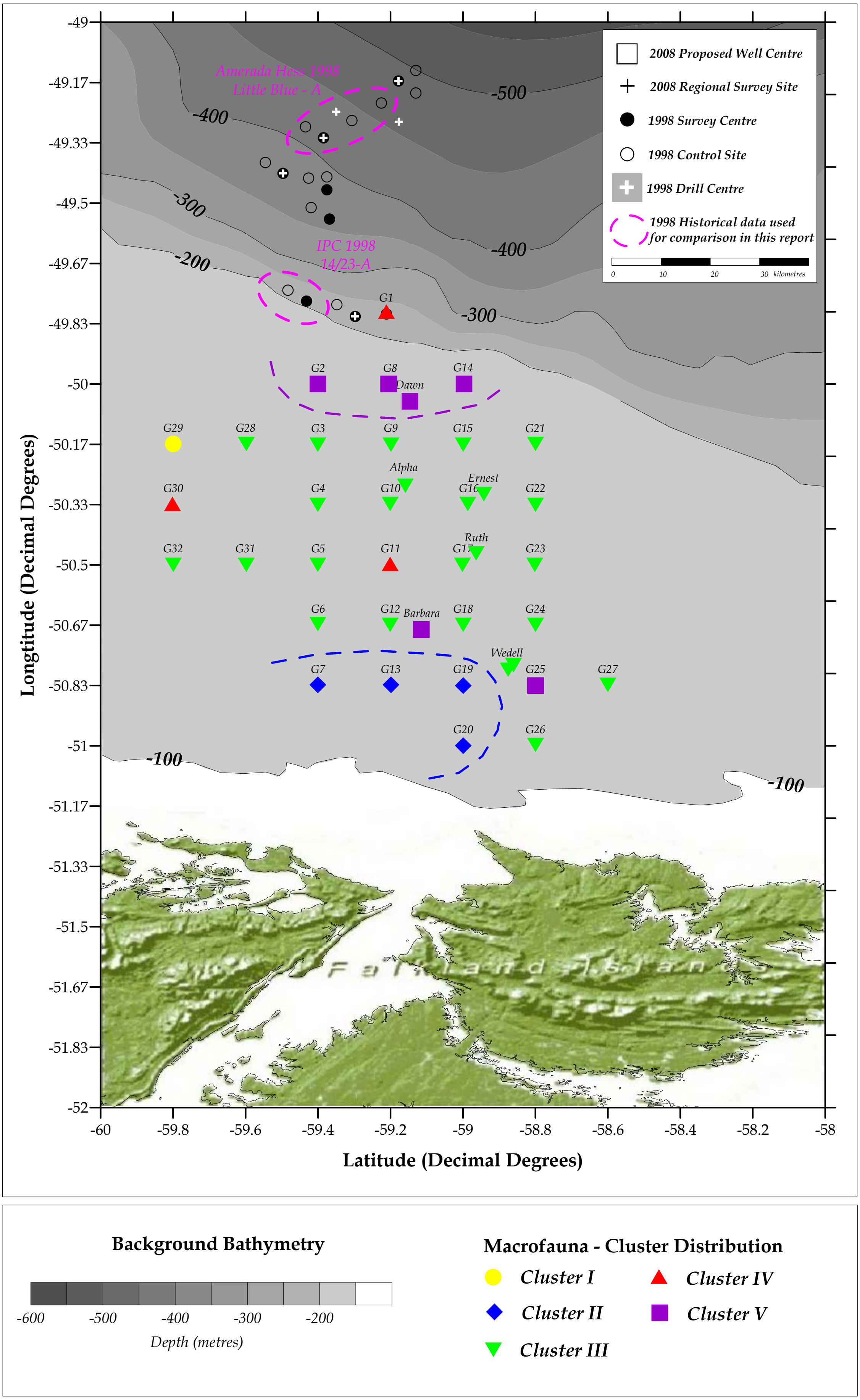


Table 4.9 SIMPER Results Showing the Top Five Characterising Species in the Five Clusters

Species	Average Abundance	Average Similarity	Contribution	Cumulative Contribution
Cluster I (only station G29)				
Urothoe sp.	25	Nc	Nc	Nc
Phoxocephaloidea sp.C (eyeless)	20	Nc	Nc	Nc
Travisia kerguelensis	12	Nc	Nc	Nc
Aricidea sp.B	9	Nc	Nc	Nc
Cirratulidae spp.	8	Nc	Nc	Nc
Cluster II (similarity 44)				
Urothoe sp.	31.75	7.72	15.91	15.91
Oligochaeta Tubificidae	36	6.54	13.48	29.39
Aff Scoloplos sp	24.5	5.86	12.08	41.47
Maldanidae spp	18.5	3.53	7.27	48.73
Cirratulidae spp.	15	2.65	5.47	54.2
Cluster III (similarity 50)				
Urothoe sp.	65.24	11.59	23.1	23.1
Aricidea sp.A	26.92	3.67	7.32	30.42
Phoxocephaloidea sp.C (eyeless)	15.04	2.8	5.58	36
Maldanidae spp	18.44	2.79	5.56	41.56
Cirratulidae spp.	15.88	2.57	5.11	46.68
Cluster IV (similarity 48%)				
Urothoe sp.	38.67	5.35	11.15	11.15
Ophiura cf meridionalis	28.67	4.94	10.31	21.46
Cryptodon falklandica	20	4.03	8.4	29.86
Fabricola / Pseudofabricia sp	44.67	3.9	8.14	38
Phoxocephaloidea sp.C (eyeless)	18	3.3	6.89	44.89
Cluster V (similarity 54%)				
Aricidea sp.A	164.5	17.46	32.21	32.21
Urothoe sp.	86.33	7.35	13.55	45.76
Cirratulidae spp.	21.17	2.3	4.25	50
Maldanidae spp	34.33	2.27	4.18	54.18
Phoxocephaloidea sp.C (eyeless)	34.17	2.23	4.11	58.29

nc = not calculated for a single station

4.6.4. Environmental Variables

Environmental variables were analysed using a number of different ways in order to relate significant relationships between abiotic and biotic factors. Tests include ordination using both Pearson's product moment analysis (PPM) which provides 2 dimensional comparisons between each of the environmental variables, and BIO-ENV (PRIMER) which provides a step-wise comparison of grouped environmental factors which best match the sample patterns seen within the faunal assemblages.

Step-wise, the grouped environmental variables showed a significant correlation between a number of parameters which, although possibly highlight inter-parameter relationships, may act to auto-correlate a number of the variables when using a more multi-dimensional technique. PPM correlations showed that the sediment parameters, in particular the mean sediment size, proportion of fines, sorting coefficient, and organic matter all showed strong correlations with most metals, hydrocarbons and the occasional univariate parameter (at $P<0.01$ & 0.001; Appendix VIII). The highest environmental correlation across parameter types was between total organic matter and mean particle size at 0.868 and Water depth and percentage fines at 0.938.

BIO-ENV was used to correlate a number of these variables with that of the similarity dendrogram created for the stations and a single or grouped environmental variable which gave the greatest correlation. Using Bray-Curtis similarity and Euclidian distance a dendrogram was used to compare and group sites based on between-site similarity. By using Spearman's Rank Correlation the parameters: the species abundance was the only single parameter to significantly correlate with the dendrogram (at 0.436 or $P<0.01$). Collectively, grouped parameters of the phi class fine sand and medium silt, water depth and number of individuals gave a very high correlation based on any three parameters (at 0.561 or $P<0.001$). As many of these parameters themselves will be auto-correlated into the key sediment parameters, these results would confirm that a separation of the sediment types by the proportion of sands and fines probably constitutes the largest driving factor for community distribution.

4.6.5. Summary of Macrofaunal Results

The benthic fauna of the Falkland Islands belongs to the Magellan faunal area, made up of the sea areas around the southern part of South America). Whilst this is comparable to the Northern Boreal Region, the fauna is characterised by a very high diversity within the crustacean, with the amphipod *Urothoe* sp the most dominant across all sites. Univariate parameters indicated consistent levels across the regional survey area as all sites gave moderate to high species richness, diversity and evenness throughout the survey. Previous benthic survey undertaken in the North Falklands Basin in 1998, indicated a similar benthic community in the deeper waters. Univariate parameters indicated only weak patterns of geographical distribution across the area. Multivariate analyses, equally confirmed a relatively diverse faunal population with a relatively high level of similarity across all stations and little variability between groups of stations. A relatively poor separation of 5 clusters was delineated at around the 50% similarity, but these were predominantly separated by the presence or dominance of only a handful of key species, including the amphipod Phoxocephaloidea sp.C (eyeless) or the polychaetes in the family cirratulidae or the species *Aricidea sp.A*. Only one small group (of 3 stations including the deepest stations G1), were separated by other taxonomic groups such as the echinoderm (ophiuroid *Ophiura cf meridionalis)* or the mollusc (*Cryptodon falklandica).*

Correlations with environmental parameters only weakly followed the multivariate trends, in that a combination of finer particle size classes, fine sands, water depth and the faunal abundance produced these trends. Correlations between clear sedimentary changes and physico-chemical variations were of a greater magnitude and whilst the mean sediment size, the proportion of finer sediments, water depth and total organic matter provided the strongest gradient for the distribution of most metals and organic components, the biological community was only weakly influenced by these factors. Overall, there was insufficient variability within the habitats recorded to clearly separate out the biological communities recorded over the regional survey area.

For this preliminary regional assessment the level of analysis has concentrated on the key separation of groups in order to identify trends within the biological community with that of the physical habitats over the northern continental shelf. Further analysis of this material will continue whilst further data, acquired at proposed well locations, is further evaluated and a more definitive species list produced.

Overall, no environmentally sensitive species or habitats considered to be of conservational value were recorded during the regional survey operations.

4.6.6. Epifaunal Results

Most of the sites sampled provided only marginal admixtures of coarser sediments, most of which relating to fine shell or pea gravels sized fractions. Consequently, the numbers and proportions of quantifiable epifaunal species was relatively small across all of the samples. Sediment types remained relatively constant around a slightly silty, partially reworked medium to fine sand and occasional glacial gravel. As some of the epifaunal species recorded during the taxonomy exist in colonial type assemblages, the incidents of some epifaunal groups into the macrofaunal analyses would have been misleading. Consequently, these data have been separated and are listed independently in Appendix V.

Due to the sandy sediments encountered epifauna was sparse; nevertheless a number of Bryozoa were regularly encountered, previously recorded during the earlier surveys in the North Falklands basin (Gardline 1998a-h). Especially common and characteristic were the upright branching *Ogivalia elegans*, and some colonies of the upright reticulate genus *Reteporella*, which can form colonies several cm high.

In addition to the bryozoans, several Hydroid fragments were also recorded. These are similar to those recorded in the northern hemisphere, and may well share a specific status. Their very wide distribution is aided by their planktonic medusa stage.

5. BIBLIOGRAPHY

AFEN (ATLANTIC FRONTIER ENVIRONMENTAL NETWORK), 1996, 1998 & 2000. Environmental Surveys of the Seafloor of the UK Atlantic Margin [CD-ROM]. Available from GEOTEK Limited, Daventry, Northants NN11 5EA, UK. ISBN 09538399-0-7

Bastida, R., Roux, A., & Martinez, D.E., 1992. Benthic Communities of the Argentine Continental Shelf. *Oceanologica Acta*, 15 (6), 687-698.

Blumer, M. & Synder, W.D., 1965**.** Isoprenoid hydrocarbons in recent sediments: presence of pristane and probably absence of phytane, *Science* 150, 1588.

Blumer, M., Guillard, R.R.L. & Chase, T. 1971. Hydrocarbons in marine phytoplankton. *Mar. Biol*.8:183-189.

Bray, J.R. & Curtis, J.T., 1957. An ordination of the upland forest communities of Southern Wisconsin. *Ecol. Monogr*. 27: 325-349.

Bryan, G.W. and Langston, W.J., 1992. Bioavalability, accumulation and effects of heavy metals in sediments with special references to United Kingdom estuaries; a review. *Environmental Pollution*. 76:89-131.

Buchman, M.F., 1999. NOAA screening Quick Reference Tables. NOAA HAZMAT Report 99-1. Seattle, WA. Coastal Protection and Restoration Division. National Oceanic and Atmospheric Administration, 12pp.

Clarke, K.R. & Warwick, R.M. 1994. Chanbes in marine communities; an approach to statistical analysis and interpretation. Plymouth Marine Laboratory, Natural Environmental Research Council, UK . 144pp.

Cole, S., Codling, I.D., Parr, W. and Zabel, T., 1999. Guidelines for managing water quality impacts with European marine sites. *Report prepared for the UK Marine SACs project.* October 1999, Swindon WRc.

Eglinton, G., Gonzalez, A.G., Hamilton, R.J & Raphael, R.A. 1962. Hydrocarbon constituents of the wax coatings of plant leaves; a taxonomic survey. Phytochemistry. 1:89-102.

Eleftheriou, A. & Basford, D.J., 1989. The macrobenthic infauna of the offshore northern North Sea. J.Mar. Biol.Ass. UK., 69: 123-143.

Folk, 1954. The destinction between grain size and mineral composition in sedimentary rock neomenclature. Journal of Geology 62: 344-349.

FUGRO ,1998. Collective geophysical site surveys operations for the Falklands Operator Sharing Agreement. Previously Britsurvey (Svitzer).

Gardline 1998a. Benthic Environmental Baseline Survey of the Sediments around the exploration "Little Blue-A" Well (February 1998), Gardline Surveys Limited.

Gardline 1998b. Benthic Environmental Baseline Survey of the Sediments around the exploration "B1" Well (February 1998), Gardline Surveys Limited.

Gardline 1998c. Benthic Environmental Baseline Survey of the Sediments around the exploration "14/14- A" Well, 1998d. Gardline Surveys Limited.

Gardline, 1998d. Benthic Environmental Baseline Survey of the Sediments around the exploration " Well 14/23-A (February 1998), Gardline Surveys Limited.

Gardline, 1998e. Benthic Environmental Baseline Survey of the Sediments around the exploration "FI 14/19-A" Well (March 1998), Gardline Surveys Limited.

Gardline, 1998f. Benthic Environmental Baseline Survey of the Sediments around the exploration FI 14/24 "Braela" Well (March 1998), Gardline Surveys Limited.

Gardline, 1998g. Benthic Environmental Baseline Survey of the Sediments around the exploration "Minke" 14/13-B Well (June 1998), Gardline Surveys Limited.

Gardline, 1998h. Post-Drill Environmental Survey of the Sediments around the Exploration Well "Little Blue- A" - Final report October 1998. Gardline Surveys Limited.

Gerrard, S., Grant, A., March, R. and London, C., 1999. Drill Cuttings Piles in the North Sea. Management options during Platform Decommissioning. Centre for Environmental Risk Report No 31. University of East Anglia.

Hart, B., 1996. Ecological Monitoring Unit - Confirmation of the reproducibility of the Malvern Mastersizer Microplus Laser Sizer and comparison of its output with the Malvern 3600E sizer. Brixham Environmental Laboratory report BL2806/B.

Hartmann-Schröder, 1983. Die Polychaeten der 15., 36. und 76. Reise vob FFS "Walther Herwig" zum patagonischen Schelf (Sudwest-Atlantik). Senchenbergiana marit 15. pp251-277.

Hartmann-Schröder, 1986. Die Polychaeten der 56. Reise vob FFS "Meteor" zu den South Shetland-Inseln (Antarktis). Mitt. Hamb. Zool. Mus. Inst, band 83 71-100pp.

Hartmann-Schröder & Rosenfeldt, 1989-1992. Die Polychaeten der Reise 68/1 nach Elephant Island (Antarktis) 1985 Teil 2: 1989: Cirratulidae bis Serpulidae. Mitt. Hamb. Zool. Mus. Inst, band 86 85-106pp. 1990: Aphroditidae bis Cirratulidae. Mitt. Hamb. Zool. Mus. Inst, band 87 89-122pp. 1991:Acrocirridae bis Sabellidae. Mitt. Hamb. Zool. Mus. Inst, band 88 73-96pp. 1992: Euphrosinidae bis Iphitimidae. Mitt. Hamb. Zool. Mus. Inst, band 86 85-106pp.

Khalaf, F., Literathy, V. and Anderlini, V., 1982. Vanadium as a tracer of oil pollution in the sediments of Kuwait. Hydrobiologica, 91-92:147-154.

Laflamme, R.E. & Hites, R.A. 1978. The global distribution of polycyclic aromatic hydrocarbons in recent sediments. *Geochim Cosmochim Acta*. 42: 289-303.

Lloyd, M. & Ghelardi, R.J., 1964. A table for calculating the "equitability" component of species diversity.J.Anim.Ecol.,3:217-225.

Luoma, S.N. and Davies, J.A., 1983. Requirements for modelling trace metal partitioning in oxidised estuarine sediments. Marine Chemistry. 12:159-181.

McDougall, J. 2000. *The* significance of hydrocarbons in the surficial sediments from Atlantic Margin regions. in Atlantic Margin Environmental Surveys of the Seafloor, 1996 & 1998. Atlantic Frontier Environmental Network. CD-Rom.

McLeese, D.W., J.B. Sprague and S. Ray. 1987. Effects of cadmium on marine biota. p. 171-198. In: Nriagu, J.O. and J.B. Sprague (eds.). Cadmium in the Aquatic Environment. Advances in Environmental Science and Technology, Volume 19. John Wiley & Sons, New York. 272 pp.

Muniz, P. Danulat, E., Yannicelli, B., Garcia-Alonso, J. and Bicego, M.C., 2004. Assessment of contamination by heavy metals and petroleum hydrocarbons in sediments of Montevideo harbour (Uraguay). Environmental International. 29: 1019-1028.

Neff, J.M. 2005. Bioaccumulation in marine organisms. Effects of contaminants from oil well produced water. Elsevier, Oxford, UK.

Orensanz, Jose. M, 1974. Los Anelidos Poliquetos de la Provincia Biogeographica Magelanica I. Catalogo de las especies citadas hasta .

Shannon, C.E. & Weaver, W., 1949. *The mathematical theory of communication*. University of Illinois Press, Urbana, 125pp.

Sleeter, T.D., Butler, J.N. and J.E. Barbash, 1980. Hydrocarbons in the Sediment of the Bermuda Region: Lagoonal to Abyssal Depths. Pp 267-288 In: Petrakis, L. and Weiss, F.T. (Eds.). Petroleum in the Marine Environment. Chem Soc., Washington, D.C.

Snelgrove, P.V.R., and Butman, C.A., 1994. Animal-sediment relationships revisited: cause versus effect. *Oceanogr. Mar. Biol. Ann. Rev.* **32**: 111-177.

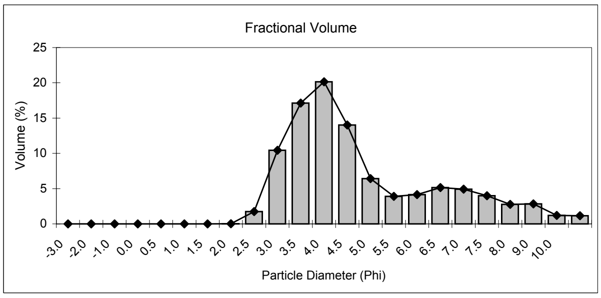
UKOOA, **2001**. An Analysis of UK Offshore Oil & Gas Environmental Surveys 1975-1995., Report by Heriot-University. 141pp.

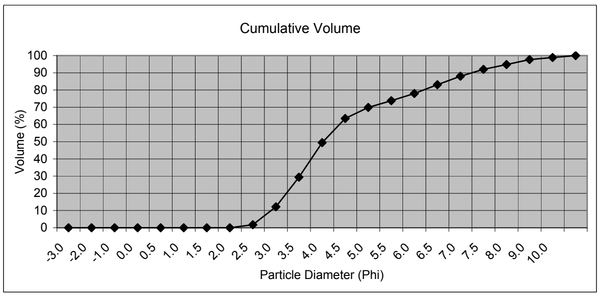
Warwick, R.M. & Clarke, K.R., 1991. A comparison of some methods for analysing changes in benthic community structure. *J. mar. biol. Ass. U.K.*, 71: 225-244.

Youngblood, W.W. & Blumer, M., 1975. Plycyclic aromatic hydrocarbons in the environment: homologues series in soils and recent marine sediments. Geochim Cosmochim Acta, 39:1303-1314

APPENDIX I: Particle Size Distribution

Sample No.:	Regional G1	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	25/09/2008 12:59



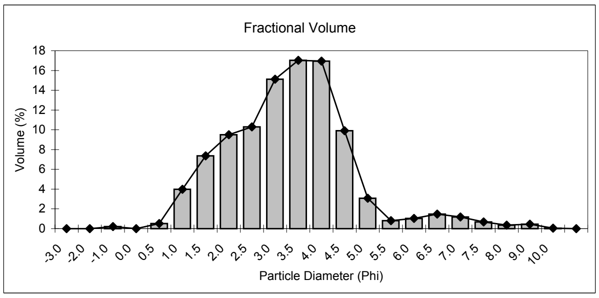


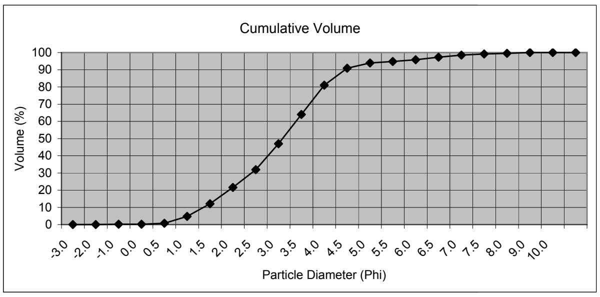
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.00	0.0	
0.355	1.5	0.00	0.0	Medium Sand
0.250	2.0	0.02	0.0	
0.180	2.5	1.74	1.8	Fine Sand
0.125	3.0	10.43	12.2	
0.900	3.5	17.13	29.3	V.Fine Sand
0.063	4.0	20.14	49.5	
0.044	4.5	14.03	63.5	Coarse Silt
0.032	5.0	6.43	69.9	
0.022	5.5	3.90	73.8	Medium Silt
0.016	6.0	4.15	78.0	
0.011	6.5	5.14	83.1	Fine silt
0.008	7.0	4.93	88.0	
0.006	7.5	4.00	92.0	V.Fine Silt
0.004	8.0	2.76	94.8	
0.002	9.0	2.84	97.6	Coarse Clay
0.001	10.0	1.21	98.8	Medium Clay
<0.001	>10.0	1.15	100.0	Fine Clay

Graphical	**mm**	**StDev (mm)**	**Phi**
Mean (MZ)	0.042	0.062	4.56
Median	0.062		4.01

Sorting	**Value**	**Inference**
Coefficient	1.70	Poorly Sorted
Skewness	0.48	Very Positive (Coarse)
Kurtosis	0.97	Mesokurtic
% Fines	50.54%	Coarse Silt
% Sands	49.46%	
% Gravel	0.00%	

Sample No.:	Regional G2	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	25/09/2008 13:05



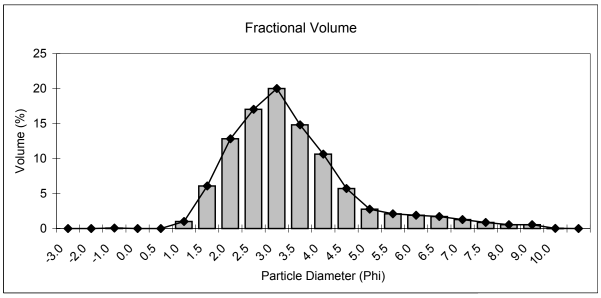


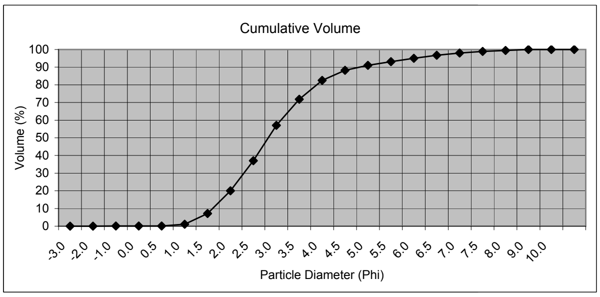
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.21	0.2	Granule
1.000	0.0	0.00	0.2	V.Coarse Sand
0.710	0.5	0.52	0.7	Coarse Sand
0.500	1.0	3.98	4.7	
0.355	1.5	7.37	12.1	Medium Sand
0.250	2.0	9.51	21.6	
0.180	2.5	10.30	31.9	Fine Sand
0.125	3.0	15.13	47.0	
0.900	3.5	17.02	64.0	V.Fine Sand
0.063	4.0	16.95	81.0	
0.044	4.5	9.91	90.9	Coarse Silt
0.032	5.0	3.08	94.0	
0.022	5.5	0.82	94.8	Medium Silt
0.016	6.0	1.03	95.8	
0.011	6.5	1.47	97.3	Fine silt
0.008	7.0	1.18	98.5	
0.006	7.5	0.68	99.2	V.Fine Silt
0.004	8.0	0.36	99.5	
0.002	9.0	0.45	100.0	Coarse Clay
0.001	10.0	0.04	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	**mm**	**StDev (mm)**	**Phi**
Mean (MZ)	0.128	0.172	2.96
Median	0.119		3.07

Sorting	**Value**	**Inference**
Coefficient	1.30	Poorly Sorted
Skewness	-0.02	Symmetrical
Kurtosis	1.14	Leptokurtic
% Fines	19.01%	Fine Sand
% Sands	80.78%	
% Gravel	0.21%	

Sample No.:	Regional G3	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 13:07

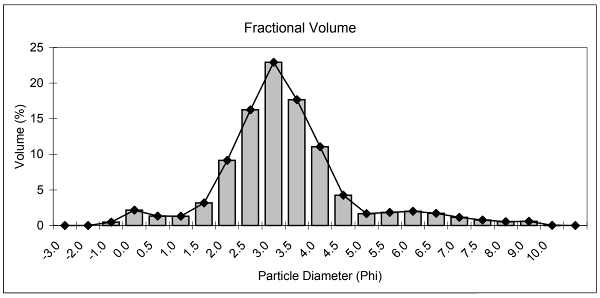


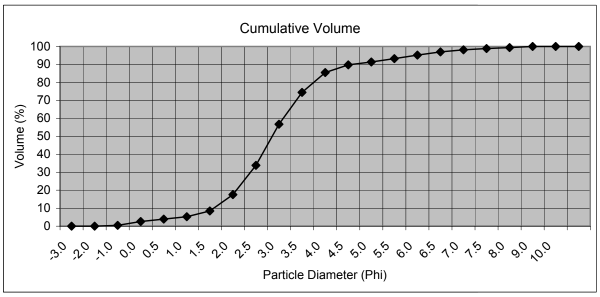


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.07	0.1	Granule
1.000	0.0	0.00	0.1	V.Coarse Sand
0.710	0.5	0.00	0.1	Coarse Sand
0.500	1.0	1.01	1.1	
0.355	1.5	6.09	7.2	Medium Sand
0.250	2.0	12.83	20.0	
0.180	2.5	17.03	37.0	Fine Sand
0.125	3.0	20.01	57.0	
0.900	3.5	14.82	71.9	V.Fine Sand
0.063	4.0	10.63	82.5	
0.044	4.5	5.72	88.2	Coarse Silt
0.032	5.0	2.78	91.0	
0.022	5.5	2.11	93.1	Medium Silt
0.016	6.0	1.90	95.0	
0.011	6.5	1.73	96.7	Fine silt
0.008	7.0	1.28	98.0	
0.006	7.5	0.87	98.9	V.Fine Silt
0.004	8.0	0.54	99.4	
0.002	9.0	0.55	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.133	0.142	2.91
Median	0.144		2.79
Sorting	**Value**	**Inference**	
Coefficient	1.28	Poorly Sorted	
Skewness	0.26	Positive(Coarse)	
Kurtosis	1.30	Leptokurtic	
% Fines	17.50%	Fine Sand	
% Sands	82.43%		
% Gravel	0.07%		

Sample No.:	Regional G4	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 13:16

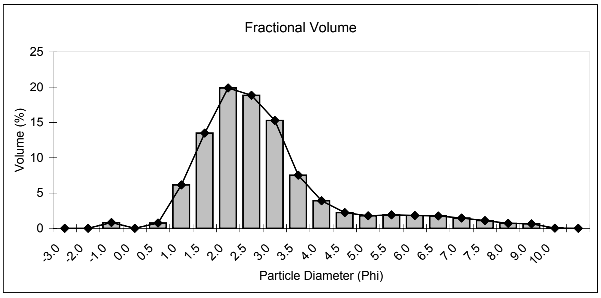


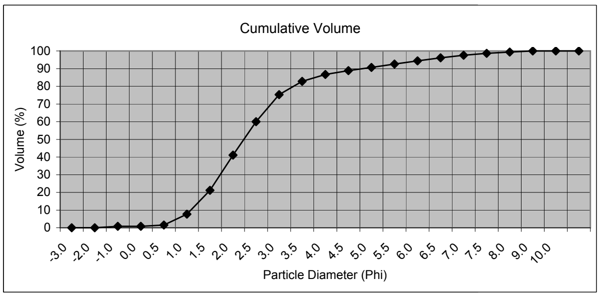


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.47	0.5	Granule
1.000	0.0	2.15	2.6	V.Coarse Sand
0.710	0.5	1.33	3.9	Coarse Sand
0.500	1.0	1.30	5.3	
0.355	1.5	3.17	8.4	Medium Sand
0.250	2.0	9.15	17.6	
0.180	2.5	16.25	33.8	Fine Sand
0.125	3.0	22.92	56.7	
0.900	3.5	17.68	74.4	V.Fine Sand
0.063	4.0	11.07	85.5	
0.044	4.5	4.24	89.7	Coarse Silt
0.032	5.0	1.66	91.4	
0.022	5.5	1.84	93.2	Medium Silt
0.016	6.0	2.00	95.2	
0.011	6.5	1.71	96.9	Fine silt
0.008	7.0	1.16	98.1	
0.006	7.5	0.77	98.9	V.Fine Silt
0.004	8.0	0.53	99.4	
0.002	9.0	0.58	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.136	0.170	2.88
Median	0.141		2.82
Sorting	**Value**	**Inference**	
Coefficient	1.27	Poorly Sorted	
Skewness	0.16	Positive(Coarse)	
Kurtosis	1.59	Very Leptokurtic	
% Fines	14.51%	Fine Sand	
% Sands	85.03%		
% Gravel	0.47%		

Sample No.:	Regional G5	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 13:03

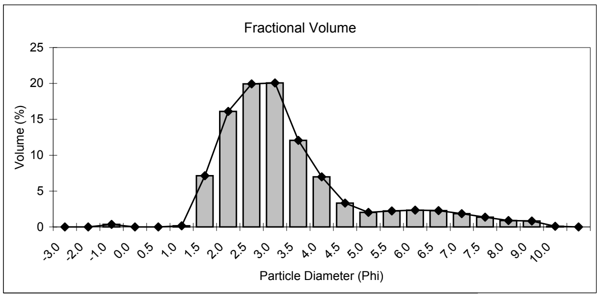


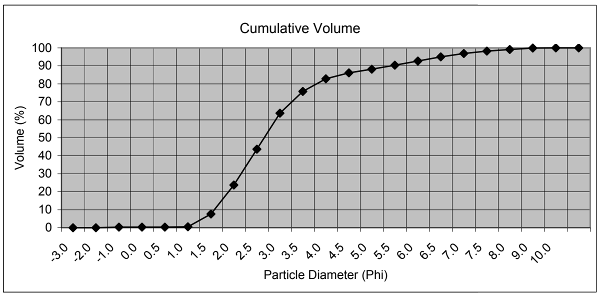


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.81	0.8	Granule
1.000	0.0	0.00	0.8	V.Coarse Sand
0.710	0.5	0.75	1.6	Coarse Sand
0.500	1.0	6.16	7.7	
0.355	1.5	13.50	21.2	Medium Sand
0.250	2.0	19.89	41.1	
0.180	2.5	18.86	60.0	Fine Sand
0.125	3.0	15.30	75.3	
0.900	3.5	7.54	82.8	V.Fine Sand
0.063	4.0	3.89	86.7	
0.044	4.5	2.21	88.9	Coarse Silt
0.032	5.0	1.76	90.7	
0.022	5.5	1.90	92.6	Medium Silt
0.016	6.0	1.82	94.4	
0.011	6.5	1.74	96.1	Fine silt
0.008	7.0	1.44	97.6	
0.006	7.5	1.09	98.6	V.Fine Silt
0.004	8.0	0.70	99.4	
0.002	9.0	0.63	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.194	0.208	2.37
Median	0.217		2.20
Sorting	**Value**	**Inference**	
Coefficient	1.40	Poorly Sorted	
Skewness	0.34	Very Positive (Coarse)	
Kurtosis	1.57	Very Leptokurtic	
% Fines	13.31%	Fine Sand	
% Sands	85.88%		
% Gravel	0.81%		

Sample No.:	Regional G6	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 12:54

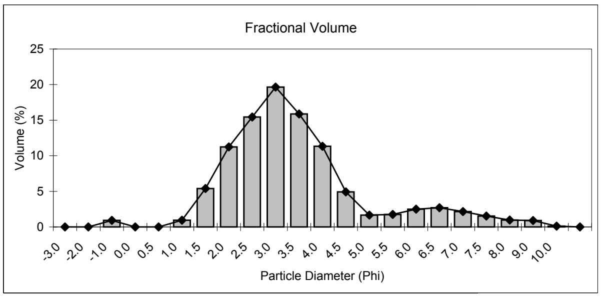


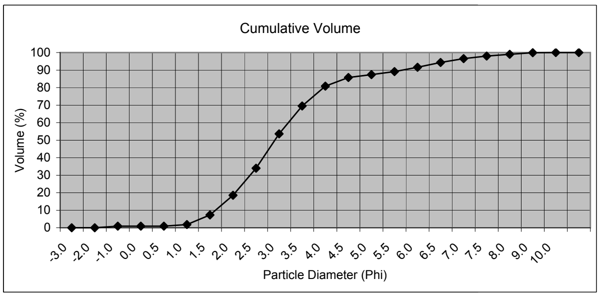


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.36	0.4	Granule
1.000	0.0	0.00	0.4	V.Coarse Sand
0.710	0.5	0.00	0.4	Coarse Sand
0.500	1.0	0.15	0.5	
0.355	1.5	7.14	7.6	Medium Sand
0.250	2.0	16.11	23.8	
0.180	2.5	19.93	43.7	Fine Sand
0.125	3.0	20.07	63.7	
0.900	3.5	12.07	75.8	V.Fine Sand
0.063	4.0	6.97	82.8	
0.044	4.5	3.33	86.1	Coarse Silt
0.032	5.0	2.03	88.1	
0.022	5.5	2.23	90.4	Medium Silt
0.016	6.0	2.34	92.7	
0.011	6.5	2.28	95.0	Fine silt
0.008	7.0	1.84	96.8	
0.006	7.5	1.36	98.2	V.Fine Silt
0.004	8.0	0.88	99.1	
0.002	9.0	0.82	99.9	Coarse Clay
0.001	10.0	0.10	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.140	0.147	2.84
Median	0.163		2.62
Sorting	**Value**	**Inference**	
Coefficient	1.40	Poorly Sorted	
Skewness	0.38	Very Positive (Coarse)	
Kurtosis	1.52	Very Leptokurtic	
% Fines	17.21%	Fine Sand	
% Sands	82.44%		
% Gravel	0.36%		

Sample No.:	Regional G7	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 13:11

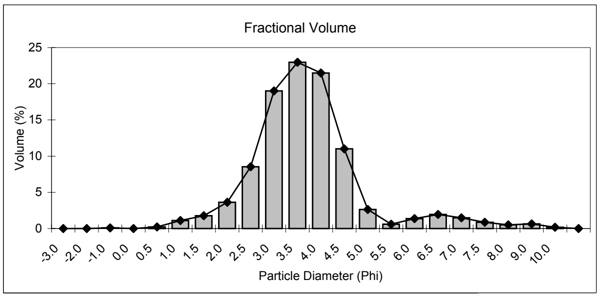


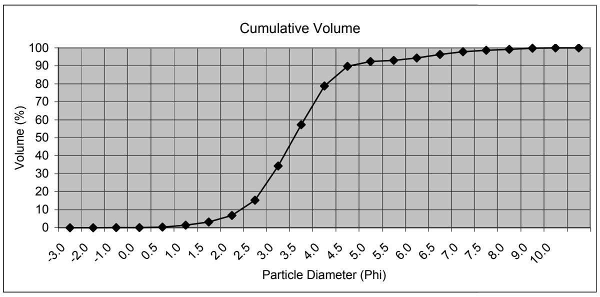


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.93	0.9	Granule
1.000	0.0	0.00	0.9	V.Coarse Sand
0.710	0.5	0.00	0.9	Coarse Sand
0.500	1.0	0.94	1.9	
0.355	1.5	5.40	7.3	Medium Sand
0.250	2.0	11.24	18.5	
0.180	2.5	15.44	33.9	Fine Sand
0.125	3.0	19.65	53.6	
0.900	3.5	15.87	69.5	V.Fine Sand
0.063	4.0	11.34	80.8	
0.044	4.5	4.91	85.7	Coarse Silt
0.032	5.0	1.66	87.4	
0.022	5.5	1.76	89.1	Medium Silt
0.016	6.0	2.49	91.6	
0.011	6.5	2.71	94.3	Fine silt
0.008	7.0	2.17	96.5	
0.006	7.5	1.52	98.0	V.Fine Silt
0.004	8.0	0.96	99.0	
0.002	9.0	0.90	99.9	Coarse Clay
0.001	10.0	0.12	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.123	0.146	3.02
Median	0.135		2.89
Sorting	**Value**	**Inference**	
Coefficient	1.42	Poorly Sorted	
Skewness	0.28	Positive(Coarse)	
Kurtosis	1.45	Leptokurtic	
% Fines	19.20%	v.Fine Sands	
% Sands	79.87%		
% Gravel	0.93%		

Sample No.:	Regional G8	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 12:57

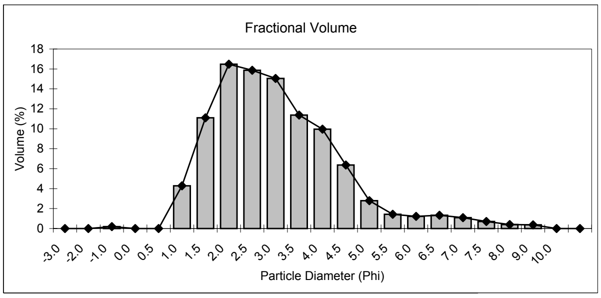


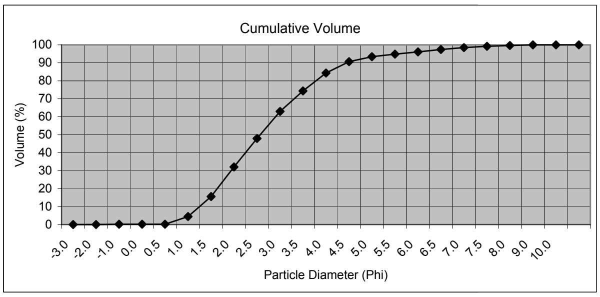


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.09	0.1	Granule
1.000	0.0	0.00	0.1	V.Coarse Sand
0.710	0.5	0.23	0.3	Coarse Sand
0.500	1.0	1.10	1.4	
0.355	1.5	1.78	3.2	Medium Sand
0.250	2.0	3.63	6.8	
0.180	2.5	8.52	15.3	Fine Sand
0.125	3.0	19.00	34.3	
0.900	3.5	22.97	57.3	V.Fine Sand
0.063	4.0	21.49	78.8	
0.044	4.5	11.00	89.8	Coarse Silt
0.032	5.0	2.62	92.4	
0.022	5.5	0.59	93.0	Medium Silt
0.016	6.0	1.37	94.4	
0.011	6.5	1.94	96.3	Fine silt
0.008	7.0	1.49	97.8	
0.006	7.5	0.87	98.7	V.Fine Silt
0.004	8.0	0.50	99.2	
0.002	9.0	0.63	99.8	Coarse Clay
0.001	10.0	0.18	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.099	0.095	3.33
Median	0.101		3.31
Sorting	**Value**	**Inference**	
Coefficient	1.10	Poorly Sorted	
Skewness	0.17	Positive(Coarse)	
Kurtosis	1.55	Very Leptokurtic	
% Fines	21.20%	V.Fine Sands	
% Sands	78.71%		
% Gravel	0.09%		

Sample No.:	Regional G9	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 12:52

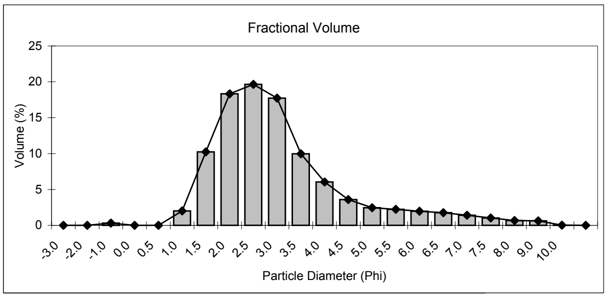


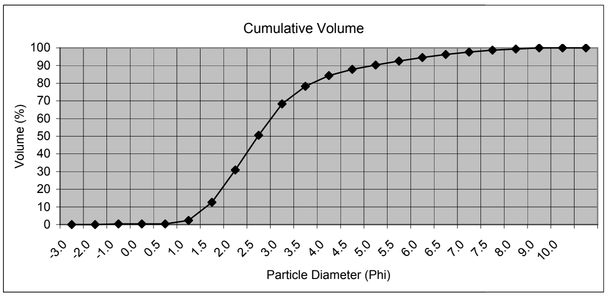


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.19	0.2	Granule
1.000	0.0	0.00	0.2	V.Coarse Sand
0.710	0.5	0.00	0.2	Coarse Sand
0.500	1.0	4.28	4.5	
0.355	1.5	11.10	15.6	Medium Sand
0.250	2.0	16.47	32.0	
0.180	2.5	15.87	47.9	Fine Sand
0.125	3.0	15.04	62.9	
0.900	3.5	11.37	74.3	V.Fine Sand
0.063	4.0	9.97	84.3	
0.044	4.5	6.37	90.7	Coarse Silt
0.032	5.0	2.79	93.4	
0.022	5.5	1.42	94.9	Medium Silt
0.016	6.0	1.22	96.1	
0.011	6.5	1.34	97.4	Fine silt
0.008	7.0	1.09	98.5	
0.006	7.5	0.71	99.2	V.Fine Silt
0.004	8.0	0.41	99.6	
0.002	9.0	0.37	100.0	Coarse Clay
0.001	10.0	0.00	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.157	0.178	2.67
Median	0.172		2.54
Sorting	**Value**	**Inference**	
Coefficient	1.30	Poorly Sorted	
Skewness	0.25	Positive(Coarse)	
Kurtosis	1.07	Mesokurtic	
% Fines	15.71%	Fine Sand	
% Sands	84.10%		
% Gravel	0.19%		

Sample No.:	Regional G10	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 13:12

