SUNCOR ENERGY

E&P – EAST COAST

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REVISION SUMMARY FORM		
Current Revision	**Revision Description / Purpose**	**Pages Revised**
M3	Format of document revised to meet technical documentation requirements uder the East Coast procedures	All
M3	Section 5.3.2 – Updated to reflect changes to the water quality monitoring program as described in the "Revised Water Quality Monitoring Component of the Environmental Effects Monitoring Plan for the Terra Nova Field Report" which was submitted to the C-NLOPB and other regulatory agencies in accordance with Condition 32 of the Terra Nova Operations Authorization No. 23001-001.	23-26
M3	Section 5.4.4 – Inclusion that analytical laboratories should be accredited to ISO/IEC 17025:2005 by a recognized accrediting body, such as the Standards Council of Canada (SCC) or the Canadian Association for Laboratory Accreditation (CALA).	45
M3	Section 6.1 – Updated to state that copies of the report are submitted to C-NLOPB for further distribution to appropriate federal and provincial government agencies.	52
M3	Section 6.3 – Revised to reflect the regulatory review process for the EEM Program and related recommendations toimprove the overall program.	52
M3	Section 7.0 – Updated from Regional Monitoring to EEM Collaboration to reflect joint operator EEM activities conducted on the Grand Banks.	52

STANDARD DISTRIBUTION LIST			
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MANAGEMENT OF CHANGE FORM FOR PROCEDURAL DOCUMENTS			
1.	**Change Category / Description**	**Y**	**N**
a.	Is this a new document (not previously issued) or are major changes being made (examples of **major changes** include changes in process, responsibilities, requirements, frequency, type)?	X	
b.	If Major Change or New, provide a description of the purpose of the changes/document: *Section 5.3.2 – Updated to reflect changes to the water quality monitoring program as described in the "Revised Water Quality Monitoring Component of the Environmental Effects Monitoring Plan for the Terra Nova Field Report" which was submitted to the C-NLOPB and other regulatory agencies in accordance with Condition 32 of the Terra Nova Operations Authorization No. 23001-001.*		
c.	Are minor changes being made (examples of **minor changes** include clarifying intent, correction of terminology or format with no change to the process)?	X	
d.	Are the changes being made as a result of facility/design modifications? If yes provide the MOC notification number: _____		X
2.	**Assessment of Change**		
a.	Do the changes have the potential to introduce new hazards or impact Safety or Environmentally Critical processes?		X
b.	Do the changes impact regulatory requirements (e.g. documents under the License to Operate, documents in the East Coast Management System, SAP routines)?	X	
c.	If **YES to a or b**, have representatives of those responsible for processes impacted by the change reviewed and accepted the proposed changes? *Revised EEM Program was reviewed and approved internally by Suncor, as well as externally by the C-NLOPB, DFO and Env. Canada.*	X	
d.	Is a Risk Assessment (RA) required prior to issue? If yes provide reference: _____		X
3.	**Training Requirements**		
a.	Do the proposed changes require formal training, orientation, or roll-out?	X	
b.	If **YES**, provide details: *Revised requirements of EEM Program have been communicated to EEM contractors and have been incorporated into the Terra Nova EEM Survey Plans.*		
4.	**Communication Requirements**		
a.	Are all changes clearly identified / marked and summarized in the Revision Summary?	X	
b	Did the review/issue processes include all those impacted by the changes?	X	
c.	Is the Standard Distribution List up to date?	X	
Completed by:	Greg Janes (Name)	Team Lead – Env, ER and Security (Position)	

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1.0 PURPOSE

The purpose of this document is to provide a reference for the execution and evaluation of the Terra Nova EEM Program.

The original EEM design document was submitted to the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) in 1998 as a condition of project approval (Canada-Newfoundland Offshore Petroleum Board Decision 97.02) and the Program has been implemented in 2000, 2001, 2002, 2004, 2006, 2008 and 2010.

The Program consists of a sediment quality, water quality and commercial fish component. In March 2009, Suncor Energy (formerly Petro-Canada) revised the water quality component of its EEM Program in accordance to Condition 32 (Operations Authorization No. 23001-001). In addition to this, various improvements were made to the Program as warranted by results and/or in response to regulatory review of EEM reports. The revised water quality component and any additional updates to the EEM Program have been incorporated into this document.

1.1 EEM Background

In 1996, Suncor prepared an Environmental Impact Statement (EIS) as part of its Development Application to the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). Pursuant to the Memorandum of Understanding concerning the Environmental Assessment of the Terra Nova Development, a Panel was established to review the EIS (Petro-Canada 1996) and addendum (Petro-Canada 1997). In both the EIS and addendum, and at the Panel hearings, Suncor on behalf of the Terra Nova Project Proponents made a commitment to design and implement an environmental effects monitoring (EEM) program.

The Panel, guided by the scoping sessions and full public hearings (April 1997), issued a document containing recommendations with respect to the Development in August 1997. Based on that set of recommendations, the C-NLOPB supported the plan to develop the Terra Nova field, subject to conditions, in December 1997 (C-NOPB Decision 97.02). The timing of the EEM program design submission was set out in Condition 23 of the C-NOPB Decision 97.02, which required that the proponent submit its environmental effects monitoring program respecting the drilling and production phases of the Terra Nova Project prior to commencing drilling operations".

2.0 SCOPE

This document describes the present EEM Program at Terra Nova. Text on general EEM design included in the original design document is not included in this document. Text from the original document has been rearranged to describe:

- the Terra Nova field and expected environmental effects;
- monitoring variables;
- field collections;
- laboratory analysis;
- data analysis;
- and reporting.

Quality assurance/control (QA/QC) protocols, originally grouped in one section, have been inserted in each appropriate section (e.g., QA/QC for field collections, QA/QC for laboratory analysis, etc.).

The EEM Program is described in full in Section 5. Section 5.2.1 summarizes the information sources used during the design of the Program. Discussions on potential monitoring variables and potential survey designs originally provided in the main body of the design document have been moved to Appendices. Monitoring variables for the existing Program are listed in Section 5.2.2 and the accepted design is summarized in Section 5.2.3. Section 5.2.4 lists monitoring hypotheses established during the initial design of the Program.

Sections 5.3 and 5.4 summarize sample collection methods and laboratory analyses, respectively, and should contain sufficient detail for the Program to be replicated from the information provided. Additional information on collection methods and laboratory processing has been added because some procedures were not yet finalized during the original design phase. Sections 5.3.2 and 5.4.2, dealing with water sample collections and laboratory analyses, respectively, have been updated based on Suncor Energy's revised water quality monitoring design (Suncor Energy[1] 2009a).

Section 5.5 provides guidelines for data management and analysis. Within that Section, Section 5.5.2.2 has been updated to describe guidelines for analysis for the revised Water Quality Component (Suncor Energy 2009a).

[1] For simplicity, historical submissions under the name Petro-Canada will be referenced as Suncor Energy.

3.0 ABBREVIATIONS AND ACRONYMS

ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BA	Before-After
BACI	Before-After Control-Impact
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
C-NLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CTD	Conductivity, Temperature, Depth
CVAAS	Cold Vapour Atomic Absorption Spectroscopy
DFO	Fisheries and Oceans Canada
EEM	Environmental Effects Monitoring
EIS	Environmental Impact Statement
FEZ	Fisheries Exclusion Zone
FPSO	Floating Production, Storage and Offloading Installation
GC/FID	Gas Chromatography – Flame Ionization Detection
GC/MIS	Gas Chromatography-Mass Spectroscopy
ICP/MS	Inductively Coupled Plasma Mass Spectroscopy
MFO	Mixed Function Oxygenase
PAH	Polyaromatic Hydrocarbon
PC	Principal Component
PCA	Principal Component Analysis
QA/QC	Quality Assurance/Quality Control
TEH	Total Extractable Hydrocarbon
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Sediment
VPH	Volatile Petroleum Hydrocarbon

4.0 TERRA NOVA FIELD DESCRIPTION

4.1 Project Setting and Field Layout

The Terra Nova Oil Field is situated on the Grand Banks, approximately 350 km east-southeast of St. John's, Newfoundland. Suncor Energy is the operator of the Development on behalf of the owners (Suncor Energy Inc., ExxonMobil Canada Properties, Husky Oil Operations Ltd., Statoil Canada Ltd., Murphy Oil Company Ltd., Mosbacher Operating Ltd. and Chevron Canada Ltd.).

The oil field is being developed using a floating production, storage and offloading (FPSO) facility and drilling operations have been conducted using a semi-submersible drilling rig. Wells were drilled through seven subsea templates, located in five glory holes to protect them from iceberg impact. Flowlines connected to flexible risers link the subsea installations to the FPSO.

Discharges at Terra Nova include drill cuttings, completion fluid, produced water, bilge water, hydrostatic testing fluid, deck drainage, chlorinated seawater and

treated sewage. Drill cuttings and completion fluid are discharged exclusively from drilling rigs, near drill centres. Produced water is discharged exclusively from the FPSO. All discharges, including applicable compliance limits are discussed in detail in the Environmental Protection Plan - Production (TN-IM-EV03-X00-011) and the Environmental Protection Plan - Drilling, Completions and Interventions (TN-IM-EV03-X00-009).

4.2 Environmental Effects

Suncor Energy assessed the potential environmental effects of operations at Terra Nova in an Environmental Impact Statement (EIS) and in an addendum document. A summary table of effects predictions is provided in Appendix A, with full details in Suncor Energy (1996, 1997). Only EIS predictions on fish, fish habitat and fisheries are relevant to the EEM Program described in this document. Assessment of effects on seabirds and marine mammals were excluded from the EEM Program during the initial selection of monitoring variables (see Section 5.2.2).

Suncor Energy monitors the environmental effects of its operations on other valued ecosystem components (e.g., seabirds, marine mammals, etc.) through other programs. Protocols to design an oil spill monitoring EEM program in the event of a major oil spill have been developed elsewhere.

4.3 Spatial Extent of Contamination

In general, development operations at Terra Nova were expected to have the greatest effects on near-field sediment physical and chemical characteristics, (components of fish habitat) through release of drill fluids and cuttings; while regular operations were expected to have the greatest effect on physical and chemical characteristics of water, through release of produced water. The zone of influence (i.e., the zone where project related physical and chemical alternation might occur) for these discharges was not expected to extend beyond approximately 15 km from source for drill cuttings, with the heaviest deposition occurring in the immediate vicinity of drill centres (Figure 4-1). The zone of influence for produced water was not expected to extend beyond approximately 5 km from the FPSO (Figure 4-2). Except for deck drainage and hydrostatic testing fluid, other waste streams were expected to have negligible effects on sediment and water. Deck drainage and hydrostatic testing fluid were expected to have more highly localized effects than drill cuttings and produced water.

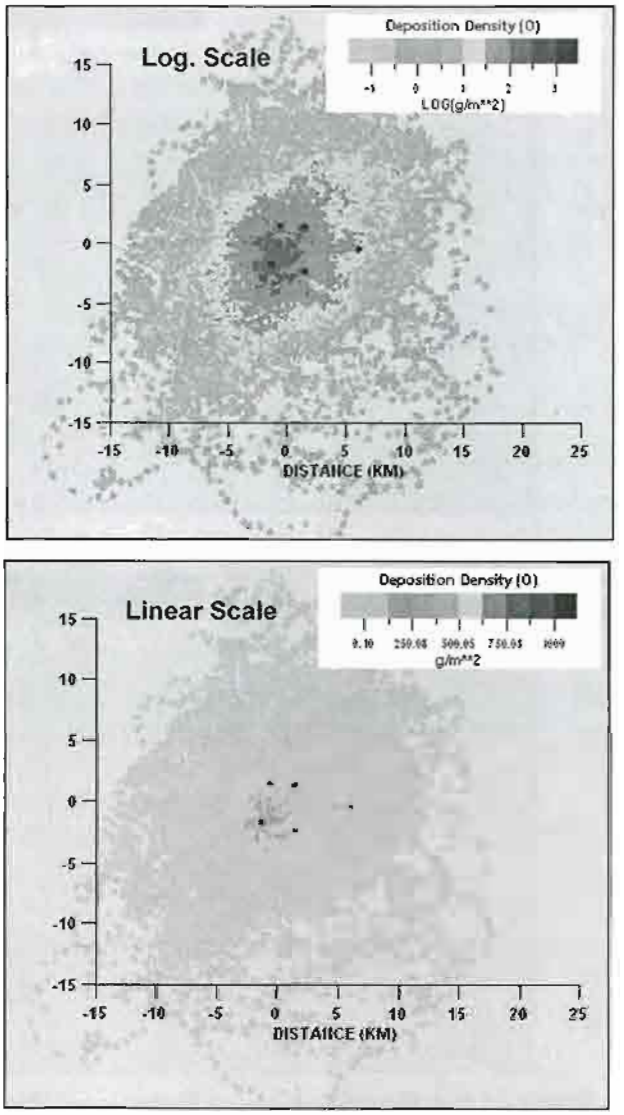

Figure 4-1 Zone of Influence for Drill Cuttings After Completion of Drilling (Seaconsult 1998)

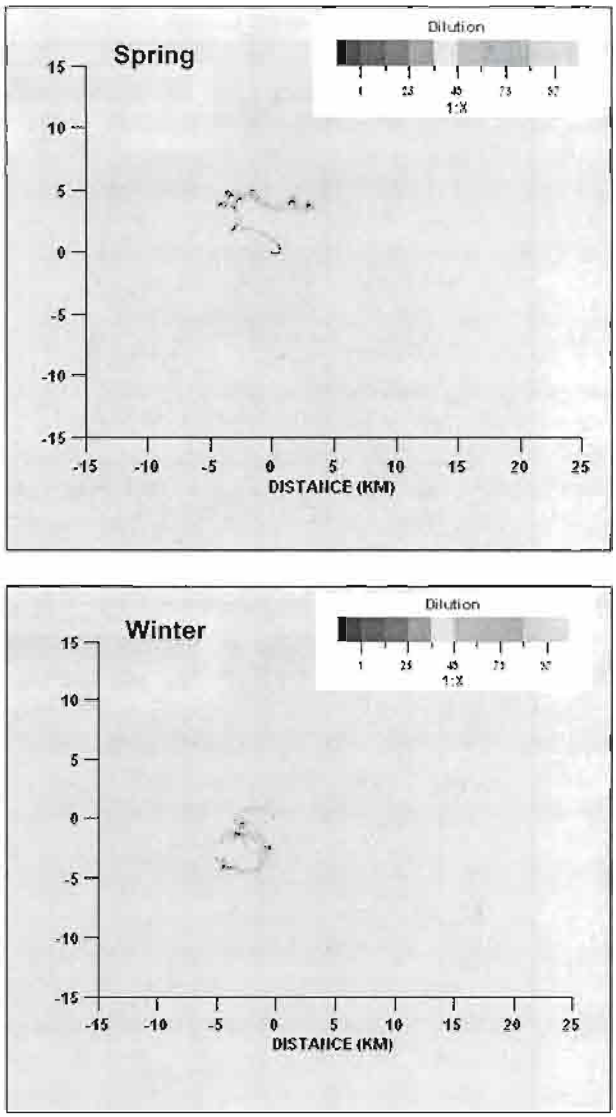

Figure 4-2 Snap-Shot of the Distribution of Produced Water (Seaconsult 1998)

4.4 Summary of Expected Biological Effects

Effects of drill cuttings on benthic invertebrates, on which some fish feed, were expected to be mild a few hundred metres away from drill centres, but fairly large in the immediate vicinity of drill centres (Note: see Suncor Energy 1996 for details on effects assessment methodology and effects ratings). However, direct effects to fish populations, rather than benthic invertebrates, as a result of drill cuttings discharge were expected to be unlikely. Effects resulting from contaminant uptake by individual fish, including taint, were expected to be negligible.

Effects of produced water on plankton and physical and chemical characteristics of water were expected to be localized near the point of discharge. Direct effects on adult fish were expected to be negligible.

Deck drainage and hydrostatic testing fluid were expected to have minor, highly localized, short-term effects on physical and chemical characteristics of water (Appendix A).

5.0 ENVIRONMENTAL EFFECTS MONITORING

5.1 EEM Program Objectives

EEM programs are designed to assess the status of the marine environment and detect changes in that status related to project activities.

Specifically, the primary objectives of the Terra Nova EEM Program are to:

- assess the spatial extent and magnitude of project-related contamination; and
- verify effects predictions made in the EIS (Suncor Energy 1996).

Secondary, and related, objectives are to:

- assess the effectiveness of the implemented mitigation measures;
- provide an early warning of changes in the environment; and
- improve understanding of environmental cause-and-effect.

5.2 EEM Program Design

5.2.1 Information Sources

In addition to an examination of the literature on EEM programs, the original design of the Terra Nova EEM Program involved review of baseline data collected prior development and stakeholder consultation and workshops.

5.2.1.1 Baseline Program

Suncor Energy undertook a Baseline Program (Suncor Energy 1998) in the fall of 1997. The purpose of the Baseline Program was to:

- evaluate candidate monitoring variables;
- evaluate the sample spatial layout of stations or collection sites;
- provide a pre-development description of selected physical, chemical and biological variables; and
- evaluate proposed approaches to data analysis.

Suncor Energy held two workshops during the development of the Baseline Program for Terra Nova. The first workshop, held June 13, 1997, was dedicated to a discussion on benthic community analysis as a candidate variable. Participants are listed in Table 5-1 and were selected to provide a thorough representation of scientific expertise.

Table 5-1 List of Participant in the Workshop on Benthic Community Sampling

Participant	Affiliation
Kathy Penney	Stantec Consulting Ltd (then Jacques Whitford Environment Limted)
Sandra Whiteway	Stantec
Dr. Robin Anderson	Fisheries and Oceans Canada
Dave Burley	Canada-Newfoundland and Labrador Offshore Petroleum Board
Jim Dempsey	Cormorant Ltd (Suncor's representative for the baseline sampling program)
Kim Coady, DOE	Newfoundland Department of Environment
Dr. Jerry Paine	Fisheries and Oceans Canada
Dr. David Schneider	Memorial University of Newfoundland
Dr. Scott Macknight	Land and Sea
Wishart Robson	Suncor
Dr. Peter Cranford	Fisheries and Oceans Canada
Dr. Roger Green	Western University
Denis Thompson	LGL Ltd
Roy Parker, DOE	Newfoundland Department of Environment
Dr. Lou Massie	Expert Private Consultant (London, England)
Prof. Cliff Johnston	IOE group, University of London
Dr Paul Kingston	IOE group, University of London
Dr. Brian Roddy	IOE group, University of London

The second workshop was held on July 9, 1997 and focused on more general aspects of the Baseline Program. Participants and affiliations are listed in Table 5-2.

Table 5-2 List of Participants in the Workshop on Baseline Sampling

Participant	Affiliation
Kathy Penney	Stantec
Sandra Whiteway	Stantec
David Pinsent	Stantec
Sue Belford	Stantec
Dr. Michael Paine	Paine, Ledge and Associates
Dr. David Schneider	Memorial University of Newfoundland
Dr. Laurie Davidson	Seaconsult Marine Research Ltd.
Dr. Lou Massie	Expert private consultant (London, England)
Prof. Cliff Johnson	IOE group, University of London

The Baseline Program involved sampling indicators of sediment quality and water quality, representative commercial fish species and benthic communities. The sampling program for the sediment survey was designed to provide maximum coverage of the Terra Nova field. Sediment samples were analyzed for chemical and physical variables, toxicity and benthic community structure. Water samples were collected at randomly selected sites from the spatial layout of sediment stations and from two control stations. Chemical variables from water samples were examined. Conductivity, Temperature, Depth (CTD) profiles were performed at water sampling stations.

The commercial fish survey focused on substrate types suitable for Iceland scallop habitat. Both Iceland scallop (scallop) and American plaice (plaice) were collected near Terra Nova and at one Reference Area. Scallop were analyzed for chemical variables (body burden) and taint. Plaice were analyzed for fish health indicators including mixed function oxygenase (MFO), enzyme activity and gill and liver histopathology.

Epibenthic sampling was attempted twice during the Baseline Program to address a recommendation from Fisheries and Oceans Canada (DFO) that epibenthos be characterized. DFO was contracted to conduct the sampling. However, despite best efforts, the sampling equipment failed to perform as expected.

Additional details on monitoring variables for the Baseline Program, sample collection, processing and results are provided in the Terra Nova Baseline Characterization Data Report (Suncor Energy 1998).

5.2.1.2 Stakeholder Consultation and Workshops

Consultation with stakeholders and workshops were conducted to obtain input on the proposed EEM Program.

Government Consultation

Suncor and members of the Stantec team met with a number of federal government agencies. Meetings were held with DFO scientific and management staff on August 11, 21 and 24, 1998. A meeting with Environment Canada was held on August 25, 1998. A report on the results of these consultations is provided in the Stakeholder Consultation Report, provided in Appendix B.

In-house Workshop

Suncor held an in-house workshop in St. John's on September 8, 1998. Discussions at the workshop focused on evaluation of candidate monitoring variables in light of regional and international offshore oil EEM work, and modelling results for discharges of drill cuttings and produced water. Scientists with regional and international expertise in offshore oil EEM programs, the proponent and the regulator (C-NLOPB) attended the workshop (Table 5-3).

Table 5-3 Participants in In-House Workshop on EEM

Participants	Affiliation
Urban Williams	Suncor
Mona Rossiter	Suncor
Kathy Penney	Stantec
Mary Murdoch	Stantec
Sandra Whiteway	Stantec
Ellen Tracy	Stantec
Judith Bobbitt	Oceans Ltd
Dr. David Schneider	Memorial University of Newfoundland
Dr. Don Hodgins	Seaconsult Marine Research
Dr. Lou Massey	Expert private consultant
Dr. Michael Paine	Paine, Ledge and Associates
David Burley	Canada-Newfoundland and Labrador Offshore Petroleum Board

Public Information Session

A public information session was held in St. John's at the Fluvarium on September 22, 1998, from 5:00 p.m. to 9:00 p.m. Prior notification was given via advertisements in *The Evening Telegram* and *The Clarenville Pacquet.* In addition, letters of invitation were sent to federal government agencies (DFO and Environment Canada), provincial government (Department of Environment and Labour), the C-NLOPB, other Grand Banks operators and to particular stakeholder groups who made presentations to the Terra Nova Development Environmental Assessment Panel. The purpose of the session was to inform the general public about the proposed EEM Program and related activities and to solicit input into the design of the Program.

Terra Nova representatives present included Greg Lever, Urban Williams and Mona Rossiter. Members of the consultant team present were Kathy Penney and Mary Murdoch (Stantec), David Schneider (Memorial University of Newfoundland) and Judith Bobbitt (Oceans Ltd).

The session featured a series of displays (Appendix B), an information package and a comment sheet. The displays and pamphlet were used to provide information about the project and input was obtained through the use of a comment sheet and discussions between Terra Nova representatives, the consultant team and session attendees. Two comment sheets were completed and returned during the session and two written submissions were received post-session.

Issues and concerns raised at the meeting are discussed in the Stakeholder Consultation Report (Appendix B).

Suncor Energy's responses to issues raised during the public consultation session are provided as Appendices C and D.

5.2.2 Monitoring Variables

The full discussion on evaluation of monitoring variables from the original design document is provided as Appendix E.

Potential monitoring variables for the EEM Program were evaluated based on the following criteria:

- predicted impacts, as provided in EIS;
- sensitivity to project discharges or project activity;
- duration of exposure;
- valued environmental components identified in the EIS, including marine resources of concern or surrogate variables;
- frequency and scale of measurement required;
- proven utility in previous monitoring programs;
- feasibility of measurement; and
- information return relative to cost.

Based on the evaluation of monitoring variables, the Terra Nova EEM Program is currently divided into three components dealing with effects on Sediment Quality, Water Quality and Commercial Fish species (Figure 5-1).

Assessment of Sediment Quality includes measurement of alterations in chemical and physical characteristics, measurement of sediment toxicity and

assessment of benthic community structure. Among chemical characteristics, ammonia, sulphur and sulphides were measured starting in 2001.

Assessment of Water Quality includes measurement of chemical characteristics, physical characteristics and chlorophyll concentration.

Assessment of effects on Commercial Fish species includes measurement of chemical body burden and taint for scallop and plaice, and measurement of various health indices for plaice. Analysis of scallop and plaice morphometric and life history characteristics was added to the EEM Program in 2001 to aid in interpretation of results for the other monitoring variables in the Commercial Fish Component.

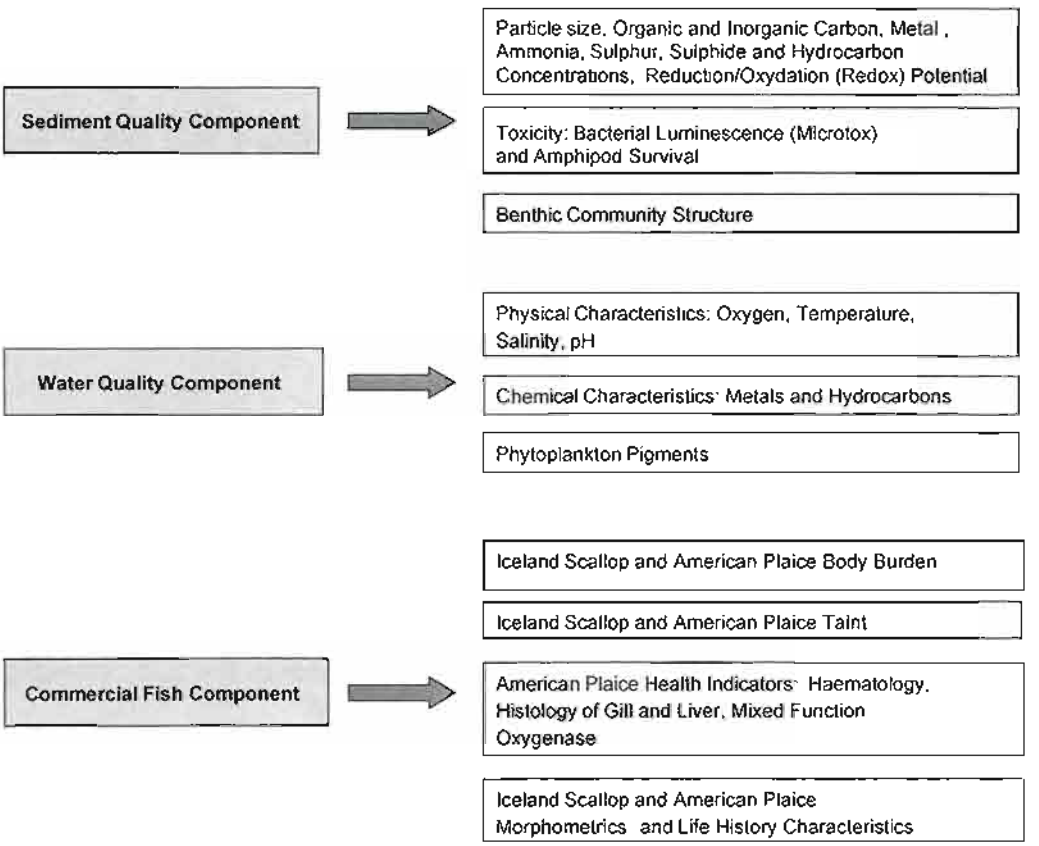

Figure 5-1 EEM Components and Monitoring Variables

5.2.3 Survey Design

Table 5-4 summarizes the designs and main statistical models for data analysis currently used for each component of the Terra Nova EEM Program. The original discussion on possible survey designs, statistical models that could be used for analysis and power analysis on selected models is provided in Appendix F.

Table 5-4 Spatial Designs and Main Statistical Models for Terra Nova EEM Monitoring Components

Component	Design	Basic Statistical Model	
		Single Year	Multiple Years
Sediment quality	Gradient	Regression of *y* on distance from source (X)	Repeated-measures regression comparing regressions of *y* on distance among years
Water quality	Control-Impact	ANCOVA comparing Areas, with depth as a covariate	Qualitative comparison
Commercial fish	Control-Impact	*t*-test comparing areas	ANOVA with area and year as factors, when applicable. Otherwise, qualitative comparison

Note: Appendix F describes repeated measures regression as repeated measures ANCOVA. Both are correct and equivalent. Repeated measures regression is the terminology used in EEM reports. Therefore, that terminology is used here.

Sediment is currently sampled at discrete stations located at varying distances from the centre of the development. Water and commercial fish are sampled near the centre of the development (Study Area) and in one or two more distant Reference Area(s) (see Section 5.3 for details on the spatial layout of stations or the distribution of Sampling Areas). The sediment survey design is commonly referred to as a gradient design, while the water and commercial fish survey designs are control-impact designs. Statistical models used to analyze data collected following these designs are described in Section 5.5.2, with details in Appendix F.

5.2.4 Monitoring Hypotheses

Monitoring or null (H_0) hypotheses related to the monitoring variables listed in Section 5.2.2 were developed as part of EEM design. Monitoring hypotheses differ from EIS effects predictions. They are an analysis and reporting construct established to aid in the assessment of effects on the environment. Monitoring hypotheses will always state "no effects" even if effects have been predicted as part of the EIS. Monitoring hypotheses were grouped by EEM component as indicated in Table 5-5.