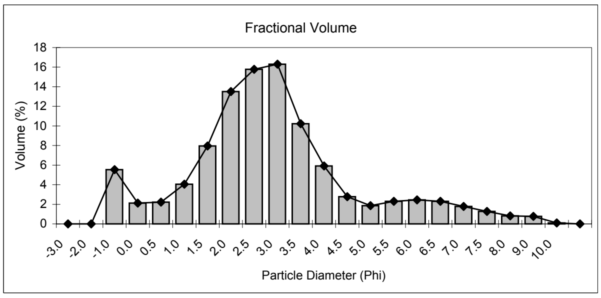


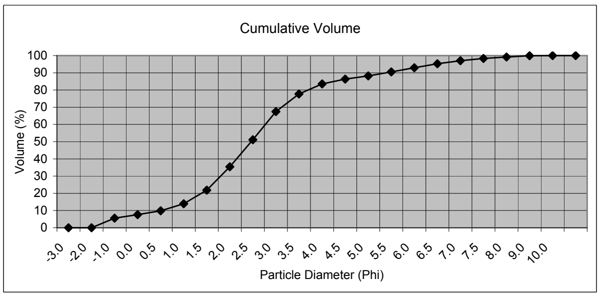


Aperture (mmm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.0	0.0	Pebble
4.000	-2.0	0.0	0.0	
2.000	-1.0	0.3	0.3	Granule
1.000	0.0	0.0	0.3	C, Coarse S
0.710	0.5	0.0	0.3	Coarse Sand
0.500	1.0	2.0	2.3	
0.355	1.5	10.2	12.6	Medium Sand
0.250	2.0	18.3	30.9	
0.180	2.5	19.6	50.6	Fine Sand
0.125	3.0	17.7	68.3	
0.900	3.5	10.0	78.3	V.Fine Sand
0.063	4.0	6.0	84.3	
0.044	4.5	3.6	87.9	Corse Silt
0.032	5.0	2.4	90.3	
0.022	5.5	2.2	92.6	Medium Silt
0.016	6.0	2.0	94.5	
0.011	6.5	1.8	96.3	Fine Silt
0.008	7.0	1.4	97.7	
0.006	7.5	1.0	98.7	V.Fine Silt
0.004	8.0	0.7	99.4	
0.002	9.0	0.6	100.0	Coarse Clay
0.001	10.0	0.0	100.0	Medium Clay
<0.001	>10.0	0.0	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.158	0.166	2.66
Median	0.182		2.46
Sorting	**Value**	**Inference**	
Coefficient	1.4	Poorly Sorted	
Skewness	0.4	Very Positive (Coarse)	
Kurtosis	1.4	Leptokurtic	
% Fines	15.71%	Fine Sand	
% Sands	83.97%		
% Gravel	0.32%		

Sample No.:	Regional G11	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 11:43

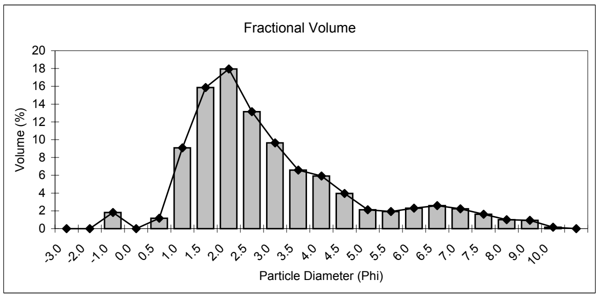


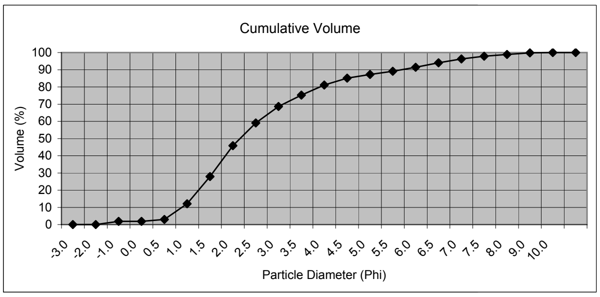


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	5.53	5.5	Granule
1.000	0.0	2.12	7.7	V.Coarse Sand
0.710	0.5	2.21	9.9	Coarse Sand
0.500	1.0	4.04	13.9	
0.355	1.5	7.95	21.9	Medium Sand
0.250	2.0	13.51	35.4	
0.180	2.5	15.78	51.1	Fine Sand
0.125	3.0	16.31	67.5	
0.900	3.5	10.22	77.7	V.Fine Sand
0.063	4.0	5.92	83.6	
0.044	4.5	2.77	86.4	Coarse Silt
0.032	5.0	1.87	88.2	
0.022	5.5	2.31	90.5	Medium Silt
0.016	6.0	2.44	93.0	
0.011	6.5	2.30	95.3	Fine silt
0.008	7.0	1.78	97.1	
0.006	7.5	1.27	98.3	V.Fine Silt
0.004	8.0	0.82	99.1	
0.002	9.0	0.76	99.9	Coarse Clay
0.001	10.0	0.09	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.173	0.692	2.53
Median	0.185		2.43
Sorting	**Value**	**Inference**	
Coefficient	1.88	Poorly Sorted	
Skewness	0.08	Symmetrical	
Kurtosis	1.79	Very Leptokurtic	
% Fines	16.41%	Fine Sand	
% Sands	78.06%		
% Gravel	5.53%		

Sample No.:	Regional G12	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 11:35

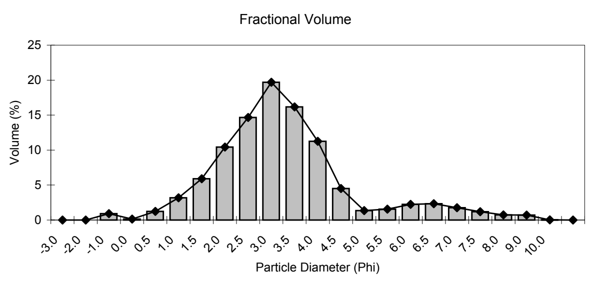


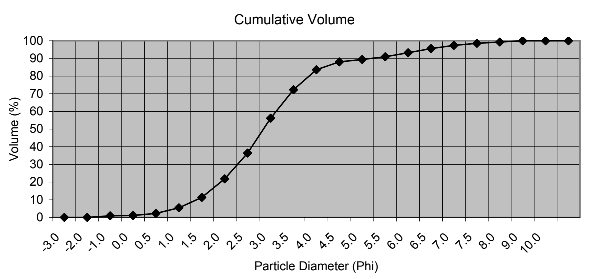


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	1.82	1.8	Granule
1.000	0.0	0.00	1.8	V.Coarse Sand
0.710	0.5	1.17	3.0	Coarse Sand
0.500	1.0	9.09	12.1	
0.355	1.5	15.86	27.9	Medium Sand
0.250	2.0	17.95	45.9	
0.180	2.5	13.15	59.0	Fine Sand
0.125	3.0	9.64	68.7	
0.900	3.5	6.57	75.2	V.Fine Sand
0.063	4.0	5.92	81.2	
0.044	4.5	3.96	85.1	Coarse Silt
0.032	5.0	2.11	87.2	
0.022	5.5	1.92	89.2	Medium Silt
0.016	6.0	2.30	91.5	
0.011	6.5	2.59	94.1	Fine silt
0.008	7.0	2.22	96.3	
0.006	7.5	1.62	97.9	V.Fine Silt
0.004	8.0	1.01	98.9	
0.002	9.0	0.93	99.8	Coarse Clay
0.001	10.0	0.16	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.174	0.249	2.53
Median	0.228		2.13
Sorting	**Value**	**Inference**	
Coefficient	1.73	Poorly Sorted	
Skewness	0.43	Very Positive (Coarse)	
Kurtosis	1.21	Leptokurtic	
% Fines	18.84%	Fine Sand	
% Sands	79.34%		
% Gravel	1.82%		

Sample No.:	Regional G13	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 11:52

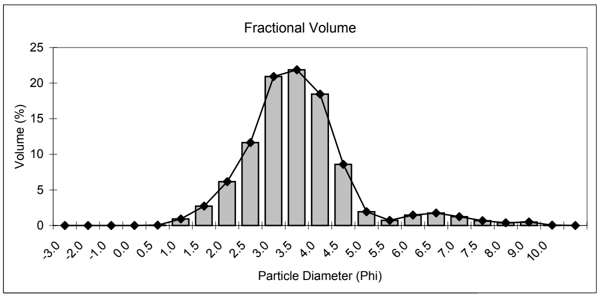


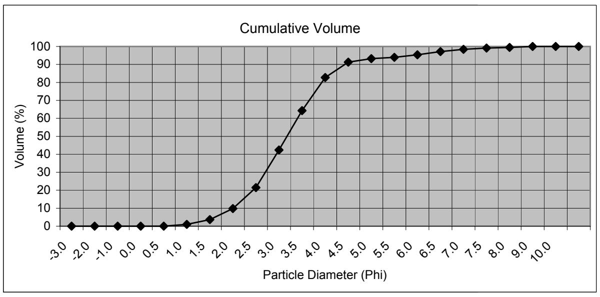


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.93	0.9	Granule
1.000	0.0	0.13	1.1	V.Coarse Sand
0.710	0.5	1.24	2.3	Coarse Sand
0.500	1.0	3.17	5.5	
0.355	1.5	5.90	11.4	Medium Sand
0.250	2.0	10.43	21.8	
0.180	2.5	14.66	36.5	Fine Sand
0.125	3.0	19.69	56.1	
0.900	3.5	16.18	72.3	V.Fine Sand
0.063	4.0	11.26	83.6	
0.044	4.5	4.50	88.1	Coarse Silt
0.032	5.0	1.34	89.4	
0.022	5.5	1.55	91.0	Medium Silt
0.016	6.0	2.25	93.2	
0.011	6.5	2.34	95.6	Fine silt
0.008	7.0	1.77	97.3	
0.006	7.5	1.19	98.5	V.Fine Silt
0.004	8.0	0.74	99.3	
0.002	9.0	0.71	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.139	0.180	2.85
Median	0.142		2.81
Sorting Coefficient	**Value** 1.41	**Inference** Poorly Sorted	
Skewness	0.17	Positive(Coarse)	
Kurtosis	1.50	Very Leptokurtic	
% Fines	16.42%	Fine Sand	
% Sands	82.65%		
% Gravel	0.93%		

Sample No.:	Regional G14	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:42

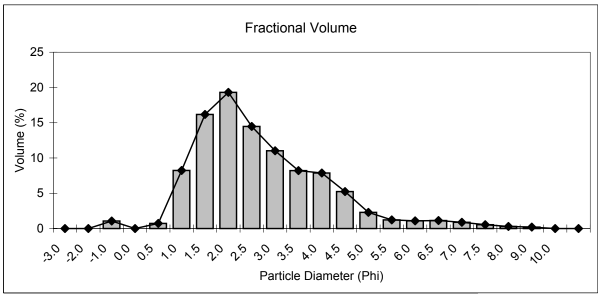


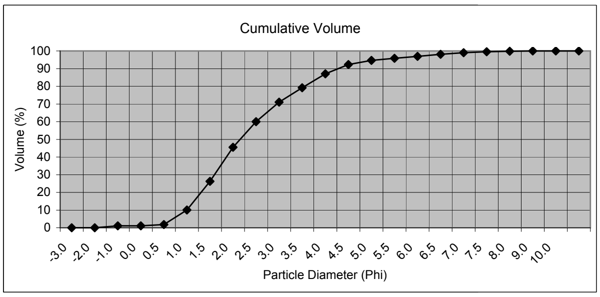


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.04	0.0	Coarse Sand
0.500	1.0	0.92	1.0	
0.355	1.5	2.71	3.7	Medium Sand
0.250	2.0	6.16	9.8	
0.180	2.5	11.64	21.5	Fine Sand
0.125	3.0	20.92	42.4	
0.900	3.5	21.87	64.3	V.Fine Sand
0.063	4.0	18.45	82.7	
0.044	4.5	8.60	91.3	Coarse Silt
0.032	5.0	1.93	93.2	
0.022	5.5	0.72	93.9	Medium Silt
0.016	6.0	1.46	95.4	
0.011	6.5	1.76	97.2	Fine silt
0.008	7.0	1.23	98.4	
0.006	7.5	0.67	99.1	V.Fine Silt
0.004	8.0	0.39	99.5	
0.002	9.0	0.51	100.0	Coarse Clay
0.001	10.0	0.04	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.113	0.106	3.15
Median	0.113		3.15
Sorting Coefficient	**Value** 1.10	**Inference** Poorly Sorted	
Skewness	0.13	Positive(Coarse)	
Kurtosis	1.45	Leptokurtic	
% Fines	17.30%	V.Fine Sands	
% Sands	82.70%		
% Gravel	0.00%		

Sample No.:	Regional G15	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	22/01/2009 11:29

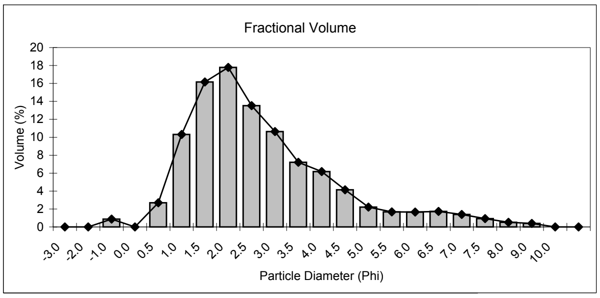


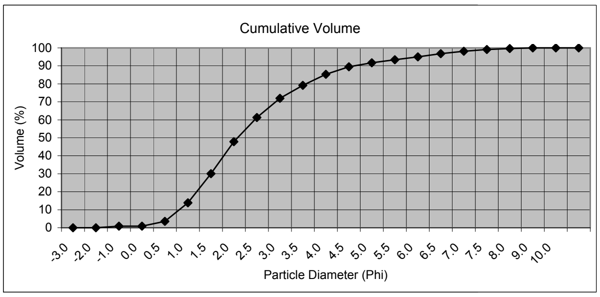


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	1.07	1.1	Granule
1.000	0.0	0.00	1.1	V.Coarse Sand
0.710	0.5	0.72	1.8	Coarse Sand
0.500	1.0	8.23	10.0	
0.355	1.5	16.17	26.2	Medium Sand
0.250	2.0	19.31	45.5	
0.180	2.5	14.47	60.0	Fine Sand
0.125	3.0	11.03	71.0	
0.900	3.5	8.22	79.2	V.Fine Sand
0.063	4.0	7.88	87.1	
0.044	4.5	5.24	92.3	Coarse Silt
0.032	5.0	2.30	94.6	
0.022	5.5	1.22	95.9	Medium Silt
0.016	6.0	1.09	96.9	
0.011	6.5	1.14	98.1	Fine silt
0.008	7.0	0.88	99.0	
0.006	7.5	0.54	99.5	V.Fine Silt
0.004	8.0	0.30	99.8	
0.002	9.0	0.20	100.0	Coarse Clay
0.001	10.0	0.00	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.196	0.222	2.35
Median	0.228		2.13
Sorting	**Value**	**Inference**	
Coefficient	1.32	Poorly Sorted	
Skewness	0.30	Positive(Coarse)	
Kurtosis	1.04	Mesokurtic	
% Fines	12.90%	Fine Sand	
% Sands	86.03%		
% Gravel	1.07%		

Sample No.:	Regional G16	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	22/01/2009 11:32

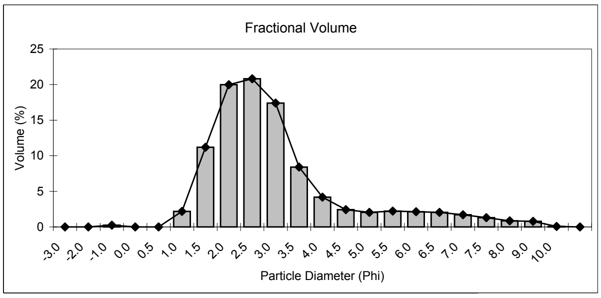


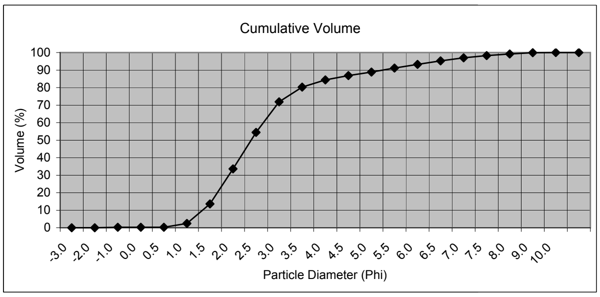


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.87	0.9	Granule
1.000	0.0	0.00	0.9	V.Coarse Sand
0.710	0.5	2.69	3.6	Coarse Sand
0.500	1.0	10.31	13.9	
0.355	1.5	16.17	30.0	Medium Sand
0.250	2.0	17.78	47.8	
0.180	2.5	13.52	61.3	Fine Sand
0.125	3.0	10.64	72.0	
0.900	3.5	7.21	79.2	V.Fine Sand
0.063	4.0	6.17	85.4	
0.044	4.5	4.14	89.5	Coarse Silt
0.032	5.0	2.21	91.7	
0.022	5.5	1.67	93.4	Medium Silt
0.016	6.0	1.66	95.0	
0.011	6.5	1.73	96.8	Fine silt
0.008	7.0	1.39	98.2	
0.006	7.5	0.93	99.1	V.Fine Silt
0.004	8.0	0.52	99.6	
0.002	9.0	0.40	100.0	Coarse Clay
0.001	10.0	0.00	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.199	0.251	2.33
Median	0.239		2.07
Sorting	**Value**	**Inference**	
Coefficient	1.52	Poorly Sorted	
Skewness	0.36	Very Positive (Coarse)	
Kurtosis	1.20	Leptokurtic	
% Fines	14.65%	Fine Sand	
% Sands	84.48%		
% Gravel	0.87%		

Sample No.:	Regional G17	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	22/01/2009 11:41

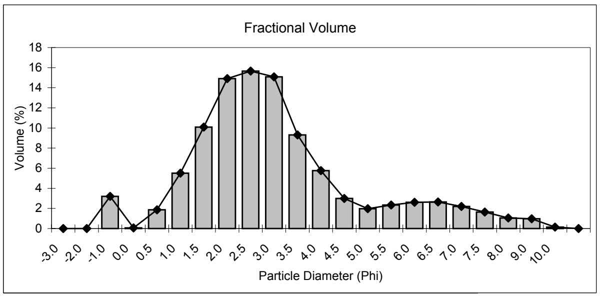


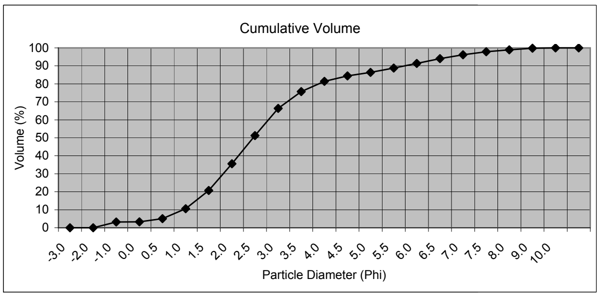


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.25	0.3	Granule
1.000	0.0	0.00	0.3	V.Coarse Sand
0.710	0.5	0.00	0.3	Coarse Sand
0.500	1.0	2.19	2.4	
0.355	1.5	11.20	13.6	Medium Sand
0.250	2.0	19.99	33.6	
0.180	2.5	20.81	54.4	Fine Sand
0.125	3.0	17.40	71.8	
0.900	3.5	8.41	80.2	V.Fine Sand
0.063	4.0	4.17	84.4	
0.044	4.5	2.42	86.8	Coarse Silt
0.032	5.0	2.04	88.9	
0.022	5.5	2.23	91.1	Medium Silt
0.016	6.0	2.13	93.2	
0.011	6.5	2.04	95.3	Fine silt
0.008	7.0	1.71	97.0	
0.006	7.5	1.31	98.3	V.Fine Silt
0.004	8.0	0.86	99.1	
0.002	9.0	0.78	99.9	Coarse Clay
0.001	10.0	0.07	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.164	0.170	2.61
Median	0.195		2.36
Sorting	**Value**	**Inference**	
Coefficient	1.40	Poorly Sorted	
Skewness	0.42	Very Positive (Coarse)	
Kurtosis	1.56	Very Leptokurtic	
% Fines	15.59%	Fine Sand	
% Sands	84.16%		
% Gravel	0.25%		

Sample No.:	Regional G18	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	22/01/2009 11:49

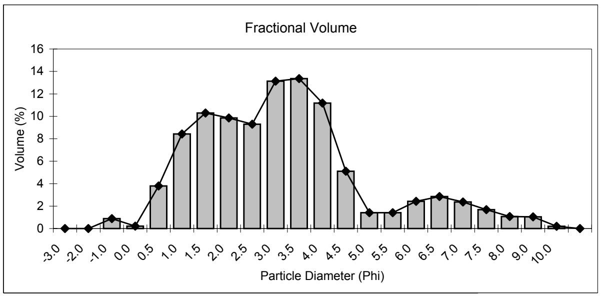


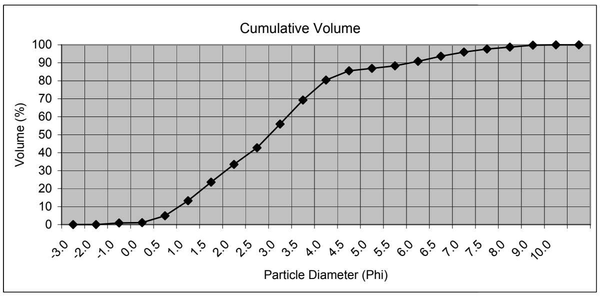


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	3.19	3.2	Granule
1.000	0.0	0.06	3.3	V.Coarse Sand
0.710	0.5	1.86	5.1	Coarse Sand
0.500	1.0	5.50	10.6	
0.355	1.5	10.09	20.7	Medium Sand
0.250	2.0	14.92	35.6	
0.180	2.5	15.67	51.3	Fine Sand
0.125	3.0	15.08	66.4	
0.900	3.5	9.32	75.7	V.Fine Sand
0.063	4.0	5.75	81.4	
0.044	4.5	2.99	84.4	Coarse Silt
0.032	5.0	1.98	86.4	
0.022	5.5	2.35	88.8	Medium Silt
0.016	6.0	2.61	91.4	
0.011	6.5	2.65	94.0	Fine silt
0.008	7.0	2.20	96.2	
0.006	7.5	1.63	97.8	V.Fine Silt
0.004	8.0	1.06	98.9	
0.002	9.0	0.97	99.9	Coarse Clay
0.001	10.0	0.14	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.154	0.255	2.70
Median	0.186		2.43
Sorting	**Value**	**Inference**	
Coefficient	1.74	Poorly Sorted	
Skewness	0.31	Very Positive (Coarse)	
Kurtosis	1.41	Leptokurtic	
% Fines	18.56%	Fine Sand	
% Sands	78.25%		
% Gravel	3.19%		

Sample No.:	Regional G19	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 11:38

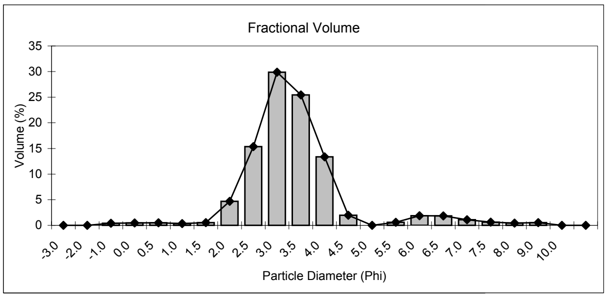


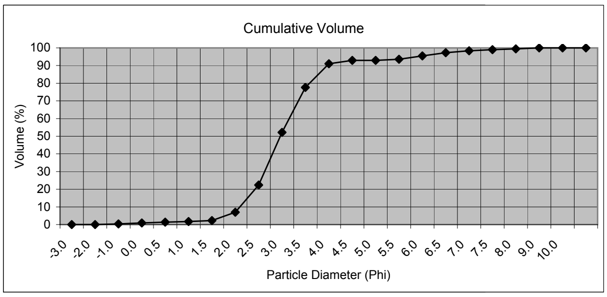


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.89	0.9	Granule
1.000	0.0	0.22	1.1	V.Coarse Sand
0.710	0.5	3.79	4.9	Coarse Sand
0.500	1.0	8.42	13.3	
0.355	1.5	10.30	23.6	Medium Sand
0.250	2.0	9.85	33.5	
0.180	2.5	9.30	42.8	Fine Sand
0.125	3.0	13.13	55.9	
0.900	3.5	13.36	69.3	V.Fine Sand
0.063	4.0	11.19	80.4	
0.044	4.5	5.11	85.5	Coarse Silt
0.032	5.0	1.41	87.0	
0.022	5.5	1.42	88.4	Medium Silt
0.016	6.0	2.42	90.8	
0.011	6.5	2.86	93.6	Fine silt
0.008	7.0	2.36	96.0	
0.006	7.5	1.68	97.7	V.Fine Silt
0.004	8.0	1.07	98.8	
0.002	9.0	1.03	99.8	Coarse Clay
0.001	10.0	0.20	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.151	0.265	2.73
Median	0.150		2.74
Sorting	**Value**	**Inference**	
Coefficient	1.75	Poorly Sorted	
Skewness	0.14	Positive(Coarse)	
Kurtosis	1.19	Leptokurtic	
% Fines	19.57%	Fine Sand	
% Sands	79.55%		
% Gravel	0.89%		

Sample No.:	Regional G20	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 11:46

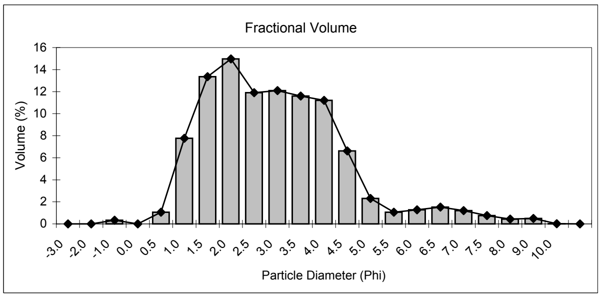


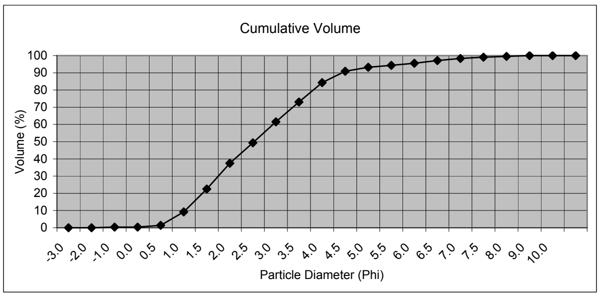


Aperture (mmm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.0	0.0	Pebble
4.000	-2.0	0.0	0.0	
2.000	-1.0	0.4	0.4	Granule
1.000	0.0	0.5	0.9	C, Coarse S
0.710	0.5	0.5	1.4	Coarse Sand
0.500	1.0	0.3	1.7	
0.355	1.5	0.5	2.3	Medium Sand
0.250	2.0	4.7	7.0	
0.180	2.5	15.4	22.3	Fine Sand
0.125	3.0	29.9	52.2	
0.900	3.5	25.4	77.7	V.Fine Sand
0.063	4.0	13.4	91.0	
0.044	4.5	2.0	93.0	Corse Silt
0.032	5.0	0.0	93.0	
0.022	5.5	0.6	93.6	Medium Silt
0.016	6.0	1.9	95.5	
0.011	6.5	1.8	97.3	Fine Silt
0.008	7.0	1.1	98.4	
0.006	7.5	0.6	99.0	V.Fine Silt
0.004	8.0	0.5	99.5	
0.002	9.0	0.5	100.0	Coarse Clay
0.001	10.0	0.0	100.0	Medium Clay
<0.001	>10.0	0.0	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.128	0.091	2.97
Median	0.129		2.95
Sorting	**Value**	**Inference**	
Coefficient	1.0	Moderately Sorted	
Skewness	0.2	Positive(Coarse)	
Kurtosis	1.9	Very Leptokurtic	
% Fines	8.99%	Fine Sand	
% Sands	90.61%		
% Gravel	0.40%		

Sample No.:	Regional G21	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	25/09/2008 14:39



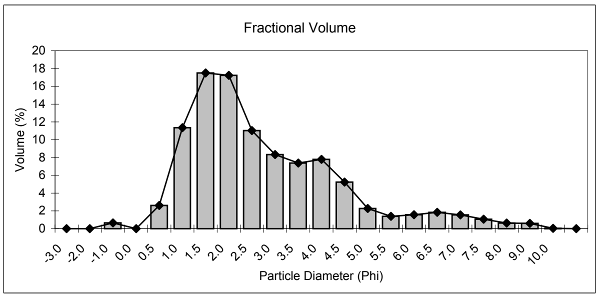


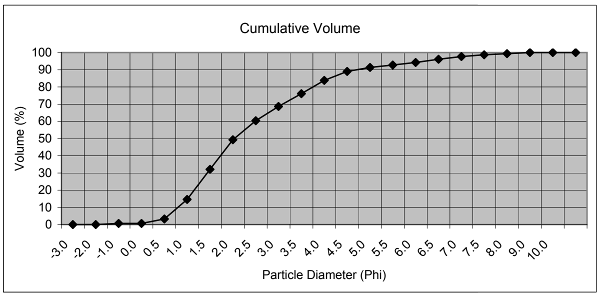
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.33	0.3	Granule
1.000	0.0	0.00	0.3	V.Coarse Sand
0.710	0.5	1.07	1.4	Coarse Sand
0.500	1.0	7.76	9.2	
0.355	1.5	13.36	22.5	Medium Sand
0.250	2.0	14.97	37.5	
0.180	2.5	11.91	49.4	Fine Sand
0.125	3.0	12.10	61.5	
0.900	3.5	11.60	73.1	V.Fine Sand
0.063	4.0	11.22	84.3	
0.044	4.5	6.62	90.9	Coarse Silt
0.032	5.0	2.31	93.2	
0.022	5.5	1.06	94.3	Medium Silt
0.016	6.0	1.28	95.6	
0.011	6.5	1.52	97.1	Fine silt
0.008	7.0	1.20	98.3	
0.006	7.5	0.76	99.1	V.Fine Silt
0.004	8.0	0.44	99.5	
0.002	9.0	0.49	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.169	0.221	2.57
Median	0.177		2.50

Sorting	Value	Inference
Coefficient	1.45	Poorly Sorted
Skewness	0.18	Positive(Coarse)
Kurtosis	1.04	Mesokurtic
% Fines	15.70%	Fine Sand
% Sands	83.98%	
% Gravel	0.33%	

Sample No.:	Regional G22	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	25/09/2008 14:16



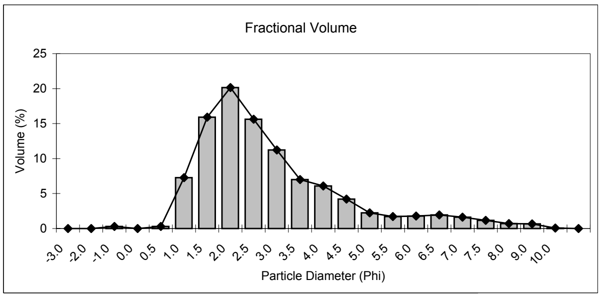


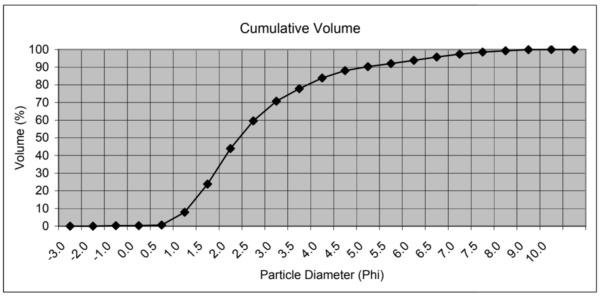
Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.64	0.6	Granule
1.000	0.0	0.00	0.6	V.Coarse Sand
0.710	0.5	2.60	3.2	Coarse Sand
0.500	1.0	11.35	14.6	
0.355	1.5	17.50	32.1	Medium Sand
0.250	2.0	17.23	49.3	
0.180	2.5	11.02	60.3	Fine Sand
0.125	3.0	8.33	68.7	
0.900	3.5	7.38	76.1	V.Fine Sand
0.063	4.0	7.78	83.8	
0.044	4.5	5.23	89.1	Coarse Silt
0.032	5.0	2.26	91.3	
0.022	5.5	1.39	92.7	Medium Silt
0.016	6.0	1.57	94.3	
0.011	6.5	1.83	96.1	Fine silt
0.008	7.0	1.55	97.7	
0.006	7.5	1.07	98.7	V.Fine Silt
0.004	8.0	0.64	99.4	
0.002	9.0	0.60	100.0	Coarse Clay
0.001	10.0	0.04	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.196	0.256	2.35
Median	0.246		2.03

Sorting	Value	Inference
Coefficient	1.59	Poorly Sorted
Skewness	0.41	Very Positive (Coarse)
Kurtosis	1.08	Mesokurtic
% Fines	16.17%	Fine Sand
% Sands	83.19%	
% Gravel	0.64%	

Sample No.:	Regional G23	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:22

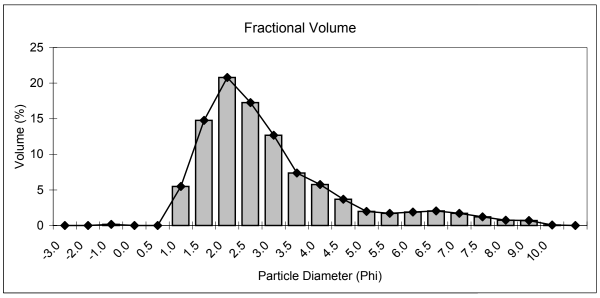


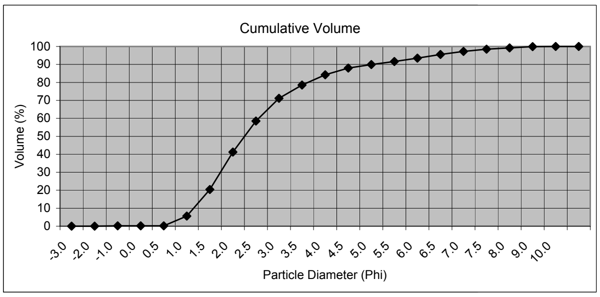


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.31	0.3	Granule
1.000	0.0	0.00	0.3	V.Coarse Sand
0.710	0.5	0.30	0.6	Coarse Sand
0.500	1.0	7.28	7.9	
0.355	1.5	15.91	23.8	Medium Sand
0.250	2.0	20.16	43.9	
0.180	2.5	15.61	59.6	Fine Sand
0.125	3.0	11.22	70.8	
0.900	3.5	7.00	77.8	V.Fine Sand
0.063	4.0	6.09	83.9	
0.044	4.5	4.20	88.1	Coarse Silt
0.032	5.0	2.23	90.3	
0.022	5.5	1.71	92.0	Medium Silt
0.016	6.0	1.79	93.8	
0.011	6.5	1.94	95.7	Fine silt
0.008	7.0	1.63	97.4	
0.006	7.5	1.16	98.5	V.Fine Silt
0.004	8.0	0.72	99.3	
0.002	9.0	0.67	99.9	Coarse Clay
0.001	10.0	0.07	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.181	0.214	2.47
Median	0.223		2.17
Sorting	**Value**	**Inference**	
Coefficient	1.53	Poorly Sorted	
Skewness	0.41	Very Positive (Coarse)	
Kurtosis	1.29	Leptokurtic	
% Fines	16.12%	Fine Sand	
% Sands	83.57%		
% Gravel	0.31%		

Sample No.:	Regional G24	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:10

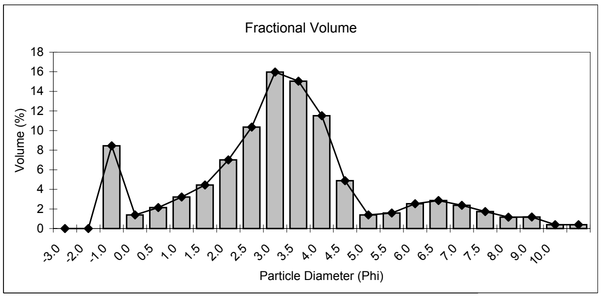


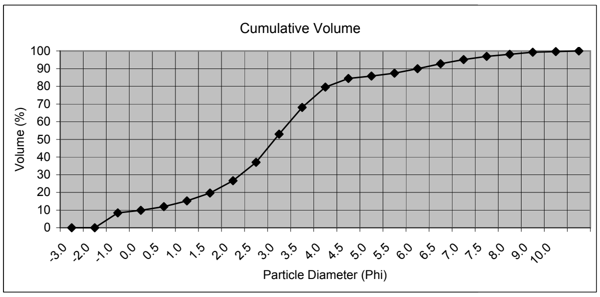


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.15	0.1	Granule
1.000	0.0	0.00	0.1	V.Coarse Sand
0.710	0.5	0.00	0.1	Coarse Sand
0.500	1.0	5.48	5.6	
0.355	1.5	14.77	20.4	Medium Sand
0.250	2.0	20.80	41.2	
0.180	2.5	17.26	58.5	Fine Sand
0.125	3.0	12.68	71.1	
0.900	3.5	7.38	78.5	V.Fine Sand
0.063	4.0	5.75	84.3	
0.044	4.5	3.68	88.0	Coarse Silt
0.032	5.0	1.97	89.9	
0.022	5.5	1.70	91.6	Medium Silt
0.016	6.0	1.89	93.5	
0.011	6.5	2.04	95.6	Fine silt
0.008	7.0	1.70	97.3	
0.006	7.5	1.21	98.5	V.Fine Silt
0.004	8.0	0.75	99.2	
0.002	9.0	0.70	99.9	Coarse Clay
0.001	10.0	0.07	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.176	0.196	2.50
Median	0.214		2.22
Sorting	**Value**	**Inference**	
Coefficient	1.48	Poorly Sorted	
Skewness	0.42	Very Positive (Coarse)	
Kurtosis	1.36	Leptokurtic	
% Fines	15.73%	Fine Sand	
% Sands	84.12%		
% Gravel	0.15%		

Sample No.:	Regional G25	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	25/09/2008 14:13

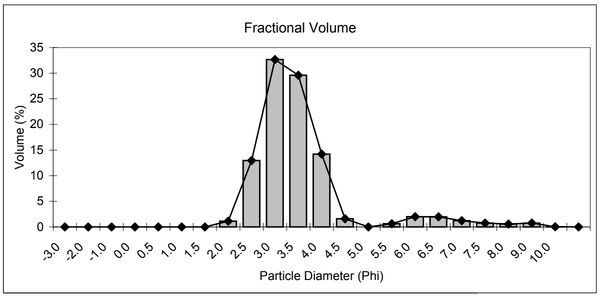


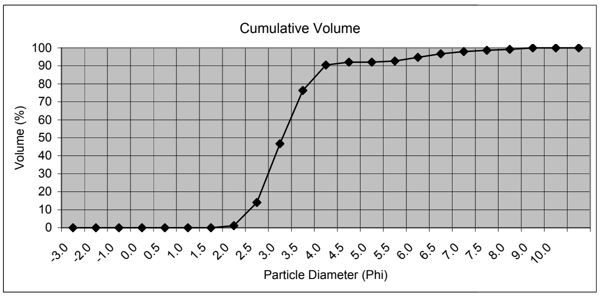


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	8.45	8.5	Granule
1.000	0.0	1.39	9.8	V.Coarse Sand
0.710	0.5	2.14	12.0	Coarse Sand
0.500	1.0	3.22	15.2	
0.355	1.5	4.44	19.6	Medium Sand
0.250	2.0	7.00	26.6	
0.180	2.5	10.36	37.0	Fine Sand
0.125	3.0	15.98	53.0	
0.900	3.5	15.04	68.0	V.Fine Sand
0.063	4.0	11.52	79.5	
0.044	4.5	4.88	84.4	Coarse Silt
0.032	5.0	1.39	85.8	
0.022	5.5	1.59	87.4	Medium Silt
0.016	6.0	2.53	89.9	
0.011	6.5	2.86	92.8	Fine silt
0.008	7.0	2.36	95.2	
0.006	7.5	1.74	96.9	V.Fine Silt
0.004	8.0	1.16	98.1	
0.002	9.0	1.17	99.2	Coarse Clay
0.001	10.0	0.38	99.6	Medium Clay
<0.001	>10.0	0.39	100.0	Fine Clay

Graphical	**mm**	**StDev (mm)**	**Phi**
Mean (MZ)	0.143	0.911	2.81
Median	0.135		2.89
Sorting Coefficient	**Value** 2.13	**Inference** Very Poorly Sorted	
Skewness	-0.05	Symmetrical	
Kurtosis	1.83	Very Leptokurtic	
% Fines	20.46%	Fine Sand	
% Sands	71.10%		
% Gravel	8.45%		

Sample No.:	Regional G26	**Operator**	Ian Wilson
Source Data:	Desire Petroleum	**Date&Time:**	25/09/2008 14:31

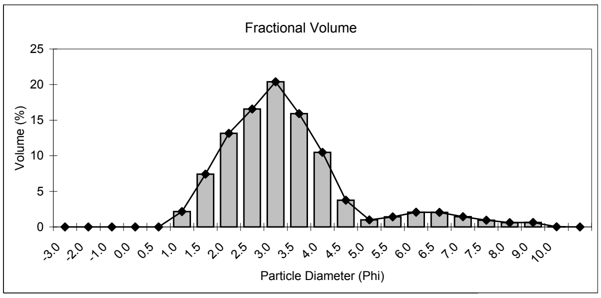


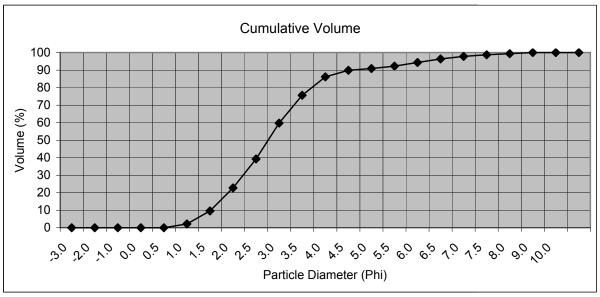


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.00	0.0	
0.355	1.5	0.00	0.0	Medium Sand
0.250	2.0	1.13	1.1	
0.180	2.5	12.95	14.1	Fine Sand
0.125	3.0	32.65	46.7	
0.900	3.5	29.59	76.3	V.Fine Sand
0.063	4.0	14.21	90.5	
0.044	4.5	1.59	92.1	Coarse Silt
0.032	5.0	0.00	92.1	
0.022	5.5	0.63	92.7	Medium Silt
0.016	6.0	1.99	94.7	
0.011	6.5	1.97	96.7	Fine silt
0.008	7.0	1.22	97.9	
0.006	7.5	0.75	98.7	V.Fine Silt
0.004	8.0	0.57	99.2	
0.002	9.0	0.74	100.0	Coarse Clay
0.001	10.0	0.03	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	**mm**	**StDev (mm)**	**Phi**
Mean (MZ)	0.117	0.071	3.09
Median	0.121		3.05
Sorting Coefficient	**Value** 0.90	**Inference** Moderately Sorted	
Skewness	0.32	Very Positive (Coarse)	
Kurtosis	1.97	Very Leptokurtic	
% Fines	9.49%	V.Fine Sands	
% Sands	90.51%		
% Gravel	0.00%		

Sample No.:	Regional G27	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:34

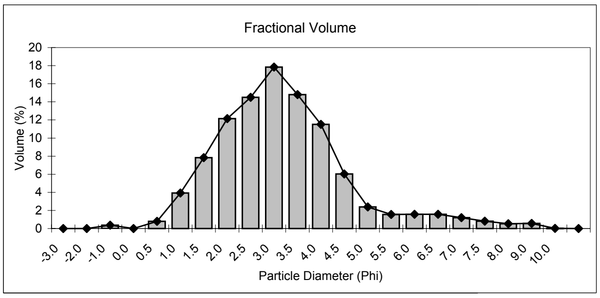


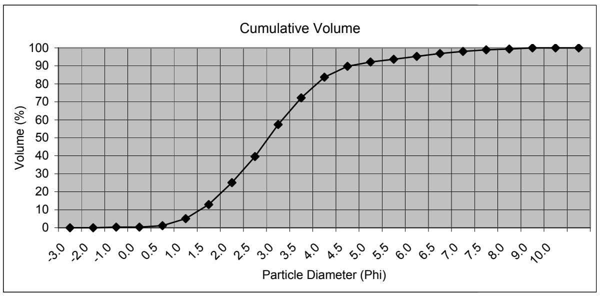


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	2.16	2.2	
0.355	1.5	7.43	9.6	Medium Sand
0.250	2.0	13.15	22.7	
0.180	2.5	16.56	39.3	Fine Sand
0.125	3.0	20.40	59.7	
0.900	3.5	15.91	75.6	V.Fine Sand
0.063	4.0	10.47	86.1	
0.044	4.5	3.77	89.9	Coarse Silt
0.032	5.0	1.00	90.8	
0.022	5.5	1.41	92.3	Medium Silt
0.016	6.0	2.07	94.3	
0.011	6.5	2.04	96.4	Fine silt
0.008	7.0	1.44	97.8	
0.006	7.5	0.94	98.7	V.Fine Silt
0.004	8.0	0.61	99.4	
0.002	9.0	0.63	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.146	0.152	2.77
Median	0.151		2.73
Sorting	Value	Inference	
Coefficient	1.29	Poorly Sorted	
Skewness	0.22	Positive(Coarse)	
Kurtosis	1.46	Leptokurtic	
% Fines	13.92%	Fine Sand	
% Sands	86.09%		
% Gravel	0.00%		

Sample No.:	Regional G28	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:19

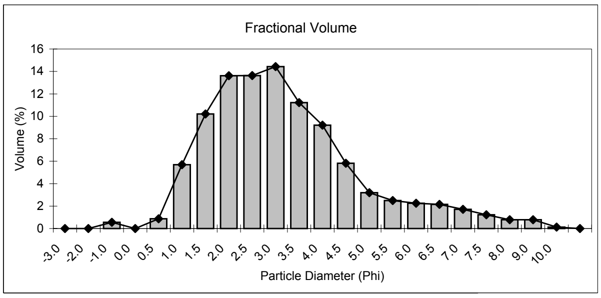


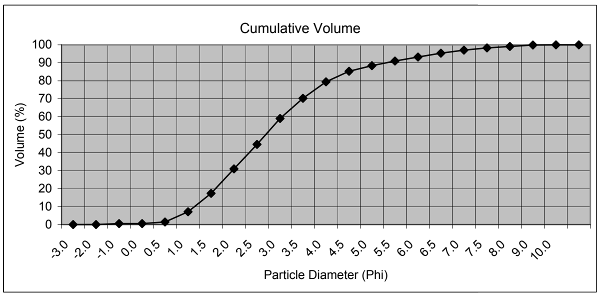


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.37	0.4	Granule
1.000	0.0	0.00	0.4	V.Coarse Sand
0.710	0.5	0.79	1.2	Coarse Sand
0.500	1.0	3.93	5.1	
0.355	1.5	7.83	12.9	Medium Sand
0.250	2.0	12.15	25.1	
0.180	2.5	14.51	39.6	Fine Sand
0.125	3.0	17.85	57.4	
0.900	3.5	14.80	72.2	V.Fine Sand
0.063	4.0	11.52	83.7	
0.044	4.5	6.03	89.8	Coarse Silt
0.032	5.0	2.40	92.2	
0.022	5.5	1.56	93.7	Medium Silt
0.016	6.0	1.57	95.3	
0.011	6.5	1.57	96.9	Fine silt
0.008	7.0	1.21	98.1	
0.006	7.5	0.82	98.9	V.Fine Silt
0.004	8.0	0.53	99.4	
0.002	9.0	0.57	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.144	0.176	2.79
Median	0.148		2.76
Sorting	Value	Inference	
Coefficient	1.34	Poorly Sorted	
Skewness	0.16	Positive(Coarse)	
Kurtosis	1.27	Leptokurtic	
% Fines	16.27%	Fine Sand	
% Sands	83.37%		
% Gravel	0.37%		

Sample No.:	Regional G29	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:37

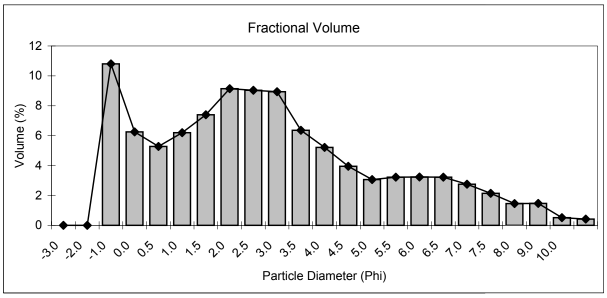


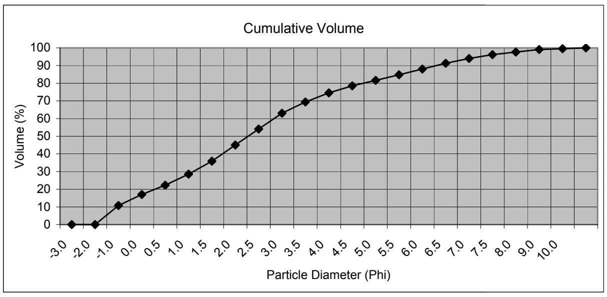


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.56	0.6	Granule
1.000	0.0	0.00	0.6	V.Coarse Sand
0.710	0.5	0.87	1.4	Coarse Sand
0.500	1.0	5.68	7.1	
0.355	1.5	10.22	17.3	Medium Sand
0.250	2.0	13.62	30.9	
0.180	2.5	13.63	44.6	Fine Sand
0.125	3.0	14.43	59.0	
0.900	3.5	11.23	70.2	V.Fine Sand
0.063	4.0	9.21	79.4	
0.044	4.5	5.82	85.3	Coarse Silt
0.032	5.0	3.20	88.5	
0.022	5.5	2.50	91.0	Medium Silt
0.016	6.0	2.26	93.2	
0.011	6.5	2.15	95.4	Fine silt
0.008	7.0	1.71	97.1	
0.006	7.5	1.22	98.3	V.Fine Silt
0.004	8.0	0.78	99.1	
0.002	9.0	0.78	99.9	Coarse Clay
0.001	10.0	0.13	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.142	0.209	2.82
Median	0.159		2.65
Sorting Coefficient	**Value**	**Inference**	
	1.59	Poorly Sorted	
Skewness	0.25	Positive(Coarse)	
Kurtosis	1.17	Leptokurtic	
% Fines	20.56%	Fine Sand	
% Sands	78.88%		
% Gravel	0.56%		

Sample No.:	Regional G30	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:29

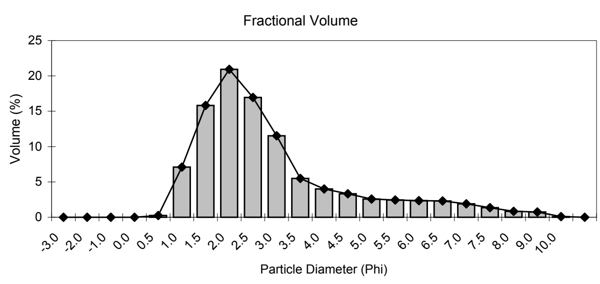


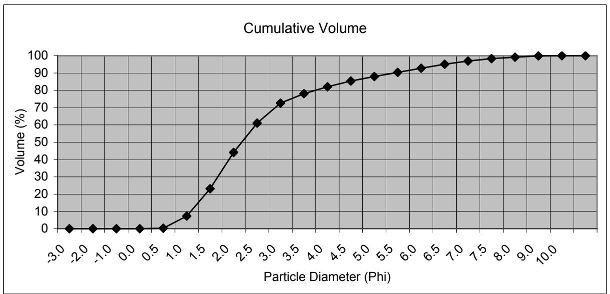


Aperture (mmm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.0	0.0	Pebble
4.000	-2.0	0.0	0.0	
2.000	-1.0	10.8	10.8	Granule
1.000	0.0	6.2	17.0	C, Coarse S
0.710	0.5	5.3	22.3	Coarse Sand
0.500	1.0	6.2	28.5	
0.355	1.5	7.4	35.9	Medium Sand
0.250	2.0	9.1	45.0	
0.180	2.5	9.0	54.1	Fine Sand
0.125	3.0	8.9	63.0	
0.900	3.5	6.4	69.4	V.Fine Sand
0.063	4.0	5.2	74.6	
0.044	4.5	4.0	78.5	Corse Silt
0.032	5.0	3.1	81.6	
0.022	5.5	3.2	84.8	Medium Silt
0.016	6.0	3.2	88.1	
0.011	6.5	3.2	91.3	Fine Silt
0.008	7.0	2.7	94.0	
0.006	7.5	2.1	96.2	V.Fine Silt
0.004	8.0	1.5	97.6	
0.002	9.0	1.5	99.1	Coarse Clay
0.001	10.0	0.5	99.6	Medium Clay
<0.001	>10.0	0.4	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.182	1.112	2.46
Median	0.212		2.24
Sorting Coefficient	**Value**	**Inference**	
	2.7	Very Poorly Sorted	
Skewness	0.1	Positive(Coarse)	
Kurtosis	1.1	Mesokurtic	
% Fines	25.41%	Fine Sand	
% Sands	63.79%		
% Gravel	10.80%		

Sample No.:	Regional G31	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:07

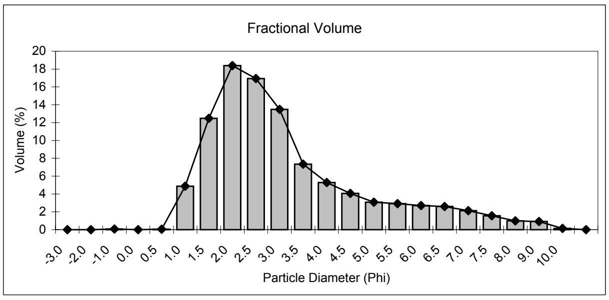


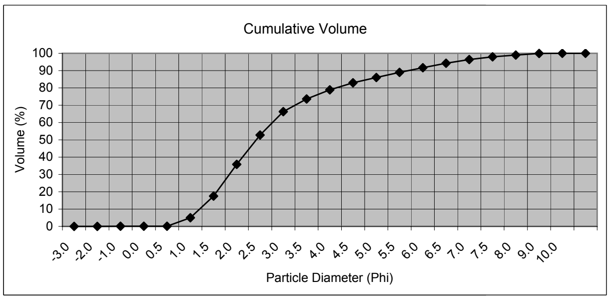


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.25	0.2	Coarse Sand
0.500	1.0	7.09	7.3	
0.355	1.5	15.83	23.2	Medium Sand
0.250	2.0	20.94	44.1	
0.180	2.5	16.94	61.1	Fine Sand
0.125	3.0	11.54	72.6	
0.900	3.5	5.50	78.1	V.Fine Sand
0.063	4.0	4.00	82.1	
0.044	4.5	3.32	85.4	Coarse Silt
0.032	5.0	2.57	88.0	
0.022	5.5	2.45	90.4	Medium Silt
0.016	6.0	2.34	92.8	
0.011	6.5	2.31	95.1	Fine silt
0.008	7.0	1.89	97.0	
0.006	7.5	1.36	98.3	V.Fine Silt
0.004	8.0	0.84	99.2	
0.002	9.0	0.75	99.9	Coarse Clay
0.001	10.0	0.09	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.170	0.212	2.55
Median	0.226		2.15
Sorting Coefficient	Value 1.61	Inference Poorly Sorted	
Skewness	0.47	Very Positive (Coarse)	
Kurtosis	1.40	Leptokurtic	
% Fines	17.92%	Fine Sand	
% Sands	82.08%		
% Gravel	0.00%		

Sample No.:	Regional G32	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	25/09/2008 14:25

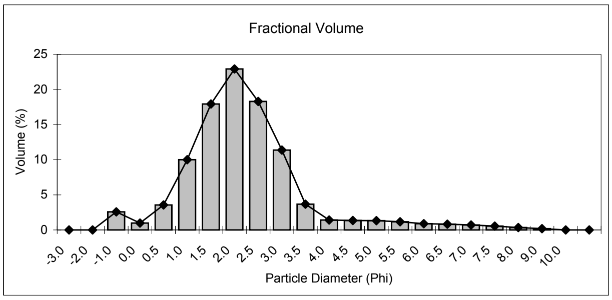


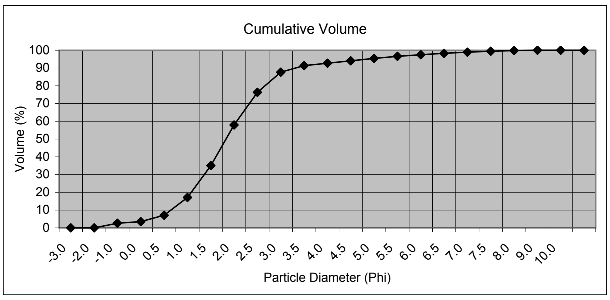


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.08	0.1	Granule
1.000	0.0	0.00	0.1	V.Coarse Sand
0.710	0.5	0.05	0.1	Coarse Sand
0.500	1.0	4.88	5.0	
0.355	1.5	12.48	17.5	Medium Sand
0.250	2.0	18.39	35.9	
0.180	2.5	16.94	52.8	Fine Sand
0.125	3.0	13.48	66.3	
0.900	3.5	7.35	73.6	V.Fine Sand
0.063	4.0	5.29	78.9	
0.044	4.5	4.07	83.0	Coarse Silt
0.032	5.0	3.08	86.1	
0.022	5.5	2.92	89.0	Medium Silt
0.016	6.0	2.71	91.7	
0.011	6.5	2.60	94.3	Fine silt
0.008	7.0	2.13	96.4	
0.006	7.5	1.55	98.0	V.Fine Silt
0.004	8.0	0.98	99.0	
0.002	9.0	0.91	99.9	Coarse Clay
0.001	10.0	0.14	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.142	0.192	2.82
Median	0.192		2.38
Sorting Coefficient	Value 1.66	Inference Poorly Sorted	
Skewness	0.46	Very Positive (Coarse)	
Kurtosis	1.21	Leptokurtic	
% Fines	21.08%	Fine Sand	
% Sands	78.84%		
% Gravel	0.08%		

Sample No.:	Alpha 0	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 12:25

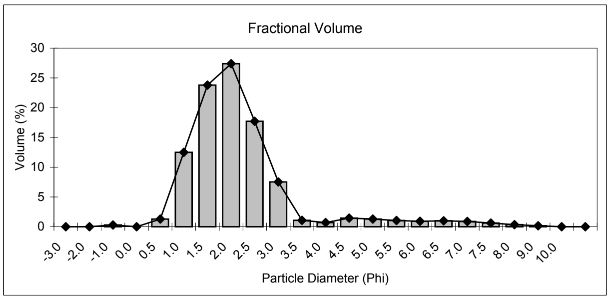


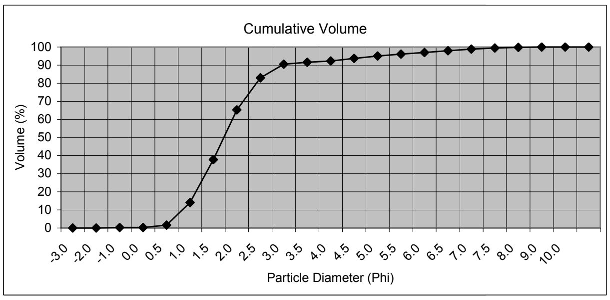


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	2.58	2.6	Granule
1.000	0.0	0.97	3.5	V.Coarse Sand
0.710	0.5	3.55	7.1	Coarse Sand
0.500	1.0	10.00	17.1	
0.355	1.5	17.94	35.0	Medium Sand
0.250	2.0	22.92	58.0	
0.180	2.5	18.31	76.3	Fine Sand
0.125	3.0	11.38	87.7	
0.900	3.5	3.67	91.3	V.Fine Sand
0.063	4.0	1.41	92.7	
0.044	4.5	1.33	94.1	Coarse Silt
0.032	5.0	1.33	95.4	
0.022	5.5	1.16	96.6	Medium Silt
0.016	6.0	0.88	97.4	
0.011	6.5	0.81	98.2	Fine silt
0.008	7.0	0.70	98.9	
0.006	7.5	0.54	99.5	V.Fine Silt
0.004	8.0	0.34	99.8	
0.002	9.0	0.18	100.0	Coarse Clay
0.001	10.0	0.00	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.278	0.284	1.85
Median	0.286		1.80
Sorting	**Value**	**Inference**	
Coefficient	1.17	Poorly Sorted	
Skewness	0.19	Positive(Coarse)	
Kurtosis	1.54	Very Leptokurtic	
% Fines	7.27%	Medium Sand	
% Sands	90.15%		
% Gravel	2.58%		

Sample No.:	Barbara 0	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 10:29

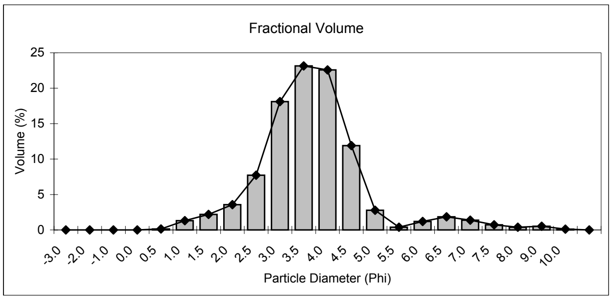


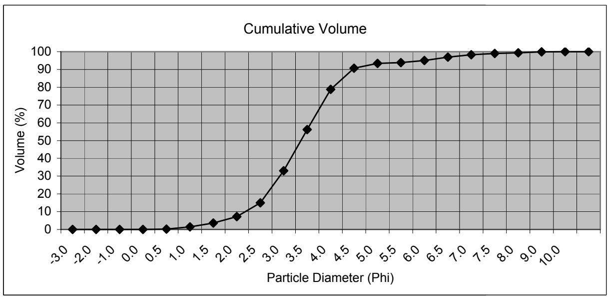


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.28	0.3	Granule
1.000	0.0	0.00	0.3	V.Coarse Sand
0.710	0.5	1.28	1.6	Coarse Sand
0.500	1.0	12.49	14.1	
0.355	1.5	23.79	37.8	Medium Sand
0.250	2.0	27.40	65.3	
0.180	2.5	17.72	83.0	Fine Sand
0.125	3.0	7.53	90.5	
0.900	3.5	1.09	91.6	V.Fine Sand
0.063	4.0	0.69	92.3	
0.044	4.5	1.46	93.7	Coarse Silt
0.032	5.0	1.30	95.0	
0.022	5.5	1.04	96.1	Medium Silt
0.016	6.0	0.93	97.0	
0.011	6.5	1.00	98.0	Fine silt
0.008	7.0	0.87	98.9	
0.006	7.5	0.63	99.5	V.Fine Silt
0.004	8.0	0.36	99.8	
0.002	9.0	0.16	100.0	Coarse Clay
0.001	10.0	0.00	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.296	0.214	1.76
Median	0.308		1.70
Sorting	**Value**	**Inference**	
Coefficient	1.04	Poorly Sorted	
Skewness	0.31	Very Positive (Coarse)	
Kurtosis	1.73	Very Leptokurtic	
% Fines	7.73%	Medium Sand	
% Sands	91.99%		
% Gravel	0.28%		

Sample No.:	Dawn 0	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 12:50

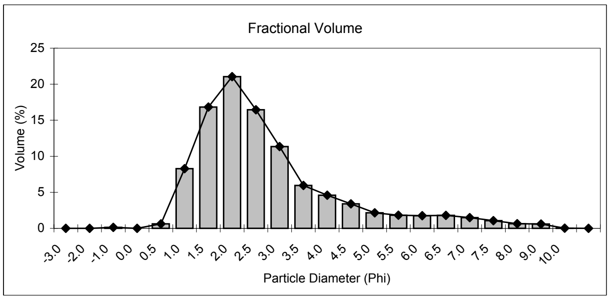


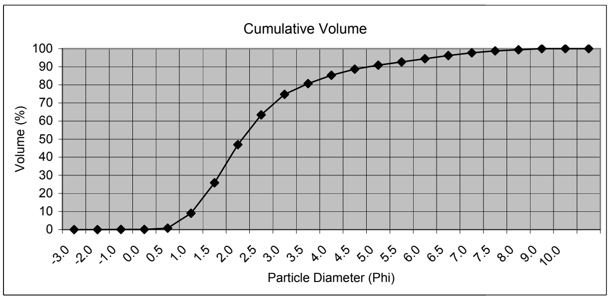


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.14	0.1	Coarse Sand
0.500	1.0	1.30	1.4	
0.355	1.5	2.20	3.6	Medium Sand
0.250	2.0	3.57	7.2	
0.180	2.5	7.72	14.9	Fine Sand
0.125	3.0	18.10	33.0	
0.900	3.5	23.15	56.2	V.Fine Sand
0.063	4.0	22.59	78.8	
0.044	4.5	11.90	90.7	Coarse Silt
0.032	5.0	2.79	93.5	
0.022	5.5	0.39	93.9	Medium Silt
0.016	6.0	1.21	95.1	
0.011	6.5	1.84	96.9	Fine silt
0.008	7.0	1.38	98.3	
0.006	7.5	0.72	99.0	V.Fine Silt
0.004	8.0	0.38	99.4	
0.002	9.0	0.52	99.9	Coarse Clay
0.001	10.0	0.10	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical		mm	StDev (mm)	Phi
Mean (MZ)		0.099	0.098	3.34
Median		0.099		3.33
Sorting Coefficient		Value 1.08	Inference: Poorly Sorted	
Skewness		0.12	Positive(Coarse)	
Kurtosis		1.54	Very Leptokurtic	
% Fines		21.22%	V.Fine Sands	
% Sands		78.78%		
% Gravel		0.00%		

Sample No.:	Ruth 0	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 12:03

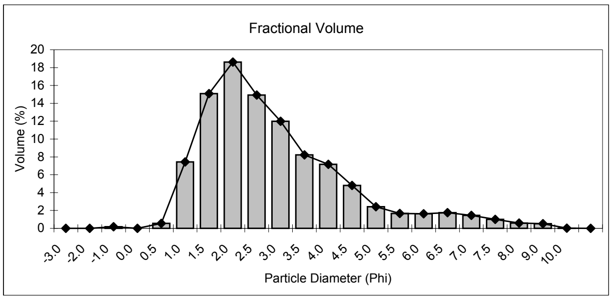


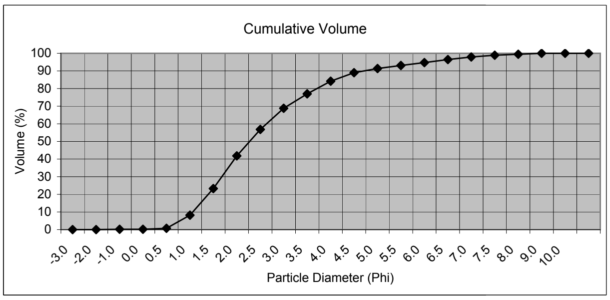


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.12	0.1	Granule
1.000	0.0	0.00	0.1	V.Coarse Sand
0.710	0.5	0.63	0.8	Coarse Sand
0.500	1.0	8.29	9.0	
0.355	1.5	16.84	25.9	Medium Sand
0.250	2.0	21.05	46.9	
0.180	2.5	16.46	63.4	Fine Sand
0.125	3.0	11.35	74.7	
0.900	3.5	5.95	80.7	V.Fine Sand
0.063	4.0	4.59	85.3	
0.044	4.5	3.40	88.7	Coarse Silt
0.032	5.0	2.16	90.8	
0.022	5.5	1.81	92.7	Medium Silt
0.016	6.0	1.75	94.4	
0.011	6.5	1.79	96.2	Fine silt
0.008	7.0	1.49	97.7	
0.006	7.5	1.06	98.7	V.Fine Silt
0.004	8.0	0.65	99.4	
0.002	9.0	0.59	100.0	Coarse Clay
0.001	10.0	0.02	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical		mm	StDev (mm)	Phi
Mean (MZ)		0.195	0.218	2.36
Median		0.237		2.08
Sorting Coefficient		Value 1.48	Inference: Poorly Sorted	
Skewness		0.41	Very Positive (Coarse)	
Kurtosis		1.43	Leptokurtic	
% Fines		14.72%	Fine Sand	
% Sands		85.16%		
% Gravel		0.12%		

Sample No.:	Ernest 0	Operator	Ian Wilson
Source Data:	Desire Petroleum	Date&Time:	22/01/2009 10:35

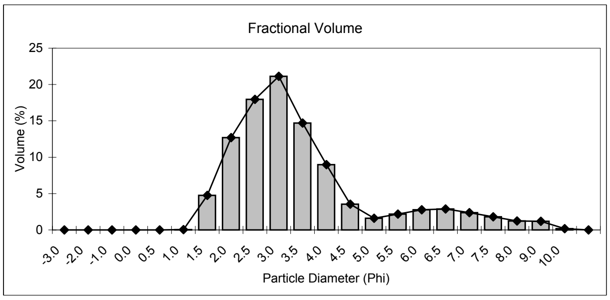


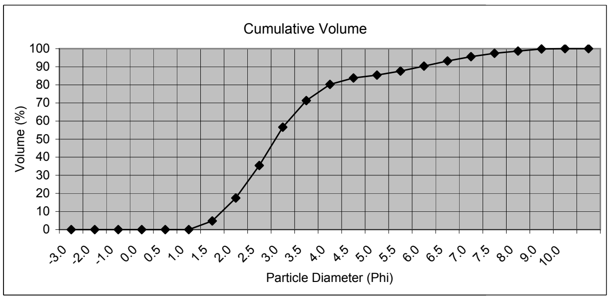


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.18	0.2	Granule
1.000	0.0	0.00	0.2	V.Coarse Sand
0.710	0.5	0.55	0.7	Coarse Sand
0.500	1.0	7.43	8.2	
0.355	1.5	15.08	23.2	Medium Sand
0.250	2.0	18.62	41.9	
0.180	2.5	14.94	56.8	Fine Sand
0.125	3.0	11.98	68.8	
0.900	3.5	8.22	77.0	V.Fine Sand
0.063	4.0	7.16	84.2	
0.044	4.5	4.81	89.0	Coarse Silt
0.032	5.0	2.43	91.4	
0.022	5.5	1.66	93.1	Medium Silt
0.016	6.0	1.63	94.7	
0.011	6.5	1.75	96.4	Fine silt
0.008	7.0	1.45	97.9	
0.006	7.5	1.00	98.9	V.Fine Silt
0.004	8.0	0.59	99.5	
0.002	9.0	0.51	100.0	Coarse Clay
0.001	10.0	0.01	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.179	0.214	2.48
Median	0.212		2.24
Sorting	**Value**	**Inference**	
Coefficient	1.49	Poorly Sorted	
Skewness	0.36	Very Positive (Coarse)	
Kurtosis	1.21	Leptokurtic	
% Fines	15.84%	Fine Sand	
% Sands	83.99%		
% Gravel	0.18%		

Sample No.:	Weddell A	Operator	Ian Wilson
Source Data:	Rockhopper Petroleum	Date&Time:	22/01/2009 13:18

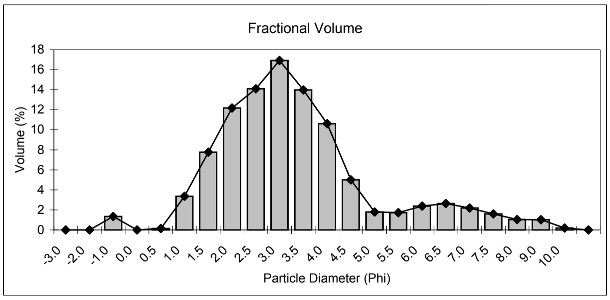


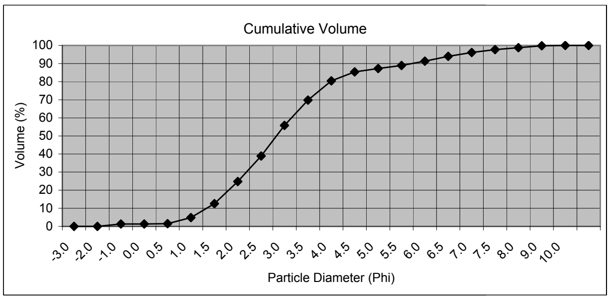


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	0.00	0.0	Granule
1.000	0.0	0.00	0.0	V.Coarse Sand
0.710	0.5	0.00	0.0	Coarse Sand
0.500	1.0	0.04	0.0	
0.355	1.5	4.76	4.8	Medium Sand
0.250	2.0	12.69	17.5	
0.180	2.5	17.95	35.4	Fine Sand
0.125	3.0	21.13	56.6	
0.900	3.5	14.70	71.3	V.Fine Sand
0.063	4.0	8.97	80.2	
0.044	4.5	3.55	83.8	Coarse Silt
0.032	5.0	1.61	85.4	
0.022	5.5	2.17	87.6	Medium Silt
0.016	6.0	2.77	90.3	
0.011	6.5	2.87	93.2	Fine silt
0.008	7.0	2.38	95.6	
0.006	7.5	1.81	97.4	V.Fine Silt
0.004	8.0	1.24	98.6	
0.002	9.0	1.19	99.8	Coarse Clay
0.001	10.0	0.18	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.116	0.132	3.10
Median	0.142		2.82
Sorting	**Value**	**Inference**	
Coefficient	1.47	Poorly Sorted	
Skewness	0.42	Very Positive (Coarse)	
Kurtosis	1.48	Leptokurtic	
% Fines	19.77%	V.Fine Sands	
% Sands	80.23%		
% Gravel	0.00%		

Sample No.:	Weddell B	Operator	Ian Wilson
Source Data:	Rockhopper Petroleum	Date&Time:	22/01/2009 12:56



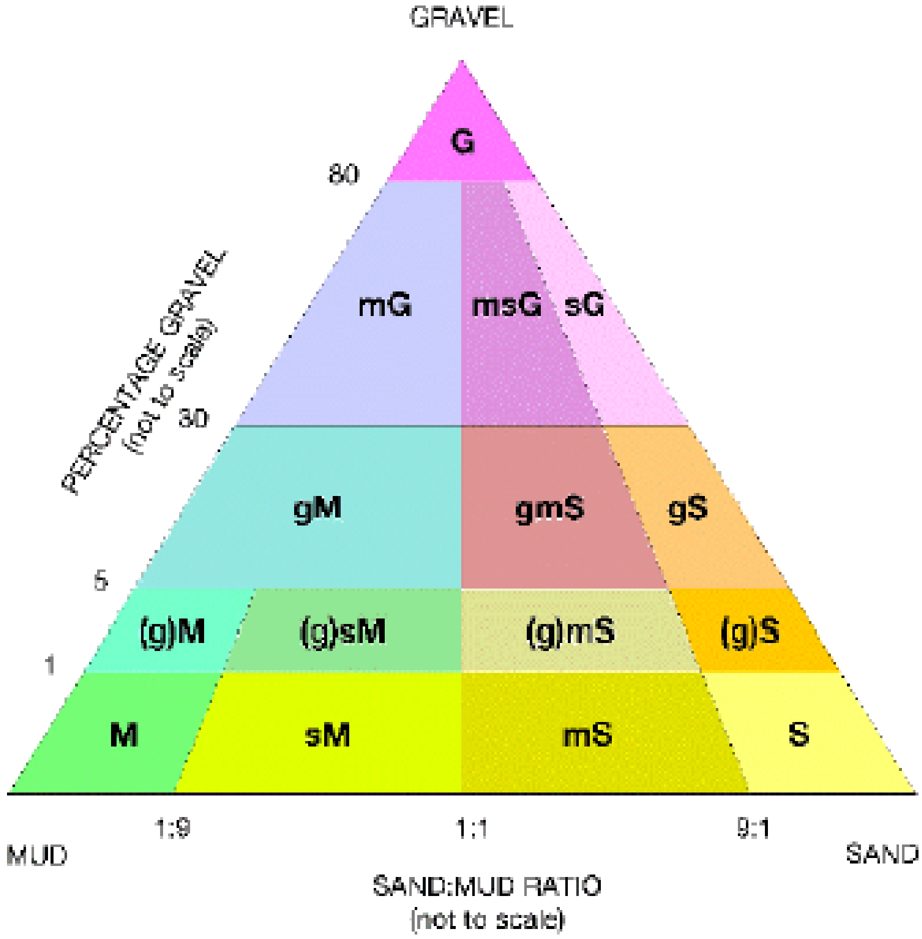


Aperture (µm)	Aperture (Phi unit)	Percentage Fractional	Cumulative	Sediment Description
8.000	-3.0	0.00	0.0	Pebble
4.000	-2.0	0.00	0.0	
2.000	-1.0	1.34	1.3	Granule
1.000	0.0	0.00	1.3	V.Coarse Sand
0.710	0.5	0.15	1.5	Coarse Sand
0.500	1.0	3.36	4.8	
0.355	1.5	7.77	12.6	Medium Sand
0.250	2.0	12.17	24.8	
0.180	2.5	14.10	38.9	Fine Sand
0.125	3.0	16.93	55.8	
0.900	3.5	13.99	69.8	V.Fine Sand
0.063	4.0	10.61	80.4	
0.044	4.5	5.00	85.4	Coarse Silt
0.032	5.0	1.80	87.2	
0.022	5.5	1.73	88.9	Medium Silt
0.016	6.0	2.38	91.3	
0.011	6.5	2.64	94.0	Fine silt
0.008	7.0	2.19	96.1	
0.006	7.5	1.59	97.7	V.Fine Silt
0.004	8.0	1.04	98.8	
0.002	9.0	1.02	99.8	Coarse Clay
0.001	10.0	0.20	100.0	Medium Clay
<0.001	>10.0	0.00	100.0	Fine Clay

Graphical	mm	StDev (mm)	Phi
Mean (MZ)	0.132	0.180	2.92
Median	0.144		2.80

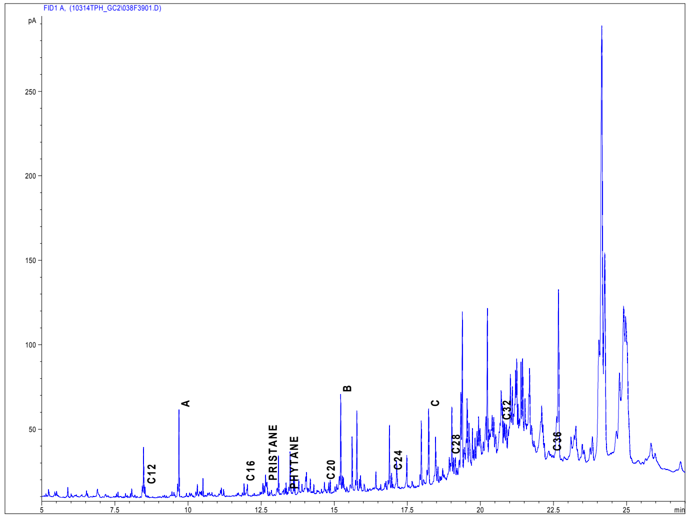
Sorting	Value	Inference
Coefficient	1.55	Poorly Sorted
Skewness	0.25	Positive(Coarse)
Kurtosis	1.38	Leptokurtic
% Fines	19.58%	Fine Sand
% Sands	79.09%	
% Gravel	1.34%	

Modified Folk Classification

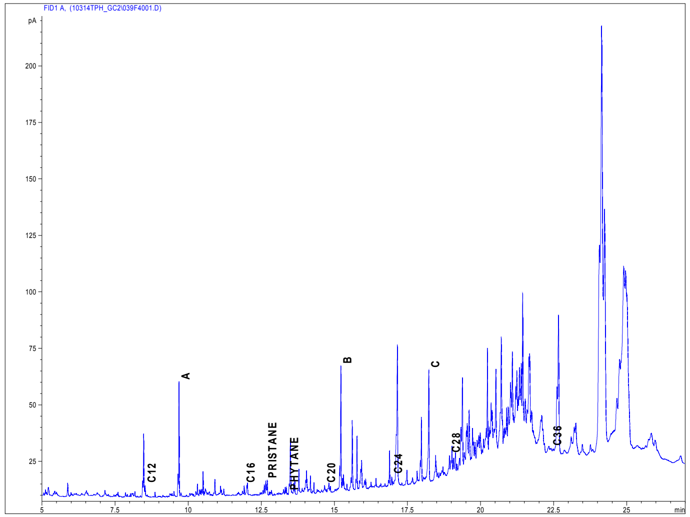


M	Mud
sM	Sandy mud
(g)M	Slightly gravelly mud
(g)sM	Slightly gravelly sandy mud
gM	Gravelly mud
S	Sand
mS	Muddy sand
(g)S	Slightly gravelly sand
(g)mS	Slightly gravelly muddy sand
gmS	Gravelly muddy sand
gS	Gravelly sand
G	Gravel
mG	Muddy gravel
msG	Muddy sandy gravel
sG	Sandy gravel