Table 5-5 Monitoring Hypotheses

Sediment Quality
H_0: There will be no attenuation of physical or chemical alterations or biological effects with distance from project discharge points.
Water Quality
H_0: Project discharges will not result in changes to physical and chemical characteristics of the water column, or to phytoplankton densities near discharge points in the Terra Nova Project area.
Commercial Fish
H_0: Project discharges will not result in taint of fish resources within the Terra Nova Project area, as measured during taste panels. H_0: Project discharges will not result in adverse effects to fish health within the Terra Nova Project area, as measured using histopathology, haematology and MFO induction.

Note: No hypotheses were developed for fish body burden and morphometric and life history characteristics as there were considered to be a supporting variable, providing information to aid in the interpretation of results from other monitoring variables, such as taint or health indicators.

5.3 Sample Collection

5.3.1 Sediment Quality Component

5.3.1.1 Survey Platform and Timing

Sediment sampling is conducted from an offshore supply vessel. Sampling was conducted every year in late summer or early autumn for the first three years (2000, 2001 and 2002). The Program is now executed every two years, again in late summer or early autumn. Sampling was originally scheduled for late summer/early autumn to avoid inclement weather later in the season.

5.3.1.2 Sampling Locations

Sediment is sampled at discrete stations located at varying distances from drill centres. An offshore survey company aids in precise station location (within 50 m) during the Program.

The distribution of sampling stations for the EEM Program underwent some minor modifications from baseline sampling sites to accommodate changes in drill centre location (proposed versus actual) and a Fisheries Exclusion Zone (FEZ) around construction activities. In 2002, the names of stations were also changed to a simpler format. Sampling locations for the Baseline and EEM Programs are provided in Figures 5-2 and 5-3, respectively. Geographic coordinates along with baseline station names and EEM station names are provided in Table 5-6. Sampling was reestablished at selected stations inside the FEZ in 2002. Drilling or construction activity prevented sampling at some stations in some EEM years (see Figure 5-3 for details).

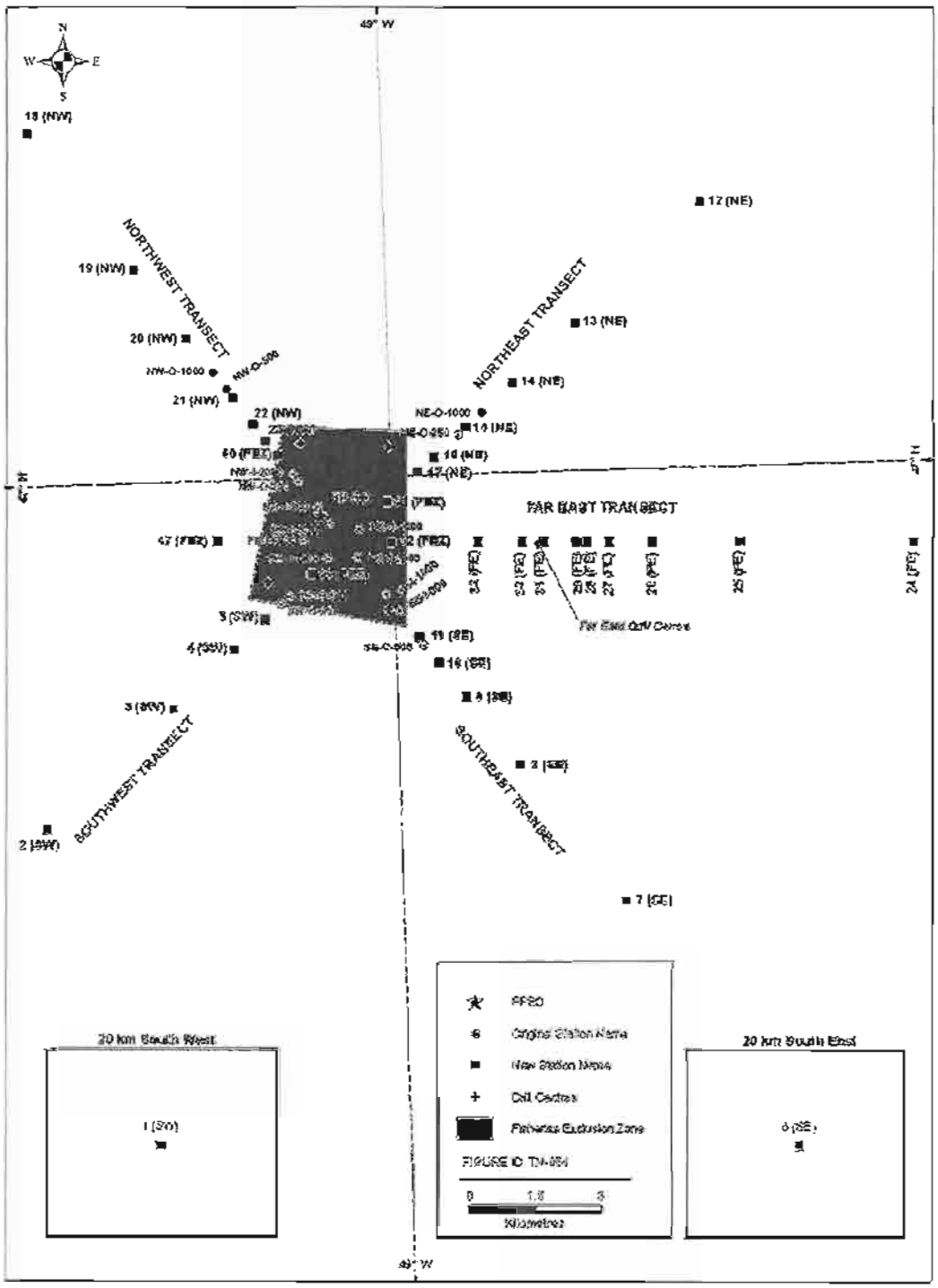

Figure 5-2 Terra Nova Baseline Sediment Stations

Note: Those stations no longer sampled as part of the EEM Program are listed with the original station name in the above Figure.

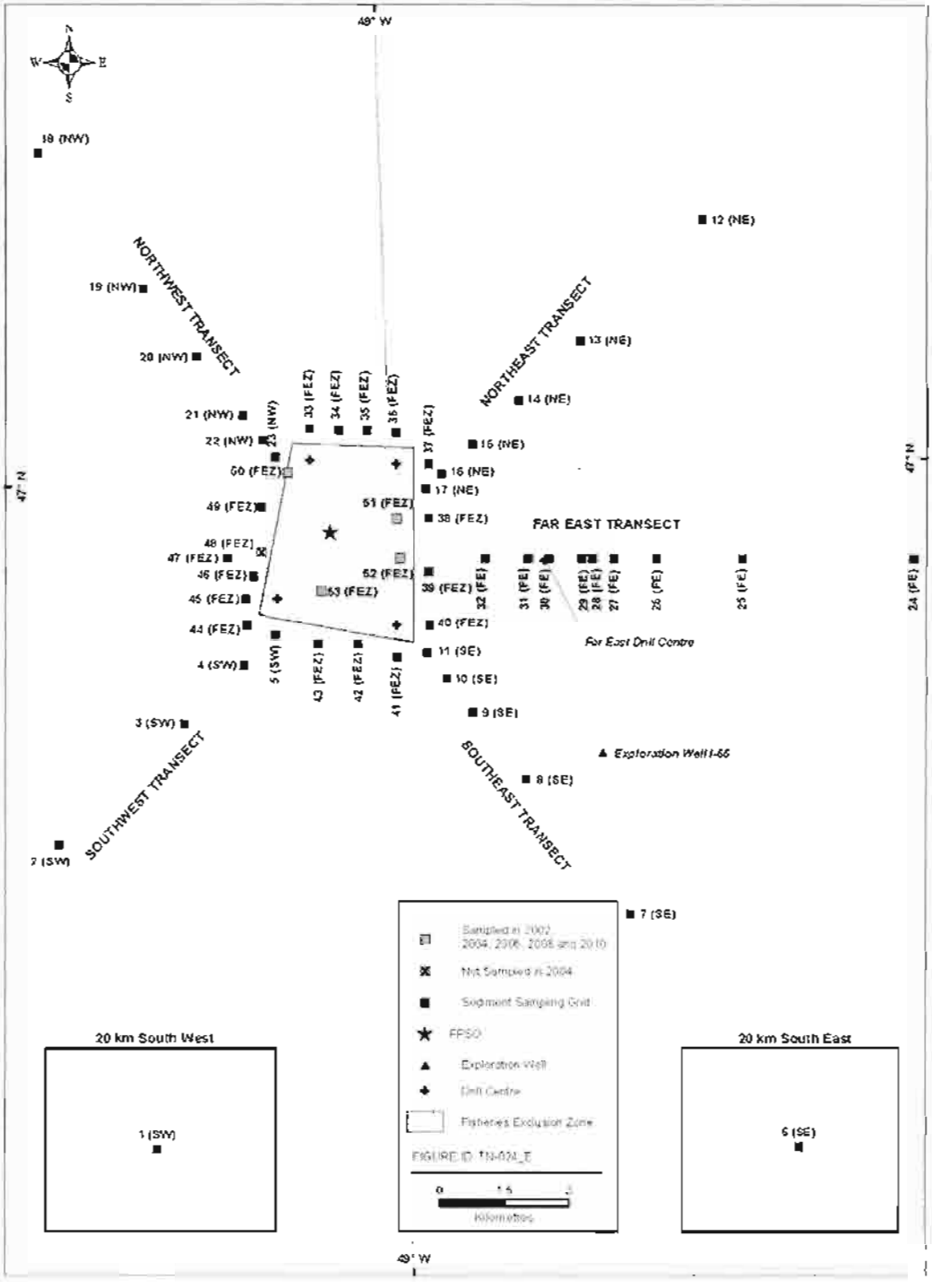

Figure 5-3 Terra Nova EEM Sediment Stations

Table 5-6 Terra Nova EEM Sediment Stations

EEM Station Name	Baseline and 2000, 2001 EEM Station Names	Latitude	Longitude
1 (SW)	SW-O-20000	46° 20.32'N	48° 40.41'W
2 (SW)	SW-O-8000	46° 24.69'N	48° 33.95'W
3 (SW)	SW-O-4000	46° 26.17'N	48° 31.62'W
4 (SW)	SW-O-2000	46° 26.88'N	48° 30.50'W
5 (SW)	SW-O-1000	46° 27.25'N	48° 29.92'W
6 (SE)	SE-O-20000	46° 18.34'N	48° 18.11'W
7 (SE)	SE-O-8000	46° 23.58'N	48° 23.60'W
8 (SE)	SE-O-4000	46° 25.33'N	48° 25.44'W
9 (SE)	SE-O-2000	46° 26.21'N	48° 26.36'W
10 (SE)	SE-O-1000	46° 26.64'N	48° 26.81'W
11 (SE)	SE-O-250	46° 26.97'N	48° 27.16'W
12 (NE)	NE-O-8000	46° 32.31'N	48° 21.89'W
13 (NE)	NE-O-4000	46° 30.85'N	48° 24.20'W
14 (NE)	NE-O-2000	46° 30.12'N	48° 25.35'W
15 (NE)	NE-O-500	46° 29.57'N	48° 26.22'W
16 (NE)	NE-I-500	46° 29.21'N	48° 26.80'W
17 (NE)	NE-I-1000	46° 29.03'N	48° 27.09'W
18 (NW)	NW-O-8000	46° 33.41'N	48° 33.95'W
19 (NW)	NW-O-4000	46° 31.66'N	48° 32.11'W
20 (NW)	NW-O-2000	46° 30.79'N	48° 31.19'W
21 (NW)	NW-O-250	46° 30.03'N	48° 30.38'W
22 (NW)	NW-I-500	46° 29.70'N	48° 30.04'W
23 (NW)	NW-I-1000	46° 29.48'N	48° 29.81'W
24 (FE)	FE-O-8000	46° 27.95'N	48° 18.24'W
25 (FE)	FE-O-4000	46° 28.03'N	48° 21.37'W
26 (FE)	FE-O-2000	46° 28.06'N	48° 22.93'W
27 (FE)	FE-O-1000	46° 28.08'N	48° 23.71'W
28 (FE)	FE-O-500	46° 28.09'N	48° 24.10'W
29 (FE)	FE-O-250	46° 28.10'N	48° 24.30'W
30 (FE)	FE-I-500	46° 28.11'N	48° 24.88'W
31 (FE)	FE-I-1000	46° 28.12'N	48° 25.27'W
32 (FE)	FE-I-2000	46° 28.13'N	48° 26.05'W
33 (FEZ)	NW-N-750	46° 29.83'N	48° 29.17'W
34 (FEZ)	NW-NE-1	46° 29.80'N	48° 28.65'W
35 (FEZ)	NW-NE-2	46° 29.79'N	48° 28.12'W
36 (FEZ)	NE-N-750	46° 29.76'N	48° 27.60'W
37 (FEZ)	NE-E-750	46° 29.34'N	48° 27.03'W
38 (FEZ)	NE-SE-1	46° 28.66'N	48° 27.05'W
39 (FEZ)	NE-SE-2	46° 27.99'N	48° 27.08'W
40 (FEZ)	SE-E-750	46° 27.31'N	48° 27.10'W
41 (FEZ)	SE-S-750	46° 26.92'N	48° 27.71'W
42 (FEZ)	SW-SE-2	46° 27.10'N	48° 28.42'W
43 (FEZ)	SW-SE-1	46° 27.11'N	48° 29.15'W
44 (FEZ)	SW-SW-1	46° 27.37'N	48° 30.42'W
45 (FEZ)	SW-W-750	46° 27.71'N	48° 30.43'W
46 (FEZ)	NW-SW-3	46° 28.00'N	48° 30.27'W
47 (FEZ)	FE-I-8000	46° 28.23'N	48° 30.74'W

EEM Station Name	Baseline and 2000, 2001 EEM Station Names	Latitude	Longitude
48 (FEZ)	NW-SW-2	46° 28.28'N	48° 30.12'W
49 (FEZ)	NW-SW-1	46° 28.87'N	48° 30.09'W
50 (FEZ)	NW-O-1000	46° 29.29'N	48° 29.60'W
51 (FEZ)	NE-I-2000	46° 28.66'N	48° 27.66'W
52 (FEZ)	FE-I-4000	46° 28.17'N	48° 27.62'W
53 (FEZ)	SW-I-500	46° 27.79'N	48° 29.05'W

5.3.1.3 Sampling Methods

Sediment samples are collected using a large-volume corer (mouth diameter = 35.6 cm, depth = 61 cm) designed to mechanically take an undisturbed sediment sample over approximately 0.1 m^2 of seabed (Figures 5-4 and 5-5). Three cores are performed at each station to collect sufficient sediment volume for assessment of sediment physical and chemical characteristics, toxicity and benthic community structure. In addition, temperature and oxidation/reduction potential (redox) are measured on each core sample using a portable temperature and redox meter. Digital photographs (with a station identifier in the photo) are taken of each core.

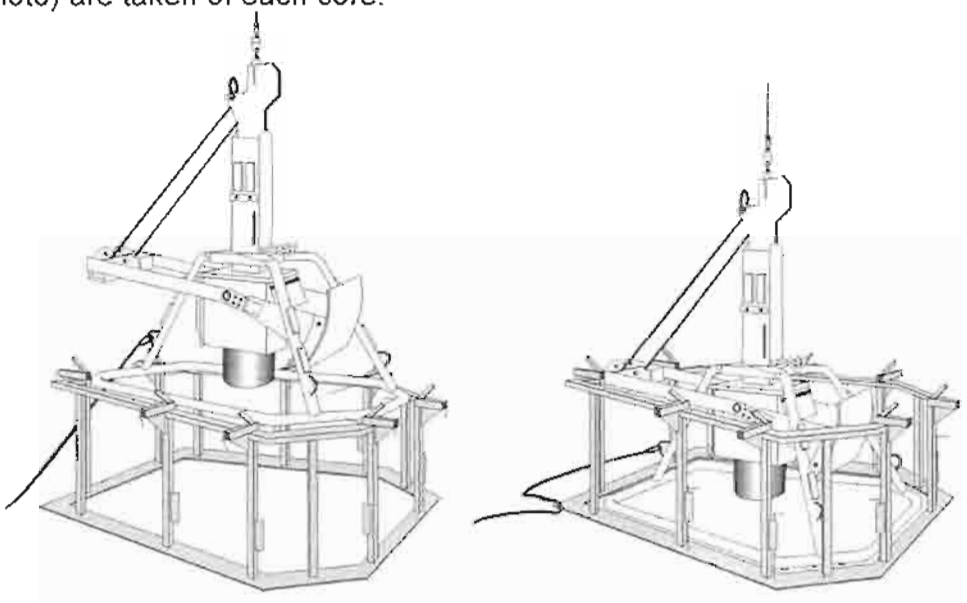

Figure 5-4 Sediment Corer Diagram

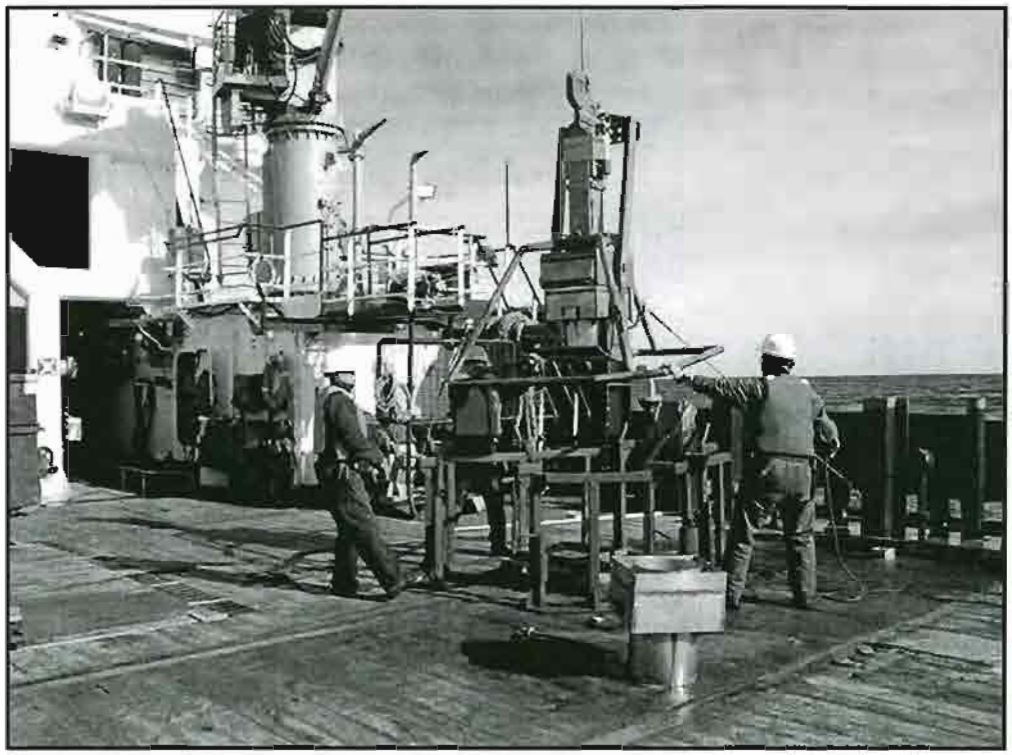

Figure 5-5 Sediment Corer

After collection, core samples are moved to a working area near the laboratory facility for processing. Sediment samples remain inside the core barrel until all sub-sampling for physical and chemical analysis and toxicity is completed. Sediment sub-samples for physical and chemical analysis and toxicity, as well as for archive, are taken from the centre portion of the core (away from the edges that come in contact with the core barrel). Sediment samples collected for physical and chemical analysis and archive are a composite from the top 3 cm of all three cores (Figure 5-6). Sediment samples collected for toxicity are collected from the top 7.5 cm of one core. After these collections, the core barrel is removed and samples for benthic analysis are taken from the top 15 cm of two cores. Storage procedures for samples are provided in Table 5-7.

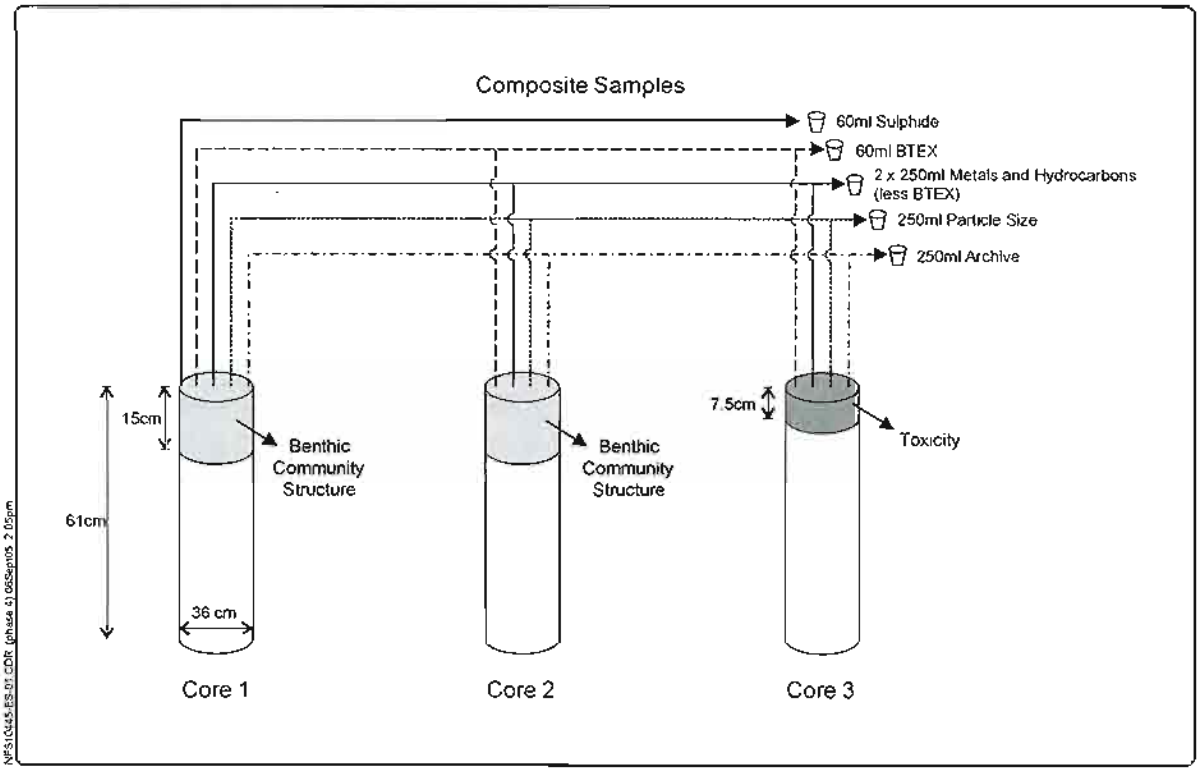

Figure 5-6 Allocation of Samples from Cores

Table 5-7 Sample Storage Procedures for Sediment Samples

Analysis	Sample Container	Preservative Description	Hold Time	Storage Temperature
Low-level (LL) TEH (C_{10}-C_{32}) / PAH / Mercury / Ammonia / Sulphur / TIC/TOC	1 x 250 ml glass jar	Fill with no headspace	LL TEH & PAH = 14 days; Hg & Sulphur = 6 months; TIC/TOC & Ammonia = 28 days	-20°C
Total Metals / Li / Low-level Cd	1 x 250 ml glass jar	Fill with no headspace	Metals = 6 months	-20°C
BTEX / VPH (C_6-C_{10})	1 x 60 ml glass jar	Fill with no headspace	7 days	-20°C
Sulphide	1 x 60 ml glass jar	Moisten surface with Zinc Acetate	7 days	4°C
Particle Size	1 x 250 ml glass jar	Fill with no headspace	Indefinite	-20°C
Archive Samples	1 x 250 ml glass jar	Fill with no headspace		-20°C
Amphipod Toxicity	1 x 4 L pail	Pails lined with plastic bag and tied with as little air space as possible	6 weeks	4°C in dark
Microtox	100 g of sediment in Whirl-Pak	As little air space as possible	6 weeks	4°C in dark
Benthic Community	2 x 11 L pails	Store with 1 L of 10% buffered formalin	12 months	Ambient

Notes:
1. TEH = total extractable hydrocarbon.
2. TIC/TOC = total inorganic carbon/total organic carbon.
3. BTEX = benzene, toluene, methylbenzene and xylenes.
4. VHP = Volatile Petroleum Hydrocarbon.

5.3.1.4 Quality Assurance/Quality Control

QA/QC protocols and standard operating procedures are followed during collection of samples.

Calibration and Certification

All equipment involved in sample collection, analysis and preservation (including freezers and coolers) are calibrated in accordance with the manufacturer's specifications. Calibration records are brought onboard vessel during the survey. Required equipment and/or sampling personnel certifications are also brought onboard vessel.

Equipment Checklist

Equipment checklists are used during program mobilization to ensure that all required sampling equipment, supplies, spare parts and alternate equipment are available for the sampling program.

Sampling Handling and Storage

All measuring instruments and work surfaces are washed with mild soap and water, disinfected with isopropyl alcohol, then rinsed with distilled water prior to the start of each station. All sampling personnel are supplied with latex gloves to be worn during sample processing then discarded after each station.

Immediately after collection, all samples (with the exception of benthic samples) are stored in refrigerators (4°C) or freezers (-20°C) according to storage direction provided in Table 5.7. Benthic samples are preserved in 10% buffered formalin and stored at ambient temperature.

Field Blanks and Duplicate Samples

Since 2001, sediment chemistry field blanks composed of clean sediment obtained from the analytical laboratory have been collected at three randomly selected stations to test for possible onboard contamination. Blank vials are opened as soon the core sampler from these three stations is brought on board the vessel and remain opened until chemistry samples from that station are processed. Blank vials are then sealed and stored with other chemistry samples. Since the beginning of the EEM Program (2000), field duplicates have been and continue to be collected for chemical analysis at five randomly selected stations.

Data Log

Data sheets containing the following information are filled out.

Project, task number	Sample location (DGPS)
Crew members	Field conditions (in particular, sea state)
Station number	Types of samples collected
Initial of sampling technician	Depths of samples
Sampling method	Redox value for sediment sample
Sample number	Temperature of sediment sample
Date and time (24 hr clock)	Description of core

Labelling

Clean sample containers are obtained from the analytical laboratories, when applicable. All sample containers are pre-labelled, wrapped completely with packing tape (to prevent loss of sample in case of breakage), sorted by station number and stored securely within storage containers for transport to and from the field.

The following information is recorded on labels:

- the project number identifier;
- station number;
- date - month and year (date and time of sampling is recorded on data sheets (see 'Data Log') and included on chain of custody forms (see 'Sample Shipment');
- analysis parameters; and
- initials of shift leader.

Field duplicate samples are labelled with the above, but the Station Number is followed by "-A". Field blanks are labelled with the above, but the Station Number is followed by "-B".

Photographs

Two digital cameras are brought on board for collection of as many photographs as is feasible beyond the required photographs of each core (see Section 5.3.1.3).

Survey Plan

A survey or cruise plan is developed before each survey and distributed to all land-based and offshore personnel involved in the survey. The plan provides

detailed information on sampling locations, field crew roles and responsibilities and logistical requirements (e.g., schedule, field reporting and communication pathways). The plan states client survey requirements, provides a clear list of objectives, gives clear direction to the vessel Captain and provides offshore operations personnel with an overview of the logistics required for the survey. The survey plan also provides details to survey personnel on sample collection (standard operating procedures are included, when applicable), use of equipment and record keeping. The survey plan includes any required equipment calibration record and equipment/personnel certifications.

Survey Report

A survey report is prepared after the survey. The report summarizes all field operations. It provides a brief description of the major activities and it summarizes methodology, deck operations, problems encountered, delays and modifications to the original plan. Station maps and tables are appended, as appropriate. The report lists all personnel (including corporate association and position) directly involved in the sampling program and provides a point-form chronology of activities at sea. Finally, field log sheets, positioning data and health and safety documentation are appended.

Sample Shipment

All samples are packed securely and shipped to laboratories for sample analysis. Samples are shipped via reliable courier service providers and waybill shipment numbers are retained for tracking purposes. Chain of custody forms are included with all sample shipments. Chain of custody forms indicate the number and type of sample containers, sample collection times and the type of analysis to be conducted. A carbon copy of the chain of custody form is retained by the shipper.

5.3.2 Water Quality Component

5.3.2.1 Survey Platform and Timing

Water quality sampling is conducted from an offshore supply vessel. Sampling was conducted every year in late summer or early autumn for the first three years (2000, 2001 and 2002). Since 2002, the Program has been executed every two years, again in late summer or early autumn. As of 2012, the Program will continue to be executed every two years, but sampling should ideally be executed in July or August when sea conditions are calm, thermal stratification is strong and constituents are expected to be at their most concentrated (Suncor Energy 2009a).

5.3.2.2 Sampling Locations

Historically there were 16 EEM water quality stations located outside the FEZ. Prior to EEM program design being revised, there was little evidence that the Terra Nova Development was affecting water quality. To increase the chances

of detecting constituents, in 2012, 8 of these 16 stations were moved closer to the discharge source to a distance of approximately 250 m from the FPSO (Suncor Energy 2009a). Sampling locations for the 2012 Program are provided in Figure 5-7. Geospatial coordinates are provided in Table 5-8.