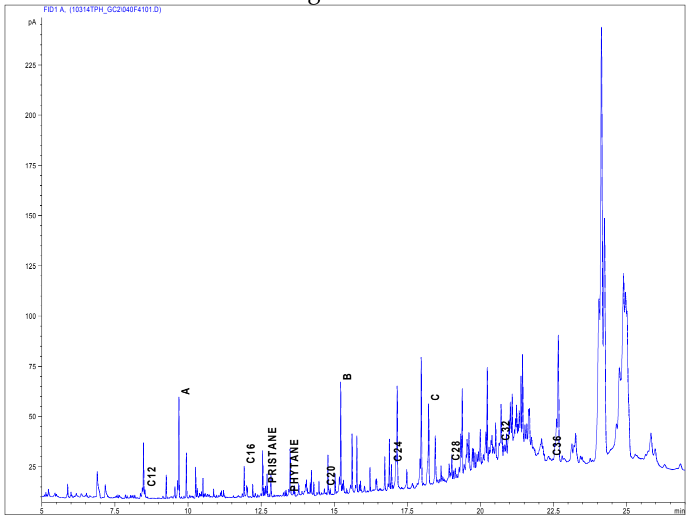
APPENDIX II: GC-FID Traces



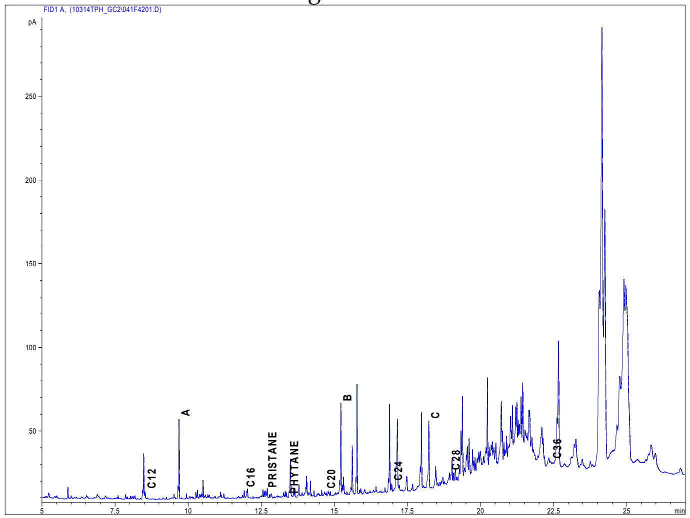
Regional G1



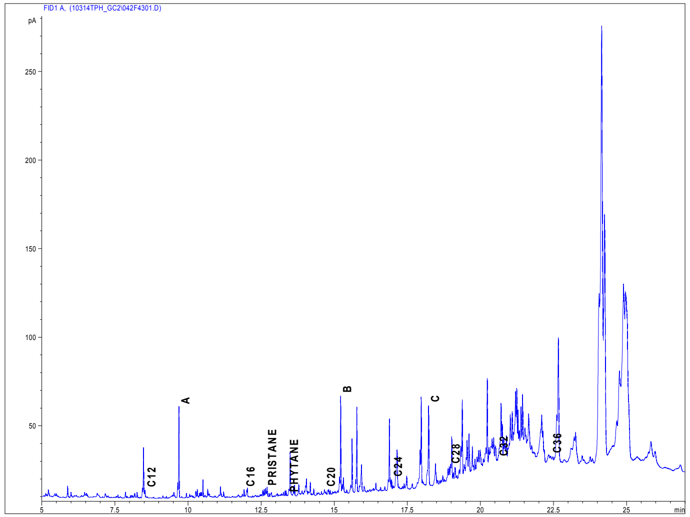
Regional G2



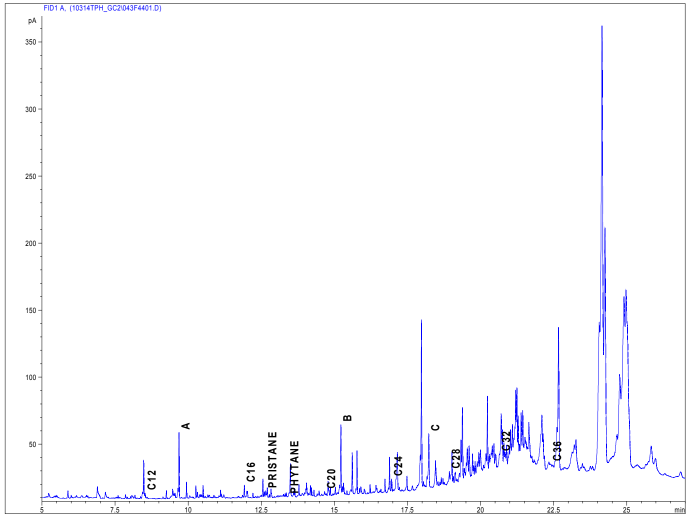
Regional G3



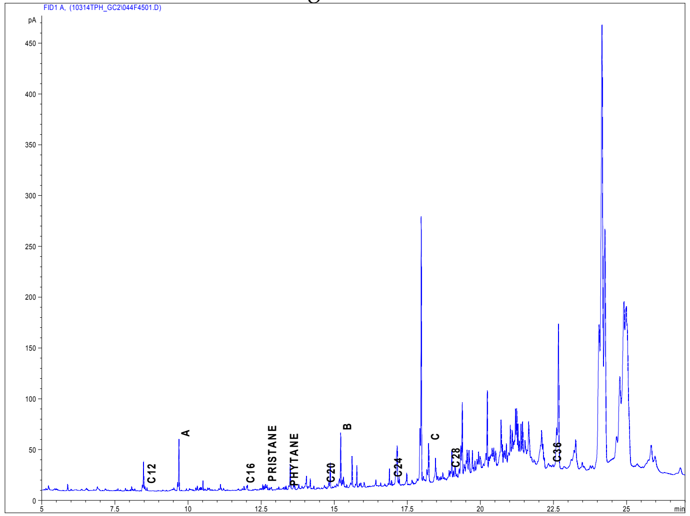
Regional G4



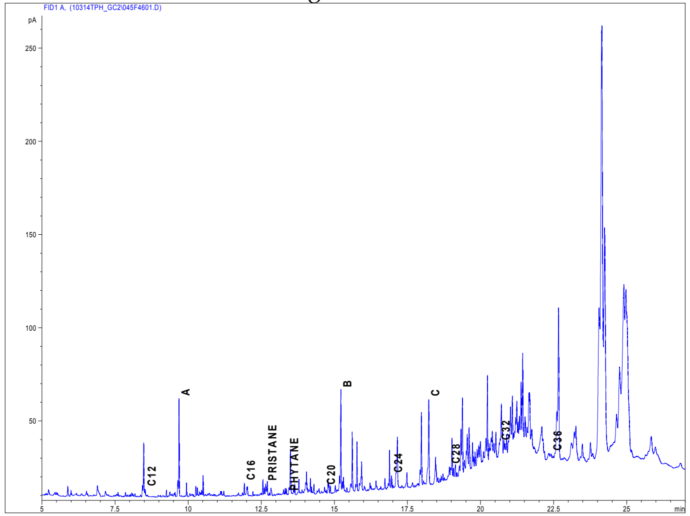
Regional G5



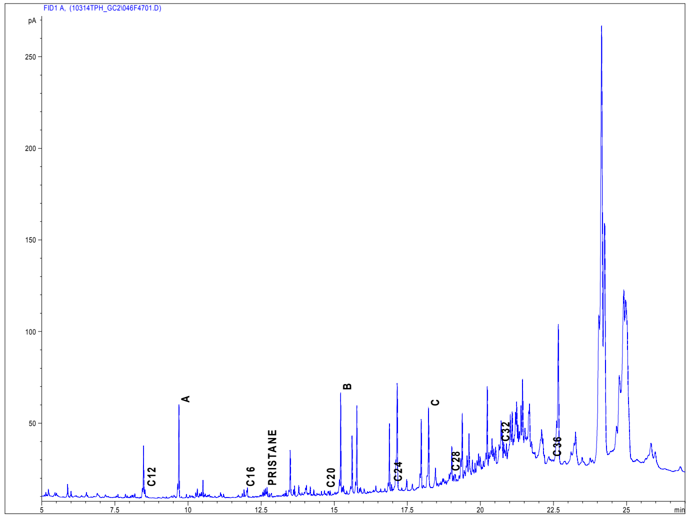
Regional G6



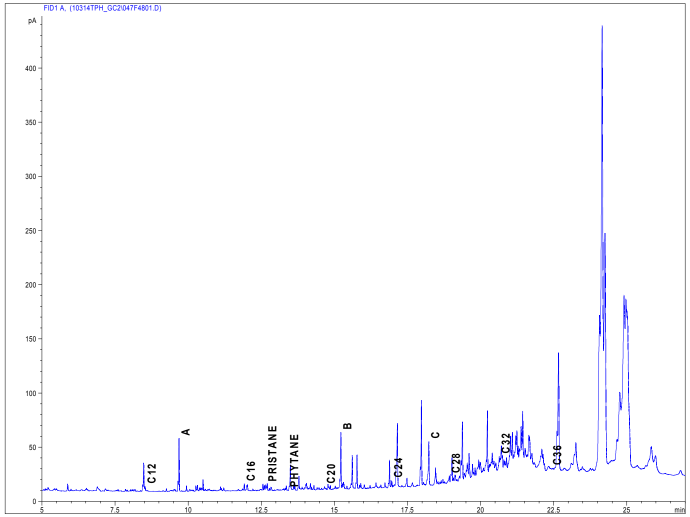
Regional G7



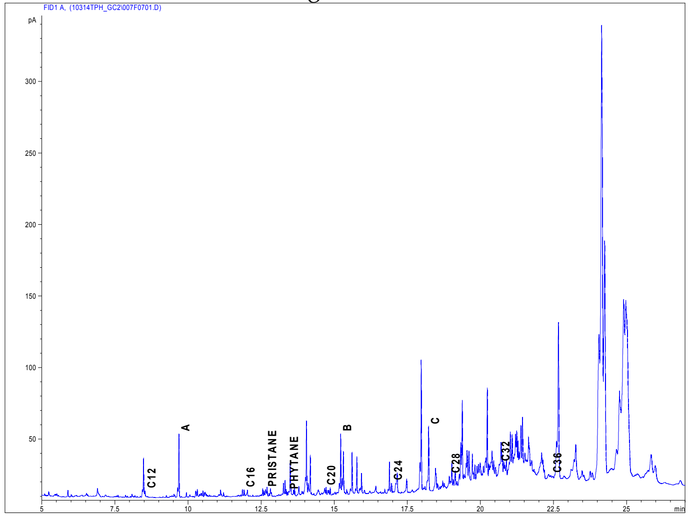
Regional G8



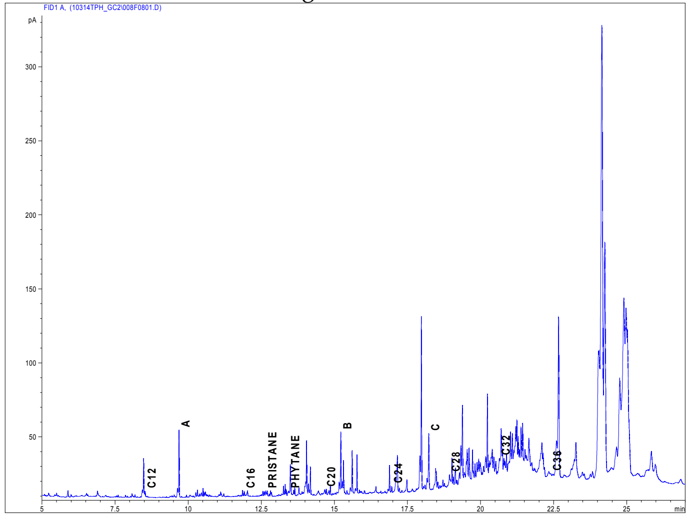
Regional G9



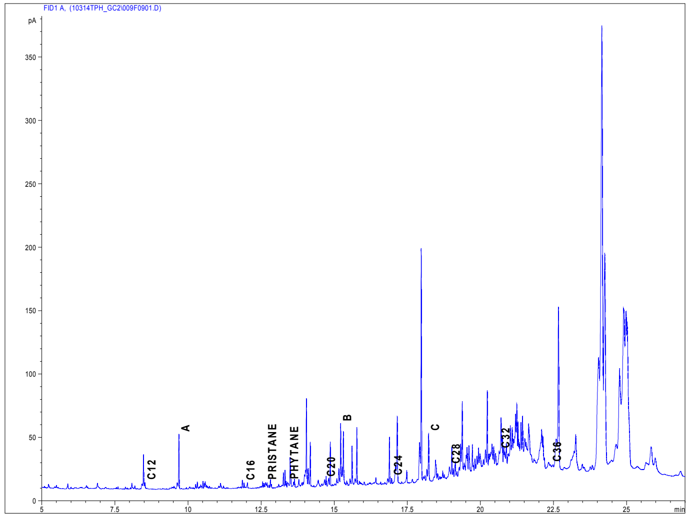
Regional G10



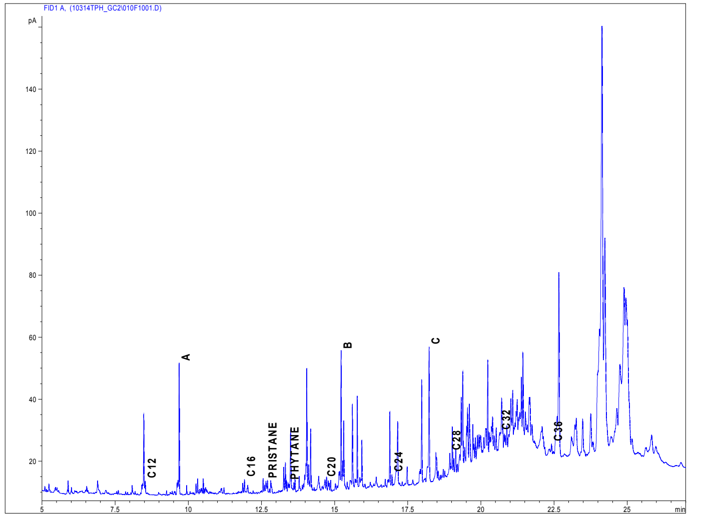
Regional G11



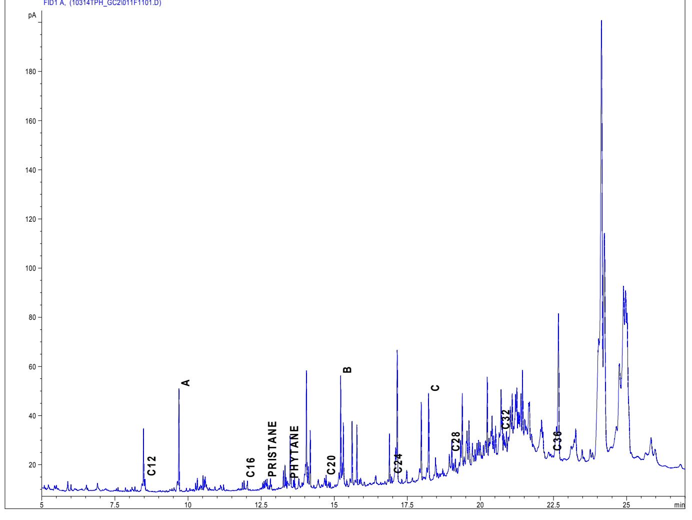
Regional G12



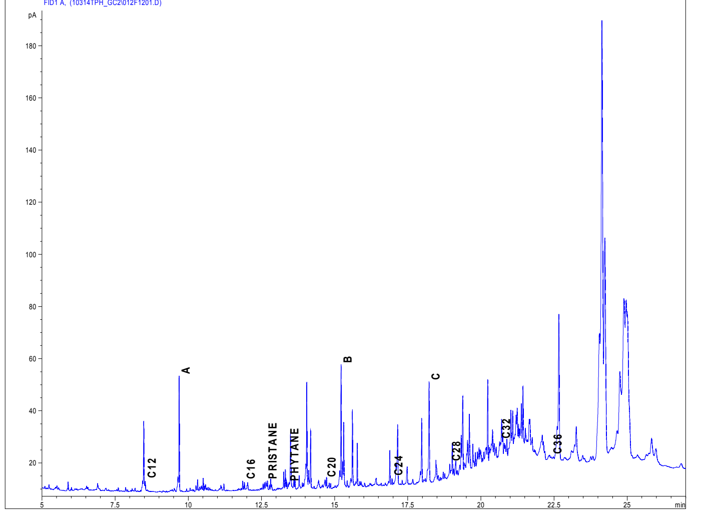
Regional G13



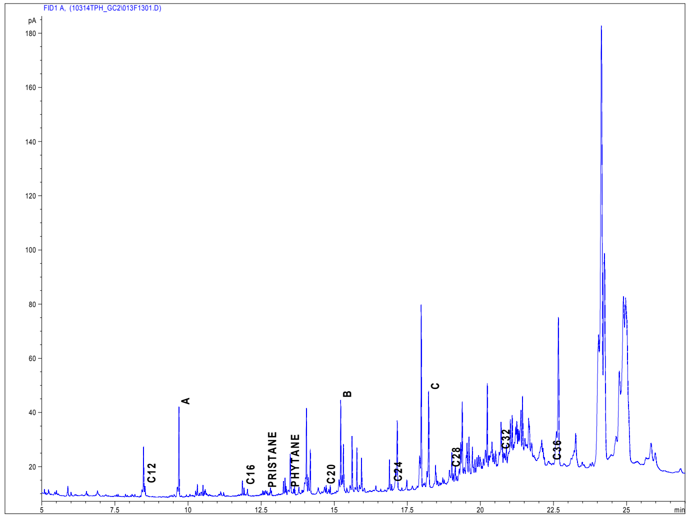
Regional G14



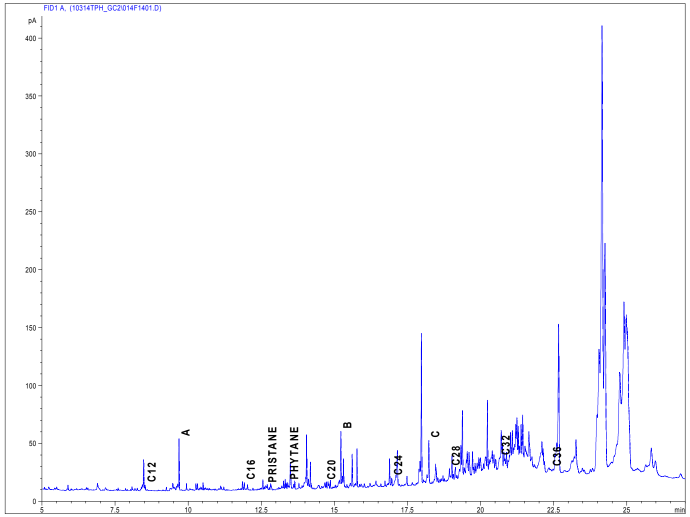
Regional G15



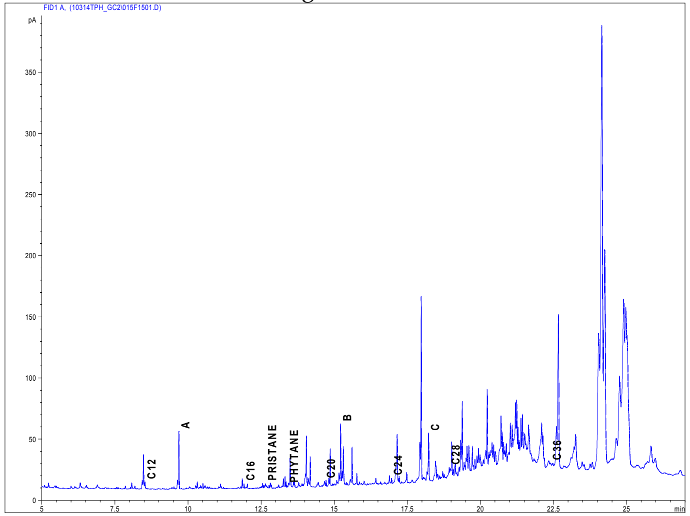
Regional G16



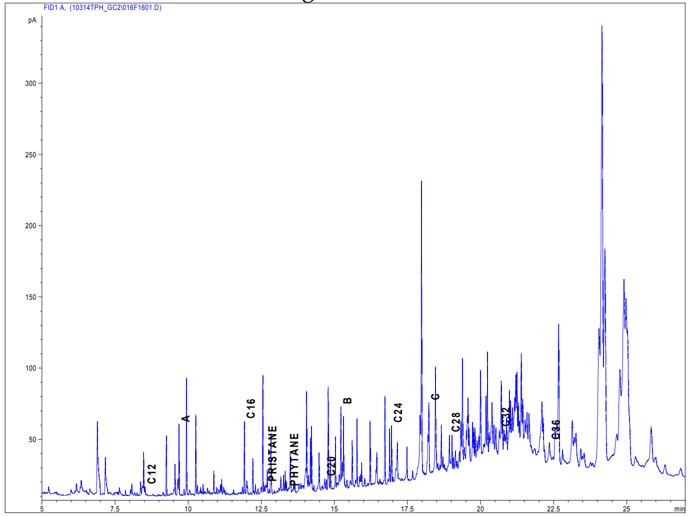
Regional G17



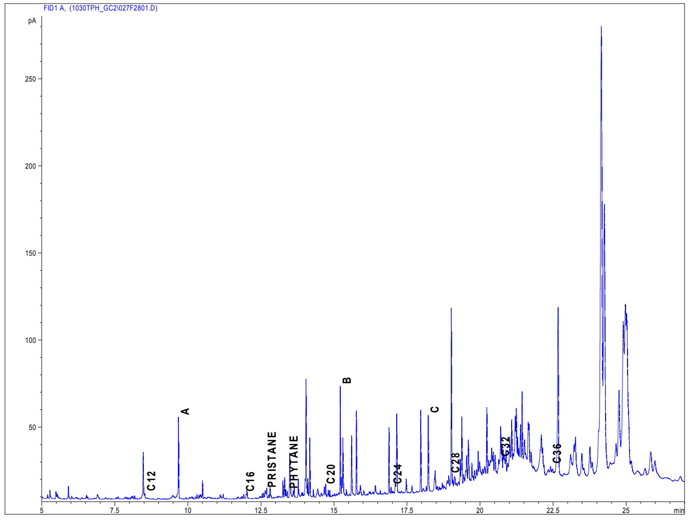
Regional G18



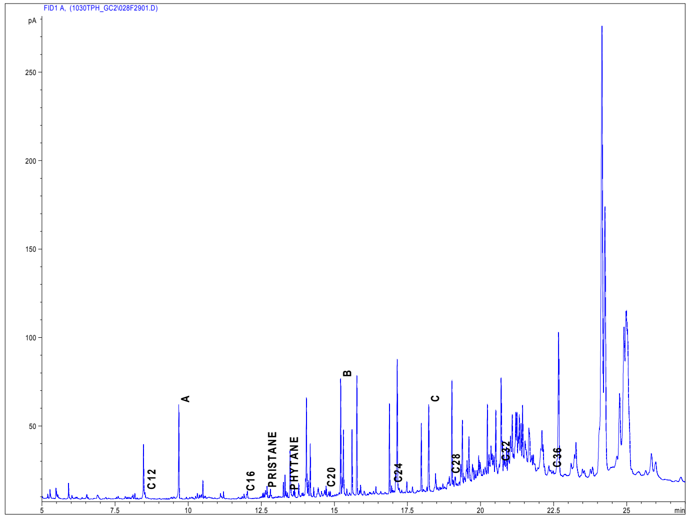
Regional G19



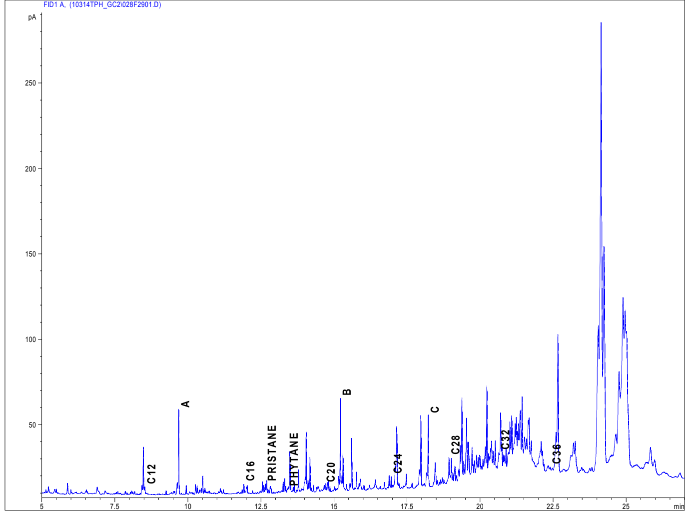
Regional G20



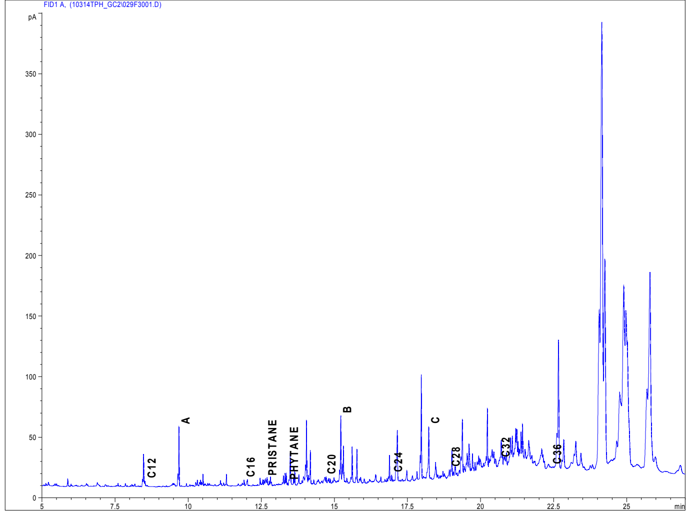
Regional G21



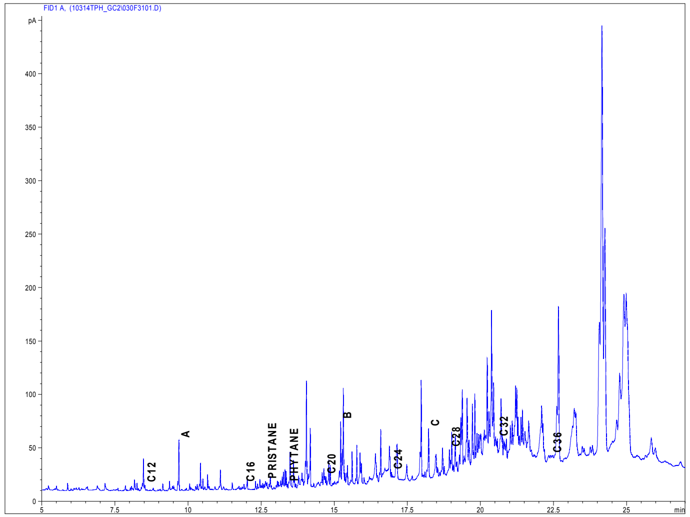
Regional G22



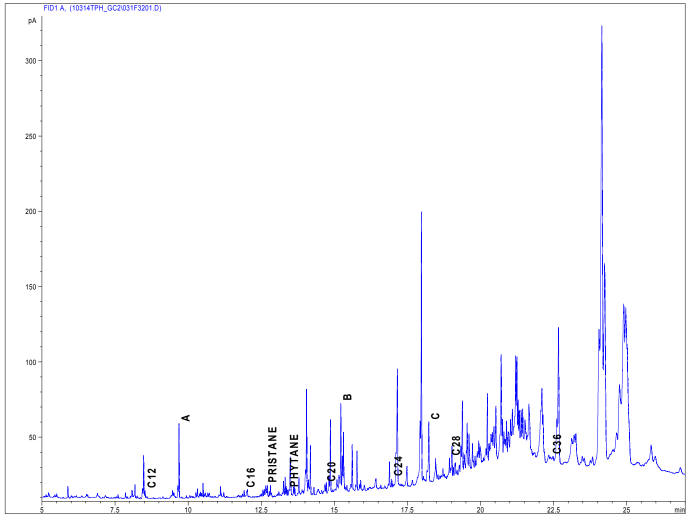
Regional G23



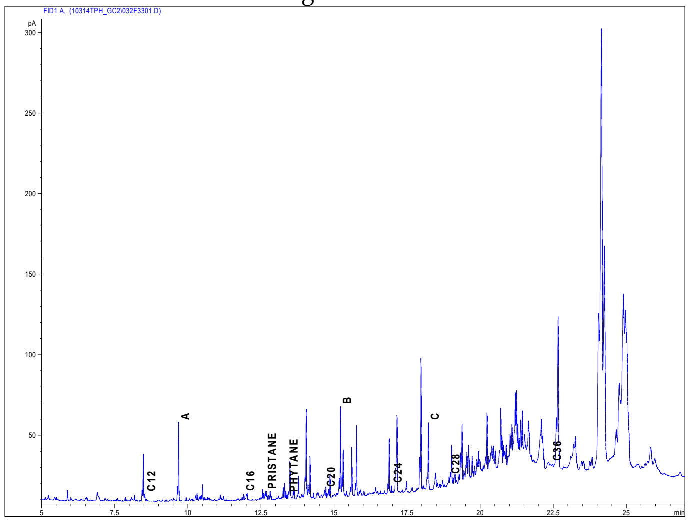
Regional G24



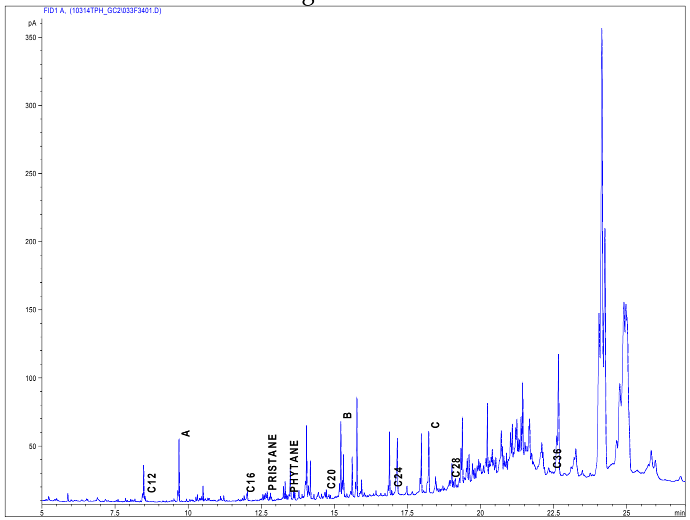
Regional G25



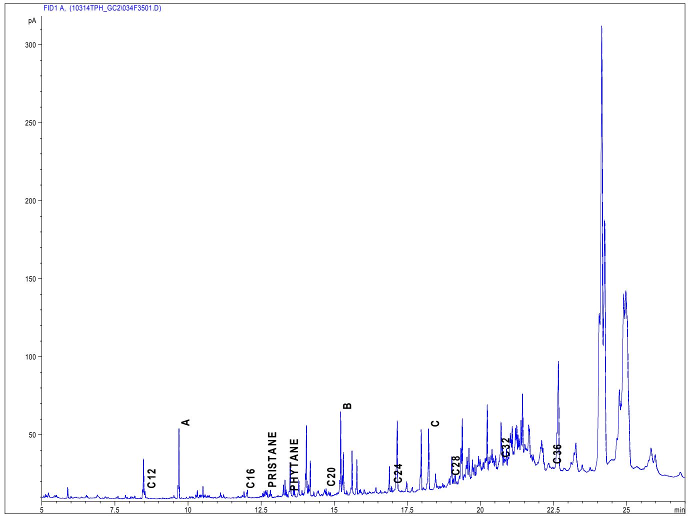
Regional G26



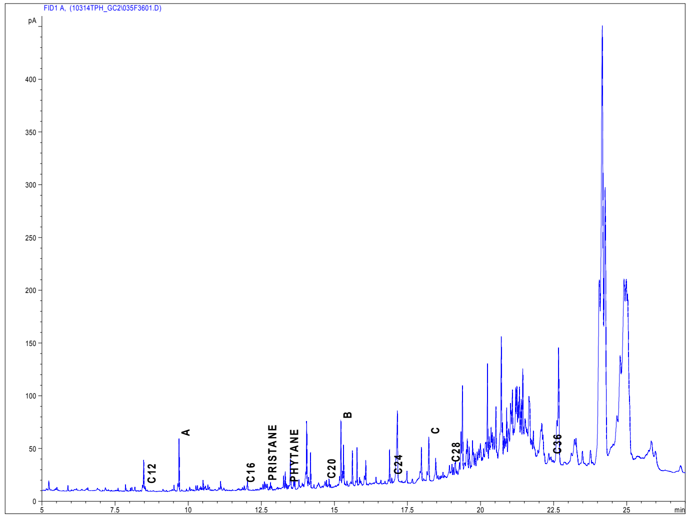
Regional G27



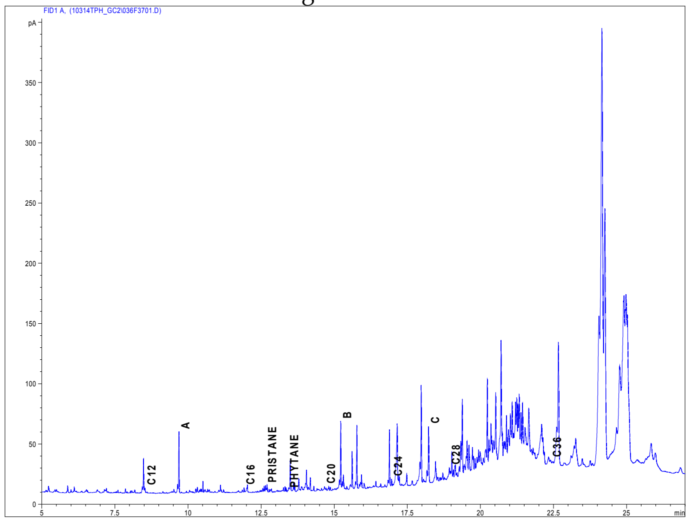
Regional G28



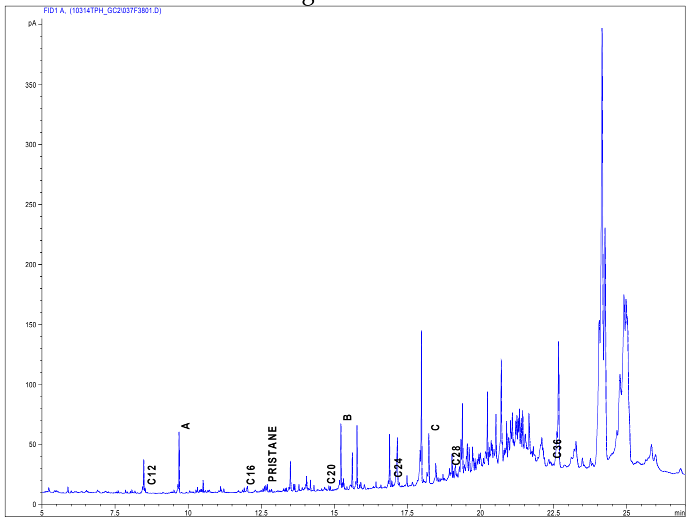
Regional G29



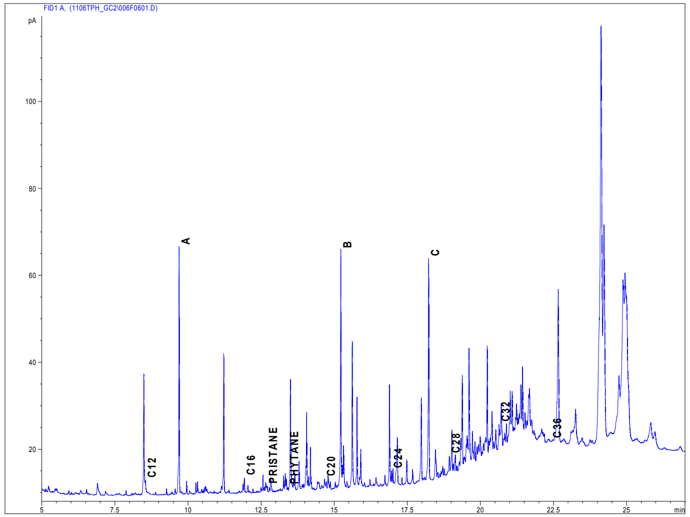
Regional G30



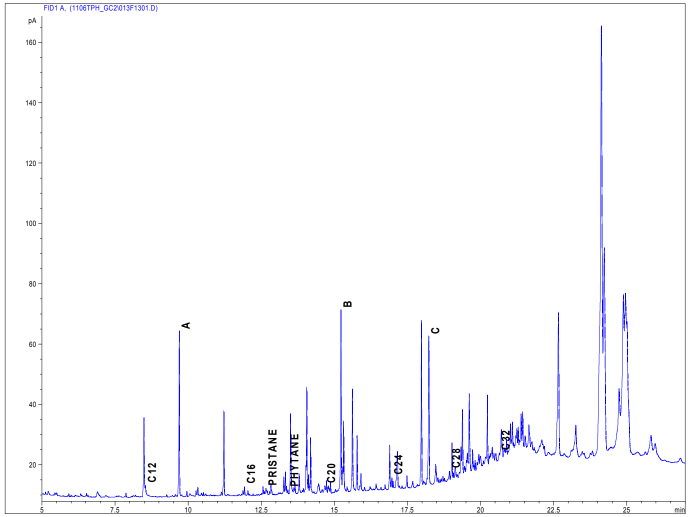
Regional G31



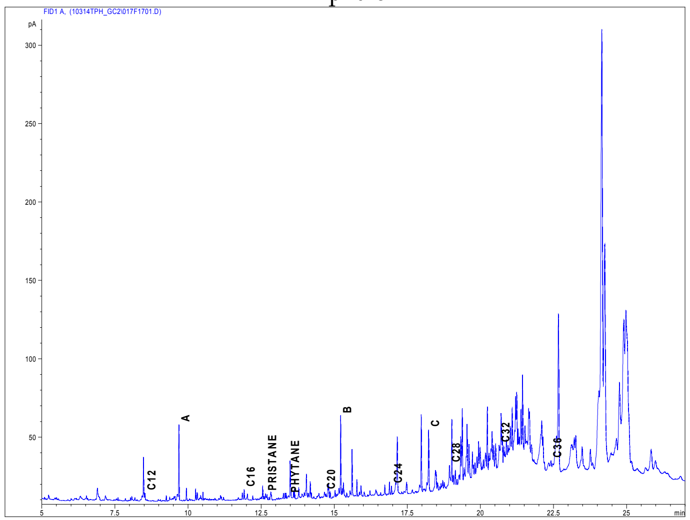
Regional G32



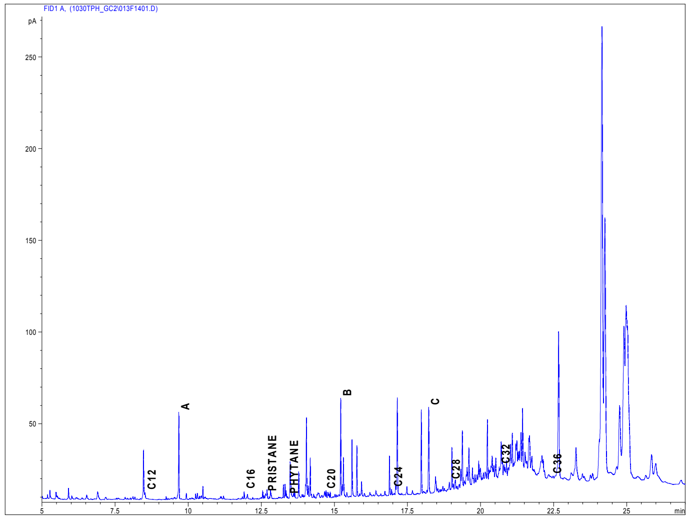
Alpha 0



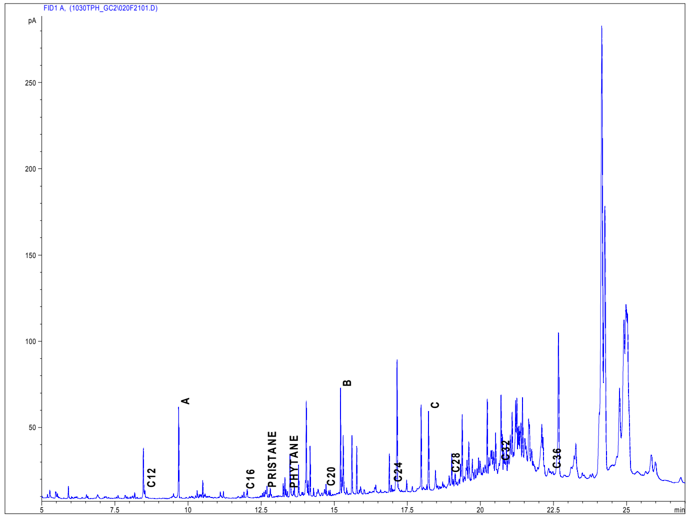
Barbara 0



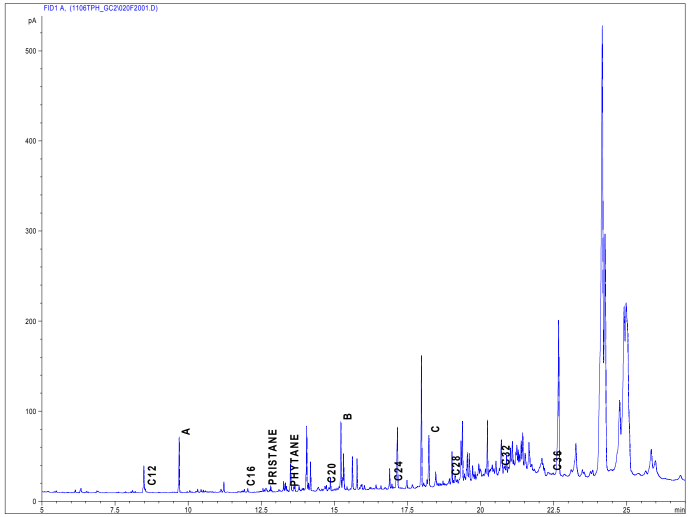
Dawn 0



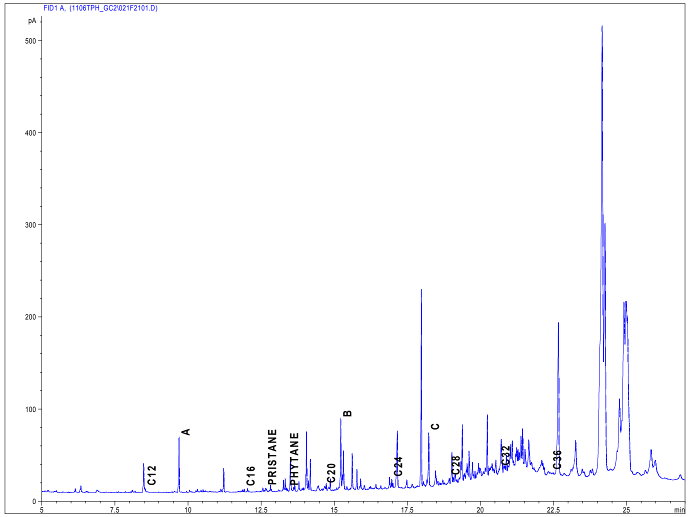
Ernest 0



Ruth 0

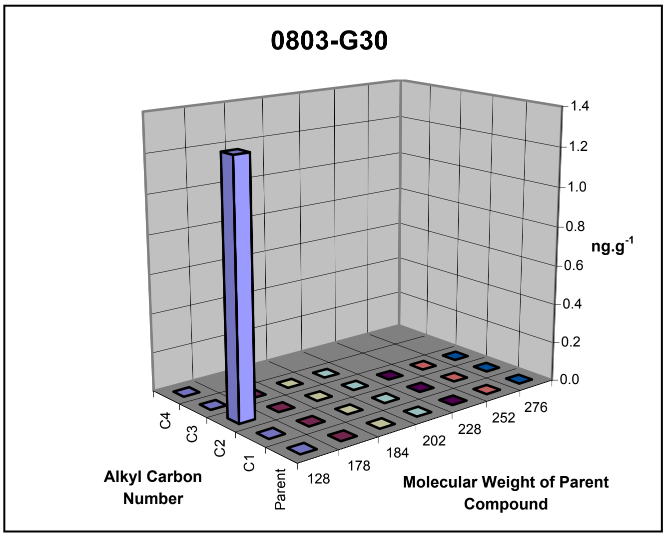


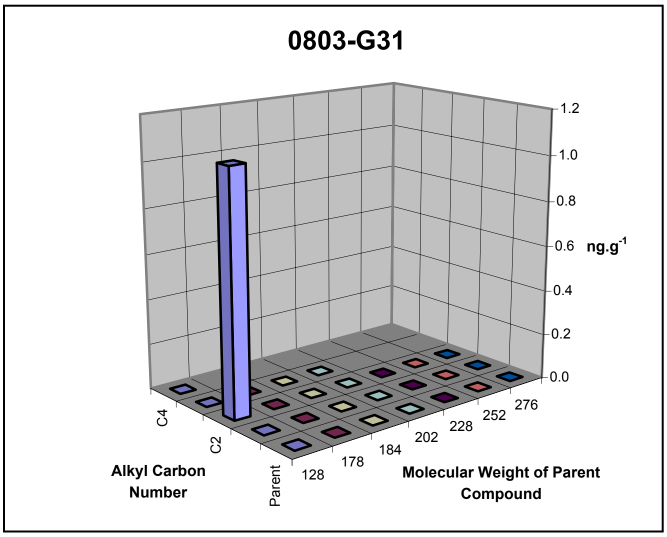
Weddell A

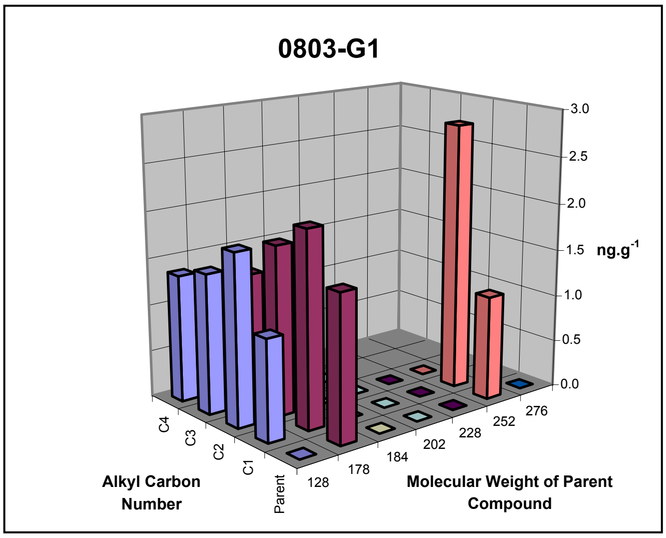


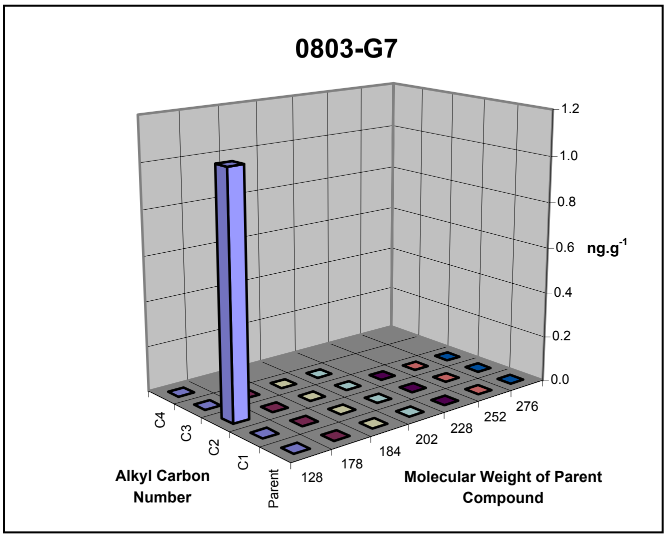
Weddell B

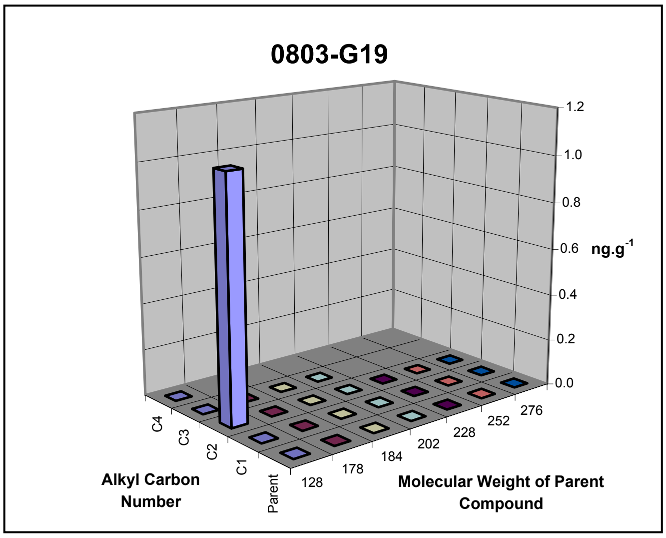
APPENDIX III: Polycyclic Aromatic Hydrocarbons

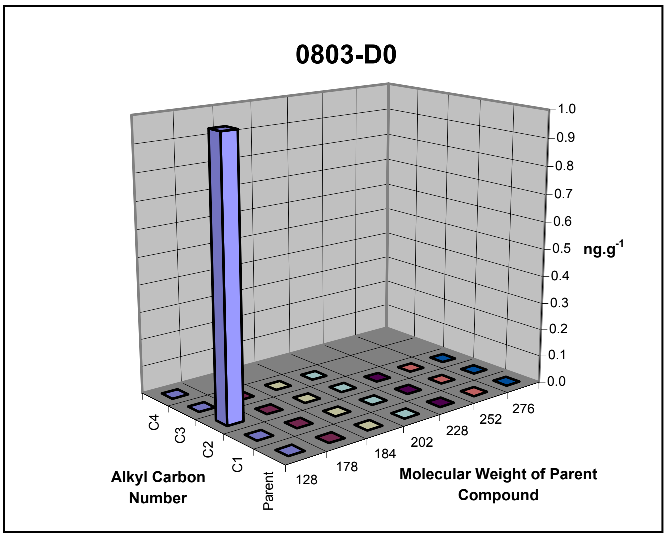

0803-G30
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


0803-G31
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ng.g-1
C4
C2
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


0803-G1
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


0803-G7
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


0803-G19
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound


0803-D0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ng.g-1
C4
C3
C2
C1
Parent
Alkyl Carbon Number
128
178
184
202
228
252
276
Molecular Weight of Parent Compound

APPENDIX IV: Sampling Log Sheets

	Number				Lat (S)		Long (W)						RDL		Sediment Description				
Date	Sample	Station	Water Depth (m bsl)	Fix #	dd	mm.mmm	dd	mm.mmm	Local Time (-4hrs GMT)	Penetration (cm)	Accept?	Fauna pot size (L)	mV (1cm/5cm/10cm)	°C (1cm/5cm/10cm)	Colour	Surface casts/tubes	Stratification	Conspicuous Fauna/Comments	Additional comments regarding analysis
28.08.08	1	**G26**	140	11	50	59.953	58	48.021	19:06	10	C & CHE	1 X 0.25	158/184/-	5.0/5.3/-	Olive grey. Fine sand	Casts	No	Ophiuroids	
28.08.08	2	**G26**	140	12	51	0.021	58	48.003	19:45	11	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Olive grey. Fine sand	Casts	No	Amphipods	
28.08.08	3	**G18**	152	13	50	39.973	58	59.964	22:06	11	FA, FB	FA 1X0.25; FB 1X1	X	X	Olive grey. Fine sand	X	No		
28.08.08	4	**G18**	152	14	50	40.011	58	59.956	22:23	X	X	X	X	X	X	X	X	Did not trigger on one side.	
28.08.08	5	**G18**	152	15	50	39.968	58	59.969	22:38	13	C, CHE	1X1	240/218/-	5.8/-/-	Dark olive fine sand with coarse sand and broken shell	X	No	Ophiuroids	Consider analysing C instead of B?
29.08.08	6	**G10**	154	18	50	19.943	59	11.989	00:59	8	C, CHE	?	239/220/-	5.6/6.0/-	Dark olive fine sand.	X	No		
29.08.08	7	**G10**	154	19	50	19.983	59	11.995	01:25	10	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive fine sand.	Small poly tubes	No	Nephytidae.	
29.08.08	8	**A6**	155	20	50	17.032	59	10.776	02:30	10	C, CHE	1X0.25	235/187/-	5.8/5.8/-	Dark olive fine sand.	X	No		
29.08.08	9	**A6**	155	21	50	17.035	59	10.771	02:54	1) 10; 2) 5	1 side only - FA	1X0.25	X	X	Dark olive fine sand.	Small poly tubes	No	?Brysopsis, Gammarid amphipods, Nephytidae.	
29.08.08	10	**A6**	155	22	50	17.048	59	10.780	03:12	10	1 side only - FB	1X0.25	X	X	Dark olive. Slightly muddy fine sand.	Small poly tubes	No		
29.08.08	11	**A5**	155	23	50	17.038	59	8.981	04:36	12	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Slightly muddy fine sand.	Small poly tubes	No	Cushion star, Nephytidae, gammarid amphipods, ?Brysopsis	
29.08.08	12	**A5**	155	24	50	17.049	59	8.971	04:58	12	C, CHE	1X0.25	239/224/-	5.3/5.8/-	Dark olive. Slightly muddy fine sand.	Small poly tubes	No	?Molgulidae Sp., gammarid amphipods, Serpulid tubes, Nephytidae.	
29.08.08	13	**A2**	155	25	50	16.579	59	9.733	06:13	11	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Slightly muddy fine sand.		No		
29.08.08	14	**A2**	155	26	50	16.570	59	9.724	06:30	11	C, CHE	1X0.25	223/175/-	6.0/6.0/-	Dark olive. Slightly muddy fine sand.		No		
29.08.08	15	**A1**	155	27	50	16.355	59	10.009	06:57	X	X	X	X	X	X	X	X	Did not trigger. No sample.	
29.08.08	16	**A1**	155	28	50	16.396	59	10.000	07:06	10	FA, FB	FA 1X0.25; FB 1X0.5	X	X	Dark olive. Slightly muddy fine sand.	Small poly tubes	No	Holothurians, Echinoids, gammarid amphipods	
29.08.08	17	**A1**	155	29	50	16.422	59	10.000	07:09	10	C, CHE	1X0.3	172/129/-	6.0/6.0/-	Dark olive. Slightly muddy fine sand.		No	Calcareous poly tubes	
29.08.08	18	**A3**	157	30	50	15.924	59	10.770	07:46	X	X	X	X	X	X	X	X	Premature trigger. No sample.	
29.08.08	19	**A3**	157	31	50	15.591	59	0.775	07:56	10	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Slightly muddy fine sand.	Small poly tubes	No		
29.08.08	20	**A3**	157	32	50	15.902	59	10.790	08:10	10	C, CHE	1X0.25	111/052/-	5.6/6.0/-	Dark olive. Slightly muddy fine sand.	Small poly tubes	No	Nephytidae, Ophiuroids, cushion star, Isopod sp., large gammarid amphipods.	
29.08.08	21	**A4**	156	33	50	15.922	59	8.974	08:55	12	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Slightly muddy fine sand.	Small poly tubes	No	Cushion star	
29.08.08	22	**A4**	156	34	50	15.896	59	8.978	09:10	FC - 11; CHEM - 9	C, CHE	1X0.25	121/-014/-	6.2/6.0/-	Dark olive. Slightly muddy fine sand.		No		
29.08.08	23	**A0**	155	35	50	16.476	59	9.843	09:33	FA - 10; FB - 9	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Slightly muddy fine sand.	Tubes and casts	No	Cirrolus, holothurians, Nephytidae, gammarid amphipods, echinoids, isopod Sp.	
29.08.08	24	**A0**	155	36	50	16.468	59	9.864	09:50	FC - 9;CHEM - 8	C, CHE	1X1 + 1X0.25	157/111/-	6.1/6.1/-	Dark olive. Slightly muddy fine sand. Patchily reworked. Possible burrow "TBC"	Tubes and casts	No. Patchy burrows	Large anemone Sp., Spatangoid, Circular crab, Serpulid tubes, "TBC".	
29.08.08	25	**G9**	160	37	50	10.002	59	11.978	10:45	9 (1 side only)	FC	1X0.25	X	X	Dark olive. Slightly muddy fine sand.		No	Sample from one side only. Cushion star, holothurian, gammarid amphipods	
29.08.08	26	**G9**	160	38	50	9.988	59	11.958	11:02	10	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Slightly muddy fine sand.	Tubes	No	Holothurians, cushion stars	
29.08.08	27	**G9**	160	39	50	10.010	59	11.960	11:19	10	CHEM		083/105/-	5.9/6.1/-	Dark olive. Fine sand.	Tubes	No		
29.08.08	28	**D6**	160	40	50	3.367	59	9.586	12:13	12	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive. Fine sand.	Tubes	No	Ophiuroids, Echinoids, holothurians, ?Molgulidae, cushion star	
29.08.08	29	**D6**	160	41	50	3.406	59	9.657	12:34	12	C, CHE	1X0.25	X	X	Dark olive. Fine sand.	Tubes	No	Ophiuroids, ?Molgulidae, gammarid amphipoda.	
29.08.08	30	**D5**	165	42	50	3.392	59	7.890	13:08	12	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive fine sand.	Tubes	No	Ophiuroids, ?Molgulidae, Echinoids (?Spatangidae), Nephytidae, Sipunculans, large gammarid amphipods.	
29.08.08	31	**D5**	165	43	50	3.389	59	7.912	13:22	13	C, CHE	1X0.25	155/115/-	6.0/6.0/-	Dark olive fine sand.	Tubes	No	Cushion star, Nephytidae, gammarid amphipods.	Consider analysing C instead of B?
29.08.08	32	**D2**	165	44	50	2.930	59	8.634	13:49	N/A	X	X	X	X	X	X	X	No sample. Did not trigger.	
29.08.08	33	**D2**	165	45	50	2.925	59	8.640	14:00	N/A	X	X	X	X	X	X	X	No sample. Did not trigger.	
29.08.08	34	**D2**	165	46	50	2.914	59	8.628	14:10	9	FA, FB	FA 1X0.25; FB 1X0.25	not recorded	not recorded	Dark olive fine sand.	Tubes	No	Ophiuroid, solitary cup coral, notable no. of bivalves	
29.08.08	35	**D2**	165	47	50	2.897	59	8.654	14:27	10	C, CHE	1X0.25	not recorded	not recorded	Dark olive fine sand.		No	Cirolus, cushion star, Spatangidae.	Consider analysing C instead of B?
29.08.08	36	**D0**	165	48	50	2.855	59	8.805	14:48	FA -8; FB - 9	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive fine sand.		No		
29.08.08	37	**D0**	165	49	50	2.862	59	8.794	15:04	N/A	X	X	X	X	X	X	X	No sample. Did not trigger.	
29.08.08	38	**D0**	165	50	50	2.858	59	8.785	15:15	N/A	X	X	X	X	X	X	X	No sample. Did not trigger.	
29.08.08	39	**D0**	165	51	50	2.815	59	8.822	15:33	11	C, CHE	1X0.25	146/138/-	5.9/5.9/-	Dark olive fine sand.		No		Consider analysing C instead of A?
29.08.08	40	**D1**	165	52	50	2.726	59	8.945	15:54	9	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive fine sand.			Cushion star, Ophiuroids, gammarid amphipods	
29.08.08	41	**D1**	165	53	50	2.725	59	8.941	16:09	9	C, CHE	1X0.25	141/121/-	6.0/6.0/-	Dark olive fine sand.			Cushion star, Cirolus	
29.08.08	42	**D3**	167	54	50	2.241	59	9.672	16:36	9	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive fine sand.			Cushion star	
29.08.08	43	**D3**	167	55	50	2.266	59	9.690	16:51	10	C, CHE	1X0.25	151/135/-	6.0/6.0/-	Dark olive fine sand.			Serpulid tubes, Isopoda	Consider analysing C instead of B?
29.08.08	44	**D4**	167	56	50	2.252	59	7.953	17:17	x	X	X	X	X	Dark olive fine sand.			No sample. Partial trigger only	
29.08.08	45	**D4**	167	57	50	2.249	59	7.928	17:28	10	FA, FB	FA 1X0.25; FB 1X0.25	X	X	Dark olive fine sand.			Ophiuroids, crushed Spatangidae.	"Analyse A & C" - why?
29.08.08	46	**D4**	167	58	50	2.253	59	7.931	17:42	10	C, CHE	1X0.25	139/123/-	6.0/6.0/-	Dark olive fine sand.				
29.08.08	47	**G8**	170	59	50	0.011	59	12.038	18:26	9	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine sand.			Gammarid amphipods, Cirolus, Holothuroidea	
29.08.08	48	**G8**	170	60	49	59.989	59	12.045	18:38	8	FC	1X1L	X	X	Dark olive fine sand.			1 side rejected as <5cm	
29.08.08	49	**G8**	170	61	50	0.004	59	12.040	18:55	10	CHEM		175/164/-	6.0/6.0/-	Dark olive fine sand.				

	Number				Lat (S)		Long (W)						RDL		Sediment Description				
Date	Sample	Station	Water Depth (m bsl)	Fix #	dd	mm.mmm	dd	mm.mmm	Local Time (-4hrs GMT)	Penetration (cm)	Accept?	Fauna pot size (L)	mV (1cm/5cm/10cm)	°C (1cm/5cm/10cm)	Colour	Surface casts/tubes	Stratification	Conspicuous Fauna/Comments	Additional comments regarding analysis
29.08.08	50	**G1**	285	62	49	48.374	59	12.721	20:20	FULL	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive green mud with firm mud/clay beneath and shell fragments			Ophiuroids, Nephytidae	
29.08.08	51	**G1**	285	63	49	48.378	59	12.683	20:43	FULL	C, CHE	1X1L	185/140/-10	5.6/6.0/6.0	Dark olive green mud with firm mud/clay beneath and shell fragments		No data on depth of soft and firm mud layers.		
29.08.08	52	**G14**	168	64	50	0.010	58	59.981	22:16	CHEM - 8; FA - 10	A, CHE	1X1L	45/50/-	5.9/6.0/-	Fine dark olive sand.			Gammarid amphipods, cushion stars, Ophiuroids. Solitary cup coral in chem grab.	
29.08.08	53	**G14**	168	65	49	59.994	58	59.959	22:35	FB - 12; FC - 10	FB, FC	FB 1X1L; FC1X1L	X	X	Fine dark olive sand.			Ophiuroids	
29.08.08	54	**G15**	155	66	50	10.015	58	59.998	23:35	FC - 9; FA - 11	FC, FA	FC 1X1L; FA 1X1L	X	X	Fine dark olive sand.			FC - Spatangidae	
29.08.08	55	**G15**	155	67	50	10.032	59	0.007	23:49	FB - 10; CHEM - 8	B, CHE	1X1L	116/103/-	6.0/6.0/-	Fine dark olive sand.			?Maldanidae, ?Molgulidae	
30.08.08	56	**E4**	155	68	50	17.715	58	55.718	00:47	7	FA, FB	FA 1X1L; FB 1X1L	X	X	Fine dark olive sand.			Solitay cup coral	
30.08.08	57	**E4**	155	69	50	17.706	58	55.752	01:02	8	C, CHE	1X1L	136/95/-	5.8/6.0/-	Fine dark olive sand.	Small poly tubes			Consider analysing C instead of B?
30.08.08	58	**E3**	151	70	50	17.718	58	57.535	01:30	FC - 8; CHEM 5	C, CHE	1X1L	185/179/-	6.0/6.0/-	Fine dark olive sand with small amount of gravel				
30.08.08	59	**E3**	151	71	50	17.704	58	57.536	01:50	FA - 8; FB - 6	FA, FB	FA 1X1L; FB 1X1L	X	X	Fine dark olive sand with small amount of gravel				FA smallest rep. Analyse B and C?
30.08.08	60	**E1**	153	72	50	18.184	58	56.768	02:11	FC - 7; CHEM - 5	C, CHE	1X1L	176/124/-	6.1/6.1/-	Fine dark olive sand with small amount of gravel			Spatangidae	
30.08.08	61	**E1**	153	73	50	18.187	58	56.763	02:28	8	FA, FB	FA 1X1L; FB 1X1L			Fine dark olive sand with small amount of gravel				
30.08.08	62	**E0**	153	74	50	18.280	58	56.621	02:45	12	FA, FB	FA 1X1L; FB 1X1L			Fine dark olive sand.				
30.08.08	63	**E0**	153	75	50	18.290	58	56.626	03:01	8	C, CHE	1X1L	187/147/-	6.0/6.0/-	Fine dark olive sand.				
30.08.08	64	**E2**	155	76	50	18.385	58	56.489	03:18	8	FA, FB	FA 1X1L; FB 1X1L			Dark olive fine, muddy sand.				
30.08.08	65	**E2**	155	77	50	18.371	58	56.450	03:32	7	C, CHE	1X1L	155/85/-	6.0/6.0/-	Dark olive fine, muddy sand.			Holothuroidea	
30.08.08	66	**E5**	155	78	50	18.847	58	55.724	03:53	X	X	X						No sample. Did not trigger.	
30.08.08	67	**E5**	155	79	50	18.840	58	55.730	04:04	X	X	X						No sample. Did not trigger.	
30.08.08	68	**E5**	155	80	50	18.843	58	55.724	04:17	8	FA, FB	FA 1X1L; FB 1X1L			Dark olive fine, muddy sand.			Large Pycnogonid	
30.08.08	69	**E5**	155	81	50	18.838	58	55.715	04:31	8	C, CHE	1X1L	198/155/-	5.8/6.0/-	Dark olive fine, muddy sand.			Large Sipunculan (?Nephasoma Sp.)	
30.08.08	70	**E6**	152	82	50	18.864	58	57.515	04:56	8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy, fine sand.				
30.08.08	71	**E6**	152	83	50	18.863	58	57.504	05:10	5	C, CHE	1X1L	21/-19/-	Temp probe no longer working. No temp readings from here onwards.	Dark olive muddy, fine sand.				
30.08.08	72	**G21**	155	84	50	10.046	58	48.045	06:40	8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy, fine sand.	Small poly tubes		?Molgulidae, gammarid amphipods, Ophiuroids, Nephytidae	
30.08.08	73	**G21**	155	85	50	9.992	58	48.023	06:54	FC - 8; CHEM 5	C, CHE	1X1L	179/139/-	X	Dark olive muddy, fine sand.			Spatangidae	
30.08.08	74	**G22**	150	86	50	20.000	58	47.999	08:00	X	X	X	X	X	X			No sample. Did not trigger. Trigger hook done up too tightly - did not release. Fixed.	
30.08.08	75	**G22**	150	87	50	19.989	58	47.982	08:10	7	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy, fine sand.			Cushion star, Holothuroidea	
30.08.08	76	**G22**	150	88	50	19.996	58	47.994	08:21	10	C, CHE	1X1L	149/119/-	X	Dark olive muddy, fine sand.	Small poly tubes			Consider analysing C instead of B?
30.08.08	77	**G16**	153	89	50	19.988	58	58.965	09:16	X	X	X	X	X	X			No sample. Did not trigger. Warp caught on bolt. Door catch snapped. Replaced.	
30.08.08	78	**G16**	153	90	50	19.988	58	58.983	09:29	8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy, fine sand.			Ophiuroids, cushion star, Sipunculan	
30.08.08	79	**G16**	153	91	50	19.993	58	59.025	09:44	10	C, CHE	1X1L	177/145/-	X	Dark olive muddy, fine sand.			No photo of FC in sieve.	Consider analysing C instead of B?
30.08.08	80	**R3**	150	92	50	27.595	58	58.704	10:38	10	C, CHE	1X1L	156/151/-	X	Dark olive muddy fine sand.				
30.08.08	81	**R3**	150	93	50	27.609	58	58.691	10:52	8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy fine sand.			Cirolus	Consider analysing C instead of B?
30.08.08	82	**R6**	150	94	50	28.742	58	58.662	11:15	8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy fine sand.			Cushion star	
30.08.08	83	**R6**	150	95	50	28.759	58	58.688	11:28	8	C, CHE	1X1L	185/135/-	X	Dark olive muddy fine sand.				
30.08.08	84	**R5**	150	96	50	28.743	58	56.888	11:52	9	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive muddy fine sand.			Cushion star, large gammarid amphipods	
30.08.08	85	**R5**	150	97	50	28.750	58	56.897	12:06	12	C, CHE	1X1L	X	X	Dark olive muddy fine sand.				Consider analysing C instead of B?
30.08.08	86	**R2**	150	98	50	28.281	58	57.643	12:28	FA - 12; CHEM - 8	A, CHE	FA 1X1L	177/137/-	X	Dark olive fine silty sand with coarse sand.				
30.08.08	87	**R2**	150	99	50	28.283	58	57.651	12:46	FB - 14; FC - 12	FB, FC	FB 1X1L; FC1X1L	X	X	Dark olive fine silty sand with coarse sand.			Cirolus	
30.08.08	88	**R0**	150	100	50	28.174	58	57.795	13:06	FC - 6	FC	1X1L	X	X	Dark olive fine silty sand with coarse sand.				
30.08.08	89	**R0**	150	101	50	28.169	58	57.801	13:23	CHEM - 10	CHEM		177/118/-	X	Dark olive fine silty sand with coarse sand.				
30.08.08	90	**R0**	150	102	50	28.179	58	57.799	13:39	X	X	X	X	X				No sample. Did not trigger.	
30.08.08	91	**R0**	150	103	50	28.173	58	57.805	13:49	10	FA	1X1L	X	X	Dark olive fine silty sand with coarse sand.			No B sample.	Process A and C
30.08.08	92	**R1**	150	104	50	28.089	58	57.959	14:07	FA - 9; FB - 10	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine silty sand with coarse sand.			Cirolus	
30.08.08	93	**R1**	150	105	50	28.085	58	57.937		X	X	X	X	X				No sample. Did not trigger.	
30.08.08	94	**R1**	150	106	50	28.079	58	57.951	14:28	9	CHEM		185/174/-	X	Dark olive fine silty sand with coarse sand.			No FC sample.	
30.08.08	95	**R4**	150	107	50	27.598	58	56.909	14:53	X	X	X	X	X				No sample. Did not trigger.	
30.08.08	96	**R4**	150	108	50	27.602	58	56.918	15:03	X	X	X	X	X				No sample. Did not trigger.	
30.08.08	97	**R4**	150	109	50	27.591	58	56.916	15:19	8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine silty sand with coarse sand.				
30.08.08	98	**R4**	150	110	50	27.598	58	56.905	15:33	10	C, CHE	1X1L	192/145/-	X	Dark olive fine silty sand with coarse sand.			Ophiuroids	Consider analysing C instead of B?
30.08.08	99	**G17**	152	111	50	30.000	59	0.013	16:14	9	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine silty sand with coarse sand.			Spatangidae, large poly tubes, cushion star	
30.08.08	100	**G17**	152	112	50	29.994	59	0.007	16:29	14	C, CHE	1X1L	209/169/-	X	Dark olive fine silty sand with coarse sand.				Consider analysing C instead of B?
30.08.08	101	**B4**	153	113	50	40.113	59	5.939	17:47	FA - 11; FB - 10	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine silty sand with coarse sand.			Ophiuroids, broken Spatangidae	
30.08.08	102	**B4**	153	114	50	40.102	59	5.969	18:10	10	C, CHE	1X1L	168/146/-	X	Dark olive fine silty sand with coarse sand.			Ophiuroids.	

Benthic Solutions

Date	Number: Sample	Number: Station	Water Depth (m bsl)	Fix #	Lat (S): dd	Lat (S): mm.mmm	Long (W): dd	Long (W): mm.mmm	Local Time (-4hrs GMT)	Penetration (cm)	Accept?	Fauna pot size (L)	RDL: mV (1cm/5cm/10cm)	RDL: °C (1cm/5cm/10cm)	Sediment Description: Colour	Sediment Description: Surface casts/tubes	Sediment Description: Stratification	Conspicuous Fauna/Comments	Additional comments regarding analysis
30.08.08	103	**B3**	150	115	50	40.138	59	7.741	18:38	X	X	X	X	X				No sample. Grab triggered but only a scrape of sed in bottom.	
30.08.08	104	**B3**	150	116	50	40.125	59	7.743	18:52	FA - 11; FB - 9	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine silty sand with coarse sand.			Serpulid tubes, ophiuroids, Nephtyidae.	
30.08.08	105	**B3**	150	117	50	40.093	59	7.742	19:08	12	C, CHE	1X1L	184/165/-	X	Dark olive fine silty sand with coarse sand.			Ophiuroids, large ?ascidian, sipunculans	Consider analysing C instead of B?
30.08.08	106	**B1**	149	118	50	40.569	59	7.011	19:28	FC - 10; CHEM - 8	C, CHE	1X1L	179/154/-	X	Dark olive fine silty sand with coarse sand.				
30.08.08	107	**B1**	149	119	50	40.580	59	6.986	19:47	FA - 9; FB - 8	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive fine silty sand with coarse sand.				Consider analysing C instead of B?
30.08.08	108	**B0**	150	120	50	40.663	59	6.837	20:04	12	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive green fine to medium sand.				
30.08.08	109	**B0**	150	121	50	40.664	59	6.848	20:19	FC - 10; CHEM - 9	C, CHE	1X1L	202/127/-	X	Dark olive fine silty sand with coarse sand.			Cirolus, ophiuroids	
30.08.08	110	**B2**	150	122	50	40.786	59	6.760	20:37	FA - 9; FB - 10	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark green olive medium sand.			Cushion star	
30.08.08	111	**B2**	150	123	50	40.766	59	6.681	20:51	10	C, CHE	1X1L	193/152/-	X	Dark green olive medium sand.			Spatangidae	
30.08.08	112	**B5**	149	124	50	41.232	59	5.913	21:12	X	X	X	X	X	X			No sample. Swivel in top of frame.	
30.08.08	113	**B5**	149	125	50	41.237	59	5.917	21:28	FA - 12; FB - 9	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark green olive medium and coarse sand.			Cushion star, Ophiuroids.	
30.08.08	114	**B5**	149	126	50	41.229	59	5.891	21:43	10	C, CHE	1X1L	218/175/-	X	Dark green olive medium and coarse sand.				Consider analysing C instead of B?
30.08.08	115	**B6**	147	127	50	41.240	59	7.703	22:10	FC - 10; CHEM - 9	C, CHE	1X1L	15/-23/-	X	Dark green olive medium and coarse sand.			?Sponge colony?	
30.08.08	116	**B6**	147	128	50	41.251	59	7.704	22:25	10	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark green olive medium and coarse sand.				
31.08.08	117	**W6**	150	129	50	45.982	58	53.204	16:23	12	FA, FB	FA 1X1L; FB 1X1L	X	X	Dark olive green fine sand with silty coarse sand, gravel and pebbles.			Ophiuroids.	
31.08.08	118	**W6**	150	130	50	45.983	58	53.205	16:41	FC - 8; CHEM - 7	C, CHE	1X1L	215/206/-	X	Dark olive green fine sand with silty coarse sand, gravel, pebbles and cobbles.			Ophiuroids.	
31.08.08	119	**W7**	150	131	50	45.975	58	51.415	17:10	X	X	X	X	X	X			No sample. Did not trigger	
31.08.08	120	**W7**	150	132	50	45.967	58	51.399	17:27	FA - 9, FB- 11	FA, FB	FA 2X1L; FB 2X1L	X	X	Fine sand with significant coarse sand and gravel. FB with some shell material			FB with more coarse material than FA.	
31.08.08	121	**W7**	150	133	50	45.977	58	51.384	17:50	14	C, CHE	1X1L	230/183/-	X					Consider analysing C instead of A?
31.08.08	122	**W5**	150	134	50	46.431	58	52.431	18:10	10	FA, FB	FA 1X1L; FB 1X1L	X	X	Some coarse material - less than W7			Ophiuroids.	
31.08.08	123	**W5**	150	135	50	46.441	58	52.426	18:39	10	C, CHE	1X1L	238/182/-	X	As above.			Spatangidae	
31.08.08	124	**WB**	150	136	50	46.544	58	52.276	18:58	FA - 11; FB - 8	FA, FB	FA 1X1L; FB 1X1L	X	X	As above.			Spatangidae	
31.08.08	125	**WB**	150	137	50	46.528	58	52.275	19:13	10	C, CHE	1X1L	237/186/-	X	As above.				Consider analysing C instead of B?
31.08.08	126	**W2**	151	No fix	Use nominal location				19:38	9	A, CHE	1X1L	221/168/-	X	As above.			Cirolus	
31.08.08	127	**W2**	151	138	50	46.703	58	53.621	21:54	FB- 9; FC - 7	FB, FC	FB 1X1L; FC 1X1L	X	X	Dark olive green fine sand			Ophiuroids	
31.08.08	128	**W1**	150	139	50	47.173	58	52.846	22:16	FC - 9; CHEM - 8	C, CHE	FC 1X1L	228/185/ -	X	Dark olive green fine sand				
31.08.08	129	**W1**	150	140	50	47.167	58	52.85	22:34	FA - 14; FB - 12	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine sand				
31.08.08	130	**WA**	150	141	50	47.262	58	52.702	22:50	FA - 10; CHEM - 9	A, CHE	FA 1X1L	222/192/ -	X	Dark olive green fine sand				
31.08.08	131	**WA**	150	142	50	47.265	58	52.68	23:03	FB - 10; FC - 8	FB, FC	FB 1X1L; FC 1X1L	X	X	Dark olive green fine sand			Ophiuroids, Cirolis	
31.08.08	132	**W8**	150	143	50	47.119	58	51.346	23:28	10	A, CHE	FA 1X1L	217/174/-	X	Dark olive green fine sand				
31.08.08	133	**W8**	150	144	50	47.123	58	51.353	23:43	10	FB,FC	FB 1X1L; FC 1X1L	X	X	Dark olive green fine sand			Echinoid, Cirolis	
1.09.08	134	**W3**	153	145	50	47.832	58	51.783	00:05	FA - 12	FA	FA 1X1L	X	X	Dark olive green fine sand				
1.09.08	135	**W3**	153	146	50	47.835	58	51.784	00:19	CHEM - 12	CHEM	X	122/55/-	X	Dark olive green fine sand			Ophiuroids	
1.09.08	136	**W3**	153	147	50	47.835	58	51.789	00:34	FB - 12; FC - 9	FB, FC	FB 1X1L; FC 1X1L	X	X	Dark olive green fine sand			Ophiuroids	
1.09.08	137	**W4**	150	148	50	47.846	58	53.593	01:01	10	A, CHE	FA 1X1L	163/148/-	X	Dark olive green fine muddy sand	tubes			
1.09.08	138	**W4**	150	149	50	47.850	58	53.582	01:17	FC - 13; FB - 10	FB, FC	FB 1X1L; FC 1X1L	X	X	Dark olive green fine muddy sand				Analyse A and C
1.09.08	139	**G24**	145	150	50	39.993	58	48.001	02:30	FC - 15; CHEM - 10	C, CHE	FC 1X1L	227/183/ -	X	Dark olive green fine muddy sand			Opiuroids, cushion star	
1.09.08	140	**G24**	145	151	50	40.003	58	47.992	02:47	12	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand	tubes		Ophiuroid, Echinoid, encrusting Bryozoan, Serpulid tubes	Analyse A and C
1.09.08	141	**G23**	148	152	50	29.996	58	47.996	03:59	FA - 8; FB - 8	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			Ophiuroids	
1.09.08	142	**G23**	148	153	50	29.996	58	47.987	04:13	FC - 8; N/S -1	FC, N/S	FC 1X1L	X	X	Dark olive green fine muddy sand				
1.09.08	143	**G23**	148	154	50	29.996	58	47.994	04:28	CHEM - 8	HEM, N	X	153/97/ -	X	Dark olive green fine muddy sand				
1.09.08	144	**G4**	158	155	50	20.008	59	23.992	06:52	FC - 12; CHEM - 10	C, CHE	FC 1X1L	160/138/ -	X	Dark olive green fine muddy sand with some gravel			Ophiuroids, erect Bryozoans	
1.09.08	145	**G4**	158	156	50	19.999	59	23.983	07:07	10	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand with some gravel			Ophiuroids, Spatangidae, cushion star	Analyse A and C
1.09.08	146	**G3**	162	157	50	10.007	59	23.987	08:16	12	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand				
1.09.08	147	**G3**	162	158	50	10.012	59	23.979	08:29	10	A, CHE	FC 1X1L	163/140/ -	X	Dark olive green fine muddy sand				
1.09.08	148	**G2**	168	159	50	0.010	59	23.998	09:36	10	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			cushion stars, Nephytidae, Molgulidae (?), Amphipods	
1.09.08	149	**G2**	168	160	50	0.000	59	23.984	09:52	10	C, CHE	FC 1X1L	203/180/ -	X	Dark olive green fine muddy sand				
1.09.08	150	**G28**	162	161	50	10.001	59	35.993	11:16	10	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			Ophiuroids, cushion star, Holothurian, Molgulidae (?), Amphipods, Serpulids	
1.09.08	151	**G28**	162	162	50	10.008	59	35.972	11:29	10	C, CHE	FC 1X1L	201/153/ -	X	Dark olive green fine muddy sand				
1.09.08	152	**G29**	160	163	50	9.997	59	47.991	12:30	FA - 10; FB - 8	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			Ophiuroids, heart urchin	
1.09.08	153	**G29**	160	NO FIX. Loss of power, use nominal pos.	Use nominal location				12:48	FC - 10; CHEM - 9	C, CHE	FC 1X1L	198/180/ -	X	Dark olive green fine muddy sand			Cirolis, Ophiuroid, cushion star	Analyse A and C

Benthic Solutions

Date	Number		Water Depth (m bsl)	Fix #	Lat (S)		Long (W)		Local Time (-4hrs GMT)	Penetration (cm)	Accept?	Fauna pot size (L)	RDL		Sediment Description			Conspicuous Fauna/Comments	Additional comments regarding analysis
	Sample	Station			dd	mm.mmm	dd	mm.mmm					mV (1cm/5cm/10cm)	°C (1cm/5cm/10cm)	Colour	Surface casts/tubes	Stratification		
1.09.08	154	**G30**	152	164	50	19.964	59	47.968	14:02	PARTIAL TRIGGER - NO SAMPLE	) SAMP	NO SAMPLE	X	X	X			no sample	
1.09.08	155	**G30**	152	165	50	19.985	59	47.964	14:13	FC - 8; N/S - <5	FC	FC 1X1L	X	X	Dark olive green fine muddy sand with coarse sand fraction				
1.09.08	156	**G30**	152	166	50	19.975	59	47.990	14:36	8	A, CHE	FA 1X1L	186/130/ -	X	Dark olive green fine muddy sand			cushion star, heart urchin	Both small samples - no FB therefore process FA and FC.
1.09.08	157	**G32**	158	167	50	29.994	59	47.991	15:50	FA - 11, FB - 9	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			Ophiuroids, Molgulidae (?), Amphipods	Analyse A and C
1.09.08	158	**G32**	158	168	50	29.993	59	47.998	16:03	FC - 11, CHEM 9	C, CHE	FC 1X1L	195/165/ -	X	Dark olive green fine muddy sand			Ophiuroids, Molgulidae (?), Amphipods, Echinoid	
1.09.08	159	**G31**	155	169	50	29.969	59	36.044	17:04	FA - 10; CHEM - 9	A, CHE	FA 1X1L	195/155/ -	X	Dark olive green fine muddy sand			Ophiuroids, Molgulidae (?), Amphipods, cushion star	
1.09.08	160	**G31**	155	170	50	29.986	59	36.014	17:20	10	FB, FC	FB 1X1L; FC 1X1L	X	X	Dark olive green fine muddy sand			Ophiuroids, Molgulidae (?), Amphipods, cushion star	
1.09.08	161	**G5**	155	171	50	29.993	59	23.963	18:22	10	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			FA - cushion star. FB - Echinoid, Ophiuroids, Amphipod, heart urchin	
1.09.08	162	**G5**	155	172	50	30.009	59	23.991	18:39	FC - 10; CHEM - 9	C, CHE	FC 1X1L	200/170/ -	X	Dark olive green fine muddy sand				Photo missing ID slate
1.09.08	163	**G11**	155	173	50	29.998	59	11.999	19:46	FA - 11, FB - 10	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			Ophiurods, cushion star	
1.09.08	164	**G11**	155	174	50	29.997	59	11.986	19:59	FC - 10; CHEM - 8	C, CHE	FC 1X1L	187/145/ -	X	Dark olive green fine muddy sand				
1.09.08	165	**G12**	148	175	50	39.985	59	12.003	21:16	FA -13, FB - 11	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand			Heart urchin, Ophiuroids	
1.09.08	166	**G12**	148	176	50	40.006	59	12.025	21:28	NO SAMPLE	) SAMP	X	X	X	Dark olive green fine muddy sand			No sample - did not trigger	
1.09.08	167	**G12**	148	177	50	40.017	59	11.988	21:45	FC - 11, CHEM 10	C, CHE	FC 1X1L	185/133/ -	X	Dark olive green fine muddy sand with coarse sand fraction				
1.09.08	168	**G6**	154	178	50	40.011	59	23.997	22:37	FA - 12, FC - 8	FA,FC	FA 1 X 1L; FC 1 X 1L	X	X	Dark olive green fine muddy sand with some gravel and pebbles			FA - heart urchin.	FC - slightly washed out - stone in jaw
1.09.08	169	**G6**	154	179	50	39.997	59	23.999	22:53	11	B, CHE	FB 1 X 1L	201/183/ -	X	Dark olive green fine muddy sand with some gravel and pebbles			Cushion star, Ophiuroids, Echinoid, Amphipods	
02.09.08	170	**G7**	145	180	50	49.975	59	24.004	00:04	12	C, CHE	FC 1X1L	195/105/ -	X	Dark olive green fine muddy sand with coarse sand fraction				Analyse A and C
02.09.08	171	**G7**	145	181	50	49.979	59	24.001	00:22	10	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand with coarse sand fraction				FB photo no ID slate
02.09.08	172	**G13**	148	182	50	50.000	59	11.983	01:19	15	FA, FB	FA 1 X1L; FB 1X1L	X	X	Dark olive green fine muddy sand with coarse sand fraction			Echinoids	
02.09.08	173	**G13**	148	183	50	49.974	59	11.950	01:34	12	C, CHE	FC 1X1L	203/167/-	X	Dark olive green fine muddy sand with coarse sand fraction				
02.09.08	174	**G20**	140	184	50	0.000	59	0.000	03:01	FC - 10; CHEM - 5	C, CHE	FC 1X1L	X	X	Dark olive green fine muddy sand			Echinoid, Molgulidae, colonial squirt, Amphipods, Ophiuroids	
02.09.08	175	**G20**	140	185	50	0.005	58	59.990	03:18	FA - 8; N/S -3	FA	FA 1X1L	X	X	Dark olive green fine muddy sand				
02.09.08	176	**G20**	140	186	51	0.015	58	59.965	03:31	FB - 12	FB	FB 1 X 1L	228/185/ -	X	Dark olive green fine muddy sand			Polyclinid (?)	Analyse B and C
02.09.08	177	**G19**	145	187	50	50.005	58	59.995	04:46	15	FA, FB	FA 1X1L; FB 1X1L	X	X	Fine sand and silt/mud			Asteroid, Ophiuroids.	
02.09.08	178	**G19**	145	188	50	49.995	58	59.991	05:00	15	C, CHE	1X1L	283/186/-	X	Fine muddy sand with coarse sand fraction			Colonial tunicates.	
02.09.08	179	**G25**	150	189	50	50.007	58	47.990	05:56	FA - 10; CHEM - 8	A, CHE	1X1L	230/187/-	X	Muddy fine sand with gravel and coarse sand fraction			Erect bryozoans	
02.09.08	180	**G25**	150	190	50	49.987	58	47.982	06:10	10	FB, FC	FB 1X1L; FC 1X1L	X	X	Muddy fine sand with gravel and coarse sand fraction			?Brysopsis, small solitary sponge, ophiuroids, poly tubes.	
02.09.08	181	**G27**	147	191	50	50.002	58	36.012	07:12	FA - 12; CHEM - 11	A, CHE	1X1L	206/168/-	X	Muddy fine sand.				
02.09.08	182	**G27**	147	192	50	49.992	58	35.994	07:28	0	X		X	X	Muddy fine sand.			No sample. Grab triggered but empty.	
02.09.08	183	**G27**	147	193	50	50.003	58	36.001	07:43	12	FB, FC	FB 1X1L; FC 1X1L	X	X	Muddy fine sand.			ophiuroids, large amphipods.	

APPENDIX V: Macrofaunal Species Lists

Macrofaunal Matrix

Preliminary Comment	Species	G1A	G1B	G2A	G2B	G3A	G3B	G4A	G4B	G5A	G5B	G6A	G6B	G7A	G7C	G8A	G8B	G9A	G9B	G10A	G10B	G11A	G11B	G12A	G12B
Macrofauna																									
	CNIDARIA																								
	Virgularia spp.			1					1								1								
	Edwardsiidae sp.			3	1				2		1							1							
	Soiltary Polyp			1						2				2	6			2							
	PLATYHELMINTHES																								
	Polycladida sp																							1	
	NEMERTEA																								
	Nemertea spp.	2		7	1						1	3	1	3		4		2		8		7	1	1	
	NEMATODA																								
	Nematoda spp.	3			1			2	5	1									2			2			
	SIPUNCULA																								
	Sipunculida sp																								
	Golfingia sp.																				1				1
	Thysanocardia sp.																						2		
	Phascolion sp.																		1						
	ANNELIDA																								
	Dorvilleidae sp	1					2								1			1			3				
poss. Eunoe	Polynoidae spp	1	1																		2	1	2		
	Pholoe sp				1					1							1								
	Phyllodocidae spp.														1								2		
	Anaitides sp.				2			1						1	2		1	1		1	2	1			
Eteone cf sculpta	*Eteone spp*			1						1				3				1	1			3			
	Eumida sp.																								1
Glycera cf kerguelensis	*Glycera cf kerguelensis*	1	1	1	5	1				2	5	2	1	1	8	6	7		2	2	2		1		3
	Glycinde armatus													1											
	Goniadidae sp.																		1						
	Syllidae sp.							1																	1
Aglaophamus ornatus	*Aglaophamus ornatus*	7	5	4	5	5	4	1	1	2	1	2	2	1	2	3	5	7	4	1	3	4	1		
	Onuphis aff holobranchiata	1	2				1		1			4	5	2	7					9	7		1	1	2
	Onuphis sp juv	2												1						15					
	Aff Scoloplos sp	3	2	4	1							16	9	12	23	8	7	1	2	1		2	3	1	
	Aricidea sp.A	2	7	8	80		2	3	11	3	13	5	1	7	7	76	126	8	45	14	12	7	15		7
	Aricidea sp.B	2	1	4	11	7	4	7	6	1	2	5	5	9	6	11	6	11	3	8	3	2		1	6
	Aricidea simplex			2	1							1				2	2	1		2		1		4	2
	Paraonoidae spp.	5	4	11	12		3	1	7	5	8	7		12	8	9	4	5	9	11	3	14	11	11	12
	Apistobranchus cf fragmentata				4				1			1	1		2		34						2		3
	Spionidae sp.																4				2				
	Minuspio sp.													1	2			1	3	1	1	1			
	Scolelepis sp.	1	3	1	2							3					1			1		1		1	
affirmed species	*Spiophanes aff bombyx*			5	7			1				3				6				1		2		2	
Spiophanes cf soederstroemi	*Spiophanes cf soederstroemi*	1	14	2	17	1	4	4	18	2	10	6	5	1	2		17		8		4	1	9	1	12
Laonice weddellia	*Laonice weddellia*			4	4	1		1						1		3		2		1		1	1	3	
	Magelona sp.		1		9	3	3							9	3		5	1	1	2					3
	Maldanidae spp	10	7	2	3	8	9	9	9	2	6	14	15	9	19	7	24	3	3	5	5	3	4	6	9
	Spiochaetopterus sp.			1													1								
	Cirratulidae spp.	4	4	4	25		19	16	14	1	3	3	1	7	1	14	3	16	18	17	4	3	2	2	14
Cirratulus sp.	Cirratulidae sp black								1					1					2						

Macrofaunal Matrix

Preliminary Comment	Species	G1A	G1B	G2A	G2B	G3A	G3B	G4A	G4B	G5A	G5B	G6A	G6B	G7A	G7C	G8A	G8B	G9A	G9B	G10A	G10B	G11A	G11B	G12A	G12B
Macrofauna																									
	CNIDARIA																								
Caulleriella sp	Cirratulidae sp black II											4													
	Sternapsis sp.		1																						
	Capitellidae spp.				4				1												1				1
	Capitomastus/Mediomastus							10				7							1	2	3			1	
affirmed species	*Notomastus aff latericeus*			2	2																				4
Travisia kerguelensis	*Travisia kerguelensis*	1		5	3	4	6	6	2		2	1	2		1		1	5		6	7		1		
	Ophelina aff acuminata	1	1	1		1	2		2	2			1	3	5			3	1						2
affirmed species	*Ophelina cylindricaudata*	2	3	1	1	4		6		7	6		6	3		1	1	5	7	10	3	3	5	2	3
	Ophelina cf breviata	2	1			1		3	2		2		1	5	2			2	1	3			1	1	
	Scalibregma cf inflatum	7																							
	Bradabyssa sp																								
	Ampharetinae spp	2	3	1	1	3		2	2	1	2	2				2		1			1	3	1	1	1
	Samytha speculatrix			6	3		1		3		3		1				9	2	1		3		1	2	1
	Amage sp.							1														2	2		
	Eclysippe sp.																						1		
	Melinna sp											1				1									
Terebellides stroemi subsp.	*Terebellides stroemi ssp*		6						1	1					1				1	1	1	1		1	1
	Streblosoma sp.														1										2
	Amaeana sp.																								
Pista patriciae?	*Pista patriciae*													1											
	Fabricinidae sp.	2	2	4	1	3		1		1		2		1		2		1			3	1			
	Fabricola / Pseudofabricia sp	4	25	9	7	2	10	2	2		1	2	2		4	3	2	1		3	8	33	62	3	5
	Oligochaeta Tubificidae			4	8	1	4		13		1	6	6	21	37		2		1	1		8			
	Serpulidae																								
	Phylo felix	1	1	2	1							4	3	1		3	2	1						1	
	Lumbrineris kerguelensis		6																						
	Lumbrineris spp	20	2	2								1				1	1							1	
	Ninoe falklandica		2																						
	Drilonereis sp													1											
	Galathowenia sp	3	2					1						2								1			
	Myriowenia cf. californicensis		2																						
	Polygordius sp.											2													
affirmed species	*Scalibregma inflatum*		2				1					1		1											
	Sphaerodorum sp	1																							
	PYCNOGONIDA																								
	Pycnogonida sp.																								
	CRUSTACEA																								
	Ostracoda spp.								1		1									1			2		
	Copepoda indet											1													
	Phtisica ap													4								3			
	Amphipod sp. A	2	3	5	2	2	1				3		3								1		2	3	1
	Amphipod sp. B										1										1				
	Stenothoidae				3																		2		
	Amphipod sp. C								1													3			1
	Amphipod E																								
	Amphipod G																						1		
	Amphipod F (aff Apherusa)																								
	Aff Westwoodilla sp	2	1						1										10			1	6		
	Urothoe sp.	6	4	36	36	15	29	47	46	14	26	18	10	24	11	46	54	64	61	27	8	34	13	15	12
	Podoceridae																								
	Phoxocephaloidae sp. A				2		2	1	4		5		2	2		3	10		1				5		2
	Phoxocephaloidea sp. B			4	1	1			1	2						1		2				4			
	Phoxocephaloidea sp.C (eyeless)	13	14	6	13	4	9	9	19	9	8	2	2		1	17	32	6	9	14	3	9	5	3	4
	Maera sp.		1															1							