Table 5-8 Geospatial Coordinates for Water Quality Stations in Earlier EEM Programs and Revised Coordinates as of 2012

Station Name 2002	Original EEM Latitude	Original EEM Longitude	Revised (2012) EEM Latitude	Revised (2012) EEM Longitude
W1	46° 20.60000'N	48° 40.39000'W	46° 20.60000'N	48° 40.39000'W
W2	46° 20.30000'N	48° 40.00000'W	46° 20.30000'N	48° 40.00000'W
W3	46° 20.06000'N	48° 40.41000'W	46° 20.06000'N	48° 40.41000'W
W4	46° 20.33000'N	48° 40.79000'W	46° 20.33000'N	48° 40.79000'W
W5	46° 18.62000'N	48° 18.13000'W	46° 18.62000'N	48° 18.13000'W
W6	46° 18.33000'N	48° 17.74000'W	46° 18.33000'N	48° 17.74000'W
W7	46° 18.09000'N	48° 18.13000'W	46° 18.09000'N	48° 18.13000'W
W8	46° 18.35000'N	48° 18.52000'W	46° 18.35000'N	48° 18.52000'W
W9	46° 29.69000'N	48° 29.54000'W	46° 29.69000'N	48° 29.54000'W
W10	46° 29.68000'N	48° 28.89000'W	46° 29.68000'N	48° 28.89000'W
W11	46° 29.65000'N	48° 28.39000'W	46° 28.66036'N	48° 28.83653'W
W12	46° 29.63000'N	48° 27.92000'W	46° 29.63000'N	48° 27.92000'W
W13	46° 29.59000'N	48° 27.24000'W	46° 29.59000'N	48° 27.24000'W
W14	46° 29.12000'N	48° 27.22000'W	46° 28.55840'N	48° 28.67416'W
W15	46° 28.32000'N	48° 27.26000'W	46° 28.51366'N	48° 28.66237'W
W16	46° 27.52000'N	48° 27.26000'W	46° 28.43000'N	48° 28.73000'W
W17	46° 27.06000'N	48° 27.34000'W	46° 27.06000'N	48° 27.34000'W
W18	46° 27.12000'N	48° 27.93000'W	46° 27.12000'N	48° 27.93000'W
W19	46° 27.25000'N	48° 28.81000'W	46° 28.39753'N	48° 28.91587'W
W20	46° 27.34000'N	48° 29.43000'W	46° 28.47269'N	48° 29.01938'W
W21	46° 27.47000'N	48° 30.25000'W	46° 27.47000'N	48° 30.25000'W
W22	46° 27.88000'N	48° 30.15000'W	46° 27.88000'N	48° 30.15000'W
W23	46° 28.58000'N	48° 29.92000'W	46° 28.49887'N	48° 29.06244'W
W24	46° 29.13000'N	48° 29.74000'W	46° 28.64522'N	48° 28.97305'W

Note: For safety reasons, near-field stations are positioned so as to be no closer than 50 m from any subsea infrastructure.

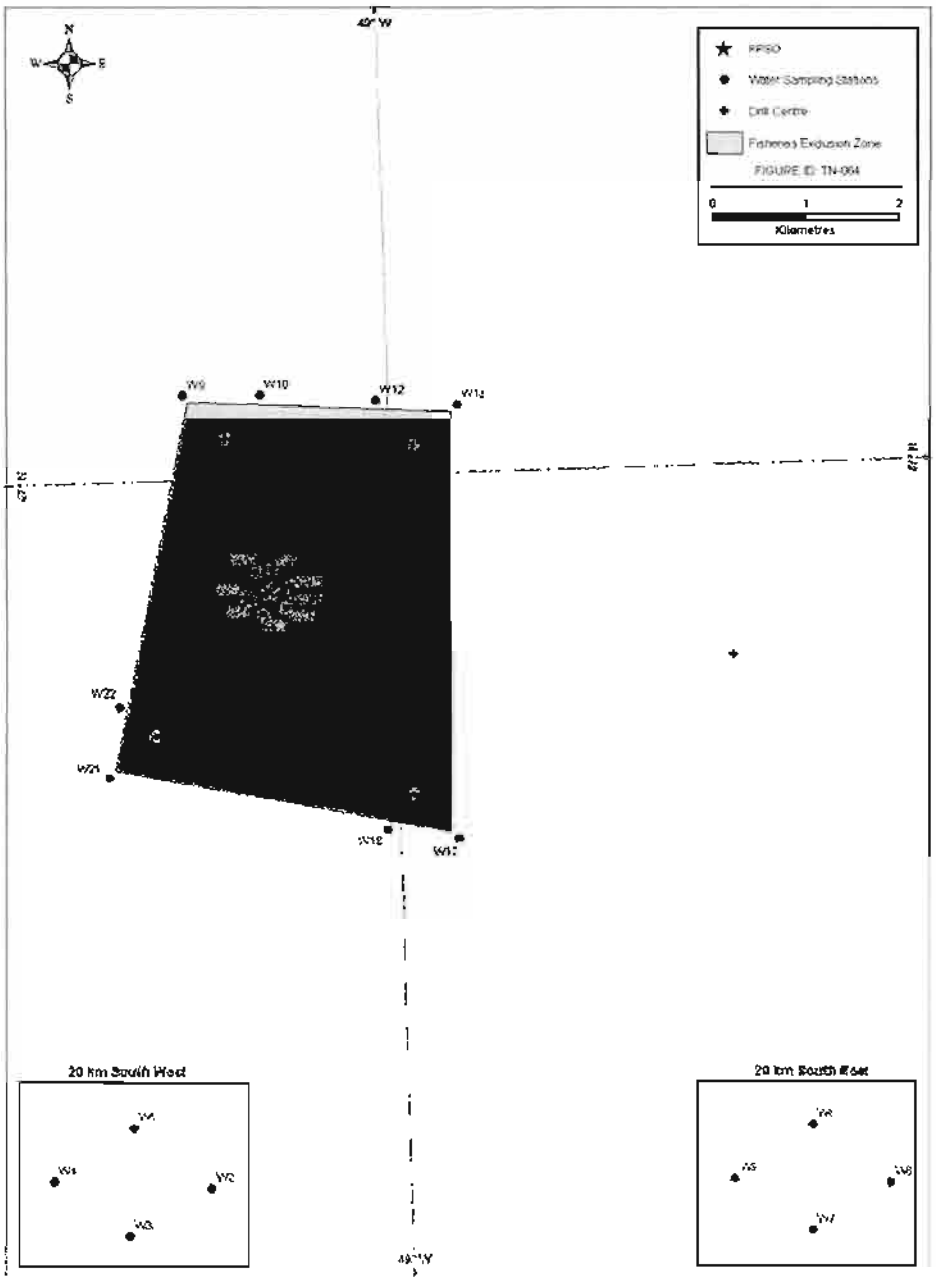

Figure 5-7 Sampling Locations for the 2012 Program

5.3.2.3 Sampling Methods

In previous years, water samples were collected using 10 L Niskin samplers (Figure 5-8) at 10 m below surface, 40 m depth and 10 m above bottom. As of 2012, surface samples will be collected at 1 to 4 m from surface (or at the shallowest depth feasible depending on weather conditions), rather than at 10 m.

Remaining sampling depths will not change. This change results from field trials with rhodamine dye that indicated that most of the produced water plume was distributed near the surface (Suncor Energy 2009a).

Water samples are analyzed for polyaromatic hydrocarbons (PAHs), total petroleum hydrocarbon (TPH), mercury, trace metals, total suspended solids (TSS), chlorophyll *a* and phaeophytin pigments. Sample storage procedures are detailed in Table 5-9.

Figure 5-8 Niskin Water Samplers

Table 5-9 Water Sample Storage Containers

Analysis	Storage Container and Storage Temperature
PAHs and Alkyl PAHs	1 - 1 L amber glass bottle (4°C)
TPH (Atlantic MUST)	2 - 250 ml clear glass bottles with sodium bisulphate 2 - 40 ml vials with sodium bisulphate
Mercury	1 -100 mL Amber glass bottle with $K_2Cr_2O_7$ in 17% HNO_3 (4°C)
Trace Metals	2 - 500 mL plastic bottles with nitric acid (10 drops per bottle) (4°C)
TSS	1 - 1 L plastic bottle (4°C)
Chlorophyll and phaeophytin	GF/F filters (1 L samples) stored in petri dish wrapped in tin foil (-20°C)

Note: Measurement of oil and grease is discontinued as of 2012 (Suncor Energy 2009a) because these constituents are captured in measurements of Atlantic MUST.

Chlorophyll and phaeophytin samples are collected in 1 L plastic bottles that are wrapped in tin foil to protect the sample from direct sunlight to avoid degradation of chlorophyll pigments. Samples are filtered within 30 minutes of collection by use of a vacuum filtration apparatus. Each one litre sample is gently filtered (less than 75 mm Hg vacuum pressure) onto a GF/F filter and the sample is "fixed" by adding approximately 20 mL of magnesium carbonate solution. After filtration, each filter pad is wrapped in tin foil, placed in a pre-labelled petri dish, taped and stored at -20 °C.

In previous years, Conductivity Temperature Depth (CTD) profiles were performed at both sediment and water quality stations to obtain information on pH, temperature, conductivity, salinity, dissolved oxygen and chlorophyll. As noted in Suncor Energy (2009a), CTD profile data collected at sediment stations have provided little additional information to the Program. In 2012 and subsequent years, CTD profiles will be performed only at water quality stations.

Weather Conditions During Sampling

As of 2012, current and wind conditions during sampling will be obtained, when available, to help interpret water quality results. Sea state during sampling will be recorded by the field crew.

5.3.2.4 Quality Assurance/Quality Control

QA/QC protocols and standard operating procedures are followed during collection of samples. QA/QC protocols for collection of sediment samples (Section 5.3.1.4) also apply to collection of water samples, with the following exceptions.

Sample Handling

Niskin bottles are brought to a clean working area and water samples are decanted into pre-labelled sample containers. Sampling personnel are supplied with new latex gloves for each station. Processed samples are transferred to cold storage within 30 minutes of collection.

Field Blanks and Field Duplicates

Field blanks for PAHs, mercury, trace metals and TPHs made up of distilled water are collected at four randomly selected station and depth combinations (i.e., four blanks are collected). Blank vials are opened as soon as water samples from these locations are brought on board and remain opened until chemistry samples from these locations are processed. Blank vials are then sealed and stored with the remainder of chemistry samples. Field duplicates are collected at five randomly selected station and depth combinations (i.e., five duplicates are collected).

5.3.3 Commercial Fish Component

5.3.3.1 Survey Platform and Timing

Scallop and plaice are collected from a fishing trawler, typically in late June or early July. Sampling had originally been planned for late fall but low fish catches at this time of year precludes sampling over this time period (see fish catches from Suncor Energy 1998). Sampling prior to late June also yields poor fish catches (Suncor Energy 2009b).

Scallop and plaice were collected annually for the first three EEM years (2000, 2001 and 2002) and are now collected every two years.

5.3.3.2 Sampling License

All work is conducted under a sampling license issued by DFO. The terms of this license specify sample collection equipment, location and time period in which samples may be collected, what species may be taken and in what numbers.

In addition to the Experimental License issued by DFO, a license pertaining to species at risk must also be obtained. This license is required for scientific research relating to the conservation of a listed species, activities that benefit the species or are required to enhance the chance of survival of a listed species in the wild, or activities that incidentally affect a listed species. The commercial fish survey applies to this activity because of the possibility of collecting wolffish as by-catch during the survey.

5.3.3.3 Sampling Locations

Scallops and plaice are collected from the Terra Nova Study Area and from a Reference Area located approximately 20 km to the southeast of Terra Nova (Figure 5-9). As of 2002, an attempt is made to distribute collections at the four corners of the FEZ. If sufficient numbers cannot be obtained using this approach, then additional collections are made in areas of high numbers in the Study Area. Collections in the Reference Area are made where numbers are high.

5.3.3.4 Sampling Methods

Scallops are collected using a scallop dredge and plaice are collected using an otter trawl, both installed on the sampling platform. Fishing gear is deployed by the ship's crew. Otter trawl catches are released directly into a chute that leads to the processing area. Scallop are removed from the dredge, placed in clean sample baskets and carried to the processing area. The otter trawl catch is sorted by species and the required numbers of plaice are held in a live well for further processing. Other by-catch species are counted, weighed in bulk and released alive unless a license for collection of additional species (see Section 5.3.3.2) has been issued prior to departure.

Preliminary processing of samples is done on board ship. Scallop and plaice that have suffered obvious dredge or trawl damage are discarded. Tissue samples, adductor muscle for scallop and top fillet for plaice, are frozen at -20°C for subsequent taste analysis. Adductor muscle and viscera for scallop and bottom fillets and liver (left half only) for plaice are frozen at -20°C for body burden analysis. Scallop shells are retained separately for possible future use. Only those plaice larger than 250 mm in length are retained for analysis.

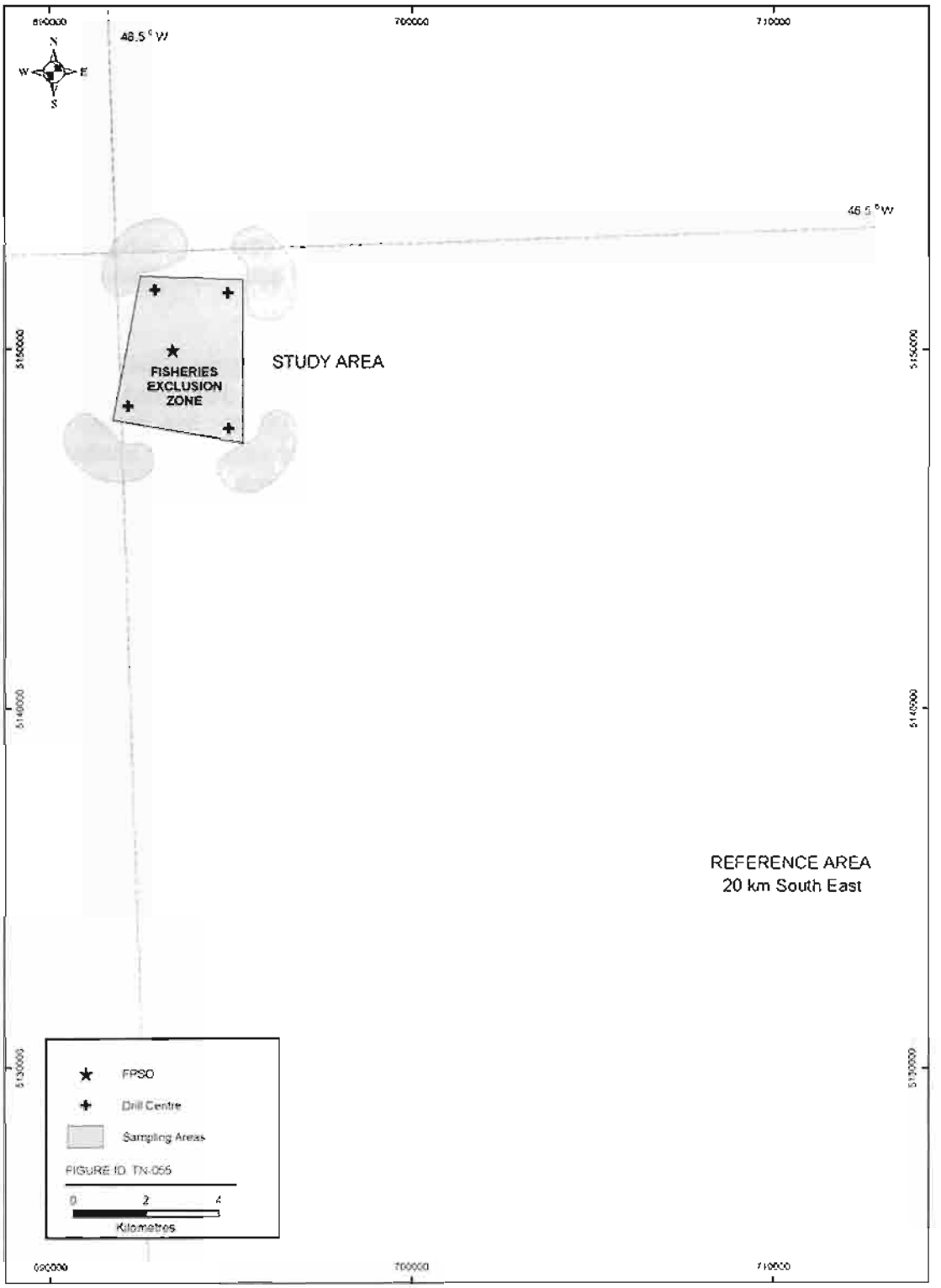

Figure 5-9 General Sampling Areas for Scallop and Plaice

Blood from plaice to be used in fish health analysis is drawn from a dorsal vessel near the tail and carefully dispensed into a tube containing an anticoagulant (EDTA) and gently mixed. Two blood smears are prepared for each fish within one hour of blood withdrawal according to standard haematological methods (Platt 1969). After collection of blood samples, fish are killed by severing the spinal cord. Each fish is assessed visually for any parasites and/or abnormalities on the skin and fins under the general framework of Autopsy-based Condition Assessment described by Goede and Barton (1990). A 4- to 5-mm thick slice from the centre portion of the right half of the liver (along the longitudinal axis) is placed in Dietrich's fixative for histological processing and the rest of the right half of the liver is frozen on dry ice until return to port, when it is placed in a -65°C freezer for MFO analysis. The first gill arch on the right of the fish is removed and placed in Dietrich's fixative for histological processing. Tissue samples of heart, spleen and head-kidney are removed and placed in Dietrich's fixative for histological processing, if required. Otoliths are removed for ageing. Throughout the dissection process, any internal parasites and/or abnormal tissues are recorded and preserved in Dietrich's fixative for subsequent identification.

As of 2001, additional measurements on scallops have included total weight, sex, tissue weight, length, width and height. For plaice, measurements since 2001 have included fish length, weight (whole and gutted), sex and maturity stage, liver weight and gonad weight.

Sample Requirements and Composite Samples

Five chemistry composites are required from both the Study and Reference Area for both scallop and plaice. A minimum of 1,500 g of edible tissue (adductor muscle for scallop and top fillet for plaice) is required from each Area for each species. Fifty plaice are required from each Area for fish health analysis. To meet these requirements, approximately 500 scallop are collected from the Study Area and 500 scallop are collected from the Reference Area. Approximately 50 plaice (larger than 25 cm) are collected from the Study Area. A similar number is collected from the Reference Area. Numbers required are determined by sizes of scallop and plaice caught, and numbers per dredge tow (for scallop) or trawl set (for plaice).

Scallops (viscera or muscle) are composited in minimum batch sizes of 20 scallop for chemistry analysis. As of 2001, no more than one composite is obtained from any one tow (although tows may be combined (once ashore) to form composites). Therefore, chemistry analysis requires a minimum of five tows containing a minimum of 20 scallop in each of the Study and Reference Areas. If catches are high and time is not limited, then six tows may be performed (two around each drill centre) in the Study Area to obtain a more balanced distribution of tows in the Study Area.

Ideally, 50 American plaice are required for health analysis in each Area. These target numbers should also provide sufficient tissue for chemistry and taste

analysis if fish are larger than 25 cm long . When fish are larger than 25 cm long, livers can be split in half for health and chemistry analysis and there is sufficient fillet meat for taste (top fillet) and chemistry (bottom fillet). When they are smaller than this, then additional fish are collected for chemistry and taste analysis. Chemistry analysis requires a minimum of five composite samples (fillet or liver) in each of the Study and Reference Area and, since 2001, composites have needed to contain at least 5 fish (25 cm)[2]. Although trawls may be combined (once ashore) to form composites, no more than one composite is obtained from any one trawl. Therefore, chemistry analysis requires a minimum of five trawls containing a minimum of 5 fish (25 cm) in each of the Study and Reference Area. If catches are high, fish are large and time is not limited, then six trawl sets may be performed (two around each drill centre) in the Study Area to obtain a more balanced distribution of trawl sets in the Study Area.

5.3.3.5 Quality Assurance/Quality Control

Calibration and Certification

All equipment involved in sample collection, analysis and preservation (including freezers) are calibrated in accordance with the manufacturer's specifications. Equipment calibration records are brought onboard vessel during the survey. Required equipment and/or sampling personnel certifications are also brought onboard vessel.

Equipment Checklists

Equipment checklists are used during program mobilization to ensure all required sampling equipment, supplies, spare parts and alternate equipment are available for the sampling program.

Sampling Handling

The fishing deck of the survey vessel is washed with degreaser then flushed with sea water at the beginning of the survey. Flushing of the fishing deck and the chute leading to the processing lab with seawater is then continuous during the survey.

All measuring instruments and work surfaces are washed with mild soap and water, disinfected with isopropyl alcohol, then rinsed with distilled water prior to the start of dredge tows or trawl sets. Boards and knives are scrubbed and then rinsed with clean sea water and then with bottled distilled water between samples within a tow or trawl.

[2] In 2000, samples from individual fish were processed for chemistry and livers from the Reference Area were not processed.

Sampling personnel are supplied with latex gloves to be worn during sample processing then discarded after each tow or set. Gloves are washed with distilled water after processing of each sample within a tow or set.

Samples are transferred to a freezer within one hour after collection. The temperature of the freezer is monitored and logged by a technician on a freezer temperature log sheet at 3-hour intervals during the survey.

Data Log

The following information is logged (at a minimum).

For each tow or set:

- Date and time
- Tow/Set ID
- Start and end latitude and longitude
- Bottom depth
- Bottom temperature

For scallop, the following additional information is logged on datasheets:

- Tow ID number
- Bulk bag ID number (see labelling)
- Scallop ID number
- Shell length
- Shell width
- Shell thickness
- Total weight (with shell)
- Adductor muscle weight
- Viscera weight
- Sex
- Gonad weight
- Maturity
- Number of scallop cluckers and half shells per tow

For plaice, the following additional information is logged on datasheets:

- Fish ID
- Total length
- Total weight
- Gutted weight

- Liver weight
- Sex
- Gonad weight
- Maturity
- Stomach content observations and percent fullness

In addition to the above, a by-catch data sheet is completed for each trawl set noting the total number and total weight of each species caught.

Labelling

Scallop from each tow are bulked together in groups of 20 and packaged in separate Ziploc bags for shell, viscera and adductor muscle. Bag labels include tow ID, bulk bad ID and tissue type.

Plaice top fillet, bottom fillet, liver and otolith are packaged individually in Ziploc storage bags or paper envelopes (for otolith) with a type identifier to indicate trawl ID, fish ID and tissue type.

Photographs

Two digital cameras are brought on board for collection of as many photographs as is feasible. Catches from each tow/trawl are photographed with a tow/trawl annotation.

Survey Plan

A survey or cruise plan is developed for the Commercial Fish survey (see Section 5.3.1.4 for generic contents of the survey plan). The commercial fish survey plan also includes the experimental fishing license and species at risk permit granted by DFO for collection of specimens.

Survey Report

A survey report is prepared after the survey (see Section 5.3.1.4 for generic contents of the survey report).

Sample Shipment

Sample shipment is described in Section 5.3.1.4.

5.4 Laboratory Analysis

5.4.1 Sediment Quality Component

Sediment samples are processed for particle size, chemistry, toxicity and benthic community structure.

Particle size is determined by the pipette method (BS 1377: 1990: Part 2 - Methods of Tests for Soils for Civil Engineering Purposes: Classification Tests) and reported as percent content of gravel, sand, silt and clay. Particle size classes in mm and on the phi scale are provided in Table 5-10.

Table 5-10 Particle Size Classes

Size Classification (Wentworth)	Size Range (mm)	phi Scale Range
Gravel	2 to 64	-1.000 to -6.000
Sand	0.063 to 2	3.989 to -1.000
Silt	0.002 to 0.063	8.966 to 3.989
Clay	< 0.002	< 8.986

Note: Silt + clay fractions are referred to as "fines".

Volatile petroleum hydrocarbons (e.g., BTEX) and total extractable hydrocarbons are analyzed following Atlantic RBCA Guidelines for Laboratories Version 3.0. PAHs are quantified using gas chromatography-mass spectroscopy (GC/MS).

Carbon and sulphur content are quantified using a LECO induction furnace with infrared detection.

Most metals are quantified using inductively coupled plasma mass spectroscopy (ICP/MS). Mercury is quantified using Cold Vapour Atomic Absorption Spectroscopy (CVAAS).

Ammonia and sulphide are quantified using an automated colorimetric analyzer. Specific variables analyzed are listed in Table 5-11, along with methods used and most recently obtained laboratory detection limits (detection limits for the 2010 EEM Program).

Two sediment toxicity tests (bacterial luminescence (Microtox) and amphipod toxicity) are performed on each sediment sample. The bacterial luminescence toxicity test (Microtox) is performed according to the Environmental Canada (2002) reference method. The amphipod toxicity test is performed according to the Environment Canada (1998) reference method. Toxicity for the amphipod test is assessed relative to laboratory controls and with reference to the two most distant stations (Reference Stations).

Table 5-11 Sediment Chemistry Variables

Variable	Method	Units	Laboratory Detection Limit
BTEX and Total Extractable Hydrocarbons			
Benzene	Calculated	mg/kg	0.03
Toluene	Calculated	mg/kg	0.03
Ethylbenzene	Calculated	mg/kg	0.03
Xylenes	Calculated	mg/kg	0.05
C_6-C_{10}	Calculated	mg/kg	3
>C_{10}-C_{21}	GC/FID	mg/kg	0.3
>C_{21}-C_{32}	GC/FID	mg/kg	0.3
PAHs			
1-Chloronaphthalene	GC/MS	mg/kg	0.01
2-Chloronaphthalene	GC/MS	mg/kg	0.01
1-Methylnaphthalene	GC/MS	mg/kg	0.01
2-Methylnaphthalene	GC/MS	mg/kg	0.01
Acenaphthene	GC/MS	mg/kg	0.01
Acenaphthylene	GC/MS	mg/kg	0.01
Anthracene	GC/MS	mg/kg	0.01
Benz[*a*]anthracene	GC/MS	mg/kg	0.01
Benzo[*a*]pyrene	GC/MS	mg/kg	0.01
Benzo[*b*]fluoranthene	GC/MS	mg/kg	0.01
Benzo[*ghi*]perylene	GC/MS	mg/kg	0.01
Benzo[*k*]fluoranthene	GC/MS	mg/kg	0.01
Chrysene	GC/MS	mg/kg	0.01
Dibenz[*a,h*]anthracene	GC/MS	mg/kg	0.01
Fluoranthene	GC/MS	mg/kg	0.01
Fluorene	GC/MS	mg/kg	0.01
Indeno[1,2,3-*cd*]pyrene	GC/MS	mg/kg	0.01
Naphthalene	GC/MS	mg/kg	0.01
Perylene	GC/MS	mg/kg	0.01
Phenanthrene	GC/MS	mg/kg	0.01
Pyrene	GC/MS	mg/kg	0.01
Carbon			
Total Carbon	LECO	g/kg	0.2
Total Organic Carbon	LECO	g/kg	0.2
Total Inorganic Carbon	By Difference	g/kg	0.2
Metals (Total)			
Aluminum	ICP/MS	mg/kg	10
Antimony	ICP/MS	mg/kg	2
Arsenic	ICP/MS	mg/kg	2
Barium	ICP/MS	mg/kg	5
Beryllium	ICP/MS	mg/kg	2
Boron	ICP-MS	mg/kg	5
Cadmium	ICP/MS	mg/kg	0.05
Chromium	ICP/MS	mg/kg	2
Cobalt	ICP/MS	mg/kg	1
Copper	ICP/MS	mg/kg	2
Iron	ICP/MS	mg/kg	50
Lead	ICP/MS	mg/kg	0.5
Lithium	ICP/MS	mg/kg	2
Manganese	ICP/MS	mg/kg	2
Mercury	CVAAS	mg/kg	0.01
Molybdenum	ICP/MS	mg/kg	2
Nickel	ICP/MS	mg/kg	2
Selenium	ICP/MS	mg/kg	2
Strontium	ICP/MS	mg/kg	5

Variable	Method	Units	Laboratory Detection Limit
Thallium	ICP/MS	mg/kg	0.1
Tin	ICP/MS	mg/kg	2
Uranium	ICP/MS	mg/kg	0.1
Vanadium	ICP/MS	mg/kg	2
Zinc	ICP/MS	mg/kg	5
Other			
Ammonia (as N)*	COBAS	mg/kg	0.3
Sulphide*	COBAS (SM4500-S2-D)	mg/kg	0.2
Sulphur*	LECO	%(w)	0.03
Moisture	Gravimetry	%	1

Notes: 1. *Ammonia, sulphide and sulphur were measured beginning in 2001.
2. Boron will be measured in 2012. Magnesium and potassium, although noted in Suncor Energy (2009a), will not be added to the program since these are depleted rather than enriched in produced water.
3. The laboratory detection limit is the lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Laboratory detection limits may vary from year to year because instruments are checked for precision and accuracy every year. The laboratory detection limits provided above are the most recently achieved (2010) detection limits.
4. GC/FID: Gas Chromatography – Flame Ionization Detection.

No standard reference method exists for sieving and identification of benthic invertebrates and samples are processed according to best practices. Sandy samples are washed through a 0.5-mm sieve. Samples with larger proportions of coarse material (gravel and shell) are elutriated and sieved by directing a high volume (1 L/s) flow of freshwater into the sample, tilting the sample bucket and catching the overflow on a 0.5-mm sieve. The procedure is adjusted to leave coarser sediment fractions in the pail. The flow suspends the less dense organisms (e.g., polychaetes) and separates small gastropods and clams, which, with a suitable balance of flow in and out of the bucket, can be separated. Elutriation continues until the water leaving the pail is free of organisms and when no additional heavier organisms can be seen after close examination of the sediment. Usually, larger organisms such as scallop and propeller clams are separated manually as they are found. Barnacles and sponges are scraped off rocks. With coarser sediments such as gravels, which are occasionally encountered, a 1.2-cm mesh in combination with the 0.5-mm screen is used to aid in separating the organisms.

All samples are sorted under a stereomicroscope at 6.4x magnification, with a final scan at 16x. Wet weight biomass (g/sample) is estimated by weighing animals to the nearest milligram at the time of sorting after blotting to remove surface water. None of the samples are sub-sampled. Organisms are identified by a specialist in marine benthic invertebrate taxonomy to an appropriate taxonomic level, typically to species, using conventional literature for the groups involved.

5.4.2 Water Quality Component

Water samples are processed for BTEX, TEH, PAHs and alkyl PAHs, metals, sulphur, phaeophytin *a* and chlorophyll *a*, and TSS. Specific variables are listed in Table 5-12. New seawater constituents to be measured starting in 2012 are highlighted in blue in Table 5-9. Methods listed are general and detection limits may change depending on the analytical laboratory selected for the work. In keeping with the revised design document for water quality (Suncor Energy 2009a), an attempt will be made to achieve lower detection limits whenever possible.

Table 5-12 Seawater Variables

Variables	Method	Units	Laboratory Detection Limit
BTEX and TEH			
Benzene	GC/MS	mg/L	0.001
Toluene	GC/MS	mg/L	0.001
Ethylbenzene	GC/MS	mg/L	0.001
Xylenes	GC/MS	mg/L	0.002
C_6-C_{10} hydrocarbon (less BTEX)	Calculated	mg/L	0.01
>C_{10}-C_{21}	GC/FID	mg/L	0.05
>C_{21}-C_{32}	GC/FID	mg/L	0.1
PAHs and Alkyl PAHs			
Acenaphthene	GC/MS	µg/L	0.01
Acenaphthylene	GC/MS	µg/L	0.01
Anthracene	GC/MS	µg/L	0.01
Benz[*a*]anthracene	GC/MS	µg/L	0.01
Benzo[*a*]pyrene	GC/MS	µg/L	0.01
Benzo[*b*]fluoranthene	GC/MS	µg/L	0.01
Benzo[*e*]pyrene	GC/MS	µg/L	0.01
Benzo[*ghi*]perylene	GC/MS	µg/L	0.01
Benzo[*k*]fluoranthene	GC/MS	µg/L	0.01
Biphenyl	GC/MS	µg/L	0.01
Chrysene	GC/MS	µg/L	0.01
Dibenz[*a,h*]anthracene	GC/MS	µg/L	0.01
Dibenzothiophene	GC/MS	µg/L	0.05
C1-dibenzothiophenes	GC/MS	µg/L	0.05
C2-dibenzothiophenes	GC/MS	µg/L	0.05
C3-dibenzothiophenes	GC/MS	µg/L	0.05
Fluoranthene	GC/MS	µg/L	0.01
Fluorene	GC/MS	µg/L	0.01
Indeno[1,2,3-*cd*]pyrene	GC/MS	µg/L	0.01
Naphthalene	GC/MS	µg/L	0.01
C1-naphthalenes	GC/MS	µg/L	0.05
C2-naphthalenes	GC/MS	µg/L	0.05
C3-naphthalenes	GC/MS	µg/L	0.05
Perylene	GC/MS	µg/L	0.01
Phenanthrene	GC/MS	µg/L	0.01
C1-phenanthrenes/anthracenes	GC/MS	µg/L	0.05
C2-phenanthrenes/anthracenes	GC/MS	µg/L	0.05
C3-phenanthrenes/anthracenes	GC/MS	µg/L	0.05
Pyrene	GC/MS	µg/L	0.01
Metals			
Arsenic	ICP/MS	µg/L	10
Aluminum	ICP/MS	µg/L	10

Variables	Method	Units	Laboratory Detection Limit
Barium	ICP/MS	µg/L	1
Beryllium	ICP/MS	µg/L	1
Boron	ICP/MS	µg/L	50
Cadmium	ICP/MS	µg/L	0.05
Calcium	ICP/MS	µg/L	50
Chromium	ICP/MS	µg/L	2
Cobalt	ICP/MS	µg/L	0.5
Copper	ICP/MS	µg/L	5
Iron	ICP/MS	µg/L	10
Lead	ICP/MS	µg/L	0.1
Lithium	ICP/MS	µg/L	20
Magnesium	ICP/MS	µg/L	1000
Manganese	ICP/MS	µg/L	1
Mercury	CVAA	µg/L	0.025
Molybdenum	ICP/MS	ug/L	1
Nickel	ICP/MS	µg/L	5
Potassium	ICP/MS	µg/L	50
Sodium	ICP/MS	µg/L	50
Strontium	ICP/MS	µg/L	10
Thallium	ICP/MS	µg/L	2
Uranium	ICP/MS	µg/L	0.1
Vanadium	ICP/MS	µg/L	10
Zinc	ICP/MS	µg/L	1
Other			
Sulphur	ICP/MS	µg/L	3000
Phaeophytin *a*	Fluorescence	µg/L	0.005
Chlorophyll *a*	Fluorescence	µg/L	0.01
TSS	Gravity	mg/L	0.5

Notes:
1. Constituents that have been added to the Program in 2012 are highlighted in blue.
2. Methods have been previously defined (see Section 5.4.1).
3. Some of the added metals will offer little information but are part of a standards suite of metals and are therefore listed here.
4. The laboratory detection limit is the lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Detection limits may vary from year to year because instruments are checked for precision and accuracy every year as part of QA/QC procedures.

5.4.3 Commercial Fish Component

5.4.3.1 Morphometrics and Life History Characteristics

Most morphometric and life history characteristic measurements are collected onboard vessel (see Section 5.3.3). Age is determined onshore according to standard procedures for groundfish using sagittal otoliths (Powles 1966; Pitt 1967).

5.4.3.2 Body Burden

Tissue samples are processed for TEHs, PAH's, metals, percent lipids and moisture (Table 5-13). All analyses are performed on wet tissue and reported as wet weight.

Table 5-13 Body Burden Variables

Variables	Method	Units	Laboratory Detection Limit
Total Extractable Hydrocarbons			
$>C_{10}$-C_{21}	GC/FID	mg/kg	15
$>C_{21}$-C_{32}	GC/FID	mg/kg	15
$>C_{10}$-C_{32}	Calculated	mg/kg	30
PAHs			
1-Chloronaphthalene	GC/MS	mg/kg	0.05
2-Chloronaphthalene	GC/MS	mg/kg	0.05
1-Methylnaphthalene	GC/MS	mg/kg	0.05
2-Methylnaphthalene	GC/MS	mg/kg	0.05
Acenaphthene	GC/MS	mg/kg	0.05
Acenaphthylene	GC/MS	mg/kg	0.05
Anthracene	GC/MS	mg/kg	0.05
Benz[*a*]anthracene	GC/MS	mg/kg	0.05
Benzo[*a*]pyrene	GC/MS	mg/kg	0.05
Benzo[*b*]fluoranthene	GC/MS	mg/kg	0.05
Benzo[*ghi*]perylene	GC/MS	mg/kg	0.05
Benzo[*k*]fluoranthene	GC/MS	mg/kg	0.05
Chrysene	GC/MS	mg/kg	0.05
Dibenz[*a,h*]anthracene	GC/MS	mg/kg	0.05
Fluoranthene	GC/MS	mg/kg	0.05
Fluorene	GC/MS	mg/kg	0.05
Indeno[1,2,3-*cd*]pyrene	GC/MS	mg/kg	0.05
Naphthalene	GC/MS	mg/kg	0.05
Perylene	GC/MS	mg/kg	0.05
Phenanthrene	GC/MS	mg/kg	0.05
Pyrene	GC/MS	mg/kg	0.05
Metals			
Aluminum	ICP/MS	mg/kg	2.5
Antimony	ICP/MS	mg/kg	0.5
Arsenic	ICP/MS	mg/kg	0.5
Barium	ICP/MS	mg/kg	1.5
Beryllium	ICP/MS	mg/kg	0.5
Boron	ICP/MS	mg/kg	1.5
Cadmium	ICP/MS	mg/kg	0.05
Chromium	ICP/MS	mg/kg	0.5
Cobalt	ICP/MS	mg/kg	0.2
Copper	ICP/MS	mg/kg	0.5

Variables	Method	Units	Laboratory Detection Limit
Iron	ICP/MS	mg/kg	15
Lead	ICP/MS	mg/kg	0.18
Lithium	ICP/MS	mg/kg	0.5
Manganese	ICP/MS	mg/kg	0.5
Mercury	CVAA	mg/kg	0.01
Molybdenum	ICP/MS	mg/kg	0.5
Nickel	ICP/MS	mg/kg	0.5
Selenium	ICP/MS	mg/kg	0.5
Silver	ICP/MS	mg/kg	0.12
Strontium	ICP/MS	mg/kg	1.5
Thallium	ICP/MS	mg/kg	0.02
Tin	ICP/MS	mg/kg	0.5
Uranium	ICP/MS	mg/kg	0.02
Vanadium	ICP/MS	mg/kg	0.5
Zinc	ICP/MS	mg/kg	1.5
Other			
Lipids	AOAC922.06	%	0.5
Moisture	Gravimetry	%	1

Notes: 1. 1- and 2- Chloronaphthalenes were measured starting in 2004.
2. Most methods have been previously defined (see Section 5.4.1).
3. AOAC922.6: Association of Official Agricultural Chemists Methods 922.6.
4. The laboratory detection limit is the lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. Detection limits may vary from year to year because instruments are checked for precision and accuracy every year as part of QA/QC procedures. Detection limits for the most recent EEM year (2010) are reported in the above Table.

5.4.3.3 Taint Testing

Samples for taint tests are delivered frozen to the testing facility. Sensory evaluation is done using taste panels following the triangle and hedonic scaling test procedures. Frozen samples are thawed for 24 hours at 2°C. All tissue from either the Reference or Study Area is homogenized and then allocated to either the triangle taste test or the hedonic scaling test. Samples are then enclosed in individual aluminum foil packets (shiny side in), labelled with a predetermined random three-digit code, cooked in a convection oven at 175°C for 15 minutes and then served at 35°C in glass cups.

Each panel includes 24 untrained panelists who are provided with score sheets (Figures 5-10 and 5-11) and briefed on the presentation of samples prior to taste tests. Panelists are instructed that samples are being tested for uncharacteristic odour or taste and that grit, cartilage and texture should not be considered in their assessment. Panelists are also instructed not to communicate with each other and to leave the panel room immediately upon completion of the taste tests.

QUESTIONNAIRE FOR TRIANGLE TEST

Name: _____ Date/Time: _____

Product. American Plaice

1. Taste the samples in the order indicated and identify the odd sample. You must choose one of the samples.

Code	Check Odd Sample
214	_____
594	_____
733	_____

2. Comments:

_____
_____
_____
_____
_____
_____
_____
_____

Figure 5-10 Questionnaire for Taste Evaluation by Triangle Test

QUESTIONNAIRE FOR HEDONIC SCALING

Name: _____ Date/Time: _____

Product: American Plaice

1. Taste these samples and check how much you like or dislike each one.

619		835	
_____	like extremely	_____	like extremely
_____	like very much	_____	like very much
_____	like moderately	_____	like moderately
_____	like slightly	_____	like slightly
_____	neither like nor	_____	neither like nor
_____	dislike	_____	dislike
_____	dislike slightly	_____	dislike slightly
_____	dislike moderately	_____	dislike moderately
_____	dislike very much	_____	dislike very much
_____	dislike extremely	_____	dislike extremely

2. Comments:

_____
_____
_____
_____
_____
_____
_____

Figure 5-11 Questionnaire for Taste Evaluation by Hedonic Scaling

5.4.3.4 Fish Health Indicators

Haematology

Blood smears are stained with Giemsa stain and examined with a Wild Leitz Aristoplan bright field microscope to identify different types of cells, based on their general form and affinity for dye (Ellis 1976).

Size, shape and degree of haemoglobinization of red blood cells are examined and recorded.

Differential blood cell counts are performed on lymphocytes, neutrophils and thrombocytes and expressed as a percentage of each type of cell on 200 white blood cells counted. Cells are counted under x400 magnification in fields along a row starting from the front edge of the smear and continuing parallel to the slide edge until the total number of cells are counted.

MFO Assay

MFO induction is assessed in liver samples of plaice as 7-ethoxyresorufin O-deethylase activity according to the method of Pohl and Fouts (1980), as modified by Porter et al. (1989).

Liver samples are thawed on ice within four weeks of storage at -65°C and homogenized in four volumes of 50 mM Tris buffer, pH 7.5 (1 g liver to 4 ml buffer) using at least 10 passes of a glass Ten Broek hand homogenizer. Homogenates are centrifuged at 9,000 g for 15 minutes at 4°C and the post-mitochondrial supernatant (S9 fraction) frozen in triplicate at -65°C until assayed. All liver samples are held and processed under the same storage and assay conditions. Assays are carried out within four weeks of storage of S9 fractions.

The reaction mixture, final volume of 1 ml, contains 50 mM Tris buffer, pH 7.5, 2 µM ethoxyresorufin (Sigma) dissolved in dimethyl sulphoxide, 0.15 mM NADPH and 20 µl of S9 protein (diluted five times). After a 15-minute incubation at 27°C, the reaction is stopped with 2 ml of methanol (High Performance Liquid Chromatography grade) and samples are centrifuged (3,600 g for five minutes) in order to remove the protein precipitate. The fluorescence of resorufin formed in the supernatant is measured at an excitation wavelength of 550 nm and an emission wavelength of 580 nm using a Perkin-Elmer LS-5 fluorescence spectrophotometer. Blanks are performed as above, with methanol added at the beginning of the incubation. All the samples are run in duplicate. Protein concentration is determined using the Lowry protein method (Lowry et al. 1951) with bovine serum albumin as standard. The rate of enzyme activity in pmol/min/mg protein is obtained from the regression of fluorescence against standard concentrations of resorufin. Two external positive controls (pools of liver homogenates from uninduced cunners and cunners induced with petroleum) are run with each batch of samples to assure consistency of measurements.

Histopathology

Fixed liver and gill samples are processed by standard histological methods (Lynch et al. 1969) using a Tissue-Tek® Vacuum Infiltration Processor. A graded ethyl alcohol series of 70%, 80%, 95% and two changes of 100% are used for dehydration of the samples. The tissues are then cleared in four changes of xylene and impregnated with three changes of molten embedding media, Tissue Prep 2™. The processed tissues are embedded in steel molds using molten embedding media and topped with labelled embedding rings. After cooling, the hardened blocks of embedded tissues are removed from their base molds. The blocks are then trimmed of excess wax. Sections are cut at 6 µm on a Leitz microtome, floated on a 47°C water bath and then picked up on labelled microscope slides. After air drying, slides are fixed at 60°C for approximately two hours to remove most of the embedding media and allow the tissue to adhere properly to the slide. Sections are stained using Mayers Haematoxylin and Eosin method (Luna 1968). Cover slips are applied using Entellan® and the slides are left to air dry and harden overnight.

Histological examination of each tissue is conducted by the same investigator. One slide with four to six sections is examined per fish. If an abnormality is found in a section, the other sections are checked for the same abnormality. To minimize interpretive bias, a "blind" system in which the examiner is not aware of the site of capture of the specimen is used.

Liver

Liver samples are assessed microscopically for the presence of different lesions previously identified as having a putative chemical aetiology in fish (e.g., Myers et al. 1987, Boorman et al. 1997, ICES 2004, Blazer et al. 2006). Among them:

1. Nuclear pleomorphism
2. Megalocytic hepatosis
3. Eosinophilic foci
4. Basophilic foci
5. Clear cell foci
6. Hepatocellular carcinoma
7. Cholangioma
8. Cholangiofibrosis
9. Proliferation of macrophage aggregates
10. Hydropic vacuolation
11. Fibrillar inclusions

Any other observations are also recorded, including inflammatory response, hepatocellular vacuolation and parasitic infestation of the biliary system.
Lesions (except macrophage aggregates) are recorded for each fish as not detected (0) or detected (1).

Macrophage aggregation is recorded on a relative scale from 0 to 7 and prevalence is calculated for fish showing a proliferation of macrophage aggregates (considered as 4 or higher on the scale).

The percentage of fish affected by each type of lesions or prevalence of lesion is then calculated.

Gill

Each gill sample is examined microscopically, first under low power (x20) for a general overview of the entire section and to record any abnormalities or parasites present. Four filaments, or primary lamellae, sectioned at a correct angle (with the central venous sinus visible in at least two-thirds of the filament and with secondary lamellae of equal length on both sides) are selected and examined under x250 magnification for the presence of gill lesions associated with chemical toxicity (Mallat 1985). This includes observations for epithelial lifting (separation of the epithelial layer from the basement membrane), telangiectasis (dilatation of blood vessel at the tip of the secondary lamellae), lamellar hyperplasia (thickening of the epithelium due to an increase in the number of epithelial cells) and fusion (fusion of two or more adjacent secondary lamellae).

A semi-quantitative examination is carried out where the total number of secondary lamellae as well as the lamellae presenting the lesions are counted on each selected filament as follows:

- basal hyperplasia is recorded when an increase in thickness of the epithelium near the base of the lamellae reaches at least one-third of the total length of the lamellae;
- distal hyperplasia is recorded when there are more than two cell layers all around the two sides of the secondary lamellae; and
- tip hyperplasia is recorded when there are more than three cell layers on at least two-thirds of the area around the secondary lamellar tip.

Results of the lamellar counts for each fish are expressed as the percentage of secondary lamellae presenting the lesion in relation to the total number of lamellae counted.

The degree of oedema present, if any, is recorded on a 0 to 3 relative scale (0-rare, 1-light, 2-moderate and 3-heavy).

5.4.4 Quality Assurance/Quality Control

Laboratories or consultants used to perform analyses must have recognized expertise or methods in the field with an acceptable quality assurance/ quality control program. Ideally, analytical laboratories should be accredited to ISO/IEC 17025:2005 by a recognized accrediting body, such as the Standards Council of Canada (SCC) or the Canadian Association for Laboratory Accreditation (CALA).

At present, most sediment, water and tissue chemistry analyses, as well as sediment toxicity, are assessed using methods accredited by the Standard Council of Canada. Methods used for quantification of sea water alkyl phenols, organic acids and alkyl PAHs are not accredited. Alkyl phenols and alkyl PAHs are

quantified using USEPA method 625 (Base/Neutrals and Acids) and the United States Geological Survey's National Water Quality Lab Method (Determination of Polycyclic Aromatic Hydrocarbon Compounds). Volatile organic acids are quantified using Standard Method 5560D (Organic and Volatile Acids).

Taste tests follow procedures established in Botta (1994). Particle size analysis follows method BS 1377: 1990: Part 2 - Methods of Tests for Soils for Civil Engineering Purposes: Classification Tests.

The benthic invertebrate laboratory QA/QC procedures include resorting of 10% of samples to assess sorting efficiency. Identification is performed by a world-renowned benthic invertebrate taxonomist, using conventional literature.

For fish health, QA/QC procedures for MFO follow protocols recommended by Hodson et al. (1991) and Stagg and McIntosh (1998). QA/QC procedures for haematology follow the practical guidelines described by Blaxhall and Daisley (1973). QA/QC procedures for histopathology follow the guidelines described by Myers and Fournie (2002). To assure accuracy in histopathological diagnosis, established standardized terminology for liver lesions (e.g. Myers et al., 1987; Boorman et al., 1997; ICES, 2004; Blazer et al., 2006) and gill lesions (Mallat, 1985) are followed. Any questionable lesions are also screened by a world-renowned fish pathologist for confirmation of diagnoses.

5.5 DATA MANAGEMENT AND ANALYSIS

5.5.1 Data Management

The EEM program generates substantial amounts of data, communications and reports. Suncor will ensure that critical information is documented and retained over the life of the EEM Program.

5.5.2 Data Analysis

5.5.2.1 Sediment Quality Component

Analysis of sediment quality data relies on regression analysis of chemistry and toxicity variables and indices of benthic community structure on distance from the nearest source (Min *d*). Relationships between variables and distance from the nearest of the FEZ (FEZ *d*) drill centres and distance from the Far East (FE *d*) drill centre have also been examined since the FE drill centre became active in 2002. Metals, excluding barium, are generally aggregated into one or two synthetic variables (i.e., axes) using principle component analysis (PCA). Indices of benthic community structure include abundance, biomass, richness, adjusted richness[3] and multivariate descriptors of community composition (i.e., axis scores

[3] Back-transformed residuals (deviations) from regressions of $\log_{10}$(richness) on $\log_{10}$(abundance).

from a non-metric multi-dimensional scaling analysis). Selected individual taxa are examined to provide insight into the responses noted for the various indices. Multi-year assessments rely on an examination of rank correlations between response variables (i.e., chemistry, toxicity, benthic community) and Min *d* across years, an examination of overall levels (medians and percentiles) across years, and repeated-measures regression of variables on distance (see Appendix F for details on repeated measures regression/ANCOVA).

When variables are strongly correlated and vary non-linearly with distance, parametric log-log bivariate and threshold ("hockey-stick") distance regression models with Min *d* are tested to provide an estimate of the zone of influence for project contaminants or the zone of effects for benthic invertebrates. Threshold distances are qualitatively compared among years.

An integrated assessment is then performed among sediment quality variables that have been identified as 'key' variables through analyses listed above. The emphasis of this analysis is on identifying the variables that fundamentally influence the composition of the invertebrate community. The assessment relies on PCA to summarize the covariation among variables. The results of the PCA are used to identify a further subset of variables that includes only the variables with relatively strong correlation with principal component (PC) axes. The relationship between these variables and indices of benthic community structure is then assessed using Spearman-rank correlations by year and scatterplots.

To date, the sediment quality analyses have been predominantly geared toward assessing potential effects of drill cuttings. As an addition to the above analyses, Suncor Energy (2009a) recommended an examination of sediment concentration of metals present in high concentration in produced water that could potentially deposit to sediments. The most enriched metal in produced water relative to seawater is iron (11,000x seawater concentration) and iron can deposit to sediments (Suncor Energy 2009a). In the 2012 EEM report, iron concentrations relative to distance from the FPSO and drill centres and any change in concentrations with distance from source since release of produced water will be examined, outside of the usual PCA on metals. Analysis of sediment iron concentration may continue in subsequent years if evidence of sediment contamination from produced water is noted in 2012.

5.5.2.2 Water Quality Component

The spatial layout of water quality stations will be modified in 2012 based on Suncor Energy (2009a) (see Section 5.3.2). With two Reference Areas, one near-field and one mid-field Study Area, the study design will now have four locations. Analysis of water quality data will test for differences in individual or summary chemistry variables among these locations. Individual variables may be those variables of specific interest (e.g., chlorophyll). Summary variables may be those derived from a PCA of multiple variables (e.g., metals). The test for significant spatial variation can proceed using conventional analysis of variance

(ANOVA). The two tests of specific interest will be: (1) are there differences between the average Reference Area concentration and the average Study Area concentration; and (2) are there differences in the average concentration in near-field and mid-field locations within the Study Area. Because concentrations may vary with water depth, depth will be taken into account as a covariable in the ANOVA. The ANOVA will proceed by first testing for differences in depth profiles between the two Reference Area, and then testing for differences in depth profiles between the Reference Areas and the Study Area, and within the Study Area (i.e., between near-field and far-field). If depth profiles do not differ among Areas, then depth will simply be used as a covariable, and the ANOVA will test for differences in mean concentrations between the Reference and Study Areas, and within the Study Area (i.e., between near-field and far-field).

Niskin bottle data will be analyzed as described above. Chlorophyll concentrations from CTD measurements will be aggregated into depth categories (i.e., 1 to 30 m, 31 to 60 m, 61 to 85 m), as in previous years, and analyzed as described above. Temperature and chlorophyll profiles from CTD will be generate for each of the four sampling areas and described qualitatively.

Across years, water quality results will be compared using graphics and summary tables of results, as they have been in previous years.

5.5.2.3 Commercial Fish Component

Morphometrics and life history characteristics

Morphometrics and life history characteristics of scallop and plaice (e.g., size, age, maturity status) are analyzed primarily to identify differences between the Study and Reference Areas that might affect other test results (e.g., chemistry, fish health analyses, taint). For each species, data are analyzed within years with summary statistics provided for previous years.

Scallop

Analyses for scallop include comparison of sex ratios, size and shape among transects within Areas and between Areas. Size and shape are also qualitatively compared between the sexes.

Sex ratios (frequencies of the two sexes) are compared among transects within Areas and between Areas, using log-likelihood ratio or *G* tests[4] (Sokal and Rohlf 1981).

Size variables include shell length, width and height (one-dimensional measures), tissue weight (adductor muscle weight + viscera weight + gonad

[4] *G* is similar to χ^2, but is strictly additive for multiple independent tests, whereas χ^2 is not.

weight) and shell weight (total weight – tissue weight) (three-dimensional measures).

PCA is used to summary size and shape using synthetic summary variables (PC axis scores). Size and shape PC scores are compared among transects within Areas and between Areas in nested ANOVA[5]. The nested ANOVA is conducted on each sex separately.

The above comparisons of sex ratios, size and shape is then repeated for the subset of scallop used for analysis of body burdens to determine if that subset is representative of all scallop collected.

Plaice

Analyses of plaice morphometrics and life history characteristics are performed predominantly to support fish health indicator assessment. For plaice, the same fish used in fish health assessment are used in body burden analysis and all or most fish sampled are used. Therefore, an analysis of the subset of animals used in these analyses versus animals sampled, as is done for scallop, is not required. Maturity stages of male and female fish are defined according to procedures used by DFO and results are expressed as frequencies (percentages) of maturity stages. The frequency of maturity stages in each sampling Area is then compared using the Fisher Exact Test.

Size and condition of plaice are analyzed separately for each sex. Plaice length, total and gutted weight, liver and gonad weight, age and condition indices in the Study and Reference Areas are compared using a conventional unpaired t-test or the Mann-Whitney Rank Sum test, when the variables are not normally distributed.

Fish condition is assessed by calculating the following indices (after Dutil et al. 1995):

- Fulton's condition factor: 100 x body weight/(length cubed) based on gutted weight;
- hepato-somatic index: 100 x liver weight/gutted weight; and
- gonado-somatic index: 100 x gonad weight/gutted weight.

Since these indices assume that body weight is proportional to the cube of length, and that liver and gonad weights are linearly related to gutted weight

[5] In the nested ANOVA, variance among transects within Areas, rather than variance among scallop within transects, is the appropriate error term for testing differences between Areas. The test of Area differences in nested ANOVA is equivalent to a *t* test comparing Areas with transect means as replicate values and those means weighted by sample size. Variance among transects within Areas is tested against variance among scallops within transects and the test is equivalent to a one-way ANOVA comparing transects with any overall Area differences removed.

(which is not always the case), log-log regressions of body gutted weight on length, and liver and gonad weight on body gutted weight are also tested in ANCOVA.

Body Burden

Tissue chemistry (typically metals and fat content) is compared among sample years and between the Study and Reference Area in two-way Year × Area ANOVA. For scallop three time (Year) contrasts are tested. The Before-After (BA) contrast compares baseline (Before project activity) values to EEM (After onset of project activity) values. The EEM Linear contrast tests for a monotonic (progressive) increase or decrease (simple trend) in body burden variable values over EEM years. The EEM Quadratic contrast tested for a parabolic (U-shaped) relationship between body burden variables after drilling began, which is effectively a reversal of monotonic trends (i.e., an increase followed by a decrease, or vice versa).

When applied to the Year term, the contrasts test for time changes common to both the Reference and Study Areas. When applied to the Year × Area interaction, the contrasts provide tests of potential project effects and other changes in differences between the two Areas over time. The BA × Area contrast is the classical Before-After Control-Impact (BACI) contrast (Green 1979), testing for a change in the difference between Reference (Control) and Study (Impact) Areas between 1997 and EEM years. The EEM Linear × Area contrast tests for a difference in monotonic trends between Areas after the onset of project activity. Similarly, the EEM Quadratic × Area contrast tests for a difference in quadratic relationships between Areas.

Analyses are similar for plaice except that the Year BA and Year × Area BACI contrasts cannot be tested because there are no baseline data.

When appropriate, PCA is used to derive summary measures of concentrations of frequently detected metals in tissue.

Concentrations of hydrocarbons and barium (two important constituents of drill muds) are qualitatively compared across years. Concentrations of these two compounds have not been above laboratory detection limit in a sufficient number of samples to warrant quantitative analysis.

Taint Testing

Taint testing consists of two separate types of taste panels, the triangle test and hedonic scaling. The triangle test datum is a value which represents the number of correct responses over the number of panelists. This value is compared to values in a standard table to determine the statistical significance of the result. A statistically significant result for the recommended panel size of 24 requires 13 correct responses (95 percent significance level).

For hedonic scaling, a nine point hedonic scale is used, with ratings varying from "like extremely" to "dislike extremely" (see Figure 5-11, Section 5.4). The panel ratings are assigned numerical values from 'like extremely' (9) to 'dislike extremely' (1). Single year data are tabulated and subjected to ANOVA and presented graphically in a frequency histogram.

Panelist comments from both tests are examined qualitatively for mention of uncharacteristic odors or taste that might be associated with taint.