Macrofaunal Matrix

Preliminary Comment	Species	G1A	G1B	G2A	G2B	G3A	G3B	G4A	G4B	G5A	G5B	G6A	G6B	G7A	G7C	G8A	G8B	G9A	G9B	G10A	G10B	G11A	G11B	G12A	G12B
Macrofauna																									
	CNIDARIA																								
	Didymochelia sp (=Lys. A)			2						2	10	1	2	34	19		1	3		1	1		7		3
	Lysianassoidea sp. B				12	2					4								1		1		18		1
	Lysianassoidea sp. C															1					1	1			
	Lysianassoidea sp. D											2							2			1			
	Lysianassoidea sp. E				1		1										1						3		
	Lysianassoidea sp. F	1								1							7	1		2		1			
very long strechted species	Lysianassoidea sp. G																								
	Argissidae sp. A					4					1	4	2				2		2						
	Ampelisca sp. A	3	2	4	11	2	11		1	9	9	2	7	3		8	8	3	2		13	1	6	4	
	Ampelisca sp. B			3	5	1		2								2	21			6					3
	Ampelisca sp. C				3	3				1						7	1				1	2			
	Ampelisca sp. D			2	3	1		2		1		4				1	2					2		3	
	Ampelisca juv.	1				8		8		11		3										11		1	
	Dexamine sp.																								
	Photis sp. A			1	1					2				1		2				1				4	
	Aoridae sp. A				3						5								1				7		
	Amphilochidae sp A			3		4							1			2									
	Leptocheirus sp.	2	1	1	9		2	1		2	7	3	2			2	1	1				4	4		5
	Gnathia praniza																					3			
	Ilyarachna sp						1		1		1		1												
	Eurycope sp																								
	Munna sp					1												1							
	Janira sp A																					4			
	Janira sp B																					1			
	Dynamenella sp			3	2	2												1						3	
	Cirolana sp.		1																						
	Serolis sp.			6	8			4	10	1	1					1		12	18	1		7	6		
	Pseudarcturella sp					1							1	2	2			1				2			
	c.f.Idothea I																								
	c.f.Idothea II																								
	c.f. Anthura																								
	Gnathia praniza																								
	Tanaidae sp A			1	1			4			1			9			1			1			1		2
	Tanaidae sp B							1			1	1		3	1	1									
	Tanaidae sp C										1			7								1			
	Tanaidae sp D											2		2	1										
	Archaeotanais hirsutus	2		3	9	3		1		1		1	1		1		2	1		1	1			1	
	Archaeotanais hirsutus juv					16																			
	Eudorella sp.		2	2				1	1								1			1					
	Leucon sp.		1																						
	Bodotriidae sp A							1	2																
	Lampropidae sp.		1															1	1						
	Diastylidae sp A		1						1		1												6		
	Diastylis sp A							1																	1
	Diastylis sp. B	1													1			5				7			
	Campylaspis spp.		1			1	1	4	1					7										1	
Carapace with spines	*Campylaspis spp.II*																								
	Mysidacea																		1						
	MOLLUSCA																								
	Scaphopoda sp.																			1					
Fam. Marginellidae	Marginellidae																1	3				1			
Skenea/Cyclotrema	Skenea ? Cyclotrema			6	2	1																			
Fusitron sp.	Fusitron sp	1																							

Macrofaunal Matrix

Preliminary Comment	Species	G1A	G1B	G2A	G2B	G3A	G3B	G4A	G4B	G5A	G5B	G6A	G6B	G7A	G7C	G8A	G8B	G9A	G9B	G10A	G10B	G11A	G11B	G12A	G12B
Macrofauna																									
	CNIDARIA																								
	Eulima sp.			1																					
	Philine falklandica								2		1								2	1				1	
	Retusa sp.	1		1																1					
	Polinices sp.				1														1						
	Nudibranchia sp.																				1				
	Bivalve sp damaged	2																							
	Cardiidae sp					2												1		1					
	Yoldiella / Ledella	4	1					1		3		42												3	
	Limopsis sp.	4	1			1											1	2	2	1					
	Pecten sp.																								
	Cyamiomactra falklandica	0	5	5	1	7	0	2	0	7	1	18	0	0	0	15	0	4	0	15	1	2	1	7	0
	Mysella arthuri		1			1		1			1	1								2	1				
	Mysella II	7																							
	Abra sp									2															
	Thracia meridonalis						1																		
	Cuspidaria sp.					1					1									1				2	
	Cuspidaria tenella							1		1			1								1	1			
	Hiatella sp.																								
	Cyamia antarctica																								
	Genaxinus debilis	1		2	1					2		1					2	2			1		1	1	2
	Cryptodon falklandica	3	16	5	1	2	7	18	5	6	9	7	1			5	2	6		9	2	24	2	7	6
not related. Looks similar to	"*Lima*"																								
	PHORONIDA																								
	Phoronis sp.		2			3								1		2	5				1		1		
	ECHINODERMATA																								
cf Amphiura lymani	cf Amphiura lymani	7	3		1						1	1					1					3	2		
	Ophiotrichidae sp																								
Ophiura cf meridionalis	Ophiura cf meridionalis	14	8			4	6	14	34	4	6		6	1	5					8		14	31	1	4
affirmed species	*Ophiomitrella falklandica*					1																			
7 arms, affirmed species	*Ophiacantha vivipara*																								
Abatus cavernosus	*Abatus cavernosus*			2	1			1		2	1	1					1		1		2				
Fam. Chiroditidae?	Synaptidae sp	1	1	4	9	1			2				1			4	7	1	11	1					
	Ctenodiscus australis Lutken			1				1		2			1		1		1	1	1				1		
	Rhophiella koehleri																								
affirmed species	*Sterechinus neumeyeri*																								
	BRACHIOPODA																								
	Brachiopod sp																								
	ENTEROPNEUSTA																								
	Enteropneusta sp.		2						3				2		3		1				3	1	1		1
	CHORDATA																								
Affirmed genus	*Eugyra sp.*	6		3	3				1	1	4								1	1	1		11	22	21
	Eugyra sp B																								
Affirmed species	*Molgula cf malvinensis*	1																							
	Species (Richness)	**51**	**51**	**56**	**58**	**44**	**28**	**44**	**42**	**41**	**44**	**47**	**37**	**44**	**35**	**37**	**50**	**49**	**42**	**48**	**44**	**54**	**49**	**40**	**39**
	Individuals (Abundance)	**177**	**184**	**215**	**368**	**140**	**146**	**205**	**242**	**121**	**178**	**223**	**114**	**223**	**197**	**282**	**433**	**208**	**246**	**224**	**129**	**256**	**276**	**130**	**165**
	Richness (Margalef)	**9.66**	**9.59**	**10.24**	**9.65**	**8.70**	**5.42**	**8.08**	**7.47**	**8.34**	**8.30**	**8.51**	**7.60**	**7.95**	**6.44**	**6.38**	**8.07**	**8.99**	**7.45**	**8.69**	**8.85**	**9.56**	**8.54**	**8.01**	**7.44**
	Evenness (Pielou's Evenness)	**0.89**	**0.87**	**0.90**	**0.81**	**0.90**	**0.85**	**0.81**	**0.80**	**0.89**	**0.87**	**0.84**	**0.89**	**0.84**	**0.82**	**0.77**	**0.71**	**0.77**	**0.74**	**0.85**	**0.91**	**0.83**	**0.80**	**0.86**	**0.89**
	Shannon-Wiener Diversity	**5.07**	**4.94**	**5.20**	**4.72**	**4.90**	**4.09**	**4.40**	**4.29**	**4.78**	**4.77**	**4.68**	**4.65**	**4.60**	**4.22**	**4.02**	**4.03**	**4.35**	**3.99**	**4.74**	**4.95**	**4.80**	**4.51**	**4.59**	**4.68**
	Simpsons (1-Lambda)	**0.96**	**0.95**	**0.96**	**0.93**	**0.96**	**0.92**	**0.92**	**0.92**	**0.96**	**0.95**	**0.94**	**0.95**	**0.94**	**0.92**	**0.89**	**0.88**	**0.89**	**0.89**	**0.95**	**0.96**	**0.94**	**0.92**	**0.94**	**0.95**

Macrofaunal Matrix

Preliminary Comment	Species	G13A	G13B	G14A	G14B	G15A	G15B	G16A	G16C	G17A	G17C	G18A	G18C	G19A	G19B	G20A	G20C	G21A	G21B	G22B	G22C	G23A	G23B	G24A	G24C	G25A	G25B	G26A	G26B
Macrofauna																													
	CNIDARIA																												
	Virgularia spp.										1																		
	Edwardsiidae sp.				1	1						1														1	1	1	1
	Soiltary Polyp							2	3													1			1				
	PLATYHELMINTHES																												
	Polycladida sp		1	1				1			1									1					1	1			
	NEMERTEA																												
	Nemertea spp.				1		1	8	1	4	1	8			1	4		3		1	1	2	1	2		6		1	4
	NEMATODA																												
	Nematoda spp.													3		1				1	2					8	2		1
	SIPUNCULA																												
	Sipunculida sp																												
	Golfingia sp.	1																			1								
	Thysanocardia sp.	1						1		3		3								2	1				1	2	2		
	Phascolion sp.																												
	ANNELIDA																												
	Dorvilleidae sp		4				2				1		4	1				1					2		1				4
poss. Eunoe	Polynoidae spp							1												1						1			
	Pholoe sp																												
	Phyllodocidae spp.																												
	Anaitides sp.		1		1			1					1												1	1	5		1
Eteone cf sculpta	*Eteone spp*		1	1		2		1	5	2										1						6	1		
	Eumida sp.		1																										
Glycera cf kerguelensis	*Glycera cf kerguelensis*	5	3		4	2	4	2	1		2	2	2	6	9	3	1	4	6	7	7	3	3		4	12	13	3	2
	Glycinde armatus																									1			
	Goniadidae sp.			1			1							2		3	3	1										6	
	Syllidae sp.													1														1	
Aglaophamus ornatus	*Aglaophamus ornatus*	5		3	1	4	3	1		1	7		3		1	12	6	5	4	1	4			1	1		1	8	6
	Onuphis aff holobranchiata	7	12			3	4	1			1	1	4	1	4			1	1		4		4		2	1		3	1
	Onuphis sp juv																		27										
	Aff Scoloplos sp	13	12	7	7							6	19	5	6	23	4									21	15	10	10
	Aricidea sp.A		13	62	42	2	30	6	8	9	26	8	61	6	13	3	1	19	5	9	16	3	8	1	10	74	95	10	12
	Aricidea sp.B		6	8	4	1	3	4	3	7	2	9	7	8	4	7		9	3	3	1	6		6	2	9	3		
	Aricidea simplex			3				1	1													1				11			
	Paraonoidae spp.	6	6	8		4	5	7	17	3	4	7	6	3	1			6	5	3	5	7	3	3	5	4	19	3	4
	Apistobranchus cf fragmentata		2		4				1	5	7									2			1						
	Spionidae sp.																												
	Minuspio sp.										1		2								2			1					
	Scolelepis sp.									1								1				1				3			
affirmed species	*Spiophanes aff bombyx*		1	2	1	1				5	4	1	5	1		1		2	2		1		1	2	1		1		1
Spiophanes cf soederstroemi	*Spiophanes cf soederstroemi*		2	3	13	1	3	1	11	3	4	1	13	2	6	1		2	1	3	1		6	2	6		10	2	
Laonice weddellia	*Laonice weddellia*	3			3	1	3			1				1							2	1		2			1		
	Magelona sp.	1	2	1	2	1	3	3		3	1		1	3	1	6	4		2		1	6	2	5	8		3	5	1
	Maldanidae spp	4	18	3	22	5	7	2	7	23	32	9	46	12	10	1	1	5	3	4	2	6	8	9	8	8	77	12	16
	Spiochaetopterus sp.										1																		
	Cirratulidae spp.	6	6	3	13	4	7	10	1	2	11	3	11	1	6	32	1	8	7		3	7	1	4	4	4	9	11	23
Cirratulus sp.	Cirratulidae sp black																					1			1				

Macrofaunal Matrix

Preliminary Comment	Species	G13A	G13B	G14A	G14B	G15A	G15B	G16A	G16C	G17A	G17C	G18A	G18C	G19A	G19B	G20A	G20C	G21A	G21B	G22B	G22C	G23A	G23B	G24A	G24C	G25A	G25B	G26A	G26B
Macrofauna																													
	CNIDARIA																												
Caulleriella sp	Cirratulidae sp black II	1						1				1																	
	Sternapsis sp.																												
	Capitellidae spp.																										3		
	Capitomastus/Mediomastus							2											1							6			
affirmed species	*Notomastus aff latericeus*		1											1														2	
Travisia kerguelensis	*Travisia kerguelensis*	1			1	1		3		4	1	2						1	1			2		1					
	Ophelina aff acuminata	5	5		1	1	3	2	10	1		2	1		6	4	3	1	2	2						6	5	1	1
affirmed species	*Ophelina cylindricaudata*	2	2	2	1	1	4	3	4	4		3	2	3		1		3	2	4	6	1		3	6	1	5	3	
	Ophelina cf breviata	3	2				1	1	3	1	5		1	1		1				1			2	3		2	1	1	
	Scalibregma cf inflatum								1						1														
	Bradabyssa sp																												
	Ampharetinae spp			1	3	2	1	2	3	3	1	1		3	1				3	3	1			1	3	5	3		
	Samytha speculatrix					4	1		1	1	2	1	1	1					1								3		
	Amage sp.																					1							
	Eclysippe sp.																												
	Melinna sp													1													1		
Terebellides stroemi subsp.	*Terebellides stroemi ssp*								1					1			2					1				5	5		
	Streblosoma sp.												4											1			7		
	Amaeana sp.												2		1												1		
Pista patriciae?	*Pista patriciae*																												
	Fabricinidae sp.						2	1	4	1			1					2	2		2	1				4	2		
	Fabricola / Pseudofabricia sp		3		44			4	4	7	13	2	1			2				2	1	2			1	7	19		12
	Oligochaeta Tubificidae	48	6							7		8	5	13	7	12		8		12							2		3
	Serpulidae																												
	Phylo felix	2	2		4						1	1					1	1					2	1		4	2	2	
	Lumbrineris kerguelensis																												
	Lumbrineris spp												1																
	Ninoe falklandica												1			2												2	
	Drilonereis sp		1																							1			
	Galathowenia sp													2												1			
	Myriowenia cf. californicensis																												
	Polygordius sp.								1								1				5								
affirmed species	*Scalibregma inflatum*													1							1								
	Sphaerodorum sp									1																			1
	PYCNOGONIDA																												
	Pycnogonida sp.																									3			
	CRUSTACEA																												
	Ostracoda spp.	5	1				1	2	3							1		3	3	5	2			4	2	10	3	2	
	Copepoda indet													1				1											
	Phtisica ap			1									2													6			
	Amphipod sp. A				2				1	1										2					3		1		
	Amphipod sp. B	2																						1					
	Stenothoidae						4		2	1				1						1	1						2		5
	Amphipod sp. C			1	1										1					2						1			
	Amphipod E																1												
	Amphipod G																									1			
	Amphipod F (aff Apherusa)																		1						1	2	1		
	Aff Westwoodilla sp	1			4		6	1	1					2						3	5				3		4		
	Urothoe sp.	22	22	42	64	48	72	49	49	38	30	28	46	14		33	1	47		34	44	42	36	32	48	32	16	66	
	Podoceridae																												
	Phoxocephaloidae sp. A			1	15	5	1	3		1	4		1		9				62	1	4		1		1	1	4	1	
	Phoxocephaloidea sp. B					1				2				3								3							
	Phoxocephaloidea sp.C (eyeless)	7	5	14	30	4	18	2	5	12	3	9	11	5	4	1		6	3	2	9	6	10		10	6	9		47
	Maera sp.	1		2						2				1												2			

Macrofaunal Matrix

Preliminary Comment	Species	G13A	G13B	G14A	G14B	G15A	G15B	G16A	G16C	G17A	G17C	G18A	G18C	G19A	G19B	G20A	G20C	G21A	G21B	G22B	G22C	G23A	G23B	G24A	G24C	G25A	G25B	G26A	G26B
Macrofauna																													
	CNIDARIA																												
	Didymochelia sp (=Lys. A)		3	2	2	1	4	1		3	1	4	12	6		5	1	1		1		1	1		6	6	19	11	5
	Lysianassoidea sp. B					2	2		1		6		4						3	1			1				11		
	Lysianassoidea sp. C									3										1				1					4
	Lysianassoidea sp. D				1		1		1									2	1							1			4
	Lysianassoidea sp. E						1	1	1	1	1					1													
	Lysianassoidea sp. F							1	1	4				1												2		9	
very long strechted species	Lysianassoidea sp. G																												
	Argissidae sp. A				1		2						1								1								
	Ampelisca sp. A		2	5	3	1	3	1	4	5	19	4	9	2	1	1	1		3		4	1	2	3	11		3	4	
	Ampelisca sp. B								1		1		6	2			3	4	1					1					8
	Ampelisca sp. C				1			1		1						2													
	Ampelisca sp. D			1		1		1		4		1				2			3					2		1	1		2
	Ampelisca juv.			1								1								42						4			
	Dexamine sp.																												
	Photis sp. A				2	1			1	2				6		2		1			2	1	1						
	Aoridae sp. A						1		10			1		1					1								1		
	Amphilochidae sp A																												
	Leptocheirus sp.			1						1	3	1	3	1					1						3		1		
	Gnathia praniza					1																							
	Ilyarachna sp				1														1						2		6		
	Eurycope sp																				1								
	Munna sp					2														1						1			1
	Janira sp A						2	1		1			1	1				1											1
	Janira sp B																												
	Dynamenella sp			1	2	3	3							3	2							4	2	4	7		1		
	Cirolana sp.	1																											
	Serolis sp.			4	11	1	5	3	1				1	3				33		3	6				1				
	Pseudarcturella sp					3	8	2					1					1	17	1	1	1	1				1		
	c.f.Idothea I									2				2				1											
	c.f.Idothea II													1						1						3			
	c.f. Anthura																									1			
	Gnathia praniza																									9			
	Tanaidae sp A	1		1					1	3										1	1				1	9	1	1	
	Tanaidae sp B	2				1		3		5	1	2				1		2		1	3	1	1	1		2		1	
	Tanaidae sp C												1																
	Tanaidae sp D	1						1		1																			
	Archaeotanais hirsutus				3	1				3	1	1						1			1			1		1			
	Archaeotanais hirsutus juv																												
	Eudorella sp.	1				1	2			1								1	1							1	1		
	Leucon sp.					3	7	5	4	2				2		1			1		5	2				1		1	1
	Bodotriidae sp A													1															
	Lampropidae sp.																				4								
	Diastylidae sp A				1		1								1				1		1								
	Diastylis sp A							1		2				4						1						1			
	Diastylis sp. B														3					3	1				1	8			
	Campylaspis spp.					2	2		2	1		2				1										1	1	3	
Carapace with spines	*Campylaspis spp.II*																												
	Mysidacea			2																									1
	MOLLUSCA																												
	Scaphopoda sp.									1		1																	
Fam. Marginellidae	Marginellidae																			1									
Skenea/Cyclotrema	Skenea ? Cyclotrema					1	3	1							1			1		2		1	1						
Fusitron sp.	Fusitron sp					1																1							

Macrofaunal Matrix

Preliminary Comment	Species	G13A	G13B	G14A	G14B	G15A	G15B	G16A	G16C	G17A	G17C	G18A	G18C	G19A	G19B	G20A	G20C	G21A	G21B	G22B	G22C	G23A	G23B	G24A	G24C	G25A	G25B	G26A	G26B
Macrofauna																													
	CNIDARIA																												
	Eulima sp.									2		1																	
	Philine falklandica	1						2	5			1																	1
	Retusa sp.																												
	Polinices sp.							1	1											1	1								
	Nudibranchia sp.																												
	Bivalve sp damaged																												
	Cardiidae sp					2		1																					
	Yoldiella / Ledella	1		2				4	1	20		5				9				2		12	1	1		1		5	
	Limopsis sp.				2			1						1		1		2				5						1	
	Pecten sp.													1															
	Cyamiomactra falklandica	0	0	7	0	5	3	5	2	13	2	14	0	4	0	3	0	15	0	8	1	11	2	14	0	11	1	6	0
	Mysella arthuri					2		3																	1			1	
	Mysella II																												
	Abra sp					1																							
	Thracia meridonalis											1														2			
	Cuspidaria sp.							2		4	1	1		2						2		6	1	3	3				
	Cuspidaria tenella			2					1				1																
	Hiatella sp.																												
	Cyamia antarctica																			1				1		1			
	Genaxinus debilis				4	2	2	1	1	2	2				1			1	1		2		1	3	3		4		
	Cryptodon falklandica		1	4	12	5	3	11	5	29	8	8	10	6	3			4		10	17	10	8	14	22	1	3		
not related. Looks similar to	*"Lima"*																												
	PHORONIDA																												
	Phoronis sp.			10	28	9	2	15		1			1					2	6		1			1					
	ECHINODERMATA																												
cf Amphiura lymani	cf Amphiura lymani																			2	1				1				
	Ophiotrichidae sp																												
Ophiura cf meridionalis	Ophiura cf meridionalis			1	4			4	138			2		37			1	1	2	4	2				6	78	7		
affirmed species	*Ophiomitrella falklandica*							1		1														1					
7 arms, affirmed species	*Ophiacantha vivipara*																					1							
Abatus cavernosus	*Abatus cavernosus*	1	2	1		2			1	2				1			1							1		1	1	1	
Fam. Chiroditidae?	Synaptidae sp			1	1	1	3	1	1		1						1	6			1								
	Ctenodiscus australis Lutken	2	1	1												1			4			2	4		1	1			
	Rhophiella koehleri													1															
affirmed species	*Sterechinus neumeyeri*																									1			
	BRACHIOPODA																												
	Brachiopod sp																												
	ENTEROPNEUSTA																												
	Enteropneusta sp.	2	2		1					1			4	2	3	1					1	1	1		6	1	7		
	CHORDATA																												
Affirmed genus	*Eugyra sp.*						1		1			3	2	1				3	1	1	1					3		1	7
	Eugyra sp B																										4		
Affirmed species	*Molgula cf malvinensis*																												
	Species (Richness)	34	34	40	45	49	48	60	51	62	40	43	45	58	28	35	20	44	40	51	52	39	32	37	43	68	58	36	32
	Individuals (Abundance)	165	152	217	369	154	251	204	337	280	214	171	322	202	107	184	38	223	195	204	194	165	119	137	210	433	431	201	191
	Richness (Margalef)	6.46	6.57	7.25	7.44	9.53	8.51	11.09	8.59	10.83	7.27	8.17	7.62	10.74	5.78	6.52	5.22	7.95	7.40	9.40	9.68	7.44	6.49	7.32	7.86	11.04	9.40	6.60	5.90
	Evenness (Pielou's Evenness)	0.78	0.86	0.74	0.78	0.80	0.78	0.82	0.65	0.84	0.81	0.87	0.77	0.85	0.90	0.79	0.92	0.80	0.75	0.80	0.82	0.82	0.80	0.82	0.82	0.78	0.76	0.77	0.80
	Shannon-Wiener Diversity	3.97	4.40	3.91	4.26	4.51	4.37	4.86	3.68	5.03	4.29	4.70	4.25	5.01	4.31	4.06	3.99	4.35	3.98	4.54	4.68	4.33	3.98	4.29	4.48	4.75	4.46	4.00	4.02
	Simpsons (1-Lambda)	0.88	0.94	0.87	0.92	0.89	0.89	0.93	0.80	0.95	0.93	0.95	0.91	0.95	0.95	0.91	0.95	0.92	0.87	0.92	0.93	0.91	0.89	0.92	0.92	0.93	0.91	0.87	0.90

Macrofaunal Matrix

Preliminary Comment	Species	G27A	G27B	G28A	G28B	G29A	G29C	G30A	G30C	G31A	G31B	G32A	G32C	A0A	A0B	B0A	BOB	D0A	D0C	E0A	E0B	R0A	R0C	WAA	WAB	WBA	WBC
Macrofauna																											
	CNIDARIA																										
	Virgularia spp.																										
	Edwardsiidae sp.	1																							1		
	Soiltary Polyp																										
	PLATYHELMINTHES																										
	Polycladida sp		1						1										1		1						
	NEMERTEA																										
	Nemertea spp.	6	1	1			1	2		5		1	2	2	2	4		4		3	1			6	1	2	1
	NEMATODA																										
	Nematoda spp.					2		6	1							1		3	3	3		2		1	1	8	4
	SIPUNCULA																										
	Sipunculida sp																		2								
	Golfingia sp.																										
	Thysanocardia sp.	1									1		1													3	
	Phascolion sp.																										
	ANNELIDA																										
	Dorvilleidae sp		1		1				1			1	4		2		4		4		1		2				2
poss. Eunoe	Polynoidae spp						4	4	1										2		2						
	Pholoe sp					1		1										2				1					
	Phyllodocidae spp.					1	3			1					1					1							
	Anaitides sp.		6		1								1		4												1
Eteone cf sculpta	*Eteone spp*	2	2			1		2				1						1		1		1			1	2	
	Eumida sp.																										
Glycera cf kerguelensis	*Glycera cf kerguelensis*	4	8		1		4			2					2	3	4	3	11	2		1	4	2	5	11	7
	Glycinde armatus																										
	Goniadidae sp.													1								2					
	Syllidae sp.															1								1			
Aglaophamus ornatus	*Aglaophamus ornatus*		1	4	4	3	1	1	1	2	3	2	3	4	2	2	2	1	2	2	6	1	4	2	1		1
	Onuphis aff holobranchiata				1					3				1		1				3	5		5		1		
	Onuphis sp juv																				44						
	Aff Scoloplos sp	21	19	1		2	3	3				10	12			1	3	11	6			1		11	14	13	27
	Aricidea sp.A	8	13	2	16		1	1	3	2		3	6	26	66	74	69	69	212	14	34	8	16	26	19	9	38
	Aricidea sp.B	3	6	5	13	2	7	2				3		4	11	3	8	13	9	3		1	5	6	8	7	5
	Aricidea simplex			1								1				4	1	1	1	2		2		1		1	
	Paraonoidae spp.	1	1	5	6			3	6	5	3	4	4	7	3	9	11	12	4	8	12	3	6	1		2	6
	Apistobranchus cf fragmentata				3	3									1	1	1	4	61		1		1		1		2
	Spionidae sp.																										
	Minuspio sp.														1		1					1		3	2		1
	Scolelepis sp.													1				4				4	2	1			
affirmed species	*Spiophanes aff bombyx*								2								2	1						2	1	2	7
Spiophanes cf soederstroemi	*Spiophanes cf soederstroemi*		6	5	4	3	2		1	4	7	4	5	2	2		11	8	12	4	8	5	1	5	8		14
Laonice weddellia	*Laonice weddellia*			1				1	1		1												2	2	1		
	Magelona sp.	7	7			1				4	2	1	1	1	1		5	1			3	3	3	1	6	4	3
	Maldanidae spp	20	14		6	4	3	5	5	3		5	13	5	8	6	5	13	36	1	4	9	4	9	16	11	26
	Spiochaetopterus sp.																										
	Cirratulidae spp.	4	4	10	21	5	3	2	7	4	2	2	4	9	23	4	11	17	20	10	10	7	1	10	14	5	12
Cirratulus sp.	Cirratulidae sp black	1		1	1	1											1						1			2	

Macrofaunal Matrix

Preliminary Comment	Species	G27A	G27B	G28A	G28B	G29A	G29C	G30A	G30C	G31A	G31B	G32A	G32C	A0A	A0B	B0A	BOB	D0A	D0C	E0A	E0B	R0A	R0C	WAA	WAB	WBA	WBC
Macrofauna																											
	CNIDARIA																										
Caulleriella sp	Cirratulidae sp black II			1																							
	Sternapsis sp.																										
	Capitellidae spp.				1				3				1								1				1		1
	Capitomastus/Mediomastus																										
affirmed species	*Notomastus aff latericeus*					1														1	2	1			1		
Travisia kerguelensis	*Travisia kerguelensis*	5	3		1	5	7	2		1	4		3	1	1	1	3		1	5	2		1	2	2	9	3
	Ophelina aff acuminata	1	1		3		1	1				6	1		4	1	1	1		3	1			2	1	2	1
affirmed species	*Ophelina cylindricaudata*	5	2	2	3	4	2	4	2	3	5	2	3	6	11	4	6	9	6	4	4	7	6	4	4	4	6
	Ophelina cf breviata	3	2	2			3	2	1			2		1				2		1					1		
	Scalibregma cf inflatum		1										1												1		
	Bradabyssa sp						4																				
	Ampharetinae spp		2	1	2	2			1	2	2	4	1		1	1	1	1		2	5	1	3	1	1	2	
	Samytha speculatrix											1			1		1	1	2				1				
	Amage sp.							1																			
	Eclysippe sp.																										
	Melinna sp					1				1																	
Terebellides stroemi subsp.	*Terebellides stroemi ssp*							1	1		1	4	1		2	1		1			1	1		1			
	Streblosoma sp.								2				3													1	1
	Amaeana sp.						2						1												1		2
Pista patriciae?	*Pista patriciae*			1					1																		
	Fabricinidae sp.			1								1			1				1	4	2		1	1		1	
	Fabricola / Pseudofabricia sp	3	4	3	1			2	8			3	1		12		3	12	7	6	1	1	1	6	2	6	3
	Oligochaeta Tubificidae	6	5	1	1		1		4	4			1	1	1			2	10	3		5	4				1
	Serpulidae						8																				
	Phylo felix		1				1					1						1	1	1	1		1	2	1	2	
	Lumbrineris kerguelensis		1																								
	Lumbrineris spp															1						1		1			
	Ninoe falklandica																										
	Drilonereis sp		1										1							1							1
	Galathowenia sp							3																		4	
	Myriowenia cf. californicensis																										
	Polygordius sp.				1								1		2						1						
affirmed species	*Scalibregma inflatum*			1																1							
	Sphaerodorum sp								1			1															
	PYCNOGONIDA																										
	Pycnogonida sp.																										
	CRUSTACEA																										
	Ostracoda spp.	1									1						1	2			2		4	2	3	2	4
	Copepoda indet	1																								1	
	Phtisica ap		1					11																			
	Amphipod sp. A		1		3		6		7				1		1				10	1			1				
	Amphipod sp. B											2															
	Stenothoidae								1						4					1	11		2				
	Amphipod sp. C																			4							
	Amphipod E														1												
	Amphipod G																			3						2	
	Amphipod F (aff Apherusa)						1						1	1													
	Aff Westwoodilla sp							1							2										2	1	
	Urothoe sp.	25	4	33	9	7	18	48	11	11	6	21	3	49	35	3	14	79	96	49	65	64	42	26	38	30	20
	Podoceridae												2														
	Phoxocephaloidae sp. A		1		3	2	1	3	10	2		3	1		2		1	2	12			2		2	1	1	1
	Phoxocephaloidea sp. B			1		1		11		1		2						2				3					
	Phoxocephaloidea sp.C (eyeless)	8	4	5	8	11	9	4	9	5	6	9	3	8	10			32	46	1	5	9		8	10	9	10
	Maera sp.																					2				2	

Macrofaunal Matrix

Preliminary Comment	Species	G27A	G27B	G28A	G28B	G29A	G29C	G30A	G30C	G31A	G31B	G32A	G32C	A0A	A0B	B0A	BOB	D0A	D0C	E0A	E0B	R0A	R0C	WAA	WAB	WBA	WBC
Macrofauna																											
	CNIDARIA																										
	Didymochelia sp (=Lys. A)	4	6				2	1						3		1	7	5				5	12		5	1	8
	Lysianassoidea sp. B		1								2	2			4		1		2				4		2		1
	Lysianassoidea sp. C									1																	
	Lysianassoidea sp. D	1	2					1							2					3	1	5					
	Lysianassoidea sp. E	1														1	1	1				1					
	Lysianassoidea sp. F							1	1		3		1		1	3		1		1		6					
very long strechted species	Lysianassoidea sp. G																										
	Argissidae sp. A																	1	22				1	1			
	Ampelisca sp. A	1		27	30	3	2	1		6		27	18	2	2	7		19		4	5	3	5	1	3	3	3
	Ampelisca sp. B			2		2		1	1			4				1		1	3			1					
	Ampelisca sp. C	1						2				3	1		1	1		5	2	6		2	1				
	Ampelisca sp. D		1	2	1	2	1	2		2		3	1	1		1		2		3	1	4	2				
	Ampelisca juv.							1		20		6				2		34		2				3			
	Dexamine sp.																										
	Photis sp. A	2		2	1			2		1		1				2		1		3	3	2				1	
	Aoridae sp. A				2	1									1				3	1	1						1
	Amphilochidae sp A																										
	Leptocheirus sp.				2		2	3					1					1	12	1			1			2	2
	Gnathia praniza																										
	Ilyarachna sp		1						2																		1
	Eurycope sp				1								1														
	Munna sp																										
	Janira sp A							1											1				1				
	Janira sp B						1																				
	Dynamenella sp		1		1		7			2			1	3	3			1		2		4	3			1	
	Cirolana sp.								4																		
	Serolis sp.	1		1	1	1	4	1	1	1			1	1	4	1	1	1	3	1	1					1	
	Pseudarcturella sp	1		2	2					1		1	2							3		1	3				
	c.f.Idothea I	1																									
	c.f.Idothea II					1		8																			
	c.f. Anthura							1																			
	Gnathia praniza																										
	Tanaidae sp A	1				2		2		1				1				2		2		11				1	6
	Tanaidae sp B		1	1				1		2				1				4		7		8	1	2		2	
	Tanaidae sp C							2																	1		
	Tanaidae sp D											1								1							
	Archaeotanais hirsutus						1			1					2			1			1		1				
	Archaeotanais hirsutus juv																										
	Eudorella sp.					1		1					1					2	2		1						
	Leucon sp.							1		1		1								4		2	1			1	1
	Bodotriidae sp A																										
	Lampropidae sp.																										
	Diastylidae sp A														1						1						
	Diastylis sp A					1		1																2			
	Diastylis sp. B		1			3		7						3						5						1	
	Campylaspis spp.	1		1		2		5				1			1								1	2		9	2
Carapace with spines	*Campylaspis spp.II*															1											
	Mysidacea																					1	1				
	MOLLUSCA																										
	Scaphopoda sp.																	1									
Fam. Marginellidae	Marginellidae																										
Skenea/Cyclotrema	Skenea ? Cyclotrema														2					2							
Fusitron sp.	Fusitron sp																						1				

Macrofaunal Matrix

Preliminary Comment	Species	G27A	G27B	G28A	G28B	G29A	G29C	G30A	G30C	G31A	G31B	G32A	G32C	A0A	A0B	B0A	BOB	D0A	D0C	E0A	E0B	R0A	R0C	WAA	WAB	WBA	WBC
	Macrofauna																										
	CNIDARIA																										
	Eulima sp.																					1					
	Philine falklandica	1	2						1	1				3	2		1			1			3				
	Retusa sp.																										
	Polinices sp.								1																		
	Nudibranchia sp.																										
	Bivalve sp damaged								1																		
	Cardiidae sp																1	1		3							
	Yoldiella / Ledella	16								2		2		3		14		1		15	1	11		32	1	5	
	Limopsis sp.	3		1		1				1		2		2		2		3		4		10		3		4	
	Pecten sp.																										
	Cyamiomactra falklandica	6	0	6	0	7	0	3	0	3	0	11	0	6	1	2	0	19	1	14	0	9	1	28	1	11	0
	Mysella arthuri																				1						
	Mysella II																										
	Abra sp					8																					
	Thracia meridonalis															1										1	
	Cuspidaria sp.	1								2		1				3	1			6		1		1			
	Cuspidaria tenella								1					1				1								3	
	Hiatella sp.						4																				
	Cyamia antarctica																				3	1					
	Genaxinus debilis			1			1	2		2		2				2					1				1	3	3
	Cryptodon falklandica		1	5				11	4	16	2	29	3	7	5	9	12	6	4	4	6	22	17	12	2	11	2
not related. Looks similar to	*"Lima"*																										
	PHORONIDA																										
	Phoronis sp.												1	4						8							
	ECHINODERMATA																										
cf Amphiura lymani	cf Amphiura lymani				1		4		2														1				
	Ophiotrichidae sp						5																				
Ophiura cf meridionalis	Ophiura cf meridionalis	1		6	11	6	2	18	1	3	3	15	6			2		5	17	4	11			2		3	1
affirmed species	*Ophiomitrella falklandica*							1		1																	
7 arms, affirmed species	*Ophiacantha vivipara*																										
Abatus cavernosus	*Abatus cavernosus*					2		2						2		1		2								3	
Fam. Chiroditidae?	Synaptidae sp			2	1		1			3			1	1	1		1	3	1				1			1	
	Ctenodiscus australis Lutken	1	2		2		1	1			1		1				1	1		1	2		1				
	Rhophiella koehleri																										
affirmed species	*Sterechinus neumeyeri*																										
	BRACHIOPODA																										
	Brachiopod sp	1					1																				
	ENTEROPNEUSTA																										
	Enteropneusta sp.		5						2	1	3	1	1		2	2	3		7		3			4	3	3	6
	CHORDATA																										
Affirmed genus	*Eugyra sp.*		1		1				5	1		14	5			4	3		1					10	16	1	
	Eugyra sp B																										
Affirmed species	*Molgula cf malvinensis*			1								2															
	Species (Richness)	**42**	**44**	**38**	**39**	**38**	**41**	**56**	**41**	**44**	**20**	**49**	**48**	**36**	**49**	**43**	**37**	**60**	**42**	**60**	**46**	**51**	**49**	**45**	**44**	**55**	**43**
	Individuals (Abundance)	**182**	**149**	**148**	**171**	**106**	**135**	**211**	**119**	**140**	**58**	**229**	**132**	**174**	**255**	**189**	**203**	**440**	**659**	**259**	**279**	**260**	**187**	**251**	**206**	**233**	**248**
	Richness (Margalef)	**7.88**	**8.59**	**7.40**	**7.39**	**7.93**	**8.15**	**10.28**	**8.37**	**8.70**	**4.68**	**8.83**	**9.63**	**6.78**	**8.66**	**8.01**	**6.78**	**9.69**	**6.32**	**10.62**	**7.99**	**8.99**	**9.18**	**7.96**	**8.07**	**9.91**	**7.62**
	Evenness (Pielou's Evenness)	**0.84**	**0.88**	**0.80**	**0.82**	**0.92**	**0.91**	**0.82**	**0.90**	**0.89**	**0.94**	**0.85**	**0.88**	**0.78**	**0.76**	**0.73**	**0.75**	**0.76**	**0.69**	**0.86**	**0.75**	**0.81**	**0.82**	**0.83**	**0.81**	**0.89**	**0.83**
	Shannon-Wiener Diversity	**4.52**	**4.79**	**4.20**	**4.36**	**4.84**	**4.86**	**4.78**	**4.82**	**4.83**	**4.06**	**4.76**	**4.90**	**4.06**	**4.27**	**3.94**	**3.93**	**4.51**	**3.73**	**5.10**	**4.16**	**4.62**	**4.60**	**4.57**	**4.44**	**5.14**	**4.51**
	Simpsons (1-Lambda)	**0.94**	**0.95**	**0.91**	**0.93**	**0.96**	**0.96**	**0.93**	**0.96**	**0.95**	**0.95**	**0.95**	**0.96**	**0.89**	**0.90**	**0.83**	**0.86**	**0.92**	**0.85**	**0.95**	**0.90**	**0.92**	**0.93**	**0.94**	**0.93**	**0.96**	**0.94**

Macrofaunal Matrix

Preliminary Comment	Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21
Macrofauna																						
	CNIDARIA																					
	Virgularia spp.		1		1				1									1				
	Edwardsiidae sp.		4		2	1				1					1	1			1			
	Soiltary Polyp		1			2		8		2							5					
	PLATYHELMINTHES																					
	Polycladida sp												1	1	1		1	1				
	NEMERTEA																					
	Nemertea spp.	2	8			1	4	3	4	2	8	8	1		1	1	9	5	8	1	4	3
	NEMATODA																					
	Nematoda spp.	3	1		7	1				2		2								3	1	
	SIPUNCULA																					
	Sipunculida sp																					
	Golfingia sp.										1		1	1								
	Thysanocardia sp.											2		1			1	3	3			
	Phascolion sp.									1												
	ANNELIDA																					
	Dorvilleidae sp	1		2				1		1	3			4		2		1	4	1		1
poss. Eunoe	Polynoidae spp	2									2	3					1					
	Pholoe sp		1			1			1													
	Phyllodocidae spp.							1				2										
	Anaitides sp.		2		1			3	1	1	3	1		1	1		1		1			
Eteone cf sculpta	*Eteone spp*		1			1		3		2		3		1	1	2	6	2				
	Eumida sp.												1	1								
Glycera cf kerguelensis	*Glycera cf kerguelensis*	2	6	1		7	3	9	13	2	4	1	3	8	4	6	3	2	4	15	4	10
	Glycinde armatus							1														
	Goniadidae sp.									1					1	1				2	6	1
	Syllidae sp.				1								1							1		
Aglaophamus ornatus	*Aglaophamus ornatus*	12	9	9	2	3	4	3	8	11	4	5		5	4	7	1	8	3	1	18	9
	Onuphis aff holobranchiata	3		1	1		9	9			16	1	3	19		7	1	1	5	5		2
	Onuphis sp juv	2						1			15											27
	Aff Scoloplos sp	5	5				25	35	15	3	1	5	1	25	14				25	11	27	
	Aricidea sp.A	9	88	2	14	16	6	14	202	53	26	22	7	13	104	32	14	35	69	19	4	24
	Aricidea sp.B	3	15	11	13	3	10	15	17	14	11	2	7	6	12	4	7	9	16	12	7	12
	Aricidea simplex		3				1		4	1	2	1	6		3		2					
	Paraonoidae spp.	9	23	3	8	13	7	20	13	14	14	25	23	12	8	9	24	7	13	4		11
	Apistobranchus cf fragmentata		4		1		2	2	34			2	3	2	4		1	12				
	Spionidae sp.								4		2											
	Minuspio sp.							3		4	2	1						1	2			
	Scolelepis sp.	4	3				3		1		1	1	1					1				1
affirmed species	*Spiophanes aff bombyx*		12		1		3		6		1	2	2	1	3	1		9	6	1	1	4
Spiophanes cf soederstroemi	*Spiophanes cf soederstroemi*	15	19	5	22	12	11	3	17	8	4	10	13	2	16	4	12	7	14	8	1	3
Laonice weddellia	*Laonice weddellia*		8	1	1			1	3	2	1	2	3	3	3	4		1		1		
	Magelona sp.	1	9	6				12	5	2	2		3	3	3	4	3	4	1	4	10	2
	Maldanidae spp	17	5	17	18	8	29	28	31	6	10	7	15	22	25	12	9	55	55	22	2	8
	Spiochaetopterus sp.		1						1									1				
	Cirratulidae spp.	8	29	19	30	4	4	8	17	34	21	5	16	12	16	11	11	13	14	7	33	15
Cirratulus sp.	Cirratulidae sp black				1			1		2												