Taint test data are not analyzed across years, but qualitative comparisons are made, if relevant.

Fish Health Indicators

Log_{10} transformed MFO enzyme activity, degree of oedema and arcsine square-root transformed percentages of blood cells and gill lesions in the Study and Reference Area are compared using a conventional unpaired t-test or the Mann-Whitney Rank Sum test, when variables are not normally distributed. The prevalence of liver lesions is analyzed by the Fisher exact test.

Since basal MFO levels vary between males and females of the same species, results are grouped by sex and reproductive state before analysis. Water temperature in each Area is also taken into consideration when interpreting results.

Data are not analyzed across years for health indicators, but qualitative comparisons are made, if relevant.

6.0 REPORTING AND PROGRAM REVIEW

6.1 Reporting

The EEM Program report contains the following basic elements:

- Executive Summary
- Introduction: project description, EIS predictions, EEM Program objectives, monitoring hypotheses;
- Methods: field collection, laboratory analysis and data analyses;
- Results: analysis results, with raw data in Appendices;
- Discussion: discussion of results relative to previous years, other EEM programs and available literature information;
- Conclusions: summary of project-effects relative to monitoring hypotheses and EIS predictions; and

- Recommendations: identification of opportunities for improvement.

Copies of the report are submitted to C-NLOPB for further distribution to appropriate federal and provincial government agencies.

6.2 Decision Making

Results of the EEM Program are used as a component of the Environmental Protection Plan. The Program provides Suncor with the necessary information to make project-related decisions in order to reduce effects to the marine receiving environment.

6.3 Program Review and Refinement

The EEM Program benefits from regulatory review. Recommendations from this review process are integrated into the EEM program if they can improve the overall Program. Recommendations made by Suncor as part of reporting (Section 6.1) are also vetted by the regulatory community to assure general agreement before any modifications are implemented.

7.0 REGIONAL MONITORING

Suncor, along with other production operators on the Grand Banks, conducts EEM Programs to understand the potential environmental effects of its operations on the marine environment. Where possible, Suncor will collaborate on EEM Programs with other operators to:

- align EEM design and implementation among site-specific programs;
- share resources (e.g., equipment, vessels, protocols, etc.) to enable the cost effective implementation of programs;
- develop common reporting formats; and
- share information to enable continual improvement of the programs.

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9.0 APPENDICES

Appendix A Summary of Environmental Impact Assessment Impact Predictions

Appendix B Stakeholder Consultation Report
- Appendix B-1 Public Notice
- Appendix B-2 Press Release
- Appendix B-3 Letter of Notification Sent to C-NLOPB
- Appendix B-4 Letter of Notification Sent to Stakeholder Groups
- Appendix B-5 Information Package
- Appendix B-6 Comment Sheet

Appendix C Response to Issues and Comments Raised During or Following Stakeholder Consultation

Appendix D Response to Written Submissions Following Stakeholder Consultation

Appendix E Selection of Monitoring Variables

Appendix F Potential Survey Designs and Analysis Models

APPENDIX A

Environmental Impact Assessment (Petro-Canada 1996) Impact Predictions

terra nova

Development Application

Terra Nova Development

Environmental Impact Statement

Prepared by Petro-Canada
On behalf of the Terra Nova Proponents

Petro-Canada
Mobil Oil Canada Properties
Husky Oil Operations Limited
Murphy Oil Company Ltd
Mosbacher Operating Limited

Table 5.8-1

Level II Matrix for Development Drilling and Construction

Development Activity/VEC	Potential Impact	Magnitude	+/-	Scale	Duration	Mitigation	Magnitude	+/-	Scale	Duration
Field development - offshore										
Presence of structures										
Safety zone and fishery moratorium lifted										
Benthos	Protection	Minor	+	Local	Long-term	None				
Fish (reef effect)	Refuge	Min.-Mod	+	Local	Long-term	None				
Fishery	Access	Minor	-	Local	Long-term	None				
Safety zone and fishery moratorium not lifted										
Benthos	Protection	Negligible								
Fish (reef effect)	Refuge	Negligible								
Fishery	Access	Negligible								
Fouling organisms	Structural integrity	Min.-Mod	-	Sublocal	Long-term	Removal	Negligible			
Terrestrial birds	Migration	Negligible								
Seabirds	Disturbance	Negligible								
Marine mammals	Disturbance	Negligible								
Lights and beacons										
Fish	Attraction	Negligible								
Seabirds	Attraction and mortality	Negligible								
Underwater construction										
Benthos	Disturbance	Negligible								
Fish	Disturbance	Negligible								
Marine mammals	Disturbance	Negligible								
Discharge of drilling muds and cuttings										
Water quality	Deterioration	Minor	-	Sublocal	Short-term	Treatment or discharge at depth				
Plankton	Mortality	Negligible								
Benthos	Mortality	Minor	-	Sublocal	Short-term	Low-toxicity mud or treatment				
Fish	Mortality	Negligible				Low-toxicity mud or treatment				
Fishery	Tainting	Negligible				Low-toxicity mud or treatment				
Seabirds	No interaction					Low-toxicity mud or treatment				
Marine mammals	No interaction									
Other drilling fluids										
Water quality	Deterioration	Minor	-	Sublocal	Short-term	Effluent treatment				
Plankton	Mortality	Negligible				Effluent treatment				
Fish	Tainting	Negligible				Effluent treatment				
Seabirds	Mortality	Negligible				Effluent treatment				
Seabirds	Reproduction	Negligible				Effluent treatment				
Marine mammals	Sub-Lethal effects	Negligible				Effluent treatment				

Table 5.8-1

Level II Matrix for Development Drilling and Construction

Development Activity/VEC	Potential Impact	Magnitude	+/-	Scale	Duration	Mitigation	Magnitude	+/-	Scale	Duration
Deck drainage										
Water quality	Deterioration	Minor	-	Sublocal	Short-term	Effluent treatment				
Plankton	Mortality	Negligible				Effluent treatment				
Fish	Tainting	Negligible				Effluent treatment				
Seabirds	Mortality	Negligible				Effluent treatment				
Seabirds	Reproduction	Negligible				Effluent treatment				
Marine mammals	Sub-Lethal effects	Negligible				Effluent treatment				
Hydrostatic testing fluids										
Water quality	Deterioration	Neg.-Minor	-	Sublocal	Short-term	None				
Plankton	All effects									
Benthos	All effects									
Fish	All effects									
Seabirds	All effects									
Marine mammals	All effects									
Cooling water										
Zooplankton	Mortality	Negligible								
Fish larvae	Mortality	Negligible								
Sanitary and domestic water										
Water quality	Deterioration	Negligible								
Garbage and other waste										
Marine environment	No Interaction					Waste brought ashore				
Small spills										
Marine environment and biota	See Accidents					Spill response - EPP				
Atmospheric emissions										
Air quality	Deterioration	Negligible								
Noise - drilling rigs										
Marine mammals	Disturbance	Neg.-minor	-	Sublocal	Long-term		Negligible (If habituation)			
Fish	Disturbance	Negligible								
Noise - supply vessels										
Marine Mammals	Disturbance	Minor	-	Sub to local	Long-term	Steady course and speed				
Seabirds	Disturbance	Negligible								
Seabird colonies	Disturbance	Min.-Mod	-		Med.-term	Avoidance - EPP	Negligible			
Fish and fisheries	Disturbance	Negligible		Local						

Table 5.8-1

Level II Matrix for Development Drilling and Construction

Development Activity/VEC	Potential Impact	Magnitude	+/-	Scale	Duration	Mitigation	Magnitude	+/-	Scale	Duration
Noise aircraft										
Marine mammals	Disturbance	Minor	-	Sublocal	Short-term					
Seal haul-outs	Disturbance	Minor	-	Local	Long-term	Avoidance - EPP	Negligible			
Seabirds - open water	Disturbance	Negligible								
Seabirds - colonies	Disturbance	Mod.-Major	-	Local	Long-term	Avoidance - EPP	Negligible			
Field development - shore facilities										
Atmospheric emissions										
Air quality	Deterioration	Negligible								
Liquid and solid releases										
Water quality	Deterioration	Negligible				Materials handling - EPP				
Marine biota	Mortality	Negligible				Handling - EPP				
Garbage and waste										
Water quality	Deterioration	Negligible				Handling - EPP				
Marine biota	Mortality	Negligible				Handling - EPP				
Noise, lights, beacons	Disturbance	Negligible								
Human presence										
Wildlife	Disturbance	Negligible								
Aircraft traffic										
People, wildlife	Disturbance	Negligible								
Vessel traffic										
Wildlife	Disturbance	Negligible								
Small spills										
Marine biota	Mortality	Minor	-	Sublocal	Short-med	Response - EPP	Neg.-Min.	-	Short-term	Short-term

Note: EPP means Environmental Protection Plan.

Table 5.8-2

Level II Matrix for Production

Development Activity/ Environmental Component	Potential Impact	Magnitude	+/-	Scale	Duration	Mitigation	Magnitude	+/-	Scale	Duration
Operations and maintenance										
Presence of structures										
Safety zone and fishery moratorium lifted										
Benthos	Protection	Minor	+	Local	Long-term	None				
Fish (reef effect)	Refuge	Min.-Mod	+	Local	Long-term	None				
Fishery	Access	Minor	-	Local	Long-term	None				
Safety zone and fishery moratorium not lifted										
Benthos	Protection	Negligible								
Fish (reef effect)	Refuge	Negligible								
Fishery	Access	Negligible								
Fouling organisms	Structural integrity	Min.-Mod	-	Sublocal	Long-term	Removal	Negligible			
Terrestrial birds	Migration	Negligible								
Seabirds	Disturbance	Negligible								
Marine mammals	Disturbance	Negligible								
Lights and beacons										
Fish	Attraction	Negligible								
Seabirds	Attraction or mortality	Negligible								
Maintenance of sub-facilities										
Benthos	Disturbance	Negligible								
Fish	Disturbance	Negligible								
Marine mammals	Disturbance	Negligible								
Injection water										
Zooplankton	Entrainment	Negligible								
Produced water										
Water quality	Deterioration	Minor	-	Sublocal	Long-term	Effluent treatment				
Plankton	Mortality	Minor	-	Sublocal	Short-term	Effluent treatment				
Benthos	No interaction									
Fish	Mortality	Negligible								
Fishery	Tainting	Negligible								
Seabirds	Mortality	Negligible								
Marine mammals	Sub-lethal effects	Negligible								
Storage displacement water						Separate ballast tanks				
Marine biota	No interaction									
Cooling water										
Zooplankton	Mortality	Negligible								
Fish larvae	Mortality	Negligible								

Table 5.8-2

Level II Matrix for Production

Development Activity/ Environmental Component	Potential Impact	Magnitude	+/-	Scale	Duration	Mitigation	Magnitude	+/-	Scale	Duration
Deck drainage										
Water quality	Deterioration	Minor	-	Sublocal	Short-term	Effluent treatment				
Plankton	Mortality	Negligible				Effluent treatment				
Fish	Tainting	Negligible				Effluent treatment				
Seabirds	Mortality	Negligible				Effluent treatment				
Seabirds	Reproduction	Negligible				Effluent treatment				
Marine mammals	Sub-lethal effects	Negligible				Effluent treatment				
Sanitary and domestic waste										
Water quality	Deterioration	Negligible								
Garbage and other waste										
Marine environment	No Interaction					Waste brought ashore				
Small spills of crude oil										
Marine environment and biota	See Accidents					Des. gr. Spill response - EPP				
Atmospheric emissions										
Air quality	Deterioration	Negligible								
Noise - FP										
Marine mammals	Disturbance	Neg.-minor	-	Sublocal	Long-term	If habituation	Negligible			

Note: *EPP means Environmental Protection Plan*

APPENDIX B

Stakeholder Consultation Report

JWEL PROJECT NO. 1173-1526

REPORT ON

TERRA NOVA DEVELOPMENT
ENVIRONMENTAL EFFECTS MONITORING PROGRAM
STAKEHOLDER CONSULTATION REPORT

FOR

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October 30, 1998

1.0 INTRODUCTION

Environmental effects monitoring (EEM) involves repetitive measuring of select environmental variables over time and is designed to assess the status in the environment, detect changes in the environment and evaluate impact predictions. Terra Nova is currently designing an EEM program for the Terra Nova Project. This EEM program is part of Terra Nova's commitment to conducting offshore oil development operations in an environmentally sound manner. As part of the design process for the Terra Nova Project EEM program, Terra Nova held a public information session and a series of informal meetings with government agencies. This report documents the consultation activities undertaken and issues and concerns identified from all sources.

2.0 PUBLIC INFORMATION SESSION

The public information session was held in St. John's at the Fluvarium on September 22, 1998 from 5:00 p.m. to 9:00 p.m. The purpose of the session was to inform the general public about the proposed EEM program and related activities, and provide an opportunity for all interested persons to request information and state their views. The session was open to all members of the public interested in the project.

2.1 Public Notification

The public information session was advertised in *The Clarenville Pacquet* during the weeks of September 14th and 21st, and *The Evening Telegram* on September 12th, 13th, 19th and 20th. The newspaper announcements described the subject of the session, and stated the date, location and time of the events. These announcements also included a contact address, telephone number and a fax number, and requested the public to forward any comments or concerns that they had about the project (Appendix B-1). Terra Nova also issued a press release concerning the proposed EEM program on September 22, 1998 (Appendix B-2).

A letter of notification was sent to the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) and invitations sent to stakeholder groups (Appendices B-3 and B-4).

2.2 Session Materials

The session featured a series of displays, an information package and a comment sheet. The displays and a pamphlet were used to provide information about the project, and input was obtained through use of a comment sheet and discussions between Terra Nova and JWEL representatives and session attendees.

The display panels highlighted the proposed EEM program and schedule, environmental features and the environmental assessment. An information pamphlet (Appendix B-5) contained 8.5 in. x 11 in. colour copies of the display panels. These packages were distributed to session participants. As well, following the session, copies of the information package were sent to invited stakeholders who did not attend.

The comment sheet was developed as a means to obtain public input about the project and was distributed to session participants (Appendix B-6).

Information on the EEM program was displayed with materials on the Terra Nova Project, including displays describing project features and copies of the Terra Nova Development Environmental Impact Statement (EIS) and other documents related to the Terra Nova Project. Documents were available for participant review.

2.3 The Session

Thirty-nine people participated in the public information session. Two comment sheets were completed and returned during the session, and two written submissions were received after the session.

Participants were given a copy of the information package and comment sheet when they entered, and were requested to sign the guest book. Participants were encouraged to complete the comment sheet at the session or return it by mail, or alternatively to submit written comments by October 13, 1998.

The public information session provided an opportunity for participants to speak directly with Terra Nova representatives and the consultant team designing the EEM program. Terra Nova representatives present were Greg Lever, Urban Williams and Mona Rossiter. Members of the consultant team present were Kathy Penney and Mary Murdoch of Jacques Whitford Environment Limited (JWEL), David Schneider and Judith Bobbitt. David Burley from C-NOPB was also present. JWEL representatives organized the session, prepared the displays and information package on the EEM program and handled logistics for the session.

A debriefing session was held at the end of the public information session for all of the study team members. This session gave team members an opportunity to review discussions from the session and ensure that all issues and concerns raised were recorded. Issues and concerns raised during the session are summarized in Section 4.0.

3.0 MEETINGS WITH GOVERNMENT AGENCIES

Meetings were held with representatives from the Department of Fisheries and Oceans (DFO) (Science Branch and Habitat Management Branch) and Environment Canada prior to the public information session to inform the agencies about the session and proposed EEM program, and to discuss issues and concerns prior to the session. Provincial government agencies were contacted, but it was not possible to schedule meetings prior to the public information session. Issues and concerns identified during these meetings have been incorporated in the summary of issues and concerns in Section 4.0.

4.0 ISSUES AND CONCERNS

The following is a summary of the issues and concerns identified during the public information session and meetings with government agencies. The issues and concerns are arranged by category. In general, most participants were pleased with the information presented and were impressed with the proposed EEM program. A comment was made that the proposed program appeared to exceed those of the North Sea by addressing all potential discharges and effects rather than focusing on only on drilling fluid discharges. No major concerns were identified, but a number of issues, questions and comments were noted throughout the consultation process. These are outlined below. Terra Nova's response to these issues, concerns and questions is provided in Appendix C of the main EEM program design document.

4.1 Baseline Information

There was concern that the baseline information collected to date and the EEM program would not adequately address the need for a baseline study. The ability of a single-season baseline survey to provide a complete picture of an ecosystem and an indication of natural variability in populations was questioned. It was commented that research in the North Sea indicated that more than 10 years research would be necessary to determine natural seasonal and annual variability. It was felt that the EEM program would not be able to separate natural population changes from environmental effects, except those that occur during a catastrophic event.

4.2 EEM Program Design

There were questions about the drilling fluid, flexibility of the EEM program, statistical design, locations of control areas, and airborne and accidental discharges, as discussed below.

There was concern about focusing on one drilling fluid type in the EEM program. It was suggested that the EEM program be designed to consider the possible use of other drilling fluids, such as silicate muds with excessive corrosive characteristics, as the use of these might become necessary at some point in the drilling operations.

It was felt that the EEM program should be flexible and adaptable with the ability to modify future programs based on the results of this program. It was suggested that the program by reviewed annually to determine whether parameters remain in the program or new parameters are added. As well, the predictions being tested by the EEM should be stated up-front in the EEM documentation.

Attenuation-by-distance design was considered an appropriate technique, as long as adjustments are made to fit the distribution of well heads. There was question as to whether the attenuation-by-distance model would address all project effects and whether it would account for improvements in drilling technology and, subsequently, an

extended project life. It was noted that any improvements in technology and extended project life would result in an increased volume of material being deposited at the site.

It was suggested that a multiple reference sampling design be considered for addressing any questions not addressed by the gradient sampling design. However, using a multiple reference sampling design raises questions about defining an impact site and avoiding unplanned contamination of reference sites from oil activity.

There was concern about the distance of control stations from the glory holes and whether they would be exposed to the same operational and accidental discharges from offshore oil activity as the study sites. There was also question about the rationale for selecting these sites and why only two control sites were selected. It was suggested that the sampling program be more intense near the Floating Production, Storage and Offloading (FPSO) vessel and areas where produced waters are released.

There was question about whether airborne and accidental discharges would be included in the EEM program. Participants inquired whether shoreline, emergency and oil spill monitoring, measuring surface currents (oceanographic data) and studying fish health would be a part of the program. It was suggested that the drifting buoy program, a requirement in the event of an oil spill, be used to enhance the oil spill model. Buoys could be thrown overboard on a regular basis and tracked to build a data base of drift tracks. It was felt that this would provide better data than the models. It was also suggested that the EEM program include monitoring surface pollutants and the effects of these on marine life. There was also an interest in the application of acoustic analysis of benthic community health to the EEM program.

4.3 EEM Program Parameters

There were comments that effects of drilling muds, drill cuttings, and produced water must be addressed by the EEM program.

There was concern that the focus of the EEM program on benthic and epibenthic communities was too narrow and should be expanded to include animals in other parts of the water column. There was question as to whether the sampling design could account for variations in benthic community variables. It was suggested that consideration be given to stratifying the sampling regime by substrate type or another variable known to explain variability in benthic communities. It was noted in consultation with government representatives that the benthic boundary layer requires further research. There was also question as to why epibenthos has been excluded from the EEM program. Testing for chronic effects on epibenthic organisms was discussed, but it was recognized that suitable methods have not been developed for these tests.

Sediment and water quality were identified as important attributes. There was some discussion about whether both benthic community and toxicity parameters should be

measured or whether just one of them, in conjunction with chemistry, would be sufficient.

It was suggested that monitoring sediment and water chemistry not be limited to the components of drilling muds, but anticipate and address all chemicals introduced into the reservoir and drilling environment by the operator and those originating directly from the reservoir.

Testing of commercial fish or shellfish tissues for taint and body burden was identified as important. Hydrocarbons have apparently been shown to bioaccumulate in fish near offshore developments in the North Sea. However, it was generally thought that hydrocarbon body burden is less important than taint as an attribute. Histopathology of fish tissues was discussed as an important attribute. It was suggest that testing should include Mixed Function Oxygenase (MFO) measurement, and should include a flatfish species and possibly a pelagic species. It was also suggested that caged bivalves be used as insurance against anticipated sampling problems.

Fish larvae and zooplankton were discussed with the suggestion that tows be conducted and samples archived for future analyses. It was suggested that biological samples be taken for analysis, including nitrogen, phosphorous, potassium and chlorophyll. It was also mentioned that there has been a shift in emphasis from benthic to pelagic organisms in terms of looking for chronic effects. There was some question as to whether surf clams should be collected as they are commercially harvested and are very long-lived. Plankton analysis in terms of vertical profile and sedimentation was discussed as an attribute.

Temperature, fluorescence, dissolved oxygen, salinity and density structure of the water column were considered important factors to be considered in the EEM program. It was noted that the National Energy Board (NEB) requires the following oceanographic data be collected: wave rider data; current information; meteorological information; salinity and temperature profiles; and iceberg management. It was also suggested that both seabird and marine mammal monitoring be incorporated in to the EEM program.

4.4 EEM Frequency and Program Length

Question was raised about the frequency of monitoring activities and the length of the EEM program. It was felt that annual surveys would not be adequate for distinguishing seasonal variations and that effects could go unnoticed for up to a year before detection.

The EEM program would not address effects associated with accidental events of a short-term duration, such as a small oil spill. It was suggested that there be more continuous monitoring and independent, trained monitors be stationed on all operation platforms. The suggested roles for these monitors are to verify proponent compliance

with environmental regulations, record incidental marine mammal observations, sample discharged materials and document environmental conditions and variables.

4.5 Seabird Observations and Monitoring

There was question as to the commitment to monitoring seabird collisions with the FPSO vessel and seabirds that fly into a flare. There was also question as to whether observers could be accommodated on the vessels that will be used for the EEM program. It was suggested that marine mammals and birds be monitored using a volunteer watch program. It was felt that this monitoring would be a good opportunity for students to obtain training and a request was made to the proponent to provide money for training students to participate in this offshore work. There was some concern among the study team about the high turnover rates associated with using student labour and the learning curve associated with conducting the work. Consistency among observers was seen as an important factor. It was also noted that the C-NOPB have approved in principle a program to place seabird observers on industry vessels. The C-NOPB also has a proposal to address issues associated with lights and gas flares on offshore platforms and vessels.

Limiting seabird monitoring to the case of a large oil spill was considered inadequate. It was suggested that the EEM program be designed to monitor the effects of all project discharges on seabirds. There was concern about relying on incidental observations and the value of the data obtained through these observations. It was commented that the EEM program should provide value for decision-making, not comfort monitoring. There was also a request for funds to operate the bird recovery unit and shoreline monitoring in Placentia Bay during an oil spill.

4.6 Cumulative Environmental Effects

There were questions about cumulative environmental effects and whether these would be addressed as part of the EEM program. There was also question about whether the attenuation-by-distance model was adequate for monitoring cumulative environmental effects.

It was suggested that fishing activity be prohibited in the vicinity of all study sites (including control sites) to prevent depletion of sampling material and to control for variations in fish populations due to fishing activity. There was also concern about the use of commercial fishing gear (specifically scallop harvesting and bottom trawl gear) and resulting damage to the ocean floor, and the effect that this damage may have on EEM results.

Concern was also expressed about pre-EEM drilling activity and the effect on the EEM results.

There was discussion of other means, such as the Environmental Studies Revolving Fund (ESRF) and C-NOPB, to address cumulative effects.

4.7 Liability

Question was raised about the ability to trace effects and attribute specific effects to individual platforms after oil development and extraction on the Grand Banks has ceased. Participants wanted a means for determining the source of effects detected after all operators have left the area. Associated with this concern was the question of who would be liable for any effects detected after the companies have left the area. It was commented that there is some mention of this matter in the *Canada-Newfoundland Atlantic Accord Implementation Act* and *Canada-Newfoundland Atlantic Accord Implementation Newfoundland Act*, but the C-NOPB is limited in its ability to attribute damage to specific operators. Question was raised as to whether decommissioning and abandonment plans would address this issue.

4.8 Independence of Consultants

Question was raised as to whether the process for choosing a consultant to design and conduct the EEM program was adequate. Some participants questioned the independence of consultants and their ability to do good work when they are hired directly by the proponent. It was felt that the contracting process was flawed and any consultants hired by the proponent were not independent.

4.9 Suppliers

There were questions about the types of services and supplies required for conducting the EEM program, and whether local suppliers could take advantage of these opportunities. There were also inquires about employment opportunities associated with the EEM program. It was suggested that individual meetings for suppliers and the EEM study team be held to develop a better understanding of the services available and what is required to conduct the program.

4.10 Condition 1

Comments were made regarding Condition 1 (Decision 97.02) which states: *As soon as it is practicable after Project Sanction, the Proponent relocate engineering and procurement activities for the Project to Newfoundland* (C-NOPB 1997). Two participants commented that they felt that this condition and the benefits agreements had not been met by Terra Nova.

4.11 Public Consultation Process

Study team members and most participants felt that the session format provided a good forum for presenting information on and discussing the proposed EEM program. However, there was some confusion about the format for the session. Study team members indicated that they had received telephone calls prior to the session and comments during the session as to whether there would be a presentation by a Terra Nova representative. In hindsight, the team members felt that they could have made better use of the media to advertise the session.

There was also concern raised about the timing and extent of public input into the design process, and about the timelines for making a submission on the EEM program. One participant questioned whether the public consultation for the EEM program adequately addressed the requirements of Condition 23.

Some participants inquired whether they would be able to review the EEM program when the design has been finalized and whether stakeholders would be able to access the data from the program. There was an interest in seeing a more flexible and iterative review process.

5.0 REFERENCES

Canada-Newfoundland Offshore Petroleum Board. 1997. Decision 97.02: Application for Approval, Terra Nova Canada-Newfoundland Benefits Plan. Canada-Newfoundland Offshore Petroleum Board, St. John's, NF.

Appendix B-1 Public Notice

PUBLIC INFORMATION SESSION

Terra Nova Development Environmental Effects Monitoring Program

September 22, 1998 – 5:00 p.m. to 9:00 p.m.
Fluvarium, Pippy Park, St. John's, NF

The purpose of this session is to provide information on the proposed environmental effects monitoring program and related activities, and to offer all interested persons an opportunity to request information and state their views.

The monitoring program is part of the Terra Nova Alliance's commitment to conducting offshore oil development operations in an environmentally sound manner.

For further information about the public information session, or to submit comments, please contact:

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Urban Williams
Terra Nova Alliance
Suite 201, Scotia Centre
235 Water Street
St. John's, NF
A1C 1B6
Telephone: (709) 724-2808
Fax: (709) 724-2897
E-mail: UrbanW@petro-canada.ca

Appendix B-2 Press Release

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Newsrelease

For Immediate Release
September 22, 1998

Terra Nova Invites Public Input Into Environmental Effects Monitoring

St. John's – The Terra Nova Development will present its proposed Environmental Effects Monitoring (EEM) program at a public information session to be held in St. John's this evening at the Fluvarium.

The session will outline the proposed program including the aspects of the environment to be monitored, study area and timeframe, information to be gathered and type of analysis and follow up that may occur. This session is intended to provide the community with an opportunity to review the proposed program and offer comments and suggestions.

"We are pleased to have a draft design for the Terra Nova Environmental Effects Monitoring program available for public review," commented Gregory Lever, Operations Manager, Terra Nova Development. "We hope people will provide comments and suggestions to be considered as we develop a final program for submission to the Canada-Newfoundland Offshore Petroleum Board at the beginning of November." He added, "Environmental monitoring is a key part of the development's comprehensive environmental protection plan, and an essential tool in ensuring there are no adverse environmental effects as a result of offshore oil operations."

Environmental effects monitoring is designed to confirm predictions and evaluate the effectiveness of mitigation and compensation measures. Specifically, provide early warning of potential future challenges; provide information to managers to allow for decisions pertaining to the marine environment; confirm impact predictions made in the environmental assessment and provide the basis for technological improvements. The development of the proposed Terra Nova EEM program was coordinated by Jacques Whitford Environment Limited of St. John's in cooperation with representatives from the Terra Nova development, Memorial University and experts involved in environmental monitoring in the North Sea. Additional input was provided by the Department of Fisheries and Oceans and Environment Canada.

A study to determine existing seabed, water and biological conditions at the site of the Terra Nova oil field was carried out in October, 1997. This information provides baseline data for comparison with information to be collected in the Environmental Effects Monitoring program during drilling and production activities.

The Terra Nova development proponents are: Petro-Canada (operator), Mobil Oil Canada Properties, Husky Oil Operations Ltd., Norsk Hydro Canada Oil & Gas Inc., Murphy Oil Company Limited, Mosbacher Operating Limited and Chevron Canada Resources.

The Terra Nova Alliance is a consortium of companies, led by Petro-Canada, to design and construct the floating production facility and subsea components necessary for the development of the Terra Nova oil field. The Alliance consists of: SBR Offshore, Halliburton Energy Services, FMC Offshore Canada Ltd., PCL Industrial Constructors Inc., Coflexip Stena Offshore Newfoundland Ltd. and Doris ConPro Offshore Ltd.

more..

Appendix B-2 Press Release (continued)

The Terra Nova oil field is located on the Grand Banks 350 kilometres east-southeast of St. John's, Newfoundland. Discovered in 1984, Terra Nova is the second largest field off Canada's East Coast. Estimated reserves are 300-400 million barrels of recoverable oil. The field will be developed using a floating production facility. Start up and first oil is expected at the end of the year 2000.

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Media and general enquiries:
please contact:

Mona Rossiter
Terra Nova Development
St. John's, Newfoundland
Canada
(709) 724-2962

Appendix B-3 Letter of Notification Sent to Canada-Newfoundland Offshore Petroleum Board

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Tel. 709 724-2500
Fax 709 724-2501

Mr. Dave Burley
Canada-Newfoundland Offshore Petroleum Board
140 Water Street, 5th Floor TD
St. John's, NF
A1C 5W1

July 31, 1998

IMS – CNO 066
File Code D.4.9

Dear ~~Mr. Burley~~ Dave:

Re: Terra Nova EEM Design Public Consultation Program

Petro-Canada is currently designing the Environmental Effects Monitoring Program (EEM) for the Terra Nova Project. Condition 23 of Decision 97.02 (Point ii), states that the general public must be given an opportunity to provide input, and review, the design of this program. To this end, we have developed an approach to facilitate public input that we trust will meet with C-NOPB approval.

The plan is to hold one public information session with this session being held after the draft EEM design has been reviewed and approved by Petro-Canada. This session will be held in St. John's during the evening of September 10, 1998. St John's was chosen as the location for the session as the greatest interest and expertise in offshore EEM is found in that city. The session will be open to all members of the public, however, invitations will be sent to key regulatory agency representatives and scientists.

Petro-Canada has contracted Jacques Whitford Environment Limited (JWEL) to organize the event. The session format will include story boards (i.e. display panels) with information on the draft EEM program and related information on the Terra Nova Project. Key members of the Petro-Canada and JWEL environmental effects monitoring design team will be available to greet session attendees and address questions/issues raised.

An information package will be prepared and distributed at the session. The information package will contain – i) background information on the project, ii) design of the EEM program, and iii) a comment form. The comment form will be a simple double-sided questionnaire for information session participants to complete. The questions will solicit comment on the participants impression of the project and their issues and concerns as they relate to EEM Program design. The package contents and comment form will be

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Appendix B-3 Letter of Notification Sent to Canada-Newfoundland Offshore Petroleum Board (continued)

developed by JWEL in consultation with Petro-Canada. In the event that there is interest from the public following the public session, packages can be provided to those interested parties. Completed comment forms, as well as written submissions, will be accepted up to September 20, 1998.

The public consultation session will be advertised in the *Evening Telegram* and the *Clarenville Packett*. Petro-Canada will follow the provincial Department of Environment and Labour guidelines specifying advertising requirements for public consultations. An advertisement for the public session will be placed in each paper on the preceding weekend and three consecutive days prior to the event.

Immediately following the public session, all Petro-Canada and JWEL representatives attending the event will participate in a debriefing session. The purpose of this session is to ensure that all issues and concerns discussed by representatives and attendees throughout the evening are documented.

Upon completion of the public consultation a report documenting the public information session and the issues and concerns identified will be prepared. Issues and concerns raised during the session, and on all comment forms received, will be documented. This report will be appended to the EEM design document and a summary will be included in the main body of the report. Petro-Canada will arrange to meet with you to discuss the public comments after the report has been finalized.

I trust that this information provides sufficient detail on the public consultation program and we look forward to a very productive evening on September 10th. Please feel free to contact me at your earliest convenience if you require elaboration on any aspect of our public consultation plan.

Sincerely,

TERRA NOVA DEVELOPMENT

Urban Williams
Senior Advisor, Environment
Petro-Canada
(709) 724-2808

Appendix B-3 Letter of Notification Sent to Canada-Newfoundland Offshore Petroleum Board (continued)

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August 14, 1998

Ref. No. IMS-MIS-0017
File No. D.4.9

Mr. Dave Burley
Canada-Newfoundland Offshore Petroleum Board
140 Water Street, 5th Floor TD
St. John's, NF
A1C 5W1

Dear Mr. Burley,

SUBJECT: Design of the EEM Program – Public Session

Listed below is confirmation of the points discussed in our telephone conversation earlier today. These points are in reference to the public session for the design of the environmental effects monitoring program.

Points Discussed:

1. Upon completion of the public consultation a report documenting the public information session and the issues and concerns identified will be prepared. All the issues/concerns raised during the public session will be addressed in this report.
2. The date of the public hearing is Tuesday, September 22, 1998.
3. Advertisements for the public session will appear in the Clarenville Pacquet during the weeks beginning September 14th and September 21st. Advertisements will appear in the Evening Telegram on September 12th, 13th, 19th and 20th.

Please feel free to give me a call at 724-2808 if you wish to discuss any of the points in more detail.

Yours faithfully,

Urban Williams
Senior Advisor, Environment
TERRA NOVA PROJECT

Appendix B-4 Letter of Notification Sent to Stakeholder Groups

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September 17, 1998

«Title» «FirstName» «LastName»
«Company»
«Address1»
«Address2»
«City», «Country»
«PostalCode»

Dear «Title» «LastName»:

On September 22, 1998, the Terra Nova development is holding a Public Information Session outlining the development's Environmental Effects Monitoring Program. The Session will be held between 5:00 p.m. and 9:00 p.m. in the Fluvarium at 5 Nagle's Place, St. John's. The information session is intended to provide the public with an opportunity to review the proposed Terra Nova Environmental Effects Monitoring Program and provide their input.

We cordially invite you to attend the public session to review the program and provide us with your comments.

If you have questions on the session or the proposed Environmental Effects Monitoring Program, please contact me at 724-2807 or Terra Nova's Environmental Advisor, Urban Williams at 724-2808.

Sincerely,

Gregory Lever
Operations Manager
Terra Nova Development

IMS-MIS 036
File Code D.4.9

Appendix B-4 Letter of Notification Sent to Stakeholder Groups (continued)

External Stakeholders List

Company	Title	Name	Surname
Canada-Newfoundland Offshore Petroleum Board	Mr.	Hal	Stanley
Canada-Newfoundland Offshore Petroleum Board	Mr.	John	Fitzgerald
Canada-Newfoundland Offshore Petroleum Board	Mr.	David	Burley
Canadian Environmental Assessment Agency	Mr.	William	Coulter
Chevron Canada Resources	Mr.	R. D.	Lyon
Department of Fisheries & Oceans	Dr.	Ben	Davis
Department of Fisheries & Oceans	Mr.	Larry	Coady
Department of Fisheries & Oceans	Mr.	Ray	Finn
Environment Canada	Mr.	Brian	Power
Environment Canada	Ms.	Kim	Coady
Government of Newfoundland and Labrador	Mr.	Joe	O'Neill
Government of Newfoundland and Labrador	Ms.	Ann Marie	Hann
Government of Newfoundland and Labrador	Mr.	Ken	Domine
Government of Newfoundland and Labrador	Mr.	Fred	Way
Government of Newfoundland and Labrador	Mr.	Max	Ruelokke
Government of Newfoundland and Labrador	Mr.	Martin	Sheppard
Government of Newfoundland and Labrador	Mr.	Keith	Healey
Hibernia Management and Development Co. Ltd.	Mr.	David	Taylor
Hibernia Management and Development Company Limite	Mr.	David	Taylor
Hibernia Management and Development Company Limite	Mr.	Ken	Dyer
Husky Oil Operations Limited	Mr.	Don	Sutherland
Leslie Harris	Dr.	Leslie	Harris
Memorial University of Newfoundland	Ms.	Janet	Russell
Memorial University of Newfoundland	Dr.	William	Montevecchi
Memorial University of Newfoundland	Dr.	Brian	Veitch
Mobil Oil Canada Properties	Mr.	James L.	Ranson
Mosbacher Operating Limited	Mr.	Richard G.	Dingwall
Murphy Oil Company Limited	Mr.	Harvey	Doerr
Natural History Society	Mr.	Len	Zedel
Newfoundland Ocean Industries Association	Mr.	Steve	Henley
Newfoundland Transshipment Limited	Mr.	Harvey	Mott
Norsk Hydro Canada Oil and Gas	Mr.	Gutlorm	Kvisten

Appendix B-5 Information Package

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PROPOSED ENVIRONMENTAL EFFECTS MONITORING PROGRAM FOR TERRA NOVA DEVELOPMENT

Public Information Session
September 22, 1998
Fluvarium, St. John's, NF

Appendix B-5 Information Package (continued)

terra nova

SIGNIFICANT MILESTONES
TERRA NOVA PROJECT

May 1984	Terra Nova Field discovered
December 1995	Terra Nova begins preparing Development Plan Application
January 1996	Terra Nova holds public information sessions in eleven Newfoundland communities
August 1996	Terra Nova Development Plan Application to the Canada-Newfoundland Offshore Petroleum Board (C-NOPB)
September 1996	Terra Nova holds public information sessions on the Development Plan Application
November 1996	Terra Nova Alliance formed, and preliminary design and engineering begins
December 1996	Production system and alliance contractor selected
January 1997	Environmental Assessment Panel appointed to review Terra Nova Development Application
April - May 1997	Environmental Assessment Panel holds public hearings in seven Newfoundland communities
August 1997	Environmental Assessment Panel recommends approval of the Terra Nova Development Plan Application
September - November 1997	Baseline Characterization Program conducted to collect physical, chemical and biological information about the Terra Nova site
December 1997	Government of Canada accepts Environmental Assessment Recommendation for Terra Nova
January 1998	C-NOPB announces approval of Terra Nova Development Plan Application
February 1998	Terra Nova partners agree to proceed with development
September 22, 1998	Public Information Session on Environmental Effects Monitoring (EEM) Program Design
November 1, 1998	EEM design to be submitted to C-NOPB for review
Summer 1999	Drilling scheduled to commence
December 2000	First oil

Appendix B-5 Information Package (continued)

terra nova

SAFETY AND ENVIRONMENTAL PROTECTION COMMITMENTS

Petro-Canada, as operator of the Terra-Nova Development, considers safety and environmental protection fundamental values. The Corporation recognizes that every employee has a vital role to play in achieving targets for safety and environmental protection. Senior management will lead in the implementation of this policy. Petro-Canada's commitment will be incorporated into business activities through the following guiding principles. Petro-Canada will:

ensure our operations comply with government legislation, target levels of safety, corporate policy and applicable industry standards concerning the protection of the environment and the public

determine, evaluate and mitigate the environmental impacts of our business during project planning, implementation, operation and decommissioning

ensure that appropriate waste and emissions management programs are developed and implemented

respond to emergencies in a prompt and effective manner

ensure that all employees and others engaged on our behalf are aware of the need, informed of the requirements and trained to protect the environment

use energy and other resources efficiently in our operations

support research on the environmental effects of our products, processes and waste materials

deal openly and fairly with members of the public regarding our activities

Appendix B-5 Information Package (continued)

terra nova

ENVIRONMENTAL PROTECTION PLAN

Terra Nova is preparing an environmental protection plan (EPP) for all phases of the Terra Nova Development. The plan will contain the following components:

- corporate environmental policy
- standards and codes of practice
- mitigation procedures for development, production, decommissioning and abandonment
- chain of command for environmental decision-making
- environmental education, training and orientation procedures
- **environmental effects monitoring (EEM)**
- environmental compliance-monitoring (ECM) practices and reporting
- list of applicable legislation, regulations and guidelines, and copies of licences, permits and approvals
- management plans for waste, atmospheric emissions and effluent releases
- contingency plan for accidental discharges
- environmental clauses for contractors
- environmental inspection and audit procedures
- fishing industry agreements and compensation procedures
- performance review practices

The focus of this public information session is EEM. We invite input and suggestions. All suggestions will be considered in developing the final EEM design report and will be specifically addressed in that report. The final EEM design report will be made available to the public.

Appendix B-5 Information Package (continued)

terra nova

CONDITION 23

C-NOPB approval of the Terra Nova Development Plan Applicaton was announced in January 1998. Approval was subject to a number of conditions, including:

Condition 23

i) The Proponent submit its environmental effects monitoring program respecting the drilling and production phases of the Terra Nova project prior to commencing drilling operations.

ii) *The Proponent provide, during the design of its environmental effects monitoring program, opportunity for the general public to obtain input into, and review, the design.*

The text accompanying Condition 23 (Section 4.4.4.1 "Environmental Effects Monitoring") is provided on separate panels.

The owners of the Terra Nova Development are committed to designing and implementing an Environmental Effects Monitoring (EEM) program for drilling and production.

Appendix B-5 Information Package (continued)

terra nova

DECISION 97- 02: Text Accompanying Condition 23

4.4.4.1 Environmental Effects Monitoring

The Proponent states that, as part of its environmental protection planning for the Terra Nova Development, it will design and implement an Environmental Effects Monitoring (EEM) program for the drilling and production phases of the project. The EEM program will include provision for the collection of baseline data prior to the commencement of field development activities.

The Proponent notes that the EEM program design will be developed in consultation with the Board and with other relevant government agencies, but that it anticipates the program will include monitoring of the following parameters:

- effects of drilling discharges, as measured by oil concentrations in sediments and effects upon benthic animals;
- effects due to produced water, as measured by oil concentrations at various distances from the discharge point;
- effects of city water upon fish, as measured by a taint testing program.

The Panel was strongly of the view that effective monitoring will be essential to prudent environmental management of offshore production operations in general, and the Terra Nova Project in particular. It offered a series of recommendations respecting the contents of the Proponent's EEM program, the process by which it will be developed, and the availability of the resulting data and analyses.

With respect to the spatial scale of sampling, the Panel recommended [63] that the Board ensure that the effects monitoring program for Terra Nova utilize a sufficiently extended sampling grid so that the zone of influence of discharges would be fully defined.

The Panel recommended [66] that the Proponent be required to undertake a study of seabird attraction to lights on offshore facilities, and suggested that the Hibernia platform would be a suitable position from which observers could watch for this effect.

The Panel also recommended [67] that observers be placed on the production vessel and on shuttle tankers until such time that "comfort is achieved" that minimal impacts upon seabirds result from these activities.

The Panel cited a suggestion from the Department of Fisheries and Oceans that the effects of noise upon marine mammals had been underestimated by the Proponent, and recommended [68] that the abundance and activities of marine mammals be monitored in relation to noise emitted by Project activities.

The Panel recommended [71] that the Board convene a workshop to identify the details of the EEM program for Terra Nova, including baseline studies, and to review the final proposed EEM program prior to its approval by the Board. It also recommended [72] that the Proponent seek a synergistic relationship with the Hibernia project in designing its program, and [73] that the Board, through provision of funding where appropriate, promote opportunities for collaborative research among the Proponent, other operators, and researchers in government and academia, which may arise in connection with the EEM program.

Finally, the Panel recommended [52] that the results of environmental monitoring program be made available by the Board to both experts and the public for review, and that such reviews be conducted in recognition of the results of basic research.

The Board observes that an EEM program is a component of the Environmental Protect Plan required pursuant to the *Newfoundland Offshore Area Petroleum Production and Conservation Regulations*, and observes that the precise elements to be included in the program will be discussed in greater detail during the review of the proposed program.

The Board agrees with the Panel's recommendation that the EEM sampling grid extend sufficiently far to fully capture the "zone of influence" of Project discharges.

The Board will ensure that the sampling grid which is proposed for the Terra Nova EEM program is based upon modelling results specific to Terra Nova conditions and that these results are examined in the light of international monitoring experience. The Board will also ensure that the grid is expanded if monitoring results indicate that the zone of influence is approaching the grid boundary.

The Board believes that the design process for the EEM program should include provision for input and review by outside experts and by interested groups or individuals in the general public, and intends to ensure that the results of EEM are made publicly available in a prompt manner following the completion of individual survey programs.

Appendix B-5 Information Package (continued)

terra nova

4.4.4.1 continued

The Board notes that it routinely consults with federal and provincial environment and fisheries departments on these matters and that these working relationships are described in Memoranda of Understanding with these departments. During its consideration of environmental effects monitoring data, the Board will consult with federal and provincial fisheries and environment departments and will welcome input from external experts or other interested parties.

The Board will require, as a condition of its development plan approval, that the Proponent provide, during the design of the environmental effects monitoring program, opportunity for the general public to obtain input into, and to review the design.

The Board observes that no scientific evidence was offered to the Panel review to support the concerns of some participants respecting seabird interaction with lights. However, the Board has since been informed by an official of Environment Canada of an incident of Leach's storm petrels being attracted to the lights of vessels passing close to Baccalieu Island and of a similar occurrence involving to Hibernia Platform. The Board believes that, in the interests of safety, personnel complements on offshore drilling and production facilities should be kept to the minimum necessary for prudent operations and has concluded that insufficient evidence has been presented to justify requiring the placement of additional, dedicated personnel on drilling or production platforms as observers.

The Board will explore with the Hibernia Management and Development Company and with representatives of the Canadian Wildlife Services of Environment Canada whether the potential attraction of seabirds to lights on offshore platforms may be credibly investigated using existing platform personnel. The Board also will propose a literature study through the auspices of the Environmental Studies Research Fund to investigate further the level of information on this topic available worldwide. The Board will expect the Proponent to participate in these studies as appropriate and to take their results into account in the design of its facilities.

The Board observes that seabirds may be affected by oil spills which may be associated with the Project, and that the severity of these effects may not be directly related to the size of an individual spill. The Board also notes that because of the wide-ranging movement patterns of seabirds, their monitoring does not easily fit within the scope of typical site-specific EEM programs, except perhaps in the case of a dedicated program mounted following a large spill. The Board believes, rather, that routine seabird monitoring may be better accomplished by means of placing observers on supply vessels during their regular transits as part of a regional monitoring effort. The Board notes that the Proponent expressed a willingness during the public hearings to consider making space available on its vessels for such a purpose. In consultation with the Proponent, the Hibernia Management and Development Company, the Canadian Wildlife Service of Environment Canada, and other interested parties, the Board will sponsor a project under the auspices of the Environmental Studies Research Fund to determine the feasibility of developing a scientifically defensible seabird monitoring program of this type, and if such a program is deemed feasible, to facilitate its implementation on the north-east Grand Banks.

The Board observes that no evidence was presented to the Panel to support the claim that the Proponent's estimation of the effects of noise, which were presented in the EIS with considerable reference to published literature, were inappropriate. The Board can see no reason at this time to conclude that effects of Project-related noise upon marine mammals are likely to be significant, nor to require inclusion of marine mammals in the EEM program for routine Project operations. The Board acknowledges, however, that marine mammal monitoring may be appropriate following an oil spill. The Board will ensure that the Proponent's spill response plan provides for the monitoring of potential effects upon marine mammals following a major spill.

Drilling discharges form a substantial portion of the wastes which are likely to be discharged into the marine environment. The potential effects of drilling discharges also were the subject of considerable concern to a number of participants in the public hearings. The Board notes that, although the Proponent has stated that it will submit the portions of its EPP which deal with drilling, it may be impractical to artificially separate those elements of the EEM plan from those associated with production discharges. The Board believes, therefore, that the full EEM program design should be ready for implementation shortly after the commencement of drilling operations.

The Board believes that the Panel's suggestion that the Proponent, during development of its EEM program, seek synergies with the Hibernia project is a sensible one, and will encourage the Proponent to do so during the EEM design process. The Board notes that its budget does not include provision for the direct funding of general research. However, it participates in setting the priorities of the federal Panel on Energy Research and Development and provides a representative to the Management Board of the Environmental Studies Research Fund.

The Board will use its good offices in these fora and in its relations with the petroleum industry to encourage the collaboration which the Board describes.

Appendix B-5 Information Package (continued)

terra nova

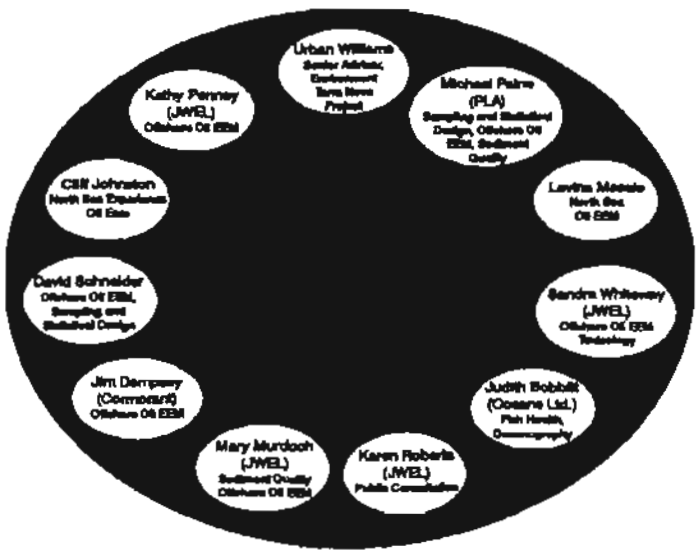
ENVIRONMENTAL EFFECTS MONITORING (EEM)

Definition

A program designed to assess the status of the marine environment to detect changes in that status, and to evaluate effectiveness of mitigation measures.

Objectives

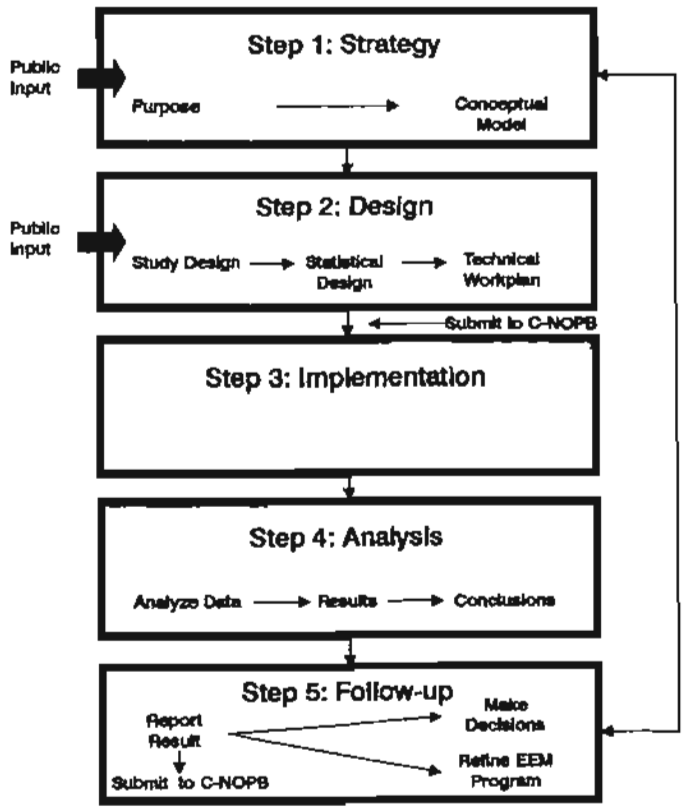
- confirm impact predictions made in the environmental assessment
- provide early warning of potential future challenges
- provide information to managers to allow for decisions pertaining to the marine environment
- provide the basis for technological improvements



Appendix B-5 Information Package (continued)

terra nova

STEPS FOR AN ENVIRONMENTAL EFFECTS MONITORING (EEM) PROGRAM



Appendix B-5 Information Package (continued)

terra nova

STEP 1: EEM STRATEGY
DEFINING WHAT IS IMPORTANT TO CONSIDER

Developing a strategy for EEM includes:

- define purpose
- review existing information
- identify project discharges
- develop a conceptual model, which includes identifying stressors and resources in the environment and determining study area and timing

Purpose

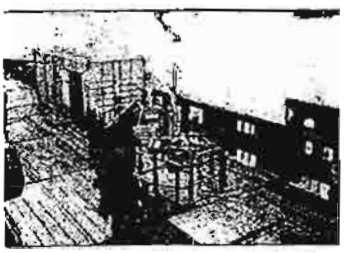
Assess the status of the marine environment and detect changes in this status to provide an early warning of effects from project activities at the site.

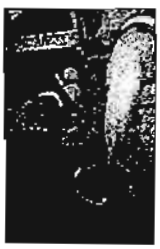
Objectives

- comply with operator's environmental protection commitments
- fulfil regulatory information requirements
- address public concerns
- scientifically defensible
- cost-effective
- collect data required for the assessment of effects
- provide managers with information for decision-making
- provide results that are understandable to the general public

Review Existing Information

Baseline information, collected prior to site development, was collected in Fall 1997. Three studies were completed:





Sediment quality study

- chemical and physical characteristics
- toxicity
- benthic communities

Water quality study

- chemical and physical characteristics
- phytoplankton

Biological study

- taint
- body burden
- health

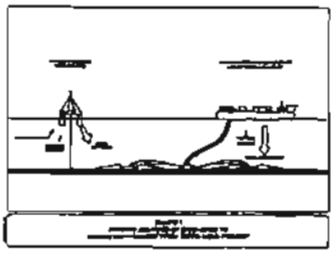
This provides information on the Terra Nova site prior to development for comparison with data that will be collected during drilling and production. This information allows evaluation of approaches for designing and conducting the EEM Program.

Appendix B-5 Information Package (continued)

terra nova

Identify Project Discharges

The two primary discharges are liquids and solids, as indicated in Figure 1.



1. Liquid discharges may include the following:

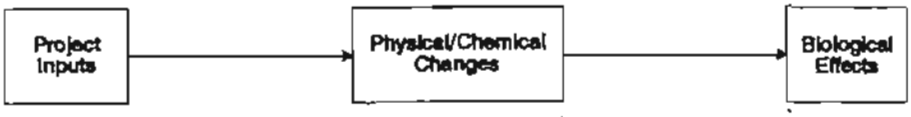
- produced water
  - water associated with oil and gas reservoirs that is produced along with oil and gas
  - there is very little water in the producing formations at Terra Nova, therefore most of the produced water will be sea water injected to enhance recovery
  - produced water will be passed through a treatment system to reduce its oil content to meet Petro-Canada's targets in compliance with Offshore Waste Treatment Guidelines
- sewage
  - treated to meet Petro-Canada's targets in compliance with Offshore Waste Treatment Guidelines
- cooling water
  - chlorinated sea water used as a coolant

2. Solid discharges may include the following:

- water-based and synthetic-based drilling muds; the Terra Nova project has selected IPAR-3, which is a food-grade synthetic drilling fluid
- drill cuttings will be discharged following treatment to meet Petro-Canada's targets in compliance with Offshore Waste Treatment Guidelines

Develop Conceptual Model of Effects

A conceptual model is based on predicted causes-and-effects. The basic conceptual model is shown below. Physical/chemical change provides an early warning of potential for biological effects, while biological effects indicate what has already occurred. EEM is intended to provide early warning of effects.



Project-related inputs may include:

- trace hydrocarbons in liquids and solids
- trace metals in liquids and solids
- particulate matter

Physical and chemical changes may result from project inputs. These changes may include:

- chemical changes to the water column and sediment resulting from discharges
- physical changes to the water column and sediment resulting from discharge of particulates

Biological effects of concern are undesirable effects to marine resources.

Appendix B-5 Information Package (continued)

Terra nova

Identify Marine Resources

Marine resources that share the environment at the Terra Nova site may include:

- seabirds
- marine mammals
- commercial fish species

These were identified as valued environmental components (VECs) in the Terra Nova Development Application Environmental Impact Statement.

Indicators of the status of these marine resources may also be considered,

- water quality
- sediment quality

Monitoring water quality and sediment quality will provide information on possible indirect effects to marine resources, particularly commercial fish species.

Define Boundaries - Study Area and Timing

Timing:

- EEM Program will be conducted throughout the duration of drilling and production
- propose to conduct the EEM program annually for the first 3 years of project operations, after which the frequency of the program will be reviewed (e.g., every second year)
- current plan is to sequentially establish five drill centres, as indicated in the schedule below

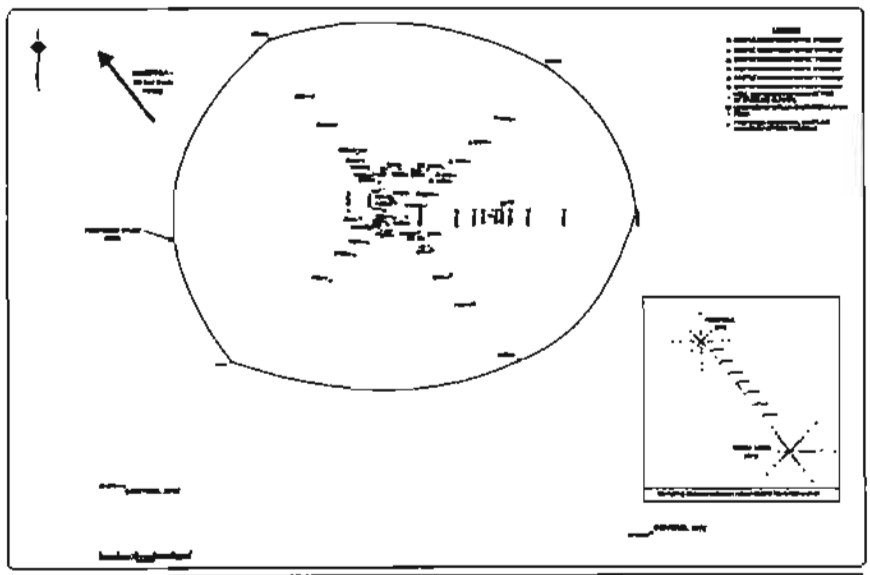
Well Sequence			
Well Number	Name	Drill Centre	Spud Date
1	P01	SW	11-Jan-99
2	P02	SW	13-Jul-99
3	GB02	SW	16-Aug-99
4	WI02	NE	8-Sep-99
5	BP04	NE	6-Oct-99
6	BP03	NE	13-Nov-00
7	P07	SE	30-Dec-00
8	WI04	NE	16-Jan-00
9	BP05	NE	10-Feb-01
10	WI03	NE	16-Mar-01
11	BP03	SW	11-Feb-01
12	BP01	NW	16-Sep-01
13	GB04	SW	23-Oct-01
14	P02	SW	19-Nov-01
15	WI05	NE	20-Dec-00
16	P07	SE	26-Jan-01
17	BP03	NE	15-Feb-01
18	WI02	NE	24-Mar-01
19	BP01	NW	14-May-01
20	BP05	NW	13-Jun-01
21	GB05	SW	31-Jul-01
22	BP04	SW	23-Aug-01
23	WI02	SW	3-Oct-01
24	BP03	SW	23-Oct-01
25	WI04	NE	1-Dec-01
26	BP04	NE	3-Jan-02
27	P09	NE	10-Feb-02

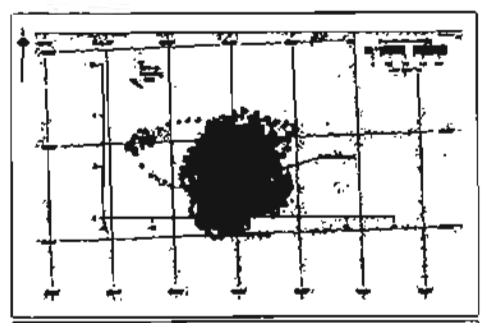
Appendix B-5 Information Package (continued)

terra nova

Study area:

- area determined by the distribution of project-related discharges to the marine environment
- proposed EEM study area shown in Figure 2 below includes and extends beyond the predicted limit of distribution of drilling muds, cuttings and produced water
- density of drill cuttings is predicted to diminish rapidly with distance from each drill centre, as indicated in the Figure 3 below





Appendix B-5 Information Package (continued)

terra nova

STEP 2: EEM DESIGN
WHAT IS INVOLVED?