Macrofaunal Matrix

Preliminary Comment	Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21
Macrofauna																						
	CNIDARIA																					
Caulleriella sp	Cirratulidae sp black II						4							1			1		1			
	Sternapsis sp.	1																				
	Capitellidae spp.		4		1						1		1									
	Capitomastus/Mediomastus				10		7			1	5		1				2					1
affirmed species	*Notomastus aff latericeus*		4										4	1						1		
Travisia kerguelensis	*Travisia kerguelensis*	1	8	10	8	2	3	1	1	5	13	1		1	1	1	3	5	2			2
	Ophelina aff acuminata	2	1	3	2	2	1	8		4			2	10	1	4	12	1	3	6	7	3
affirmed species	*Ophelina cylindricaudata*	5	2	4	6	13	6	3	2	12	13	8	5	4	3	5	7	4	5	3	1	5
	Ophelina cf breviata	3		1	5	2	1	7		3	3	1	1	5		1	4	6	1	1		
	Scalibregma cf inflatum	7															1			1		
	Bradabyssa sp																					
	Ampharetinae spp	5	2	3	4	3	2		2	1	1	4	2		4	3	5	4	1	4		3
	Samytha speculatrix		9	1	3	3	1		9	3	3	1	3			5	1	3	2	1		1
	Amage sp.				1							4										
	Eclysippe sp.											1										
	Melinna sp						1		1											1		
Terebellides stroemi subsp.	*Terebellides stroemi ssp*	6			1	1		1		1	2	1	2				1			1	2	
	Streblosoma sp.							1					2						4			
	Amaeana sp.																		2	1		
Pista patriciae?	*Pista patriciae*							1														
	Fabricinidae sp.	4	5	3	1	1	2	1	2	1	3	1				2	5	1	1			4
	Fabricola / Pseudofabricia sp	29	16	12	4	1	4	4	5	1	11	95	8	3	44		8	20	3		2	
	Oligochaeta Tubificidae		12	5	13	1	12	58	2	1	1	8		54				7	13	20	12	8
	Serpulidae																					
	Phylo felix	2	3				7	1	5	1			1	4	4			1	1		1	1
	Lumbrineris kerguelensis	6																				
	Lumbrineris spp	22	2				1		2				1						1			
	Ninoe falklandica	2																	1		2	
	Drilonereis sp							1						1								
	Galathowenia sp	5			1			2				1								2		
	Myriowenia cf. californicensis	2																				
	Polygordius sp.						2										1				1	
affirmed species	*Scalibregma inflatum*	2		1			1	1												1		
	Sphaerodorum sp	1																1				
	PYCNOGONIDA																					
	Pycnogonida sp.																					
	CRUSTACEA																					
	Ostracoda spp.				1	1					1	2		6		1	5				1	6
	Copepoda indet						1													1		1
	Phtisica ap							4				3			1				2			
	Amphipod sp. A	5	7	3		3	3				1	2	4		2		1	1				
	Amphipod sp. B					1					1			2								
	Stenothoidae		3									2				4	2	1		1		
	Amphipod sp. C				1							3	1		2					1		
	Amphipod E																				1	
	Amphipod G											1										
	Amphipod F (aff Apherusa)																					1
	Aff Westwoodilla sp	3			1					10		7		1	4	6	2			2		
	Urothoe sp.	10	72	44	93	40	28	35	100	125	35	47	27	44	106	120	98	68	74	14	34	47
	Podoceridae																					
	Phoxocephaloidae sp. A		2	2	5	5	2	2	13	1		5	2		16	6	3	5	1	9		62
	Phoxocephaloidea sp. B		5	1	1	2			1	2		4				1		2		3		
	Phoxocephaloidea sp.C (eyeless)	27	19	13	28	17	4	1	49	15	17	14	7	12	44	22	7	15	20	9	1	9
	Maera sp.	1								1				1	2			2		1		

Macrofaunal Matrix

Preliminary Comment	Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21
Macrofauna																						
	CNIDARIA																					
	Didymochelia sp (=Lys. A)		2			12	3	53	1	3	2	7	3	3	4	5	1	4	16	6	6	1
	Lysianassoidea sp. B		12	2		4				1	1	18	1			4	1	6	4			3
	Lysianassoidea sp. C								1		1	1						3				
	Lysianassoidea sp. D						2			2		1			1	1	1					3
	Lysianassoidea sp. E		1	1					1			3				1	2	2			1	
	Lysianassoidea sp. F	1				1			7	1	2	1					2	4		1		
very long strechted species	Lysianassoidea sp. G																					
	Argissidae sp. A			4		1	6		2	2					1	2			1			
	Ampelisca sp. A	5	15	13	1	18	9	3	16	5	13	7	4	2	8	4	5	24	13	3	2	3
	Ampelisca sp. B		8	1	2				23		6		3				1	1	6	2	3	5
	Ampelisca sp. C		3	3		1			8		1	2			1		1	1			2	
	Ampelisca sp. D		5	1	2	1	4		3			2	3		1	1	1	4	1		2	3
	Ampelisca juv.	1		8	8	11	3					11	1		1				1			
	Dexamine sp.																					
	Photis sp. A		2			2		1	2		1		4		2	1	1	2		6	2	1
	Aoridae sp. A		3			5				1		7				1	10		1	1		1
	Amphilochidae sp A		3	4			1		2													
	Leptocheirus sp.	3	10	2	1	9	5		3	1		8	5		1			4	4	1		1
	Gnathia praniza											3				1						
	Ilyarachna sp			1	1	1	1								1							1
	Eurycope sp																					
	Munna sp			1						1						2						
	Janira sp A											4				2	1	1	1	1		1
	Janira sp B											1										
	Dynamenella sp		5	2						1			3		3	6				5		
	Cirolana sp.	1												1								
	Serolis sp.		14		14	2			1	30	1	13			15	6	4		1	3		33
	Pseudarcturella sp			1			1	4		1		2				11	2		1			18
	c.f.Idothea I																	2		2		1
	c.f.Idothea II																			1		
	c.f. Anthura																					
	Gnathia praniza																					
	Tanaidae sp A		2		4	1		9	1		1	1	2	1	1		1	3				
	Tanaidae sp B				1	1	1	4	1					2		1	3	6	2		1	2
	Tanaidae sp C					1		7				1							1			
	Tanaidae sp D						2	3						1			1	1				
	Archaeotanais hirsutus	2	12	3	1	1	2	1	2	1	2		1		3	1		4	1			1
	Archaeotanais hirsutus juv			16																		
	Eudorella sp.	2	2		2				1		1			1		3		1				2
	Leucon sp.	1														10	9	2		2	1	1
	Bodotriidae sp A				3															1		
	Lampropidae sp.	1								2												
	Diastylidae sp A	1			1	1						6			1	1				1		1
	Diastylis sp A				1								1				1	2		4		
	Diastylis sp. B	1						1		5		7								3		
	Campylaspis spp.	1		2	5			7					1			4	2	1	2		1	
Carapace with spines	*Campylaspis spp.II*																					
	Mysidacea									1					2							
	MOLLUSCA																					
	Scaphopoda sp.										1							1	1			
Fam. Marginellidae	Marginellidae								1	3		1										
Skenea/Cyclotrema	Skenea ? Cyclotrema		8	1												4	1			1		1
Fusitron sp.	Fusitron sp	1														1						

Macrofaunal Matrix

Preliminary Comment	Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21
Macrofauna																						
	CNIDARIA																					
	Eulima sp.		1															2	1			
	Philine falklandica				2	1				2	1		1	1			7		1			
	Retusa sp.	1	1								1											
	Polinices sp.		1							1							2					
	Nudibranchia sp.										1											
	Bivalve sp damaged	2																				
	Cardiidae sp			2						1	1					2	1					
	Yoldiella / Ledella	5			1	3	42						3	1	2		5	20	5		9	
	Limopsis sp.	5		1					1	4	1				2		1			1	1	2
	Pecten sp.																			1		
	Cyamiomactra falklandica	5	6	7	2	8	18		15	4	16	3	7		7	8	7	15	14	4	3	15
	Mysella arthuri	1		1	1	1	1				3					2	3					
	Mysella II	7																				
	Abra sp					2										1						
	Thracia meridonalis			1															1			
	Cuspidaria sp.			1		1					1		2				2	5	1	2		
	Cuspidaria tenella				1	1	1				1	1			2		1		1			
	Hiatella sp.																					
	Cyamia antarctica																					
	Genaxinus debilis	1	3			2	1		2	2	1	1	3		4	4	2	4		1		2
	Cryptodon falklandica	19	6	9	23	15	8		7	6	11	26	13	1	16	8	16	37	18	9		4
not related. Looks similar to	"*Lima*"																					
	PHORONIDA																					
	Phoronis sp.	2		3				1	7		1	1			38	11	15	1	1			8
	ECHINODERMATA																					
cf Amphiura lymani	cf Amphiura lymani	10	1			1	1		1			5										
	Ophiotrichidae sp																					
Ophiura cf meridionalis	Ophiura cf meridionalis	22		10	48	10	6	6			8	45	5		5		142		2	37	1	3
affirmed species	*Ophiomitrella falklandica*			1													1	1				
7 arms, affirmed species	*Ophiacantha vivipara*																					
Abatus cavernosus	*Abatus cavernosus*		3		1	3	1		1	1	2			3	1	2	1	2		1	1	
Fam. Chiroditidae?	Synaptidae sp	2	13	1	2		1		11	12	1				2	4	2	1			1	6
	Ctenodiscus australis Lutken		1		1	2	1	1	1	2		1		3	1						1	4
	Rhophiella koehleri																			1		
affirmed species	*Sterechinus neumeyeri*																					
	BRACHIOPODA																					
	Brachiopod sp																					
	ENTEROPNEUSTA																					
	Enteropneusta sp.	2			3		2	3	1		3	2	1	4	1			1	4	5	1	
	CHORDATA																					
Affirmed genus	*Eugyra sp.*	6	6		1	5				1	2	11	43			1	1		5	1		4
	Eugyra sp B																					
Affirmed species	*Molgula cf malvinensis*	1																				
	Species (Richness)	**69**	**70**	**56**	**65**	**64**	**61**	**56**	**63**	**69**	**69**	**78**	**60**	**50**	**62**	**64**	**77**	**73**	**66**	**69**	**43**	**60**
	Individuals (Abundance)	**361**	**583**	**286**	**447**	**299**	**337**	**420**	**715**	**454**	**353**	**532**	**295**	**317**	**586**	**405**	**541**	**494**	**493**	**309**	**222**	**418**
	Richness (Margalef)	**11.55**	**10.84**	**9.72**	**10.49**	**11.05**	**10.31**	**9.11**	**9.43**	**11.11**	**11.59**	**12.27**	**10.37**	**8.51**	**9.57**	**10.49**	**12.08**	**11.61**	**10.48**	**11.86**	**7.77**	**9.78**
	Evenness (Pielou's Evenness)	**0.88**	**0.84**	**0.85**	**0.77**	**0.85**	**0.85**	**0.81**	**0.71**	**0.73**	**0.85**	**0.80**	**0.85**	**0.80**	**0.74**	**0.77**	**0.72**	**0.81**	**0.78**	**0.85**	**0.80**	**0.82**
	Shannon-Wiener Diversity	**5.37**	**5.15**	**4.96**	**4.62**	**5.11**	**5.05**	**4.68**	**4.26**	**4.44**	**5.21**	**5.04**	**5.01**	**4.51**	**4.40**	**4.64**	**4.52**	**5.02**	**4.70**	**5.22**	**4.34**	**4.83**
	Simpsons (1-Lambda)	**0.97**	**0.95**	**0.95**	**0.93**	**0.96**	**0.95**	**0.94**	**0.89**	**0.90**	**0.96**	**0.94**	**0.95**	**0.93**	**0.91**	**0.90**	**0.89**	**0.95**	**0.93**	**0.96**	**0.92**	**0.94**

Macrofaunal Matrix

Preliminary Comment	Species	G22	G23	G24	G25	G26	G27	G28	G29	G30	G31	G32	Alpha	Barbara	Dawn	Ernest	Ruth	Weddell A	Weddell B	Total
Macrofauna																				
	CNIDARIA																			
	Virgularia spp.																			**4**
	Edwardsiidae sp.				2	2	1											1		**17**
	Soiltary Polyp		1	1																**20**
	PLATYHELMINTHES																			
	Polycladida sp	1		1	1		1			1					1	1				**12**
	NEMERTEA																			
	Nemertea spp.	2	3	2	6	5	7	1	1	2	5	3	4	4	4	4		7	3	**136**
	NEMATODA																			
	Nematoda spp.	3			10	1			2	7				1	6	3	2	2	12	**69**
	SIPUNCULA																			
	Sipunculida sp														2					**2**
	Golfingia sp.	1																		**4**
	Thysanocardia sp.	3		1	4		1				1	1							3	**24**
	Phascolion sp.																			
	ANNELIDA																			
	Dorvilleidae sp		2	1		4	1	1		1		5	2	4	4	1	2		2	**51**
poss. Eunoe	Polynoidae spp	1			1				4	5					2	2				**23**
	Pholoe sp								1	1					2		1			**8**
	Phyllodocidae spp.								4		1		1			1				**10**
	Anaitides sp.			1	6	1	6	1				1	4						1	**37**
Eteone cf sculpta	*Eteone spp*	1			7		4		1	2		1			1	1	1	1	2	**44**
	Eumida sp.																			**2**
Glycera cf kerguelensis	*Glycera cf kerguelensis*	14	6	4	25	5	12	1	4		2		2	7	14	2	5	7	18	**235**
	Glycinde armatus				1															**2**
	Goniadidae sp.					6							1				2			**21**
	Syllidae sp.					1								1				1		**6**
Aglaophamus ornatus	*Aglaophamus ornatus*	5		2	1	14	1	8	4	2	5	5	6	4	3	8	5	3	1	**203**
	Onuphis aff holobranchiata	4	4	2	1	4		1			3		1	1		8	5	1		**118**
	Onuphis sp juv															44				**89**
	Aff Scoloplos sp				36	20	40	1	5	3		22		4	17		1	25	40	**411**
	Aricidea sp.A	25	11	11	169	22	21	18	1	4	2	9	92	143	281	48	24	45	47	**1746**
	Aricidea sp.B	4	6	8	12		9	18	9	2		3	15	11	22	3	6	14	12	**360**
	Aricidea simplex		1		11			1				1		5	2	2	2	1	1	**50**
	Paraonoidae spp.	8	10	8	23	7	2	11		9	8	8	10	20	16	20	9	1	8	**438**
	Apistobranchus cf fragmentata	2	1					3	3				1	2	65	1	1	1	2	**149**
	Spionidae sp.																			**6**
	Minuspio sp.	2		1									1	1			1	5	1	**25**
	Scolelepis sp.		1		3								1		4		6	1		**32**
affirmed species	*Spiophanes aff bombyx*	1	1	3	1	1				2				2	1			3	9	**77**
Spiophanes cf soederstroemi	*Spiophanes cf soederstroemi*	4	6	8	10	2	6	9	5	1	11	9	4	11	20	12	6	13	14	**357**
Laonice weddellia	*Laonice weddellia*	2	1	2	1			1		2	1						2	3		**49**
	Magelona sp.	1	8	13	3	6	14		1		6	2	2	5	1	3	6	7	7	**159**
	Maldanidae spp	6	14	17	85	28	34	6	7	10	3	18	13	11	49	5	13	25	37	**782**
	Spiochaetopterus sp.																			**3**
	Cirratulidae spp.	3	8	8	13	34	8	31	8	9	6	6	32	15	37	20	8	24	17	**614**
Cirratulus sp.	Cirratulidae sp black		1	1			1	2	1					1			1		2	**14**

Macrofaunal Matrix

Preliminary Comment	Species	G22	G23	G24	G25	G26	G27	G28	G29	G30	G31	G32	Alpha	Barbara	Dawn	Ernest	Ruth	Weddell A	Weddell B	Total
Macrofauna																				
	CNIDARIA																			
Caulleriella sp	Cirratulidae sp black II							1												**8**
	Sternapsis sp.																			
	Capitellidae spp.				3			1		3		1				1		1	1	**18**
	Capitomastus/Mediomastus				6															**33**
affirmed species	*Notomastus aff latericeus*					2			1							3	1	1		**18**
Travisia kerguelensis	*Travisia kerguelensis*		2	1			8	1	12	2	5	3	2	4	1	7	1	4	12	**133**
	Ophelina aff acuminata	2			11	2	2	3	1	1		7	4	2	1	4		3	3	**118**
affirmed species	*Ophelina cylindricaudata*	10	1	9	6	3	7	5	6	6	8	5	17	10	15	8	13	8	10	**263**
	Ophelina cf breviata	1	2	3	3	1	5	2	3	3		2	1		2	1		1		**75**
	Scalibregma cf inflatum						1					1						1		**12**
	Bradabyssa sp								4											**4**
	Ampharetinae spp	4		4	8		2	3	2	1	4	5	1	2	1	7	4	2	2	**105**
	Samytha speculatrix				3							1	1	1	3		1			**59**
	Amage sp.		1							1										**7**
	Eclysippe sp.																			
	Melinna sp				1				1		1									**6**
Terebellides stroemi subsp.	*Terebellides stroemi ssp*		1		10					2	1	5	2	1	1	1	1	1		**45**
	Streblosoma sp.			1	7					2		3							2	**22**
	Amaeana sp.				1				2			1						1	2	**10**
Pista patriciae?	*Pista patriciae*							1		1										**3**
	Fabricinidae sp.	2	1		6			1				1	1		1	6	1	1	1	**59**
	Fabricola / Pseudofabricia sp	3	2	1	26	12	7	4		10		4	12	3	19	7	2	8	9	**399**
	Oligochaeta Tubificidae	12			2	3	11	2	1	4	4	1	2		12	3	9		1	**294**
	Serpulidae								8											**8**
	Phylo felix		2	1	6	2	1		1			1			2	2	1	3	2	**56**
	Lumbrineris kerguelensis						1													**7**
	Lumbrineris spp													1			1	1		**32**
	Ninoe falklandica					2														**7**
	Drilonereis sp				1		1					1				1			1	**7**
	Galathowenia sp				1					3									4	**19**
	Myriowenia cf. californicensis																			**2**
	Polygordius sp.	5						1				1	2			1				**14**
affirmed species	*Scalibregma inflatum*	1						1								1				**9**
	Sphaerodorum sp					1				1		1								**5**
	PYCNOGONIDA																			
	Pycnogonida sp.				3															**3**
	CRUSTACEA																			
	Ostracoda spp.	7		6	13	2	1				1			1	2	2	4	5	6	**74**
	Copepoda indet						1												1	**5**
	Phtisica ap				6		1			11										**28**
	Amphipod sp. A	2		3	1		1	3	6	7		1	1		10	1	1			**69**
	Amphipod sp. B			1								2								**7**
	Stenothoidae	2			2	5				1			4			12	2			**41**
	Amphipod sp. C	2			1											4				**15**
	Amphipod E												1							**2**
	Amphipod G				1											3			2	**7**
	Amphipod F (aff Apherusa)			1	3				1			1	1							**8**
	Aff Westwoodilla sp	8		3	4					1			2					2	1	**57**
	Urothoe sp.	78	78	80	48	66	29	42	25	59	17	24	84	17	175	114	106	64	50	**2417**
	Podoceridae											2								**2**
	Phoxocephaloidae sp. A	5	1	1	5	1	1	3	3	13	2	4	2	1	14		2	3	2	**204**
	Phoxocephaloidea sp. B		3					1	1	11	1	2			2		3			**46**
	Phoxocephaloidea sp.C (eyeless)	11	16	10	15	47	12	13	20	13	11	12	18		78	6	9	18	19	**678**
	Maera sp.				2												2		2	**14**

Macrofaunal Matrix

Preliminary Comment	Species	G22	G23	G24	G25	G26	G27	G28	G29	G30	G31	G32	Alpha	Barbara	Dawn	Ernest	Ruth	Weddell A	Weddell B	Total
Macrofauna																				
	CNIDARIA																			
	Didymochelia sp (=Lys. A)	1	2	6	25	16	10		2	1			3	8	5		17	5	9	**242**
	Lysianassoidea sp. B	1	1		11		1				2	2	4	1	2		4	2	1	**89**
	Lysianassoidea sp. C	1		1		4					1									**13**
	Lysianassoidea sp. D				1	4	3			1			2			4	5			**31**
	Lysianassoidea sp. E						1							2	1		1			**17**
	Lysianassoidea sp. F				2	9				2	3	1	1	3	1	1	6			**49**
very long strechted species	Lysianassoidea sp. G																			
	Argissidae sp. A	1													23		1	1		**45**
	Ampelisca sp. A	4	3	14	3	4	1	57	5	1	6	45	4	7	19	9	8	4	6	**373**
	Ampelisca sp. B			1		8		2	2	2		4		1	4		1			**86**
	Ampelisca sp. C						1			2		4	1	1	7	6	3			**48**
	Ampelisca sp. D			2	2	2	1	3	3	2	2	4	1	1	2	4	6			**69**
	Ampelisca juv.	42			4					1	20	6		2	34	2		3		**159**
	Dexamine sp.																			
	Photis sp. A	2	2				2	3		2	1	1		2	1	6	2		1	**52**
	Aoridae sp. A				1			2	1				1		3	2			1	**41**
	Amphilochidae sp A																			**10**
	Leptocheirus sp.			3	1			2	2	3		1			13	1	1		4	**89**
	Gnathia praniza																			**4**
	Ilyarachna sp			2	6		1			2									1	**18**
	Eurycope sp	1						1				1								**3**
	Munna sp	1			1	1														**7**
	Janira sp A					1				1					1		1			**15**
	Janira sp B								1											**2**
	Dynamenella sp		6	11	1		1	1	7		2	1	6		1	2	7		1	**72**
	Cirolana sp.									4										**6**
	Serolis sp.	9		1			1	2	5	2	1	1	5	2	4	2			1	**173**
	Pseudarcturella sp	2	2		1		1	4			1	3				3	4			**62**
	c.f.Idothea I						1													**6**
	c.f.Idothea II	1			3				1	8										**14**
	c.f. Anthura				1					1										**2**
	Gnathia praniza				9															**9**
	Tanaidae sp A	2		1	10	1	1		2	2	1		1		2	2	11		7	**70**
	Tanaidae sp B	4	2	1	2	1	1	1		1	2		1		4	7	9	2	2	**65**
	Tanaidae sp C									2								1		**13**
	Tanaidae sp D											1				1				**10**
	Archaeotanais hirsutus	1		1	1				1		1		2		1	1	1			**48**
	Archaeotanais hirsutus juv																			**16**
	Eudorella sp.				2				1	1		1			4	1				**25**
	Leucon sp.	5	2		1	2				1	1	1				4	3		2	**48**
	Bodotriidae sp A																			**4**
	Lampropidae sp.	4																		**7**
	Diastylidae sp A	1											1			1				**16**
	Diastylis sp A	1			1				1	1								2		**15**
	Diastylis sp. B	4		1	8		1		3	7			3			5			1	**50**
	Campylaspis spp.				2	3	1	1	2	5		1	1				1	2	11	**56**
Carapace with spines	*Campylaspis spp.II*													1						
	Mysidacea					1											2			**6**
	MOLLUSCA																			
	Scaphopoda sp.														1					**4**
Fam. Marginellidae	Marginellidae	1																		**6**
Skenea/Cyclotrema	Skenea ? Cyclotrema	2	2										2			2				**24**
Fusitron sp.	Fusitron sp		1														1			**4**

Benthic Solutions

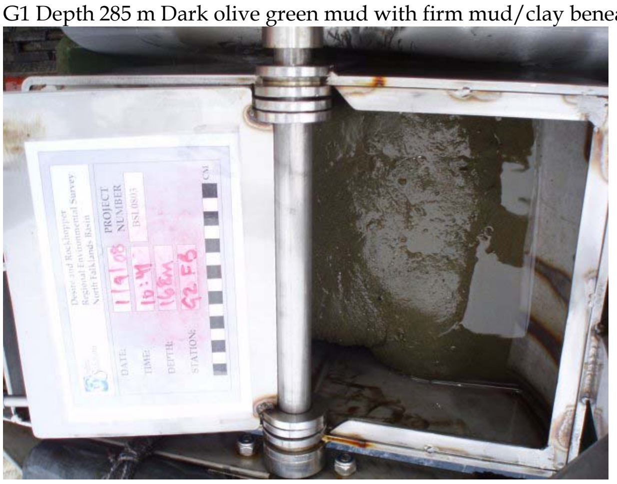
Macrofaunal Matrix

Preliminary Comment	Species	G22	G23	G24	G25	G26	G27	G28	G29	G30	G31	G32	Alpha	Barbara	Dawn	Ernest	Ruth	Weddell A	Weddell B	Total
Macrofauna																				
	CNIDARIA																			
	Eulima sp.																1			**5**
	Philine falklandica					1	3			1	1		5	1		1	3			**32**
	Retusa sp.																			**3**
	Polinices sp.	2								1										**7**
	Nudibranchia sp.																			
	Bivalve sp damaged									1										**3**
	Cardiidae sp													1	1	3				**12**
	Yoldiella / Ledella	2	13	1	1	5	16				2	2	3	14	1	16	11	33	5	**221**
	Limopsis sp.		5			1	3	1	1		1	2	2	2	3	4	10	3	4	**61**
	Pecten sp.																			
	Cyamiomactra falklandica	9	13	14	12	6	6	6	7	3	3	11	7	2	20	14	10	29	11	**347**
	Mysella arthuri			1		1										1				**16**
	Mysella II																			**7**
	Abra sp								8											**11**
	Thracia meridonalis				2									1					1	**6**
	Cuspidaria sp.	2	7	6			1				2	1		4		6	1	1		**46**
	Cuspidaria tenella									1			1		1				3	**15**
	Hiatella sp.								4											**4**
	Cyamia antarctica	1		1	1											3	1			**7**
	Genaxinus debilis	2	1	6	4			1	1	2	2	2		2		1		1	6	**64**
	Cryptodon falklandica	27	18	36	4		1	5		15	18	32	12	21	10	10	39	14	13	**527**
not related. Looks similar to	"*Lima*"																			
	PHORONIDA																			
	Phoronis sp.	1		1								1	4			8				**104**
	ECHINODERMATA																			
cf Amphiura lymani	cf Amphiura lymani	3		1				1	4	2							1			**31**
	Ophiotrichidae sp								5											**5**
Ophiura cf meridionalis	Ophiura cf meridionalis	6		6	85		1	17	8	19	6	21		2	22	15		2	4	**564**
affirmed species	*Ophiomitrella falklandica*			1						1	1									**6**
7 arms, affirmed species	*Ophiacantha vivipara*		1																	
Abatus cavernosus	*Abatus cavernosus*			1	2	1			2	2			2	1	2				3	**39**
Fam. Chiroditidae?	Synaptidae sp	1						3	1		3	1	2	1	4		1		1	**77**
	Ctenodiscus australis Lutken		6	1	1		3	2	1	1	1	1		1	1	3	1			**42**
	Rhophiella koehleri																			
affirmed species	*Sterechinus neumeyeri*				1															
	BRACHIOPODA																			
	Brachiopod sp						1		1											**2**
	ENTEROPNEUSTA																			
	Enteropneusta sp.	1	2	6	8		5			2	4	2	2	5	7	3		7	9	**96**
	CHORDATA																			
Affirmed genus	*Eugyra sp.*	2			3	8	1	1		5	1	19		7	1			26	1	**162**
	Eugyra sp B				4															**4**
Affirmed species	*Molgula cf malvinensis*							1				2								**4**
	Species (Richness)	**73**	**49**	**62**	**91**	**53**	**64**	**57**	**63**	**77**	**51**	**71**	**64**	**58**	**72**	**77**	**74**	**59**	**68**	**171**
	Individuals (Abundance)	**398**	**284**	**347**	**864**	**392**	**331**	**319**	**241**	**330**	**198**	**361**	**429**	**392**	**1099**	**538**	**447**	**457**	**481**	**16766**
	Richness (Margalef)	**12.03**	**8.50**	**10.43**	**13.31**	**8.71**	**10.86**	**9.71**	**11.30**	**13.11**	**9.46**	**11.89**	**10.39**	**9.55**	**10.14**	**12.09**	**11.96**	**9.47**	**10.85**	
	Evenness (Pielou's Evenness)	**0.80**	**0.79**	**0.79**	**0.76**	**0.80**	**0.82**	**0.78**	**0.90**	**0.85**	**0.88**	**0.83**	**0.74**	**0.72**	**0.70**	**0.80**	**0.79**	**0.81**	**0.84**	
	Shannon-Wiener Diversity	**4.98**	**4.44**	**4.71**	**4.97**	**4.60**	**4.95**	**4.57**	**5.36**	**5.30**	**5.00**	**5.12**	**4.43**	**4.20**	**4.30**	**5.00**	**4.93**	**4.76**	**5.10**	
	Simpsons (1-Lambda)	**0.94**	**0.91**	**0.92**	**0.93**	**0.93**	**0.95**	**0.93**	**0.97**	**0.95**	**0.96**	**0.96**	**0.90**	**0.85**	**0.89**	**0.93**	**0.93**	**0.94**	**0.96**	

Comment	Species	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20	G21	G22B	G23	G24	G25	G26	G27	G28	G29	G30	G31	G32	A0	B0	D0	E0	R0	WA	WB
Epifaunal and Colonial Species																																								
	ANNELIDA																																							
	Phyllodocidae spp juv																																							2
	Onuphis sp juv	2						1			15											27															44			
	Terebellidae sp. juv.	2			1	2	2				1	2		2			1			1				1	1			1		1	1									
	CRUSTACEA																																							
	Ampelisca juv.	1		8	8	11	3					11	1		1				1				42			4					1	20	6		2	34	2		3	
	Archaeotanais hirsutus juv			16																																				
	MOLLUSCA																																							
	Bivalve sp damaged	2																													1									
	ECHINODERMATA																																							
	Asteroidea sp. juv.		1		3					5	9				1		2	1	1			1	1	6				2	2	13	10						3	2		
	Ophiuroida sp juv	11		3	51			3			6	97		9			121		6	7						3					11		1							
	Spatangoid spp juv						1																										2							
	FORAMINIFERA																																							
	Foraminifera sp A (long sandy)									7	14							1				2	4	1	4			3			1	1		4		4	5	9	7	10
	Cyclammina									1										7																				
	Foraminifera sp. B (long white)		1		1																					1			2									4		
	Haplophragmoides sp.	20																																						
Epifaunal Species																																								
	Hydroida spp																													P	P						P			
	Clava sp.																	P				P												P			P	P		
	Diphasia sp.																									P														
	Campanularia sp.																							P		P														
	Halecium sp.																						P			P														
Affirmed genus	*Sertularella sp.*		P							P	P	P											P													P				P
	Tubularia sp.										P																													
	Alcyonidium sp.																																							
	Gorgonaria spp																									P														
	Porifera (glass spicules)											P														P				P										P
	Porifera																																							P
	Halichondria sp.																									P														
	Haliclona sp.																									P														
	Bryozoa spp																			P					P	P				P		P		P				1		
	c.f. Stomatopora												P	P				P		P			P	P	P				P					P				P		
	c.f. Hornera											P	P							P			P			P														
	c.f.Hornera II											P																									P			
	c.f.Hornera III																									P														P
	c.f.Tubulipora									P																P		P												
	Amphiblestrum sp																									P														
	Callopora sp.																									P														
Affirmed genus	*Cellaria sp.*												P									P													P					
Affirmed species	*Microporella stenoporta*									P		P	P	P			P					P				P						P			P					
Affirmed genus	*Reteporella sp*																									P									P					
Affirmed species	*Ogivalia elegans*					P						P		P								P			P	P					P				P					
Affirmed genus	*Osthimosis sp.*												P	P											P															
	Smittina spp																								P					P										
	Figularia sp.																						P		P	P			P								P			
	Bryozoa sp (sandy)																			6	5											18								P
	Gromulid spp.		1	2	1			5	1	2	2	1	4	6			1	1		1		1	5	1				1	1	1			1	2	3			48	7	1

APPENDIX VI: Sample Photograph

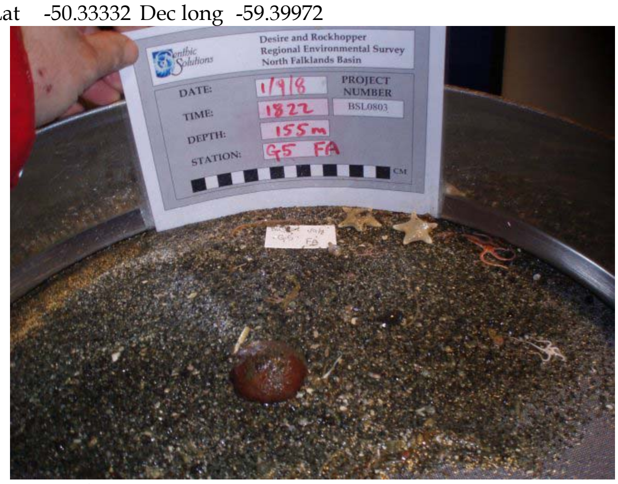
G1 Depth 285 m Dark olive green mud with firm mud/clay beneath and shell fragments Dec Lat -49.80630 Dec long -59.21138



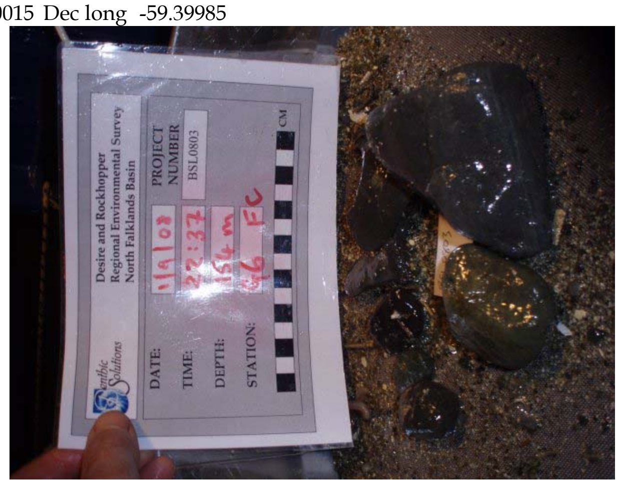
G2 Depth 168 m Dark olive green fine muddy sand Dec Lat -50.00000 Dec long -59.39973

G3 Depth 162 m Dark olive green fine muddy sand Dec Lat -50.16687 Dec long -59.39965

G4 Depth 158 m Dark olive green fine muddy sand with some gravel   Dec Lat   -50.33332 Dec long   -59.39972

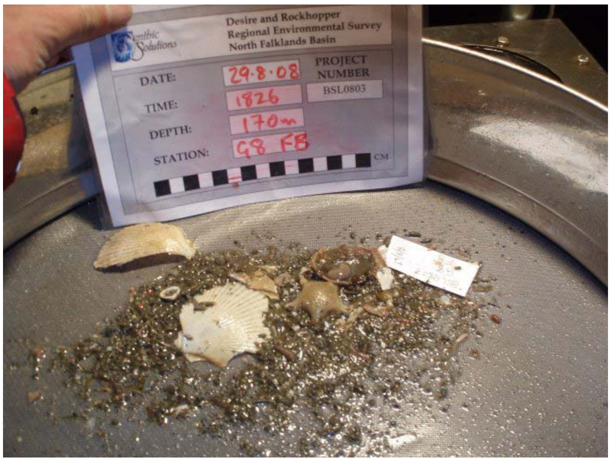


G5 Depth 155 m Dark olive green fine muddy sand   Dec Lat   -50.50015 Dec long   -59.39985

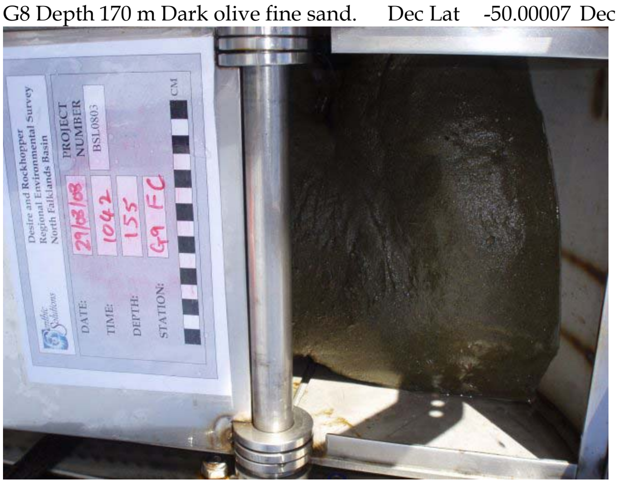


G6 Depth 154 m Dark olive green fine muddy sand with some gravel and pebbles   Dec Lat   -50.66662 Dec long   -59.39998

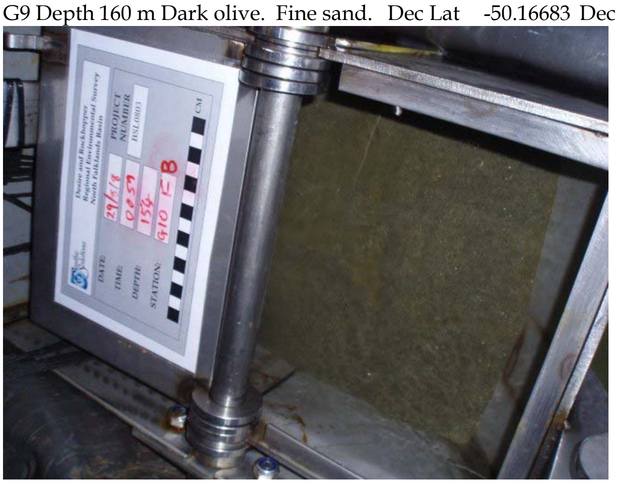
G7 Depth 145 m Dark olive green fine muddy sand with coarse sand fraction   Dec Lat   -50.83298 Dec long   -59.40002



G8 Depth 170 m Dark olive fine sand. Dec Lat -50.00007 Dec long -59.200



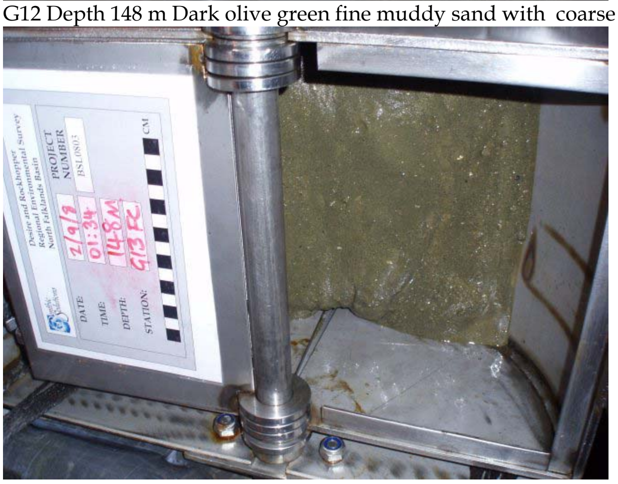
G9 Depth 160 m Dark olive. Fine sand. Dec Lat -50.16683 Dec long -59.19933



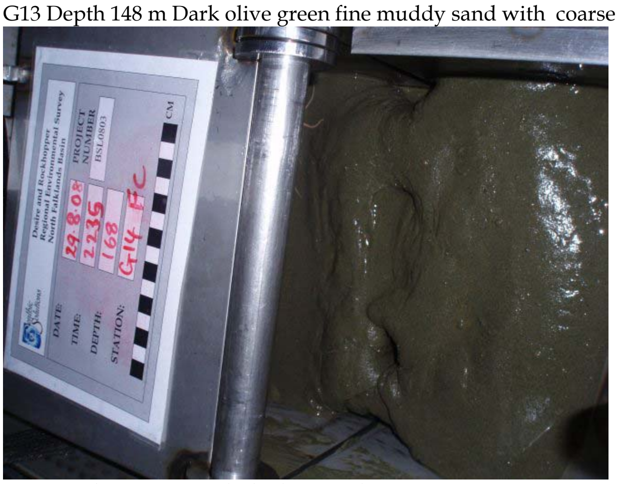
G10 Depth 154 m Dark olive fine sand. Dec Lat -50.33305 Dec long -59.19992

G11 Depth 155 m Dark olive green fine muddy sand Dec Lat -50.49995 Dec long -59.19977

G12 Depth 148 m Dark olive green fine muddy sand with coarse sand fraction Dec Lat -50.66695 Dec long -59.19980

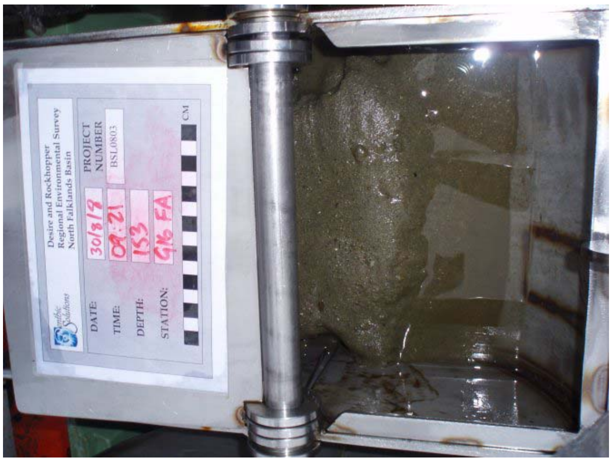


G13 Depth 148 m Dark olive green fine muddy sand with coarse sand fraction Dec Lat -50.83290 Dec long -59.19917



G14 Depth 168 m Fine dark olive sand. Dec Lat -49.99990 Dec long -58.99932

G15 Depth 155 m Fine dark olive sand. Dec Lat -50.16720 Dec long -59.00012

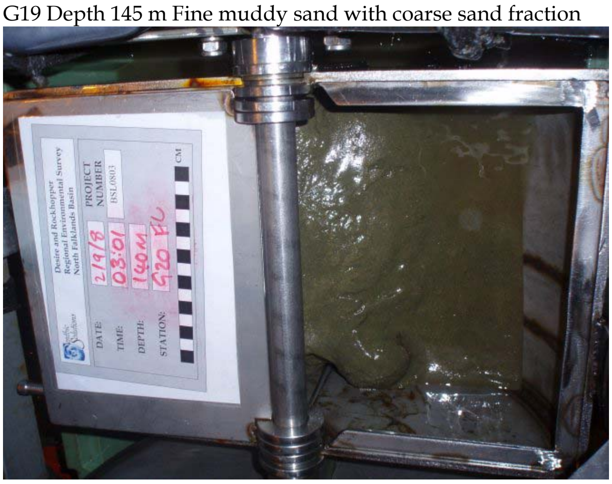


G16 Depth 153 m "Dark olive muddy, fine sand." Dec Lat -50.33322 Dec long -58.98375

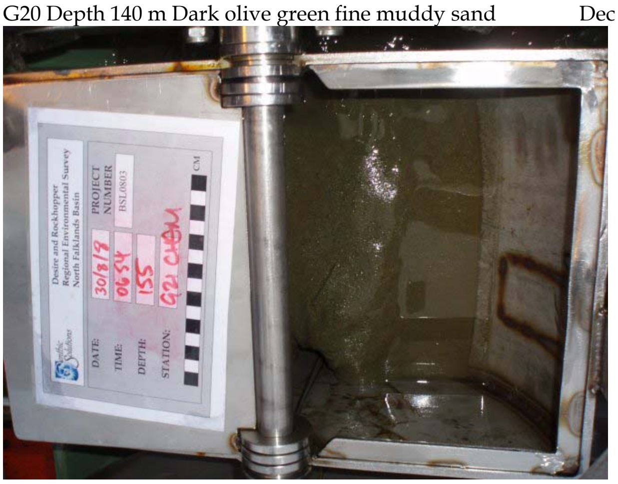
G17 Depth 152 m Dark olive fine silty sand with coarse sand. Dec Lat -50.49990 Dec long -59.00012

G18 Depth 152 m Dark olive fine sand with coarse sand and broken shell Dec Lat -50.66613 Dec long -58.99948

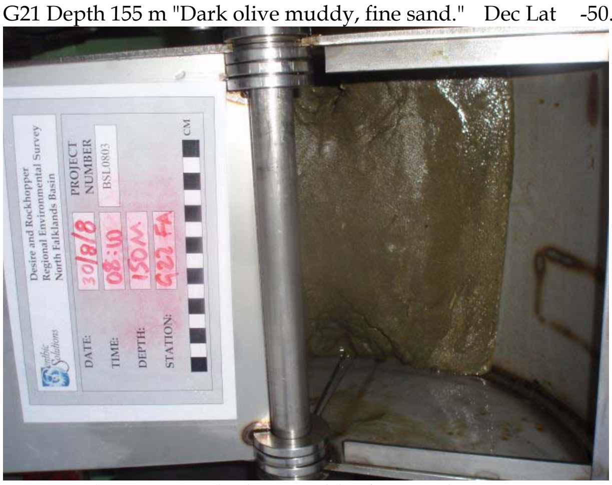
G19 Depth 145 m Fine muddy sand with coarse sand fraction Dec Lat -50.83325 Dec long -58.99985



G20 Depth 140 m Dark olive green fine muddy sand Dec Lat -51.00025 Dec long -58.99942

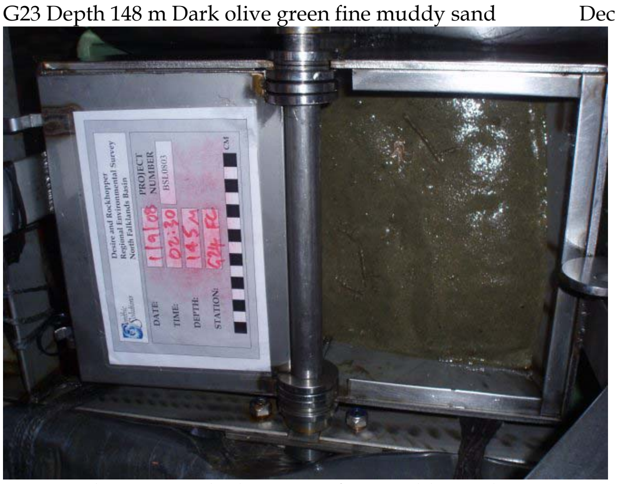


G21 Depth 155 m "Dark olive muddy, fine sand." Dec Lat -50.16653 Dec long -58.80038