EEM design involves the following:

- select monitoring variables
- choose a statistical design
- develop a sampling design

Monitoring Variables to be Considered

Monitoring variables are aspects of the marine resources that are used to determine if adverse effects may occur or have occurred.

Monitoring variables being considered for the EEM program, and specific questions to be addressed by the variables, include the following:

Commercial Fish Species

- taint
  - presence of a flavor or odour in organisms which, when captured or harvested, is not typical of the flavor or odour of the organisms themselves

> *Taint testing will determine if taint has occurred within the study area compared with control areas.*

- body burden
  - hydrocarbon and metal concentrations in tissues to indicate uptake by the organism from the marine environment

> *Body burden is a measure of bioavailability (i.e., uptake) and may provide an early warning of potential taint.*

- health
  - tissue analysis for abnormalities
  - enzyme indicators of exposure to pollutants or stress
  - population measures such as age, size, reproduction

> *Health indicator analysis will determine if there is a deterioration in commercial fish health within the study area compared to control areas.*

Appendix B-5 Information Package (continued)

terra nova

Monitoring Variables cont.

Water Quality

- chemical characteristics: hydrocarbon and metal concentrations
- physical characteristics: water column profiles
- phytoplankton: microscopic marine plant density

Water analyses will determine if there is deterioration of water quality within the study area and whether there is a relationship with distance from source.

Sediment Quality

- chemical characteristics: hydrocarbon and metal concentrations
- physical characteristics: particle size analysis
- toxicity: lethal and sublethal effects on organisms
- benthic communities: species presence and abundance in sediment

Sediment analyses will determine if there is deterioration of sediment quality within the study area and whether there is a relationship with distance from source.

Seabirds

- Landings on and collisions with project structures

Provide information on interaction of seabirds with project structures.

Marine Mammals

- Incidence in project area

Provide information on interaction of marine mammals with project structures.

Appendix B-5 Information Package (continued)

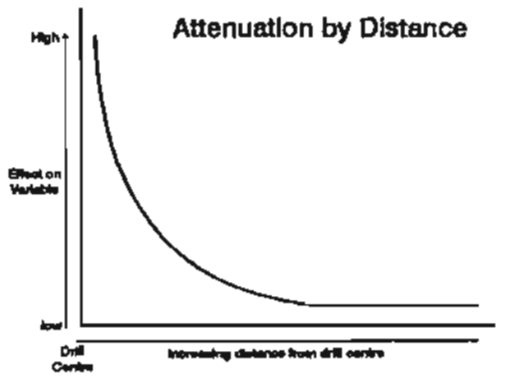
terra nova

Statistical Design

Statistical design involves selecting an appropriate statistical model and should be chosen before the sampling design is chosen.

The statistical design being proposed for the EEM is **Attenuation by Distance**, which is based on the relationship between monitoring variables and spatial distances. This will be used to determine if effects are detected, and if so, whether they change over distance.

For example, the relationship between magnitude of the effect on a variable, such as sediment quality or water quality, and distance from the source may be as depicted below.



For commercial fish species, a Control-Impact model will be used to determine if there are differences in biological variables, such as taint, between samples collected within the study area, and samples collected in control areas.

Appendix B-5 Information Package (continued)

terra nova

Sampling Design and Workplan

Sampling design is the determination of how to sample monitoring variables to meet requirements of the statistical design.

The workplan provides technical direction on how to implement the design.

The EEM program will be conducted throughout the duration of drilling and production. Sampling design and workplan options being considered include:

Commercial Fish Species

- sample commercial fish species using commercial fishing gear within the proposed EEM study area and at control sites
- Icelandic scallop and/or American plaice
- analyze samples for taint, body burden and health (may include tissue analysis, enzyme analysis and population measures)
- sample once per EEM cycle

Water Quality

CTD

- randomly select ten or more stations for monitoring from within the proposed EEM study area; these stations will coincide with stations sampled for sediment quality (see next panel)
- analyze samples for hydrocarbons, metals, phytoplankton density
- conduct water column profiling at the same stations; measures will be taken using a CTD and will include: conductivity, temperature, dissolved oxygen
- sample once per EEM cycle

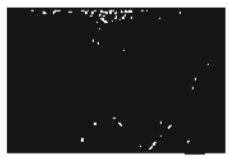
Appendix B-5 Information Package (continued)

terra nova

Sampling Design and Workplan cont.

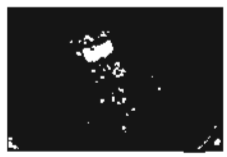
Sediment Quality

- sample over 50 stations within the proposed EEM study area using a box corer
- stations will be sampled at specific distances from drill centres, as proposed in Figure 2
- analyze samples for:
  - particle size, hydrocarbons and metals
  - toxicity using standard tests to determine if there are lethal or sublethal effects to test organisms
  - benthic community status in terms of which species are present and their abundance
- sample once per EEM cycle



Sample Collection

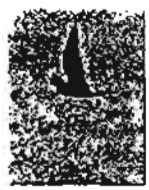
Toxicity Testing



Benthic Community Status

Seabirds

- monitor seabird landings on and collisions with platforms during operations
- develop action plan for recovering and releasing birds following collisions
- develop monitoring program for seabirds in the case of a large spill
- provide space for observers on project platforms/vessels



Leach's Storm Petrel

Marine Mammals

- record incidental observations from project platforms
- develop monitoring program for marine mammals in the case of a large spill
- provide space for observers on project platforms/vessels

Humpback Whale

Appendix B-5 Information Package (continued)

terra nova

STEP 3 - IMPLEMENTATION COLLECTING THE DATA

After developing the technical workplan, the EEM program may be implemented using the following steps:

Sampling platforms: vessels must be chosen that will allow for effective collection, transportation and storage of samples.

Sampling schedule: must consider project activities, availability of sampling platforms and weather considerations.

Documentation:

Cruise Plan: provides detailed information on sampling locations, roles and responsibilities of field crew, logistical details (including schedule, reporting requirements, communications)

Field Manual: provides details on sample collection, quality assurance/quality control plan (measures in place to ensure sample integrity and legal defensibility), standard operating procedures (sample collection, records, equipment operation)

Sample Collection: samples are typically collected on two separate cruises:

Water and Sediment Collection Cruise

Biological Sample Collection Cruise

Cruise Report: provides chronology of the activities associated with the sample collection cruises. This report is submitted to C-NOPB.

Appendix B-5 Information Package (continued)

terra nova

STEP 4 - ANALYSIS
REPORTING THE RESULTS

This includes analysis of the data, reporting of the results and developing a set of conclusions. Statistical analyses will be conducted to allow testing of specific hypotheses for monitoring variables and to meet the statistical design.

A report will be written for each EEM cycle and will provide raw data, methods of analysis, results and conclusions. This report will be submitted to the C-NOPB.

Appendix B-5 Information Package (continued)

terra nova

STEP 5 - FOLLOW-UP
WHERE DO WE GO FROM HERE?

There are two main steps in follow-up.

Provide information:
Results of the EEM Program will be used to provide managers with the information necessary to make project-related decisions, such as operational changes to reduce effects to the marine receiving environment.

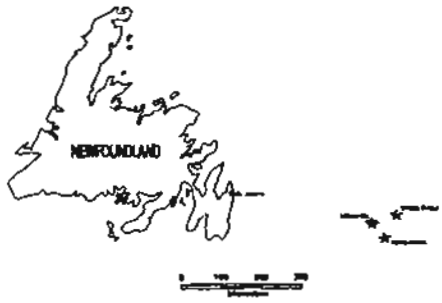
EEM Program review:
The EEM Program will be reviewed after each round of implementation. Each of the steps in the Program will be evaluated and if necessary, refined to better meet the objectives of the EEM.

In addition, the Terra Nova EEM Program is intended to be part of a **regional EEM program** to look at impacts of offshore oil and gas development on the Grand Banks. Development of a regional EEM program will consider:

- parallels in EEM design and implementation
- joint approach to data management
- common reporting format
- opportunities to reduce costs, such as by sharing vessels

A regional EEM program will provide a number of benefits, including:

- bring strength to individual EEM programs by information sharing
- allow determination of regional/cumulative impacts



Appendix B-6 Comment Sheet

Terra Nova Project
Environmental Effects Monitoring Program

Terra Nova is interested in learning of any concerns that you may have about the proposed environmental effects monitoring (EEM) program for the Terra Nova Project. We would appreciate it if you could take a few minutes to answer the following questions. The information that you provide will be used in the program design.

1. **What is your overall impression of the proposed EEM program for the Terra Nova Project?**

2. **Do you have any concerns about the EEM program design?** ☐ **Yes** ☐ **No**
   If yes, what are they?

3. **What steps do you think Terra Nova could take to address your concerns?**

See Reverse

Appendix B-6 Comment Sheet (continued)

4. **Which of the following best describes your feelings about the proposed EEM program?**

- ☐ Very Satisfied
- ☐ Satisfied
- ☐ Neither Satisfied nor Dissatisfied
- ☐ Dissatisfied
- ☐ Very Dissatisfied

5. **Additional comments:**

_____

_____

_____

_____

_____

_____

Thank you for taking the time to give us your input.
We appreciate your assistance.

Name: _____
Affiliation: _____
Address: _____
Telephone: _____ **Fax:** _____

Please leave your completed questionnaire or any other written comments at the reception desk or forward to:

Urban Williams
Terra Nova Alliance
Suite 301, Scotia Centre
235 Water Street
St. John's, NF
A1C 1B6

Phone: 709-724-2808
Fax: 709-724-2871
E-mail: UrbanW@petro-canada.ca

APPENDIX C

Response to Issues/Comments Raised During or Following Stakeholder Consultation

JWEL PROJECT NO. 1173-1526

REPORT ON

TERRA NOVA DEVELOPMENT
ENVIRONMENTAL EFFECTS MONITORING PROGRAM
RESPONSE TO ISSUES/COMMENTS RAISED
DURING OR FOLLOWING STAKEHOLDER CONSULTATION

FOR

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October 30, 1998

Issues and concerns raised during the stakeholder consultation process are summarized in the Stakeholder Consultation Report, provided in Appendix B. Issues and concerns are copied from this report (using the same section numbering) and presented in *italics*. Terra Nova's responses are provided in plain typeface.

4.1 Baseline Information

There was concern that the baseline information collected to date and the EEM program would not adequately address the need for a baseline study. The ability of a single-season baseline survey to provide a complete picture of an ecosystem and an indication of natural variability in populations was questioned. It was commented that research in the North Sea indicated that more than 10 years research would be necessary to determine natural seasonal and annual variability. It was felt that the EEM program would not be able to separate natural population changes from environmental effects, except those that occur during a catastrophic event.

Control-Impact and Attenuation-By-Distance statistical models have been chosen to permit discrimination of natural variation from effects related to operational discharges over space and time. Emphasis has been placed on spatial patterns associated with project discharges, more so than temporal patterns; the focus is to monitor magnitude and extent of environmental effects over time.

Before After design requires more baseline data (than does Control-Impact and Attenuation-By-Distance designs) and emphasizes presence/absence of an effect rather than magnitude and extent. It should be recognized that some sediment stations within the study area will likely reflect "control" conditions for a period of perhaps years because drill centres will be developed sequentially and dispersion of drill cuttings over larger distances will take some time. For more discussion on temporal designs, see Section 4.1.2 of the EEM program design document.

4.2 EEM Program Design

There were questions about the drilling fluid, flexibility of the EEM program, statistical design, locations of control areas, and airborne and accidental discharges, as discussed below.

There was concern about focusing on one drilling fluid type in the EEM program. It was suggested that the EEM program be designed to consider the possible use of other drilling fluids, such as silicate muds with excessive corrosive characteristics, as the use of these might become necessary at some point in the drilling operations.

Water-based drilling muds and synthetic-based (IPAR-3) drilling muds will be used. If there is a need to use drilling muds other than these, the EEM program will be reviewed and if necessary refined to ensure that the design considers possible effects from the alternate drilling muds.

It was felt that the EEM program should be flexible and adaptable with the ability to modify future programs based on the results of this program. It was suggested that the program by reviewed annually to determine whether parameters remain in the program or new parameters are added. As well, the predictions being tested by the EEM should be stated up-front in the EEM documentation.

The EEM program design will be evaluated and refined after each cycle. The design is intended to be reviewed and, if necessary, refined for each cycle based on new data, new information and new technological developments.

Attenuation-By-Distance design was considered an appropriate technique, as long as adjustments are made to fit the distribution of well heads. There was question as to whether the attenuation-by-distance model would address all project effects and whether it would account for improvements in drilling technology and, subsequently, an extended project life. It was noted that any improvements in technology and extended project life would result in an increased volume of material being deposited at the site.

The Attenuation-By-Distance model is flexible and can be adjusted, if need be, to fit the location of drill centres. The sampling grid for sediment quality will be expanded if new information predicts that effects may extend beyond the existing station distribution. The rationale behind selection of statistical designs and how effects would be detected are provided in Section 4 of the EEM Program Design document.

It was suggested that a multiple reference sampling design be considered for addressing any questions not addressed by the gradient sampling design. However, using a multiple reference sampling design raises questions about defining an impact site and avoiding unplanned contamination of reference sites from oil activity.

The multiple reference design is appropriate when there are a number of suitable reference locations available. This is not the case for the Terra Nova Development, since there is an operational oil platform and planned developments to the northeast and northwest and possible future developments to the west and east.

There was concern about the distance of control stations from the glory holes and whether they would be exposed to the same operational and accidental discharges from offshore oil activity as the study sites. There was also question about the rationale for selecting these sites and why only two control sites were selected. It was suggested that the sampling program be more intense near the Floating Production, Storage and Offloading (FPSO) vessel and areas where produced waters are released.

Control sites were selected 20 km to the southwest and southeast of the Floating Production, Storage and Offloading vessel (FPSO). These sites are considered to be well beyond the probable extent of

distribution of project discharges, based on information that there is no mean direction to the movement of seawater in the Terra Nova Development area (Seaconsult 1998), modeling of drill cuttings distribution indicating dispersion close to the source (Seaconsult 1998), and experience in the North Sea (e.g., Gray et al. 1996). Control stations could not be added to the north because they would be too close to Hibernia and planned developments.

The Attenuation-By-Distance model for monitoring sediment quality does not rely on data from control sites to determine if impacts have occurred. However, the Control Impact (CI) design for monitoring other parameters, such as fish health, requires that control sites be relatively unaffected by operational discharges. Data from each EEM cycle will be used to verify models of distribution of project discharges. Models will be updated and if necessary refined with each EEM cycle. The location of control sites will be re-evaluated if there is any evidence that contamination from operational discharges has occurred or may occur.

There was a question about whether airborne and accidental discharges would be included in the EEM program.

Inputs to the water column from airborne sources will be monitored by the marine EEM program. In addition, Condition 19 of Decision 97-02 required that Terra Nova evaluate and report to C-NOPB the technical and economic feasibility of incorporating measures into the design of its production facilities which will reduce the amount of greenhouse gases released from these facilities. Results of this evaluation have been submitted to and accepted by C-NOPB.

Participants inquired whether shoreline, emergency and oil spill monitoring, measuring surface currents (oceanographic data) and studying fish health would be a part of the program.

In the event of an accidental discharge (i.e., oil spill), a specific monitoring program will be developed in consultation with appropriate regulatory authorities. As recognized by C-NOPB, thorough advance planning for monitoring effects of an oil spill is a necessary precaution. Terra Nova will ensure that this is addressed in the contingency plan, which is a separate program from the operational EEM program.

Fish health is included in the EEM program (see Section 3. 2.3).

It was suggested that the drifting buoy program, a requirement in the event of an oil spill, be used to enhance the oil spill model. Buoys could be thrown overboard on a regular basis and tracked to build a database of drift tracks. It was felt that this would provide better data than the models.

Comment noted.

It was also suggested that the EEM program include monitoring surface pollutants and the effects of these on marine life.

The EEM program monitors water quality for effects at surface, mid-depth (just below the thermocline) and near bottom depth.

There was also an interest in the application of acoustic analysis of benthic community health to the EEM program.

Comment noted.

A question was raised about data management.

Data management involves a number of systematic processes and protocols that are designed to provide a framework for recording, review and retrieval of environmental data. The major components of a data management system used for environmental programs should include or consider items such as:

- data documentation in terms of computer programs, and statistical, normalization and error control procedures;
- data recording in terms of laboratory reports, field notebooks, field maps and auxiliary data records;
- data custody and transfer in terms of chain of custody records, QA/QC procedures for authorizing changes to data, QA/QC documentation of transfer formats, data recording forms, and data verification and validation;
- data validation and verification in terms of cross-referencing field data sheets and laboratory results, transmittal errors, flagged or rejected data, data comparability, and data review and evaluation;
- data presentation in terms of tables, graphs and figures; and
- data storage in terms of digital format and hard copy.

For more details on data management, see Section 7.1 of the EEM program design document.

4.3 *EEM Program Parameters*

There was concern that the focus of the EEM program on benthic and epibenthic communities was too narrow and should be expanded to include animals in other parts of the water column.

The EEM program addresses impacts to the water column and to commercial fish species, in addition to addressing impacts on benthic communities.

There was question as to whether the sampling design could account for variations in benthic community variables. It was suggested that consideration be given to stratifying

the sampling regime by substrate type or another variable known to explain variability in benthic communities.

Stratified sampling by substrate type is unnecessary for a number of reasons. First, the Attenuation-By-Distance model allows for identification and removal of confounding factors during statistical analysis. Second, the substrate is surprisingly homogeneous throughout the project area. Finally, a map of surface (upper 15 cm) substrate type for the project area would be required prior to conducting stratified sampling; such a map does not presently exist.

It was noted in consultation with government representatives that the benthic boundary layer requires further research. There was also question as to why epibenthos has been excluded from the EEM program.

Research on benthic boundary layer is currently being conducted but is not yet ready to be used in Terra Nova's operational EEM program.

Epibenthic sampling was pursued twice during baseline characterization to address suggestion from Department of Fisheries and Oceans (DFO) that epibenthos be characterized in addition to benthic infauna. DFO was contracted to conduct the sampling. However, despite best efforts by DFO the sampling equipment failed to perform as expected. Epibenthic sampling may be considered for future EEM cycles if technology improves.

Sediment and water quality were identified as important attributes. There was some discussion about whether both benthic community and toxicity parameters should be measured or whether just one of them, in conjunction with chemistry, would be sufficient.

An integrated approach to assessing sediment quality through use of the Sediment Quality Triad (SQT) is a proven approach used in offshore oil EEM for platforms in the North Sea and in the Gulf of Mexico. Benthic community, chemistry and toxicity are the three traditional components of the SQT approach.

It was suggested that monitoring sediment and water chemistry not be limited to the components of drilling muds, but anticipate and address all chemicals introduced into the reservoir and drilling environment by the operator and those originating directly from the reservoir.

Water and sediment chemistry parameters will be reviewed and amended with each EEM cycle to ensure that subsequent cycles address possible effects from project discharges.

Testing of commercial fish or shellfish tissues for taint and body burden was identified as important. Hydrocarbons have apparently been shown to bioaccumulate in fish near

offshore developments in the North Sea. However, it was generally thought that hydrocarbon body burden is less important than taint as an attribute. Histopathology of fish tissues was discussed as an important attribute. It was suggest that testing should include Mixed Function Oxygenase (MFO) measurement, and should include a flatfish species and possibly a pelagic species.

Agreed. Commercial fish species variables are included in the EEM program, including taint, body burden and fish health (histopathology, MFO).

It was also suggested that caged bivalves be used as insurance against anticipated sampling problems.

Sufficient numbers of Icelandic scallop are present at the site for use in monitoring, therefore the caged bivalve approach is not currently necessary. Furthermore, the caged bivalve approach is currently undergoing research to determine its feasibility for use in offshore oil programs.

Fish larvae and zooplankton were discussed with the suggestion that tows be conducted and samples archived for future analyses. It was suggested that biological samples be taken for analysis, including nitrogen, phosphorous, potassium and chlorophyll. It was also mentioned that there has been a shift in emphasis from benthic to pelagic organisms in terms of looking for chronic effects. There was some question as to whether surf clams should be collected as they are commercially harvested and are very long-lived. Plankton analysis in terms of vertical profile and sedimentation was discussed as an attribute.

Temperature, fluorescence, dissolved oxygen, salinity and density structure of the water column were considered important factors to be considered in the EEM program. It was noted that the National Energy Board (NEB) requires the following oceanographic data be collected: wave rider data; current information; meteorological information; salinity and temperature profiles; and iceberg management.

Phytoplankton will be sampled as part of water quality analysis for effects. Surf clams are not available in sufficient numbers in the study area for use in the EEM program. Chemistry and physical profiling of the water column are also included in the EEM program.

It was also suggested that both seabird and marine mammal monitoring be incorporated in to the EEM program.

The EIS predicted residual impacts to seabirds following mitigation with respect to avoidance. There is no doubt that the offshore Grand Banks supports a large number and variety of seabirds and that seabirds may be expected to pass through the Terra Nova field area. However, seabirds are not recommended for offshore EEM programs due to their wide-ranging movement patterns (Dunnet and Clark 1994). This was

recognized by the Environmental Assessment Panel and cited by C-NOPB in Decision 97-02. However, it is recognized that monitoring of seabirds may be more appropriate for a regional monitoring program addressing cumulative effects of offshore oil developments on the Grand Banks.

To contribute to the knowledge base of seabird interactions with offshore structures, Terra Nova will develop a feasible monitoring program for seabirds in the case of a large spill as part of the contingency plan. Terra Nova will support an observer program for seabirds by providing space for observers aboard Terra Nova project platforms and vessels, assigning Terra Nova staff to participate in the observer program, and consulting with regulatory agencies with respect to appropriate observer procedures. Terra Nova will develop an action plan for recovering and releasing birds following collisions. In addition, Terra Nova is providing funding support for a study examining seabird attraction to light and seabird monitoring in the Atlantic Region.

The EIS predicted negligible impacts to marine mammals from the Terra Nova Development, with the exception of potential for negligible to minor, sublocal to local and long-term effects from project-related noise. However, marine mammals are not suitable for inclusion in a site-specific offshore oil EEM program due to their transient residence within the area (Dunnet and Clark 1994). Exclusion of marine mammals is supported by C-NOPB in Decision 97-02. However, Terra Nova recognizes that monitoring of marine mammals may be appropriate following an oil spill. As a result, Terra Nova will support an observer program for marine mammals by providing space for observers aboard Terra Nova project platforms and vessels and assigning Terra Nova staff to participate in the observer program. In addition, Terra Nova will develop a feasible monitoring program in the case of a large spill as part of the contingency plan.

4.4 EEM Frequency and Program Length

Question was raised about the frequency of monitoring activities and the length of the EEM program. It was felt that annual surveys would not be adequate for distinguishing seasonal variations and that effects could go unnoticed for up to a year before detection.

The EEM program will continue throughout drilling and operations phases of the Terra Nova oil field. The frequency will be annual for the first three years, after which EEM will be conducted every two years.

With respect to time frames for monitoring effects within an EEM program, there is usually a direct relationship between the time required for effects to occur and the lifespan of organisms. For example, effects on short-lived benthic invertebrates may be evident within a year, whereas potential effects on long-lived pelagic species may not be evident for a decade. Even for the same organism, time scales differ among effects of interest. In fish, uptake of contaminants and tainting are effects that occur over weeks or months. Effects on growth and especially reproduction (usually annual) may be

evident with one or a few years. Higher-level effects on population abundances may only be evident after a decade or longer. The EEM program is designed to detect impacts on a temporal basis with annual changes being the shortest time frame.

The EEM program would not address effects associated with accidental events of a short-term duration, such as a small oil spill. It was suggested that there be more continuous monitoring and independent, trained monitors be stationed on all operation platforms. The suggested roles for these monitors are to verify proponent compliance with environmental regulations, record incidental marine mammal observations, sample discharged materials and document environmental conditions and variables.

In the event of an accidental discharge (i.e., oil spill), a specific monitoring program will be developed in consultation with appropriate regulatory authorities. As recognized by C-NOPB, thorough advance planning for monitoring effects of an oil spill is a necessary precaution. Terra Nova will ensure that this is addressed in the contingency plan, which is a separate program from the operational EEM program.

4.5 Seabird Observations and Monitoring

There was question as to the commitment to monitoring seabird collisions with the FPSO vessel and seabirds that fly into a flare. There was also question as to whether observers could be accommodated on the vessels that will be used for the EEM program. It was suggested that marine mammals and birds be monitored using a volunteer watch program. It was felt that this monitoring would be a good opportunity for students to obtain training and a request was made to the proponent to provide money for training students to participate in this offshore work. There was some concern among the study team about the high turnover rates associated with using student labour and the learning curve associated with conducting the work. Consistency among observers was seen as an important factor. It was also noted that the C-NOPB have approved in principle a program to place seabird observers on industry vessels. The C-NOPB also has a proposal to address issues associated with lights and gas flares on offshore platforms and vessels.

Limiting seabird monitoring to the case of a large oil spill was considered inadequate. It was suggested that the EEM program be designed to monitor the effects of all project discharges on seabirds. There was concern about relying on incidental observations and the value of the data obtained through these observations. It was commented that the EEM program should provide value for decision-making, not comfort monitoring. There was also a request for funds to operate the bird recovery unit and shoreline monitoring in Placentia Bay during an oil spill.

See last bullet in Section 4.3 regarding seabird monitoring. In addition, Terra Nova is presently considering the request to provide funds to operate the bird recovery unit and shoreline monitoring in Placentia Bay.

4.6 Cumulative Environmental Effects

There were questions about cumulative environmental effects and whether these would be addressed as part of the EEM program. There was also question about whether the attenuation-by-distance model was adequate for monitoring cumulative environmental effects.

Cumulative effects of other projects on marine resources at the Terra Nova Development are considered to be beyond the scope of the site-specific EEM program. It is suggested that a regional monitoring program would be more appropriate to assess cumulative impacts from offshore oil developments on the Grand Banks and in the Atlantic region. Terra Nova is committed to working with other operators towards development of a regional monitoring program.

It was suggested that fishing activity be prohibited in the vicinity of all study sites (including control sites) to prevent depletion of sampling material and to control for variations in fish populations due to fishing activity. There was also concern about the use of commercial fishing gear (specifically scallop harvesting and bottom trawl gear) and resulting damage to the ocean floor, and the effect that this damage may have on EEM results.

Commercial fishing activity within the Terra Nova study area is the jurisdiction of Department of Fisheries and Oceans (DFO). The Canadian Coast Guard will put in place fisheries exclusion zones around Terra Nova Development assets.

Concern was also expressed about pre-EEM drilling activity and the effect on the EEM results.

Exploratory drilling was conducted within the Terra Nova field between 1984 and 1988, nine years prior to the baseline characterization survey. The baseline characterization survey documented existing conditions at the site in 1997 for future comparison.

4.7 Liability

Question was raised about the ability to trace effects and attribute specific effects to individual platforms after oil development and extraction on the Grand Banks has ceased. Participants wanted a means for determining the source of effects detected after all operators have left the area. Associated with this concern was the question of who would be liable for any effects detected after the companies have left the area. It was commented that there is some mention of this matter in the Canada-Newfoundland Atlantic Accord Implementation Act and Canada-Newfoundland Atlantic Accord Implementation Newfoundland Act, but the C-NOPB is limited in its ability to attribute damage to specific operators. Question was raised as to whether decommissioning and abandonment plans would address this issue.