G22 Depth 150 m "Dark olive muddy, fine sand." Dec Lat -50.33327 Dec long -58.79990

G23 Depth 148 m Dark olive green fine muddy sand Dec Lat -50.49993 Dec long -58.79990



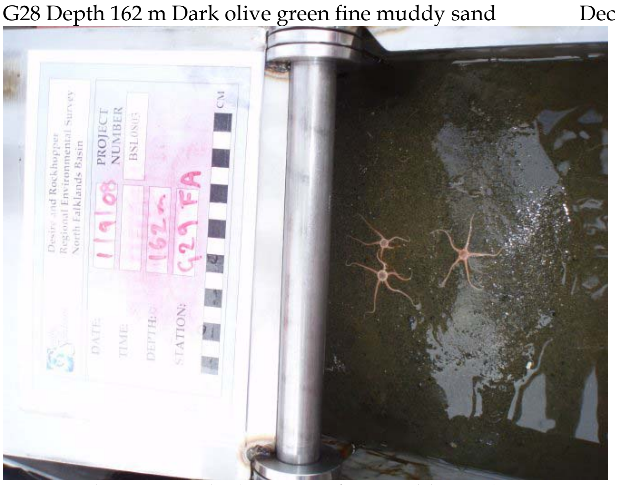
G24 Depth 145 m Dark olive green fine muddy sand Dec Lat -50.66672 Dec long -58.79987

G25 Depth 150 m Muddy fine sand with gravel and coarse sand fraction Dec Lat -50.83312 Dec long -58.79970

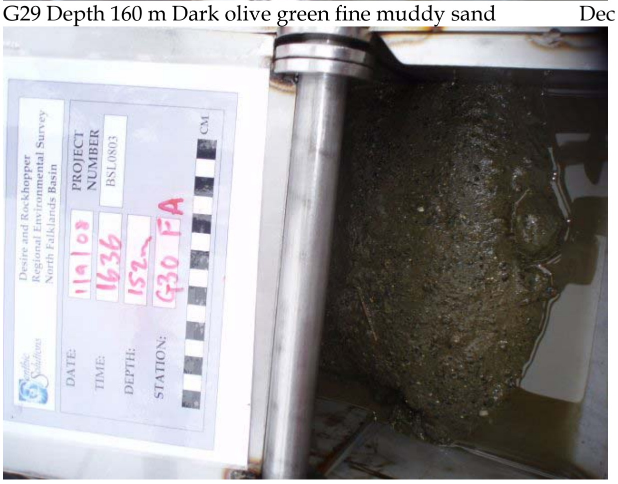
G26 Depth 140 m Olive grey. Fine sand Dec Lat -51.00035 Dec long -58.80005

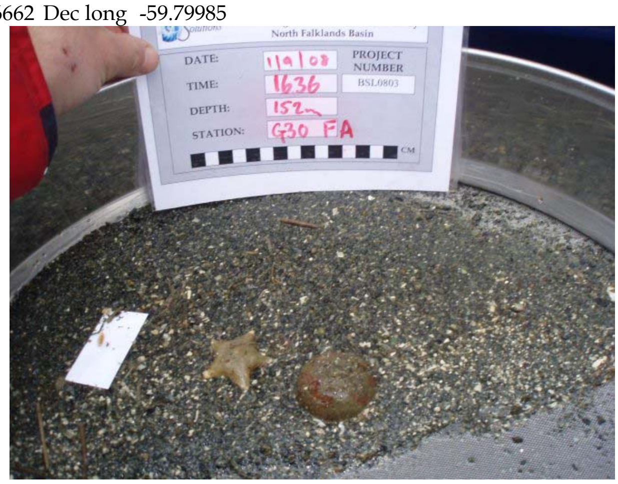
G27 Depth 147 m Muddy fine sand. Dec Lat -50.83338 Dec long -58.60002

G28 Depth 162 m Dark olive green fine muddy sand Dec Lat -50.16680 Dec long -59.59953



G29 Depth 160 m Dark olive green fine muddy sand Dec Lat -50.16662 Dec long -59.79985



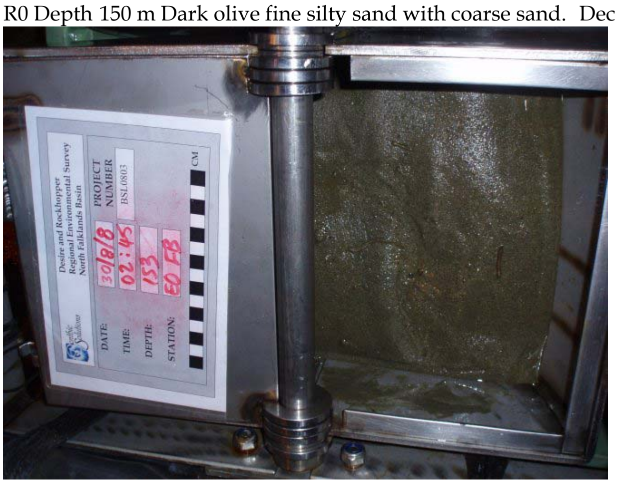


G30 Depth 152 m Dark olive green fine muddy sand Dec Lat -50.33292 Dec long -59.79983

G31 Depth 155 m Dark olive green fine muddy sand Dec Lat -50.49977 Dec long -59.60023

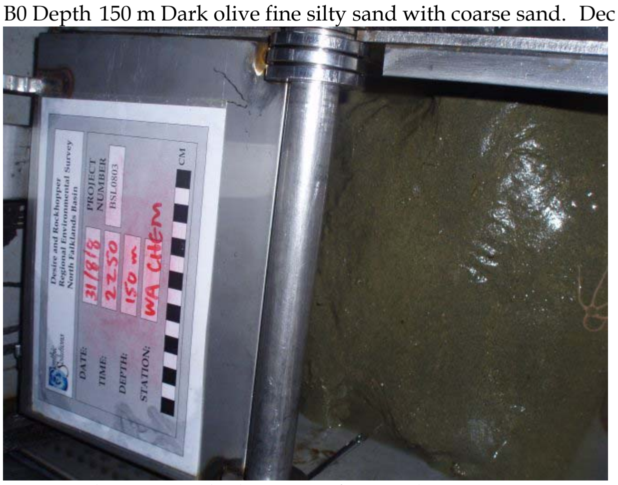
G32 Depth 158 m Dark olive green fine muddy sand Dec Lat -50.49988 Dec long -59.79997

R0 Depth 150 m Dark olive fine silty sand with coarse sand. Dec Lat -50.46955 Dec long -58.96342



E0 Depth 153 m Fine dark olive sand. Dec Lat -50.30483 Dec long -58.94377

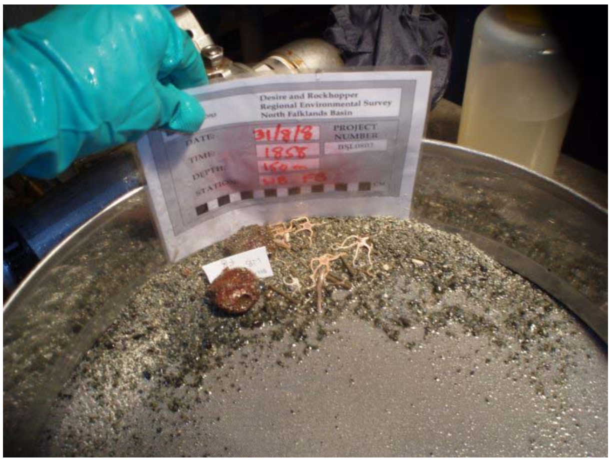
B0 Depth 150 m Dark olive fine silty sand with coarse sand. Dec Lat -50.67773 Dec long -59.11413



WA Depth 150 m Dark olive green fine sand Dec Lat -50.78775 Dec long -58.87800

A0 Depth 155 m Dark olive. Slightly muddy fine sand. Patchily reworked. Possible burrow Dec Lat -50.27447 Dec long -59.16440

D0 Depth 165 m Dark olive fine sand. Dec Lat -50.04692 Dec long -59.14703



WB Depth 150 m Dark olive green fine sand. Dec Lat -50.77547 Dec long -58.87125

APPENDIX VII: Pearson's Multivariate Correlations

Pearson Product Moment Correlation Coefficient	Mean (mm)	Median (mm)	Mean (phi)	Median (phi)	Sorting	Skewness	Kurtosis	% Fines	% Sands	% Gravel	-3.0	-2.0	-1.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0	>10.0	Moisture (%)	Total Organic Matter %	Total Organic Carbon	Total Carbonates	Proportion TOC (%)	TPH ($ng.g^{-1}$)	Total Alkanes	Carbon Preference Index	Pristane/ Phytane	P/B ratio	Alkane Proportion	Total PAHs	NPD	Total Arsenic	Total Barium	Total Cadmium	Total Chromium	Total Copper	Total Lead	Total Mercury	Total Nickel	Total Strontium	Total Vanadium	Total Zinc	Total Aluminium	Total Iron	Number of Species (S)	Number of Individuals (N)	Richness (Margalef)	Evenness (Pielou's Evenness)	Shannon-Wiener Diversity	Simpsons	MDS Axis 1	MDS Axis 2	Water Depth
Regional G1	42.4	62.3	4.56	4.01	1.70	0.48	0.97	50.5%	49.5%	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.74	10.43	17.13	20.14	14.03	6.43	3.90	4.15	5.14	4.93	4.00	2.76	2.84	1.21	1.15	30.3	2.69	0.6	0.47	22.3	6314	327.9	2.49	4.3	0.15	5.19%	16.3	12.55	4	315	0.7	30	8	9	0.02	7	239	45	39	57100	19900	69	361	11.55	0.8786	5.367	0.9675	1.46	-0.16	285
Regional G2	128.5	118.9	2.96	3.07	1.30	-0.02	1.14	19.0%	80.8%	0.2%	0.00	0.00	0.21	0.00	0.52	3.98	7.37	9.51	10.30	15.13	17.02	16.95	9.91	3.08	0.82	1.03	1.47	1.18	0.68	0.36	0.45	0.04	0.00	20.6	1.76	0.5	0.12	28.4	4275	179.3	1.29	NC	0.15	4.19%	ND	ND	4	291	0.5	28	5	6	0.01	6	205	36	27	53900	15100	70	583	10.84	0.8394	5.145	0.9491	-0.83	-0.07	168
Regional G3	133.3	144.4	2.91	2.79	1.28	0.26	1.30	17.5%	82.4%	0.1%	0.00	0.00	0.07	0.00	0.00	1.01	6.09	12.83	17.03	20.01	14.82	10.63	5.72	2.78	2.11	1.90	1.73	1.28	0.87	0.54	0.55	0.02	0.00	20.6	1.65	0.45	0.22	23.6	4296	203	1.55	NC	0.17	4.73%	ND	ND	3	228	0.4	27	4	6	0.01	5	167	27	22	39200	13700	56	286	9.724	0.8538	4.958	0.9523	0.61	-0.11	162
Regional G4	136.1	141.2	2.88	2.82	1.27	0.16	1.59	14.5%	85.0%	0.5%	0.00	0.00	0.47	2.15	1.33	1.30	3.17	9.15	16.25	22.92	17.68	11.07	4.24	1.66	1.84	2.00	1.71	1.16	0.77	0.53	0.58	0.02	0.00	21.4	1.72	0.47	0.46	27.3	5224	208.8	1.85	NC	0.12	4.00%	ND	ND	3	229	0.3	26	3	5	0.01	6	168	24	19	25700	12600	65	447	10.49	0.7674	4.622	0.9255	-0.03	-0.49	158
Regional G5	193.8	217.0	2.37	2.20	1.40	0.34	1.57	13.3%	85.9%	0.8%	0.00	0.00	0.81	0.00	0.75	6.16	13.50	19.89	18.86	15.30	7.54	3.89	2.21	1.76	1.90	1.82	1.74	1.44	1.09	0.70	0.63	0.02	0.00	19.3	1.17	0.38	0.52	32.5	4128	155.7	2.14	NC	0.16	3.77%	ND	ND	4	273	0.3	24	6	8	0.02	6	240	32	26	55800	15100	64	299	11.05	0.8512	5.107	0.9581	0.45	-0.36	155
Regional G6	140.0	162.7	2.84	2.62	1.40	0.38	1.52	17.2%	82.4%	0.4%	0.00	0.00	0.36	0.00	0.00	0.15	7.14	16.11	19.93	20.07	12.07	6.97	3.33	2.03	2.23	2.34	2.28	1.84	1.36	0.88	0.82	0.10	0.00	22.5	1.57	0.58	0.63	36.9	5124	218.6	2.08	NC	0.14	4.27%	ND	ND	4	284	0.3	26	6	6	0.02	6	275	31	26	55900	14600	61	337	10.31	0.8512	5.048	0.9546	0.61	0.8	154
Regional G7	123.2	135.1	3.02	2.89	1.42	0.28	1.45	19.2%	79.9%	0.9%	0.00	0.00	0.93	0.00	0.00	0.94	5.40	11.24	15.44	19.65	15.87	11.34	4.91	1.66	1.76	2.49	2.71	2.17	1.52	0.96	0.90	0.12	0.00	24.3	1.79	0.57	1.05	31.8	5840	252	2.73	NC	0.1	4.31%	1.06	1.06	2	237	0.5	20	4	6	0.01	6	240	25	21	39900	10700	56	420	9.106	0.8052	4.676	0.9389	0.05	1.6	145
Regional G8	99.1	101.2	3.33	3.31	1.10	0.17	1.55	21.2%	78.7%	0.1%	0.00	0.00	0.09	0.00	0.23	1.10	1.78	3.63	8.52	19.00	22.97	21.49	11.00	2.62	0.59	1.37	1.94	1.49	0.87	0.50	0.63	0.18	0.00	23.7	2.07	0.63	0.08	30.4	3830	185.7	1.47	NC	0.15	4.85%	ND	ND	4	298	0.5	28	8	7	0.02	6	200	32	26	54300	15000	63	715	9.434	0.7128	4.261	0.8865	-1.29	0.08	170
Regional G9	157.0	172.3	2.67	2.54	1.30	0.25	1.07	15.7%	84.1%	0.2%	0.00	0.00	0.19	0.00	0.00	4.28	11.10	16.47	15.87	15.04	11.37	9.97	6.37	2.79	1.42	1.22	1.34	1.09	0.71	0.41	0.37	0.00	0.00	18.3	1.66	0.36	0.14	21.7	3537	171.2	1.64	NC	0.14	4.84%	ND	ND	4	225	0.4	27	4	7	0.01	6	174	29	34	43500	11800	69	454	11.11	0.7264	4.438	0.8951	-0.76	-0.45	160
Regional G10	157.7	182.0	2.66	2.46	1.35	0.36	1.38	15.7%	84.0%	0.3%	0.0	0.0	0.3	0.0	0.0	2.0	10.2	18.3	19.6	17.7	10.0	6.0	3.6	2.4	2.2	2.0	1.8	1.4	1.0	0.7	0.6	0.0	0.0	20.4	1.45	0.31	0.31	21.4	4288	215.5	1.74	NC	0.13	5.03%	ND	ND	4	233	0.4	29	3	6	0.01	6	191	34	33	48000	12200	69	353	11.59	0.8525	5.207	0.9633	0.23	0.07	154
Regional G11	172.6	185.1	2.53	2.43	1.88	0.08	1.79	16.4%	78.1%	5.5%	0.00	0.00	5.53	2.12	2.21	4.04	7.95	13.51	15.78	16.31	10.22	5.92	2.77	1.87	2.31	2.44	2.30	1.78	1.27	0.82	0.76	0.09	0.00	20.7	1.65	0.5	0.6	30.3	3728	221.8	2.05	1.03	0.17	5.95%	ND	ND	4	236	0.4	26	3	5	0.01	7	209	30	34	42900	12300	78	532	12.27	0.8021	5.042	0.9417	0.26	-1.19	155
Regional G12	173.6	228.1	2.53	2.13	1.73	0.43	1.21	18.8%	79.3%	1.8%	0.00	0.00	1.82	0.00	1.17	9.09	15.86	17.95	13.15	9.64	6.57	5.92	3.96	2.11	1.92	2.30	2.59	2.22	1.62	1.01	0.93	0.16	0.00	21	1.7	0.44	0.72	25.9	3909	231.7	2.17	NC	0.12	5.93%	ND	ND	4	227	0.4	25	7	6	0.01	6	225	33	29	45100	16100	60	295	10.37	0.8481	5.009	0.9513	0.83	0.2	148
Regional G13	139.0	142.2	2.85	2.81	1.41	0.17	1.50	16.4%	82.7%	0.9%	0.00	0.00	0.93	0.13	1.24	3.17	5.90	10.43	14.66	19.69	16.18	11.26	4.50	1.34	1.55	2.25	2.34	1.77	1.19	0.74	0.71	0.02	0.00	25.5	1.88	0.48	0.8	25.5	4990	247.2	2.05	0.49	0.16	4.95%	ND	ND	3	251	0.4	20	3	6	0.03	6	226	24	25	41400	12400	50	317	8.509	0.7986	4.507	0.9296	0.2	1.15	148
Regional G14	113.0	112.8	3.15	3.15	1.10	0.13	1.45	17.3%	82.7%	0.0%	0.00	0.00	0.00	0.00	0.04	0.92	2.71	6.16	11.64	20.92	21.87	18.45	8.60	1.93	0.72	1.46	1.76	1.23	0.67	0.39	0.51	0.04	0.00	22.5	1.64	0.39	0.13	23.8	2508	198.4	1.45	0.5	0.15	7.91%	ND	ND	3	264	0.4	25	5	6	0.01	12	175	28	30	44700	14600	62	586	9.571	0.7385	4.397	0.9141	-0.86	-0.15	168
Regional G15	195.8	228.3	2.35	2.13	1.32	0.30	1.04	12.9%	86.0%	1.1%	0.00	0.00	1.07	0.00	0.72	8.23	16.17	19.31	14.47	11.03	8.22	7.88	5.24	2.30	1.22	1.09	1.14	0.88	0.54	0.30	0.20	0.00	0.00	18.8	1.22	0.35	0.29	28.7	3516	184.1	1.45	0.58	0.19	5.24%	ND	ND	2	177	0.1	20	4	6	0.01	5	135	20	5	21200	9650	64	405	10.49	0.7732	4.639	0.8965	-0.43	-0.55	155
Regional G16	199.3	238.7	2.33	2.07	1.52	0.36	1.20	14.6%	84.5%	0.9%	0.00	0.00	0.87	0.00	2.69	10.31	16.17	17.78	13.52	10.64	7.21	6.17	4.14	2.21	1.67	1.66	1.73	1.39	0.93	0.52	0.40	0.00	0.00	16.8	1.17	0.27	0.54	23.1	2554	154.2	1.67	0.78	0.16	6.04%	ND	ND	2	161	0.2	18	5	4	0.01	5	129	19	23	19200	8500	77	541	12.08	0.7208	4.517	0.8908	-0.23	-1.1	153
Regional G17	163.7	194.9	2.61	2.36	1.40	0.42	1.56	15.6%	84.2%	0.3%	0.00	0.00	0.25	0.00	0.00	2.19	11.20	19.99	20.81	17.40	8.41	4.17	2.42	2.04	2.23	2.13	2.04	1.71	1.31	0.86	0.78	0.07	0.00	19.3	1.47	0.33	0.37	22.4	2369	146.5	1.41	NC	0.19	6.18%	ND	ND	2	157	0.2	22	5	6	0.01	8	118	19	32	17400	10600	73	494	11.61	0.8107	5.018	0.9478	-0.24	0.03	152
Regional G18	154.2	185.7	2.70	2.43	1.74	0.31	1.41	18.6%	78.2%	3.2%	0.00	0.00	3.19	0.06	1.86	5.50	10.09	14.92	15.67	15.08	9.32	5.75	2.99	1.98	2.35	2.61	2.65	2.20	1.63	1.06	0.97	0.14	0.00	23	1.79	0.51	0.67	28.5	4518	265.6	1.66	0.29	0.13	5.88%	ND	ND	4	248	0.4	30	8	5	0.01	7	225	33	32	43800	17700	66	493	10.48	0.7775	4.699	0.9334	-0.36	0.24	152
Regional G19	151.0	149.7	2.73	2.74	1.75	0.14	1.19	19.6%	79.6%	0.9%	0.00	0.00	0.89	0.22	3.79	8.42	10.30	9.85	9.30	13.13	13.36	11.19	5.11	1.41	1.42	2.42	2.86	2.36	1.68	1.07	1.03	0.20	0.00	24.4	2.08	0.56	1.56	26.9	4878	240	2	1.58	0.14	4.92%	1.04	1.04	3	209	0.4	21	4	5	0.01	6	234	23	22	22500	10100	69	309	11.86	0.8539	5.216	0.9609	0.92	0.59	145
Regional G20	127.6	129.1	2.97	2.95	0.98	0.23	1.86	9.0%	90.6%	0.4%	0.0	0.0	0.4	0.5	0.5	0.3	0.5	4.7	15.4	29.9	25.4	13.4	2.0	0.0	0.6	1.9	1.8	1.1	0.6	0.5	0.5	0.0	0.0	28.5	1.85	0.48	1.37	25.9	5363	298	1.55	NC	0.31	5.56%	ND	ND	2	261	0.6	18	4	6	0.01	5	257	18	18	22600	10300	43	222	7.774	0.7993	4.337	0.9248	0.73	1.65	140
Regional G21	168.8	177.2	2.57	2.50	1.45	0.18	1.04	15.7%	84.0%	0.3%	0.00	0.00	0.33	0.00	1.07	7.76	13.36	14.97	11.91	12.10	11.60	11.22	6.62	2.31	1.06	1.28	1.52	1.20	0.76	0.44	0.49	0.02	0.00	19.1	1.36	0.29	1.53	21.3	3974	218.1	1.7	0.57	0.14	5.49%	ND	ND	2	156	0.3	20	6	4	<0.01	5	121	19	20	18800	10100	60	418	9.776	0.8173	4.828	0.9435	-0.59	-0.93	155
Regional G22	195.6	245.7	2.35	2.03	1.59	0.41	1.08	16.2%	83.2%	0.6%	0.00	0.00	0.64	0.00	2.60	11.35	17.50	17.23	11.02	8.33	7.38	7.78	5.23	2.26	1.39	1.57	1.83	1.55	1.07	0.64	0.60	0.04	0.00	17	1.2	0.34	1.4	28.3	3965	180.6	1.79	0.55	0.14	4.55%	ND	ND	2	129	0.3	26	4	4	<0.01	5	109	22	23	15100	7560	73	398	12.03	0.8048	4.981	0.9358	0.01	-0.71	150
Regional G23	181.0	222.9	2.47	2.17	1.53	0.41	1.29	16.1%	83.6%	0.3%	0.00	0.00	0.31	0.00	0.30	7.28	15.91	20.16	15.61	11.22	7.00	6.09	4.20	2.23	1.71	1.79	1.94	1.63	1.16	0.72	0.67	0.07	0.00	18.7	1.39	0.26	0.36	18.7	3025	206.1	1.72	NC	0.13	6.81%	ND	ND	2	142	0.3	23	7	5	<0.01	5	119	21	21	16600	10800	49	284	8.497	0.791	4.441	0.9051	0.08	-0.16	148
Regional G24	176.4	214.3	2.50	2.22	1.48	0.42	1.36	15.7%	84.1%	0.1%	0.00	0.00	0.15	0.00	0.00	5.48	14.77	20.80	17.26	12.68	7.38	5.75	3.68	1.97	1.70	1.89	2.04	1.70	1.21	0.75	0.70	0.07	0.00	16.5	1.53	0.32	0.54	20.9	3644	198.8	2.12	1.38	0.22	5.46%	ND	ND	7	120	0.6	28	8	4	<0.01	7	109	18	19	13000	10700	62	347	10.43	0.7906	4.707	0.9232	0.14	-0.24	145
Regional G25	143.0	135.3	2.81	2.89	2.13	-0.05	1.83	20.5%	71.1%	8.5%	0.00	0.00	8.45	1.39	2.14	3.22	4.44	7.00	10.36	15.98	15.04	11.52	4.88	1.39	1.59	2.53	2.86	2.36	1.74	1.16	1.17	0.38	0.39	26.8	1.17	0.64	0.93	54.7	8097	302.3	2.54	0.96	0.18	3.73%	ND	ND	4	247	0.5	31	5	5	0.01	7	215	31	34	33100	22000	91	864	13.31	0.7637	4.97	0.9319	-1.36	0.69	150
Regional G26	117.3	121.1	3.09	3.05	0.90	0.32	1.97	9.5%	90.5%	0.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	12.95	32.65	29.59	14.21	1.59	0.00	0.63	1.99	1.97	1.22	0.75	0.57	0.74	0.03	0.00	27	1.67	0.45	0.75	26.9	6579	214.4	2.23	1.07	0.21	3.26%	ND	ND	3	279	0.6	22	5	7	<0.01	7	218	22	19	23800	12400	53	392	8.708	0.803	4.6	0.9333	-0.3	0.65	140
Regional G27	146.4	151.2	2.77	2.73	1.29	0.22	1.46	13.9%	86.1%	0.0%	0.00	0.00	0.00	0.00	0.14	2.16	7.43	13.15	16.56	20.40	15.91	10.47	3.77	1.00	1.41	2.07	2.04	1.44	0.94	0.61	0.63	0.02	0.00	22.5	1.87	0.4	0.38	21.4	4184	166.9	1.83	0.81	0.21	3.99%	ND	ND	6	195	0.5	41	4	5	<0.01	6	145	32	19	25900	38200	64	331	10.86	0.8242	4.945	0.9516	0.19	0.91	147
Regional G28	144.5	147.8	2.79	2.76	1.34	0.16	1.27	16.3%	83.4%	0.4%	0.00	0.00	0.37	0.00	0.79	3.93	7.83	12.15	14.51	17.85	14.80	11.52	6.03	2.40	1.56	1.57	1.57	1.21	0.82	0.53	0.57	0.02	0.00	21.3	1.75	0.44	0.18	25.1	3859	206.8	1.65	0.64	0.16	5.36%	ND	ND	4	291	0.5	36	7	6	0.01	7	205	38	37	44300	18300	57	319	9.713	0.7837	4.571	0.9279	0.56	-0.2	162
Regional G29	142.1	159.3	2.82	2.65	1.59	0.25	1.17	20.6%	78.9%	0.6%	0.00	0.00	0.56	0.00	0.87	5.68	10.22	13.62	13.63	14.43	11.23	9.21	5.82	3.20	2.50	2.26	2.15	1.71	1.22	0.78	0.78	0.13	0.00	19.9	1.63	0.52	0.35	31.9	4278	184.1	1.62	1.03	0.18	4.30%	ND	ND	5	364	0.5	37	6	6	<0.01	8	266	45	62	48200	18300	63	241	11.3	0.8963	5.357	0.9684	1.61	-0.37	160
Regional G30	182.1	211.6	2.46	2.24	2.73	0.12	1.08	25.4%	63.8%	10.8%	0.0	0.0	10.8	6.2	5.3	6.2	7.4	9.1	9.0	8.9	6.4	5.2	4.0	3.1	3.2	3.2	3.2	2.7	2.1	1.5	1.5	0.5	0.4	20.2	2.17	0.76	0.97	35	7616	323.2	1.99	0.52	0.11	4.24%	1.28	1.28	6	347	0.5	36	8	6	0.01	10	267	45	41	42100	20900	77	330	13.11	0.8457	5.3	0.9519	0.61	-0.82	152
Regional G31	170.3	225.7	2.55	2.15	1.61	0.47	1.40	17.9%	82.1%	0.0%	0.00	0.00	0.00	0.00	0.25	7.09	15.83	20.94	16.94	11.54	5.50	4.00	3.32	2.57	2.45	2.34	2.31	1.89	1.36	0.84	0.75	0.09	0.00	21.7	1.53	0.7	0.2	45.8	5481	210.7	2.49	NC	0.11	3.85%	1.06	1.06	4	308	0.4	35	7	6	<0.01	8	260	39	32	46900	17100	51	198	9.455	0.8822	5.004	0.9601	1.25	-0.79	155
Regional G32	141.7	191.6	2.82	2.38	1.66	0.46	1.21	21.1%	78.8%	0.1%	0.00	0.00	0.08	0.00	0.05	4.88	12.48	18.39	16.94	13.48	7.35	5.29	4.07	3.08	2.92	2.71	2.60	2.13	1.55	0.98	0.91	0.14	0.00	21.3	1.22	0.28	0.44	23	5850	221.3	2.19	NC	0.11	3.78%	ND	ND	4	307	0.4	35	5	13	<0.01	8	293	42	34	54600	17300	71	361	11.89	0.832	5.117	0.9553	0.9	0.03	158
Alpha 0	277.5	286.5	1.85	1.80	1.17	0.19	1.54	7.3%	90.1%	2.6%	0.00	0.00	2.58	0.97	3.55	10.00	17.94	22.92	18.31	11.38	3.67	1.41	1.33	1.33	1.16	0.88	0.81	0.70	0.54	0.34	0.18	0.00	0.00	16.9	0.77	0.38	0.3	49.4	1227	82.8	1.95	NC	0.13	6.75%	ND	ND	3	216	0.3	24	8	5	<0.01	5	169	25	41	34200	11300	64	429	10.39	0.7381	4.428	0.9024	-0.51	-0.13	155
Barbara 0	296.1	308.4	1.76	1.70	1.04	0.31	1.73	7.7%	92.0%	0.3%	0.00	0.00	0.28	0.00	1.28	12.49	23.79	27.40	17.72	7.53	1.09	0.69	1.46	1.30	1.04	0.93	1.00	0.87	0.63	0.36	0.16	0.00	0.00	20	1.85	0.5	0.7	27	1333	93.8	2.07	1	0.21	7.04%	ND	ND	3	218	0.3	27	6	5	<0.01	6	192	33	27	34300	18000	58	392	9.546	0.717	4.2	0.8529	-0.92	0.54	150
Dawn 0	98.7	99.4	3.34	3.33	1.08	0.12	1.54	21.2%	78.8%	0.0%	0.00	0.00	0.00	0.00	0.14	1.30	2.20	3.57	7.72	18.10	23.15	22.59	11.90	2.79	0.39	1.21	1.84	1.38	0.72	0.38	0.52	0.10	0.00	25.5	2.25	0.59	0.18	26.2	4573	235.5	1.25	NC	0.14	5.15%	1	1	4	303	0.6	29	5	8	0.03	7	201	32	33	40200	15400	72	1099	10.14	0.6969	4.3	0.8933	-1.76	-0.04	165
Ernest 0	178.9	211.9	2.48	2.24	1.49	0.36	1.21	15.8%	84.0%	0.2%	0.00	0.00	0.18	0.00	0.55	7.43	15.08	18.62	14.94	11.98	8.22	7.16	4.81	2.43	1.66	1.63	1.75	1.45	1.00	0.59	0.51	0.01	0.00	17.8	1.33	0.23	0.59	17.3	3213	175.3	1.41	1.13	0.18	5.46%	ND	ND	2	169	0.3	21	6	4	<0.01	6	144	21	14	21200	8990	77	538	12.09	0.7981	5.002	0.9322	-0.56	-0.54	153
Ruth 0	194.5	237.0	2.36	2.08	1.48	0.41	1.43	14.7%	85.2%	0.1%	0.00	0.00	0.12	0.00	0.63	8.29	16.84	21.05	16.46	11.35	5.95	4.59	3.40	2.16	1.81	1.75	1.79	1.49	1.06	0.65	0.59	0.02	0.00	18.2	1.36	0.5	0.2	36.8	4485	224.7	1.59	0.41	0.15	5.01%	ND	ND	2	139	0.3	17	4	4	<0.01	4	128	17	15	17600	8040	74	447	11.96	0.7939	4.93	0.925	-0.23	-0.34	150
Weddell A	116.4	142.1	3.10	2.82	1.47	0.42	1.48	19.8%	80.2%	0.0%	0.00	0.00	0.00	0.00	0.00	0.04	4.76	12.69	17.95	21.13	14.70	8.97	3.55	1.61	2.17	2.77	2.87	2.38	1.81	1.24	1.19	0.18	0.00	26.7	2.64	0.49	0.28	18.6	3307	179.8	2.3	1.7	0.15	5.44%	ND	ND	3	239	0.4	26	6	5	0.01	6	213	28	22	16100	16000	59	457	9.47	0.8086	4.757	0.9446	-0.2	0.31	150
Weddell B	132.3	143.9	2.92	2.80	1.55	0.25	1.38	19.6%	79.1%	1.3%	0.00	0.00	1.34	0.00	0.15	3.36	7.77	12.17	14.10	16.93	13.99	10.61	5.00	1.80	1.73	2.38	2.64	2.19	1.59	1.04	1.02	0.20	0.00	23.9	1.82	0.54	0.49	29.7	3793	189.4	2.48	0.9	0.15	4.99%	ND	ND	8	222	0.5	46	5	5	0.01	6	193	36	32	36500	46900	68	481	10.85	0.8382	5.103	0.9562	-0.22	0.36	150
Mean (mm)		0.948	-0.946	-0.922				-0.626	0.518						0.452	0.823	0.867	0.824	0.480	-0.536	-0.771	-0.804	-0.635			-0.482	-0.584	-0.491	-0.414	-0.425	-0.560	-0.461		-0.712	-0.615				-0.523	-0.590		-0.539			-0.801	-0.799		-0.450	-0.625																			-0.463
Median (mm)			-0.903	-0.978		0.439		-0.540	0.500							0.780	0.935	0.911	0.482	-0.528	-0.870	-0.860	-0.656				-0.438				-0.458	-0.499	-0.479	-0.790	-0.835	-0.714			-0.548	-0.523		-0.626			-0.988	-0.988		-0.746	-0.649			-0.530			-0.516	-0.473		-0.516	-0.520								-0.411	-0.560
Mean (phi)				0.947				0.846	-0.805							-0.651	-0.788	-0.834	-0.636		0.647	0.785	0.762	0.648		0.587	0.725	0.700	0.667	0.685	0.775	0.831	0.818	0.785	0.868	0.639			0.559	0.618		0.847			0.989	0.989		0.659	0.683			0.639			0.430	0.609	0.416	0.500	0.635									0.853
Median (phi)								0.677	-0.634							-0.721	-0.896	-0.924	-0.599		0.819	0.885	0.748	0.472		0.408	0.548	0.498	0.451	0.471	0.584	0.646	0.631	0.801	0.860	0.695			0.548	0.552		0.747			0.994	0.994		0.732	0.676			0.588			0.479	0.535		0.516	0.566									0.703
Sorting									-0.446	0.629			0.629		0.567	0.499	0.426			-0.667	-0.629	-0.426			0.597	0.540	0.513	0.553	0.571	0.540	0.449										0.490																			0.447		0.554		0.547		0.425		
Skewness														-0.414			0.409	0.445		-0.408	-0.547	-0.452			0.561				0.457	0.455												0.456			0.912	0.912					0.483										-0.428					0.429		
Kurtosis								-0.446						0.499		-0.505	-0.439		0.493	0.767			-0.495	-0.607																					-0.840	-0.840																						
% Fines									-0.951									-0.524	-0.706			0.504	0.738	0.875	0.634	0.717	0.872	0.910	0.900	0.894	0.927	0.974	0.940	0.533	0.728	0.458			0.438	0.520	0.426	0.937			1.000	1.000			0.524	0.437	0.420	0.537				0.671	0.502	0.413	0.616					0.419				0.938
% Sands										-0.429								0.504	0.689			-0.445	-0.680	-0.846	-0.675	-0.759	-0.894	-0.926	-0.917	-0.909	-0.933	-0.966	-0.920	-0.531	-0.722	-0.488			-0.436	-0.548	-0.459	-0.920			-1.000	-1.000		-0.414	-0.510	-0.448		-0.503				-0.693	-0.539	-0.431	-0.633					-0.443				-0.911
% Gravel													1.000	0.545	0.479																														-0.999	-0.999																						
-3.0												1.000																																									#####															
-2.0																																																					#####															
-1.0														0.831	0.479																														-0.999	-0.999																						
0.0															0.677																														-0.501	-0.501					-0.444																	
0.5																0.536																					0.555								-0.501	-0.501						-0.510										0.438						
1.0																	0.902	0.572		-0.771	-0.696	-0.472												-0.599	-0.559	-0.531			-0.416			-0.462			-0.586	-0.587		-0.652	-0.481			-0.530			-0.466			-0.502	-0.452								-0.473	
1.5																		0.926		-0.736	-0.905	-0.736	-0.429											-0.808	-0.752	-0.716			-0.545	-0.532		-0.524			-0.880	-0.880		-0.763	-0.596			-0.494			-0.571			-0.490	-0.477								-0.463	-0.432
2.0																			0.691	-0.448	-0.897	-0.901	-0.655				-0.465				-0.458	-0.520	-0.494	-0.825	-0.809	-0.713			-0.532	-0.589		-0.642			-0.993	-0.993		-0.684	-0.629			-0.414			-0.487				-0.425									-0.549
2.5																						-0.742	-0.832	-0.577			-0.531	-0.549	-0.493	-0.474	-0.548	-0.676	-0.633	-0.443	-0.585							-0.793			-0.894	-0.894			-0.437																			-0.666
3.0																					0.826			-0.480										0.472											-0.725	-0.725		0.467			-0.444				0.437					-0.472		-0.533					0.574	
3.5																						0.859	0.461											0.712	0.612	0.587			0.409	0.414					0.758	0.758		0.635	0.536						0.432							-0.511					0.472	
4.0																							0.823									0.445	0.432	0.600	0.679	0.544						0.569			1.000	1.000		0.575	0.554			0.408																0.552
4.5																								0.694								0.501	0.468		0.465							0.635			0.728	0.726			0.409												0.464							0.700
5.0																									0.586		0.472	0.579	0.587	0.551	0.555	0.669	0.649									0.652	-0.421		0.936	0.937										0.539		0.446						0.426			-0.460	0.818
5.5																										0.802	0.673	0.719	0.772	0.769	0.691	0.600	0.545								0.423	0.561			0.669	0.673										0.511						0.451	0.616	0.689	0.593	0.671		0.431
6.0																											0.940	0.902	0.901	0.915	0.904	0.749	0.638	0.523	0.468	0.429			0.625	0.680	0.606	0.637			0.760	0.763									0.519	0.442							0.587	0.595	0.653	0.601		
6.5																												0.981	0.960	0.961	0.973	0.877	0.756	0.611	0.573	0.482			0.604	0.716	0.562	0.744			0.915	0.917			0.504						0.467	0.446							0.481	0.524	0.551	0.454		0.568
7.0																													0.992	0.985	0.977	0.917	0.807	0.508	0.526	0.437			0.513	0.640	0.549	0.786			0.933	0.935			0.431							0.466							0.469	0.547	0.511	0.440		0.643
7.5																														0.996	0.972	0.916	0.819	0.450	0.480				0.475	0.591	0.566	0.794			0.918	0.919										0.468							0.489	0.571	0.515	0.469		0.648
8.0																															0.982	0.920	0.832	0.485	0.492	0.411			0.497	0.602	0.578	0.797			0.910	0.911										0.462							0.497	0.564	0.526	0.481		0.645
9.0																																0.940	0.853	0.577	0.565	0.452			0.566	0.670	0.523	0.793			0.932	0.934			0.509						0.412	0.473							0.481	0.535	0.535	0.441		0.682
10.0																																	0.954	0.508	0.521	0.479			0.485	0.598	0.418	0.808			0.939	0.941			0.483							0.513								0.428				0.807
>10.0																																		0.437					0.465	0.559		0.778			0.940	0.942			0.423							0.422												0.838
Moisture (%)																																			0.666	0.562			0.558	0.605		0.541			0.820	0.818		0.515	0.641						0.566												0.626	
Total Organic Matter %																																				0.554				0.422		0.615			0.745	0.746		0.426	0.585																			0.420
Total Organic Carbon																																						0.561	0.563	0.498								0.637	0.481						0.615	0.508		0.419										
Total Carbonates																																																																				
Proportion TOC (%)																																													-0.525	-0.524																						
TPH ($ng.g^{-1}$)																																								0.830	0.428			-0.735				0.480	0.518						0.559										0.480			
Total Alkanes																																													0.642	0.646			0.533						0.453													
Carbon Preference Index																																										0.527													0.432													
Pristane/ Phytane																																													0.959	0.957			0.527			0.587											0.439			0.475		0.837
P/B ratio																																													0.575	0.572																						
Alkane Proportion																																													0.508	0.506																	-0.442	-0.454	-0.490			
Total PAHs																																														1.000			0.768		0.526	0.756				0.524	0.459	0.681	0.465					0.469		0.437		0.990
NPD																																																	0.768		0.530	0.755				0.527	0.462	0.682	0.468					0.472		0.438		0.990
Total Arsenic																																																	0.521	0.825						0.587	0.424		0.754									
Total Barium																																																	0.526	0.458		0.609	0.418	0.510	0.861	0.804	0.626	0.788										
Total Cadmium																																																		0.422					0.438	0.433												
Total Chromium																																																						0.409		0.773	0.557	0.415	0.837									
Total Copper																																																																				
Total Lead																																																					0.591		0.579	0.528		0.620										
Total Mercury																																																																				
Total Nickel																																																								0.507	0.514											
Total Strontium																																																								0.672	0.474	0.701								0.448		
Total Vanadium																																																									0.738	0.787	0.549					0.439				0.435
Total Zinc																																																										0.573										
Total Aluminium																																																																				0.415
Total Iron																																																																				
Number of Species (S)																																																													0.559	0.929						
Number of Individuals (N)																																																															-0.628			-0.808		
Richness (Margalef)																																																																0.629			-0.461	
Evenness (Pielou's Evenness)																																																																0.854	0.916	0.803		
Shannon-Wiener Diversity																																																																	0.873	0.582		
Simpsons																																																																		0.672		
MDS Axis 1																																																																				
MDS Axis 2																																																																				
Water Depth																																																																				

Key

Pearson correlation >0.408 (p=0.01, 99% significant)

Pearson correlation >0.507 (p=0.001, 99.9% significant)

APPENDIX VIII: Service Warranty

SERVICE WARRANTY

This report, with its associated works and services, has been designed solely to meet the requirements of the contract agreed with you, our client. If used in other circumstances, some or all of the results may not be valid and we can accept no liability for such use. Such circumstances include different or changed objectives, use by third parties, or changes to, for example, site conditions or legislation occurring after completion of the work. In case of doubt, please consult Benthic Solutions Limited.

APPENDIX IV ROCKHOPPER EXPLORATION HSE POLICY STATEMENT

ROCKHOPPER EXPLORATION

oil and gas exploration

HSE Policy Statement

Rockhopper Exploration plc is committed to effective corporate governance; foremost this includes preventing accidents to people and damage to the environment. Maintaining high standards of Health, Safety and Environmental (HSE) protection throughout its operations is an integral part of this and is achieved through:

- Strong leadership and clearly defined responsibilities and accountabilities for HSE at all levels of the organization, from the directors, managers to individuals;
- Selection of competent personnel responsible for both managing our activities and HSE performance;
- Compliance with regulatory and other applicable requirements, or where regulations do not exist, application of industry standards;
- Identifying, assessing and managing HSE risks and preventing pollution;
- Developing specific HSE targets and plans for each operational project;
- Selecting competent contractors and ensuring that they manage HSE in line with this HSE policy and supporting management systems;
- Preparing and testing response plans to ensure that any incident can be quickly and efficiently controlled, reported and investigated to prevent recurrence;
- Continual improvement of HSE performance through monitoring and regular reporting against targets and periodic audits;
- Periodic management reviews to identify and implement improvements to our HSE systems.

This policy is implemented through our HSE Management System which provides a systematic approach to HSE management designed to ensure compliance with the law and to achieve continuous improvement in performance. Our policy is used to guide all our activities and it will not be compromised by other business priorities.

Sam Moody
Managing Director

Date: 4th March 2009