Terra Nova operators are accountable and liable for all effects of the operation. Terra Nova operators are committed to operating and decommissioning the field in compliance with all associated legislation.

4.9 Independence of Consultants

Question was raised as to whether the process for choosing a consultant to design and conduct the EEM program was adequate. Some participants questioned the independence of consultants and their ability to do good work when they are hired directly by the proponent. It was felt that the contracting process was flawed and any consultants hired by the proponent were not independent.

The process used in the design of the Terra Nova Development EEM program has been open and transparent since its inception. Input has been solicited from government agencies, non-governmental organizations, regional and international experts in EEM programs, the university community and the general public. All issues identified were addressed in the EEM program design.

Terra Nova expects its consultants to be independent and to be experts in their field. Information resulting from the EEM program will be made public.

4.10 Suppliers

There were questions about the types of services and supplies required for conducting the EEM program, and whether local suppliers could take advantage of these opportunities. There were also inquires about employment opportunities associated with the EEM program. It was suggested that individual meetings for suppliers and the EEM study team be held to develop a better understanding of the services available and what is required to conduct the program.

Comment noted.

4.11 Condition 1

Comments were made regarding Condition 1 (Decision 97.02) which states: As soon as it is practicable after Project Sanction, the Proponent relocate engineering and procurement activities for the Project to Newfoundland (C-NOPB 1997). Two participants commented that they felt that this condition and the benefits agreements had not been met by Terra Nova.

Comment noted.

4.12 Public Consultation Process

Study team members and most participants felt that the session format provided a good forum for presenting information on and discussing the proposed EEM program. However, there was some confusion about the format for the session. Study team members indicated that they had received telephone calls prior to the session and comments during the session as to whether there would be a

presentation by a Terra Nova representative. In hindsight, the team members felt that they could have made better use of the media to advertise the session.

There was also concern raised about the timing and extent of public input into the design process, and about the timelines for making a submission on the EEM program. One participant questioned whether the public consultation for the EEM program adequately addressed the requirements of Condition 23.

Some participants inquired whether they would be able to review the EEM program when the design has been finalized and whether stakeholders would be able to access the data from the program. There was an interest in seeing a more flexible and iterative review process.

Public input requirement under Condition 23 of Decision 97-02 pertains to the EEM program, not the baseline characterization program. However, design of the baseline characterization program took into consideration all issues and concerns raised during the EIS panel hearings. Furthermore, public input has been instrumental in finalizing the design of the Terra Nova EEM program.

APPENDIX D

Response to Written Submissions Following Stakeholder Consultation

RESPONSE TO WRITTEN SUBMISSION

DURING PUBLIC INFORMATION SESSION
Questionnaire Submitted September 22, 1998

Issues raised or comments made in the questionnaire are *italicized* by question number and copied verbatim. Terra Nova responses are provided in plain typeface.

1. What is your overall impression of the proposed EEM program for the Terra Nova Project?

The proposed EEM program appears to exceed all of the programs I have witnessed in the North Sea. The concern in the North Sea appears to be focussed excessively on drilling fluid discharges rather than discharges (including unused cement, etc.) as a whole. The Terra Nova EEM appears to address all the potential impacts quite well.

Thank you. The Terra Nova EEM program builds on EEM experience with offshore oil in the North Sea and Gulf of Mexico, as well as baseline characterization conducted for Terra Nova and Hibernia on the Grand Banks.

2. Additional comments:

It might be wise to consider the potential use of additional drilling fluid types as it appears that inevitable changes in well plans may necessitate the use of silicate muds with excessive corrosive characteristics. One fluid type will probably not be sufficient, especially in high incliniation tophole sections. You might also consider additional chemical discharges such as cement. (I've witnessed several tonnes discharged regularly.)

Thank you for your suggestions. At the present time, water-based drilling muds and synthetic-based (IPAR-3) drilling muds will be used. If there is a need to use drilling muds other than these, the EEM program will be reviewed and if necessary refined to ensure that the design considers possible effects from the alternate drilling muds. The EEM program will monitor a broad suite of analytical parameters and has been designed to consider effects from a number of liquid and solid discharges originating from Terra Nova project platforms.

3. What is your overall impression of the proposed EEM program for the Terra Nova Project?

Well represented by highly qualified and experienced personnel and consultants.

Thank you.

4. Do you have any concerns about the EEM program design? *YES*

If yes, what are they?

What role will local suppliers of instrumentation and consumable products play in accomplishing the EEM objectives ?

Local suppliers are encouraged to contact Terra Nova. Terra Nova is committed to Canada-Newfoundland benefits.

5. What steps do you think Terra Nova could take to address your concerns?

Individual meetings at the service locations should be arranged to assist EEM personnel understand services available and direct the service industry in areas of potential growth.

Comment noted.

6. Which of the following best describes your feelings about the proposed EEM program?

   ✓ *Very Satisfied*

7. Additional comments:

Looking forward to a partnership of growth within an environmentally conscious development.

Comment noted.

RESPONSE TO WRITTEN SUBMISSION

FOLLOWING PUBLIC INFORMATION SESSION

Janet Russell, October 12, 1998

Issues raised in the letter are *italicized* and copied from the letter verbatim using the same numbering. Responses are provided in plain typeface.

1. *The predictions being tested by the EEM should be stated up front such that they form testable hypotheses and these predictions should appear as part of the EEM documentation i.e., the reader should not be sent back to the EIS to find out what predictions were made.*

Agreed. Impact predictions from the Environmental Impact Statement for the Terra Nova Development (Petro-Canada 1997) are included in the Terra Nova Environmental Effects Monitoring Program Design Report.

2. *The proposed EEM addresses aqueous operational discharges only. What plans are there to monitor the effects of:*

a) *Airborne operational discharges.*

Inputs to the water column from airborne sources will be monitored by the marine EEM program. In addition, Condition 19 of Decision 97-02 required that Terra Nova evaluate and report to C-NOPB the technical and economic feasibility of incorporating measures into the design of its production facilities which will reduce the amount of greenhouse gases released from these facilities. Results of this evaluation have been submitted to and accepted by C-NOPB.

b) *Accidental discharges?*

In the event of an accidental discharge (i.e., oil spill), a specific monitoring program will be in place. This monitoring program will be developed in consultation with appropriate regulatory authorities. As recognized by C-NOPB, thorough advance planning for monitoring effects of an oil spill is a necessary precaution. Terra Nova will ensure that this is addressed in the contingency plan, which is a separate program from the operational EEM program.

c) *Why are these plans not stated clearly in the EEM proposal?*

The contingency plan is listed as a component of the Environmental Protection Plan for the Terra Nova Development. The EEM Program is a component of the overall EPP.

3. *Control sites are by definition not subject to the same treatment as the "experimental" or in this case monitoring sites.*

a) *What was the rationale for the selection of the control site locations?*

Control sites were selected 20 km to the southwest and southeast of the Floating Production, Storage and Offloading vessel (FPSO) and are considered to be well beyond the probable extent of distribution of project discharges. The site selection was based on information that there is no mean direction to the movement of seawater in the Terra Nova Development area (Seaconsult 1998), modelling of drill cuttings distribution indicates dispersion close to the source (Seaconsult 1998), and experience in the North Sea (e.g., Gray et al. 1996). Control

stations could not be added to the north because they would be too close to Hibernia and planned developments.

b) What measures will be taken to ensure that control sites are not themselves subject to the same "treatment" as the monitored sites, i.e., exposed to operational and/or accidental discharges from offshore oil activity?

The Attenuation-By-Distance model for monitoring sediment quality does not rely on data from control areas to determine if impacts have occurred. However, the Control Impact (CI) design for monitoring other parameters, such as fish health, requires that control areas be relatively unaffected by operational discharges. Data from each EEM cycle will be used to verify models of distribution of project discharges. Models will be refined, if necessary, based on new data and new information. The location of control areas will be re-evaluated if there is any evidence that contamination from operational discharges has occurred or may occur.

c) What is the rationale for limiting the provision of control sites to 2?

Two control areas are considered to be sufficient for the CI design. Statistical designs will be evaluated and, if necessary, refined based on new data and new information.

4. With regard to the sampling of commercial fish species (Icelandic scallop and/or American Plaice) it must be noted that those present within a certain distance of the development site will not be subject to fishing pressure. It is suggested that all study sites including the control sites be protected from harvesting to prevent the possible depletion of scarce sampling material and to control for spurious effects due to fishing.

Commercial fishing activity within the Terra Nova study area is the jurisdiction of Department of Fisheries and Oceans (DFO). The Canadian Coast Guard will put in place fisheries exclusion zones around Terra Nova Development assets.

5. The Attenuation by Distance model assumes localized deposition of material which will attenuate with distance.

a) Does the EEM anticipate any effects for which the Attenuation by Distance model is inappropriate?

Yes. The Attenuation-By-Distance model is suitable for monitoring changes in sediment quality. The Control-Impact model will be used to test commercial fish species variables and water quality.

b) Is the scale of the gradient large enough for the monitoring of cumulative environmental effects?

The scale of the gradient is suitable for monitoring effects of cumulative project discharges from the Terra Nova Development. The Terra Nova EEM program is designed to address patterns associated with operational discharges from the Terra Nova Development. Cumulative effects of other projects to marine resources at the Terra Nova Development are considered to be beyond the scope of the site-specific EEM program. It is suggested that a regional monitoring program would be more appropriate to assess cumulative impacts from offshore oil developments on the Grand Banks and in the Atlantic region. Terra Nova is committed to working with other operators towards development of a regional monitoring

program. The Terra Nova Project has conducted a joint survey between the Terra Nova and Hibernia sites as a prepatory step in the development of this program.

c) *Does the scale of the gradient sampling design anticipate the potential for improvements in drilling technology to lengthen the life of the development and to increase the volume of material and time over which material will be deposited at the site?*

There will be an opportunity to refine statistical design and station distribution, if necessary, after each EEM cycle, and if there is a significant change in project operations.

6. *The EEM proposes to use commercial fishing gear for the sampling of commercial fish species. Commercial scallop harvesting and bottom trawl gear cause physical damage to the bottom and incidentally destroy bottom organisms. Has the potential for spurious results from the use of such gear been considered?*

Yes. The sediment quality survey will be conducted in advance of the biological survey to avoid obtaining spurious results.

7. *Figure 2 does not indicate the presence of any exploratory drilling activity in the study area. Is this accurate? Does the EEM anticipate the possibility of spurious results due to pre-EEM drilling activity?*

Exploratory drilling was conducted within the Terra Nova field between 1984 and 1988, nine years prior to the baseline characterization survey. The baseline characterization survey documented existing conditions at the site in 1997 for future comparison.

8. *The Terra Nova Baseline report indicates that benthic community variables were patchy, variable and possibly associated with substrate type. Is the proposed gradient design robust to such variable initial conditions? It is suggested that consideration be given to stratifying the sampling regime by substrate type or some other variable which is known to explain a portion of the variability in benthic communities.*

As expected, there was some variability in benthic community measures for the baseline characterization survey. Substrate type was surprisingly homogenous throughout the study area. The gradient design is robust, and allows for confounding variables to be recognized and removed in the data analysis, as demonstrated in the baseline characterization report.

9. *The epibenthic sampling planned for the Baseline Study was not done due to inclement weather and equipment difficulties. The EEM does not mention the epibenthos. What is the rationale for their exclusion?*

Epibenthic sampling was pursued twice during baseline characterization to address suggestions from Department of Fisheries and Oceans (DFO) that epibenthos be characterized in addition to benthic infauna. DFO was contracted to conduct the sampling. However, despite best efforts by that Department the sampling equipment failed to perform as expected. Epibenthic sampling may be considered for future EEM cycles if technology improves.

10. *Monitoring of sediment and water column chemistry should anticipate and reflect all chemicals introduced into the reservoir and drilling environment by the operator as well as those generated by the reservoir itself i.e., chemical monitoring should not be limited solely to the ingredients of oil-based drilling muds.*

Parameters for monitoring sediment and water chemistry have been chosen based on components expected to be present in operational discharges as well as parameters which aid in data interpretation. These parameters include a comprehensive suite of metals, hydrocarbons, organic carbon and particle size. The parameter list will be evaluated after each EEM cycle based on new data and new information and will be refined, if necessary.

11. *The EEM plans to monitor collisions between seabirds and the platform. What is the plan for the monitoring of seabirds potentially incinerated by flying into a flare?*

The monitoring program for seabird collisions with project platforms will include direction on recording observations of birds flying into a flare.

12. *An intention is stated to develop a monitoring program for seabirds in the case of a large spill. Given that the vulnerability of seabirds to oil spills is not limited to large spills this plan is inadequate. It is suggested that an EEM component be designed as rigorously as any other to monitor the effects on seabirds of all project discharges. We propose the same be done for marine mammals. Because of the mobility of these organisms and the seasonal changes in species present, both of these studies necessitate the use of rigorous surveys to delineate distribution patterns throughout the year. This anticipates problems of not being able to detect effects directly due to an inability to collect effected organisms. Rather if spills are known to have occurred at least some modelling is possible to estimate the potential encounter rates between birds and pollutants on or near the surface.*

The EIS predicted residual impacts to seabirds following mitigation. There is no doubt that the offshore Grand Banks supports a large number and variety of seabirds and seabirds may be expected to pass through the Terra Nova field area. However, seabirds are not recommended for offshore EEM programs due to their wide-ranging movement patterns (Dunnet and Clark 1994). This was recognized by the Environmental Assessment Panel and cited by C-NOPB in Decision 97-02. However, it is recognized that monitoring of seabirds may be more appropriate for a regional monitoring program addressing cumulative effects of offshore oil developments on the Grand Banks.

To contribute to the knowledge base of seabird interactions with offshore structures, Terra Nova will develop a feasible monitoring program for seabirds in the case of a large spill as part of the contingency plan. Terra Nova will support an observer program for seabirds by providing space for observers aboard Terra Nova project platforms and vessels, assigning Terra Nova staff to participate in the observer program, and consulting with regulatory agencies with respect to appropriate observer procedures. Terra Nova will develop an action plan for recovering and releasing birds following collisions and support an observer program. In addition, Terra Nova is providing funding support for a study examining seabird attraction to light and seabird monitoring in the Atlantic Region.

The EIS predicted negligible impacts to marine mammals from the Terra Nova Development, with the exception of potential for negligible to minor, sublocal to local and long-term effects from project-related noise. However, marine mammals are not suitable for inclusion in a site-

specific offshore oil EEM program due to their transient residence within the area (Dunnet and Clark 1994). Exclusion of marine mammals is supported by C-NOPB in Decision 97-02. Terra Nova recognizes that monitoring of marine mammals may be appropriate following an oil spill. As a result, Terra Nova will support an observer program for marine mammals by providing space for observers aboard Terra Nova project platforms and vessels and assigning Terra Nova staff to participate in the observer program. In addition, Terra Nova will develop a feasible monitoring program in the case of a large spill, as part of the contingency plan.

13. *It is suggested that the incorporation of a multiple reference sampling design be considered to address questions not appropriate for the gradient sampling design. There will be two significant problems with the use of multiple reference sampling design which will have to be addressed.*
    a) *How will "impact site" be defined?*
    b) *How will the potential for unplanned contamination of reference sites from oil activity be avoided?*

The multiple reference design is appropriate when there are a number of suitable reference locations available. This is not the case for the Terra Nova Development, since there is an operational oil platform in the area and possible future developments to the west and east. Terra Nova is confident that the selection of control areas is well beyond the probable extent of distribution of operational discharges. This will be verified after each EEM cycle.

14. *It is suggested that the use of caged bivalves be included as insurance against sampling problems which are anticipated.*

Sufficient numbers of Icelandic scallop are present at the site for use in monitoring, therefore the caged bivalve approach is not currently necessary. Furthermore, the caged bivalve approach is currently undergoing research to determine its feasibility for use in offshore oil programs.

15. *The EEM Proposal document provided on September 22, 1998 contained a flowchart entitled <u>Steps for an Environmental Effects Monitoring Program</u>. Public input was indicated as part of the Step 1 (Strategy) and Step 2 (Design) boxes. Submission to C-NOPB followed Step 2. This flowchart misrepresents the opportunity for public input into the EEM development process. The arrow indicating Public Input should more properly follow Step 2 and point just above the juncture for submission to the C-NOPB. The development process has been active since at least June 13, 1997 when Jacques Whitford Environment held a Workshop on Benthic Invertebrate Monitoring to which the public were not invited. A full 16 months later, one month before submission of the EEM proposal to the C-NOPB, and after the design and collection of a Baseline Study have been completed the public is invited to view a general summary of the EEM proposal and respond within 8 days. While I appreciate being invited to the Public Information Session and acknowledge an extension to October 12 within which to make my response this opportunity does not constitute a serious "...provision for input and review by.... The general public..." as was suggested by the C-NOPB in the text accompanying Condition 23 of Decision 97-02.*

Public input requirement under Condition 23 of Decision 97-02 pertains to the EEM program, not the baseline characterization program. However, design of the baseline characterization program took into consideration all issues and concerns raised during the EIS panel hearings. Furthermore, public input has been instrumental in finalizing the design of the Terra Nova EEM program.

RESPONSE TO WRITTEN SUBMISSION

FOLLOWING PUBLIC INFORMATION SESSION

Natural History Society of Newfoundland and Labrador
(Len Zedel, Past President) September 30, 1998

Issues raised in the letter are *italicized* and copied from the letter verbatim using the same numbering. Responses are provided in plain typeface.

1. *Baseline Information*

We feel that the EEM as presented does not adequately address the need for a baseline study. A single survey done at one particular season (the fall) cannot provide a complete view of an ecosystem. In particular, there will be no indication of natural variability in populations. Researchers working off Holland in the North Sea suggested that more than 10 years would be required to identify natural seasonal and annual variability. There will be no way of separating natural changes in population over the entire sample space from those associated with environmental impact except in the case of a catastrophic impact.

The Control-Impact and Attenuation By Distance statistical models have been chosen to permit discrimination of natural variation from effects related to operational discharges over space and time. Emphasis has been placed on spatial patterns associated with project discharges, more so than temporal patterns; the focus is to monitor magnitude and extent of environmental effects over time. A Before After design requires more baseline data (than does Control-Impact and Attenuation-By-Distance designs) and emphasizes presence/absence of an effect, rather than magnitude and extent. Therefore, we feel that the baseline is sufficient for the EEM Program.

2. *Environmental Effects*

The quantitative environmental effects being monitored as part of the planned program are concentrated on benthic and epibenthic communities. While these species are possibly the most at risk from operational discharges, there are also potential impacts that will occur to animals in other parts of the water column. The sea surface forms an important interface where pollutants can collect and where many animals (birds and marine mammals in particular) may come in contact with that pollution. It is very likely that an oil sheen will occur associated with discharge of oil and cutting fluids in drill cuttings. In addition, it is a certainty that there will be small accidental spills through the life of the project. A small quantity of oil at the ocean surface could effect a large area: a much larger area than that being surveyed by the proposed sampling scheme. Some monitoring program should be in place to monitor the presence of surface pollutants and the effects that these pollutants have on marine life.

Monitoring variables in the EEM program include commercial fish species and water quality, in addition to sediment quality. The EEM program will address effects of oily water on water quality and commercial fish species.

In the event of an accidental discharge (i.e., oil spill), a specific monitoring program will be developed in consultation with appropriate regulatory authorities. As recognized by C-NOPB, thorough advance planning for monitoring effects of an oil spill is a necessary precaution. Terra Nova will ensure that this is addressed in the contingency plan, which is a separate program from the operational EEM program.

3. ***Monitoring Program***

The monitoring program indicates annual surveys for three years and than a less frequent program of sample surveys. This sampling program will not even resolve seasonal changes and certainly will not be able to distinguish seasonal signals from more significant effects. An effect could go unnoticed for as long as a year before being detected and more time would pass before a suitable response action was formulated. This response latency will be even longer when surveys are done at less than an annual rate.

Effects of some impacts are likely to be very episodic in nature. Without more frequent monitoring it will be impossible to identify the specific cause of the impact. For example, small oil spills could be very disastrous if they occurred at the wrong time of year when many seabirds were present at the waters surface. We would proposed a more continuous monitoring effort with an independent, trained individual stationed on any operational platform at all times. The presence of such an individual would provide the public with an assurance that environmental interests were being observed. Such an observer would serve the proponent by providing an independent verification of compliance with any environmental regulations. Specific tasks that such an individual could fulfil include:

Record "Incidental" marine mammal observations.

Take samples of discharged materials (water, cuttings etc.)

Record environmental conditions and variables.

EEM will be conducted annually for the first three years, after which the program will be conducted every two years during drilling and operations phases. There is an opportunity after each EEM cycle to evaluate design including sampling frequency.

With respect to time frames for monitoring effects within an EEM program, there is usually a direct relationship between the time required for effects to occur and the lifespan of organisms. For example, effects on short-lived benthic invertebrates may be evident within a year, whereas potential effects on long-lived pelagic species may not be evident for a decade. Even for the same organism, time scales differ among effects of interest. In fish, uptake of contaminants and tainting are effects that occur over weeks or months. Conversely, depuration and recovery can occur within a similar time frame. Effects on growth and especially reproduction (usually annual) may be evident with one or a few years. Higher-level effects on population abundance's may only be evident after a decade or longer. The EEM

program is designed to detect impacts on a temporal basis with annual changes being the shortest time frame.

APPENDIX E

Selection of Monitoring Variables

CONTENTS

The following text was originally provided as part of the main body report in the original submission of the Terra Nova EEM design. Because the text is now provided as an Appendix, a literature cited section specific to this text has been added at the end of this Appendix.

1. INTRODUCTION

Monitoring variables under consideration were evaluated based on the following criteria to determine suitability for inclusion in the EEM program:

- predicted impacts, as provided in Environmental Impact Statement (Suncor Energy 1996);
- sensitivity to project discharges or project activity;
- persistence of exposure;
- valued environmental components (VECs), including marine resources of concern, and surrogate variables;
- frequency and scale of measurement;
- proven utility in previous monitoring programs;
- logistical feasibility; and
- information return relative to cost.

Inclusion or exclusion of candidate variables was based on results of this evaluation.

The following monitoring variables were evaluated:

- commercial fish:
  - ✓ taint
  - ✓ body burden
  - ✓ health (histopathology, enzyme indicators of exposure or stress, life history characteristics)
- water quality:
  - ✓ physical characteristics
  - ✓ chemical characteristics
  - ✓ phytoplankton density
- sediment quality:
  - ✓ physical and chemical characteristics
  - ✓ toxicity
  - ✓ benthic community status
- seabirds: and
- marine mammals.

A number of information sources were reviewed to facilitate this evaluation. These include:

- review of valued environmental components (VECs) identified in the Environmental Impact Statement (Suncor Energy[1] 1996);
- monitoring variables committed to for EEM in the Environmental Impact Statement (Suncor Energy 1996);

[1] For simplicity, historical submissions under the name Petro-Canada are now listed as Suncor Energy.

- literature on the North Sea and Gulf of Mexico offshore oil developments;
- comprehensive review of other relevant literature on effects of oil;
- monitoring variables considered and applied in Hibernia baseline characterization program (HMDC 1994) and EEM program (HMDC 1995, 1996); and
- baseline characterization program results for Terra Nova (Suncor Energy 1998).

In addition, a number of activities were conducted to solicit input from the regulatory community, regional and international science community, and the public. These activities included:

- in-house workshop on utility of benthic community monitoring (Suncor Energy 1997);
- informal consultations with government agencies;
- in-house workshop on EEM program design for Terra Nova; and
- public information session.

The rationale used in the design of the EEM was to focus on variables of greatest concern that would provide the most information. The most suitable variables will be sensitive to project discharges and activities, commercially or biologically relevant, and cost-effective to monitor. In addition to monitoring VECs and other marine resources of interest, EEM programs could employ surrogate variables. These surrogates could be used in place of, or in addition to, the VECs and are sometimes easier to monitor or are a better indication or prediction of effects (NRC 1990). In addition, surrogate variables often provide information on chemical and physical changes in the receiving environment and information on habitat and food sources of VECs.

2. COMMERCIAL FISH SPECIES

Drilling and operational discharges have the potential to affect fish species in the project area. "Commercial fish species" was identified as a VEC in the Environmental Impact Statement (Suncor Energy 1996). The EIS predicted that potential effects on commercial fish species related to drilling and operations at the Terra Nova development were primarily negligible in magnitude. The few impacts rated as minor or moderate involved both positive and negative effects. The impact of the safety zone around the offshore structures together with the lifting of the fishery moratorium was rated as a positive, minor to moderate effect for fish stocks; however, it was also rated as a negative, minor effect with regard to access to the fishery.

Three monitoring variables with respect to commercial fish species were considered: taint, body burden and health. Prior to evaluating monitoring variables, an appropriate fish species must be identified. An appropriate species should have the highest probability of persistent exposure to project discharges and activities, be available in

sufficient numbers, be relatively restricted in movement, and be commercially relevant. During the baseline characterization survey in 1997 (Suncor Energy 1996), a number of fish species were collected that are commercially exploited on the Grand Banks; however, only two species were obtained in sufficient numbers (given a reasonable level of effort) in the project area for use in an EEM program - Icelandic scallops (*Chlamys islandica*) and American plaice (*Hippoglossoides platessoides*).

Icelandic scallop is a sessile species and more likely to undergo persistent, continual exposure to project discharges during drilling and operation. Sea scallops (*Placopecten magellanicus*) and bay scallops (*Argopecten irradians*) have been shown to be sensitive to offshore oil development drilling wastes (Hamilton et al. 1981; Neff et al. 1981; Neff 1987; Cranford et al. 1999). Icelandic scallops live in contact with sediment and filter-feed such that they take in particulate matter from the water column. Bottom sediment and the water column will be receiving environments for project outputs and therefore sources of project-related contaminants to Icelandic scallops.

American plaice, a groundfish species, is less likely to be persistently exposed to project discharges as a result of its relative mobility. Studies have shown that American plaice can travel distances of over 34 nautical miles in 400 days as juveniles and over 52 nautical miles in 250 days as adults (Morgan 1996). There is also evidence that American plaice may undergo seasonal movement on the Grand Banks (Morgan and Brodie 1991). However, given that there is a history of using fish in offshore EEM programs in the North Sea (Stagg 1998), and given the historical importance of the fishery on the Grand Banks, it is prudent to include American plaice in the Terra Nova EEM program. Caution must be used in interpreting the results because any "effects" measured would be difficult to attribute to a given platform. Movement of individual fish may extend well beyond the 35 km distance between the Hibernia and Terra Nova fields.

TAINT

"Taint" is a term applied to food that has an abnormal or foreign odor, flavor or taste (DFO 1990, ISO 1992). Taint, both real and perceived, is recognized as a possible impact of offshore oil activities, particularly with respect to hydrocarbons, and as a result testing has been incorporated into EEM programs for offshore oil elsewhere in the world (GESAMP 1993). The Terra Nova EIS predicted negligible tainting impacts on fish with respect to the discharge of drilling muds and cuttings, other drilling fluids, deck drainage and produced water. Monitoring of taint in a fish species was a commitment made in the Terra Nova Environmental Impact Statement (Suncor Energy 1996). In addition, tainting of fish is a federal regulatory concern, in that fish cannot be sold that are considered to be "tainted, unwholesome or decomposed" (*Fish Inspection Act*).

There are two main causative agents for taint, namely spoilage or presence of contaminants in the flesh. Contaminants causing taint may not be present in fish tissues in sufficient concentrations to do physiological damage to the individual fish. Taint is therefore not necessarily so much a biological effect as it is an economic effect, resulting from public concerns with offshore developments in close proximity to harvested food resources. "Perceived taint" can be as serious a problem as actual taint and is part of the rationale for inclusion of taint in the EEM. Another important consideration is that chemical and instrumental analyses can not determine if a product is tainted – only human taste and smell can perform that task. Therefore, unless a relationship between a specific chemical and taint (determined by taste and or smell) has been well established, presence of that chemical in an edible aquatic resource does not determine the presence of taint (Botta 1994). Any assessment of taint must incorporate procedures to detect and measure changes in flavor in conjunction with an assessment of flavor impairment. Another consideration in taint testing is that taint may be pleasant or unpleasant.

Icelandic scallop is an ideal species for taint testing due to life history, and probability for persistent and continual exposure to project discharges. Scallops are filter feeders that process large volumes of water and sediment during feeding, live in direct contact with the sediment, and are sessile. These conditions maximize the potential for uptake of project-associated contaminants and the potential for taint. American plaice is also an important species to include in taint testing due to their historical importance in the fishery and their niche in the aquatic food web.

Analytical costs associated with taint testing are low when compared to costs for measuring other variables under consideration. Therefore, the information return relative to cost is high. Taint testing on Icelandic scallop was conducted for the baseline characterization program and sensory evaluation did not detect statistical differences between samples from the study and control areas. There are no reasons to expect any difficulties with respect to interpreting results of taint testing in an EEM program. As a result of this evaluation, taint testing of Icelandic scallops is considered to be a suitable monitoring variable for effects assessment in the Terra Nova EEM program.

BODY BURDEN

Body burden is the result of bioaccumulation, a process by which chemical substances are ingested or taken up by organisms, either from the environment directly or through the consumption of food containing the chemicals. Bioaccumulation of project-related contaminants, particularly heavy metals and hydrocarbons, may occur in biota exposed to project discharges. Body burden is used as a supporting monitoring variable in North Sea offshore oil EEM programs, as outlined in PARCOM (1989) and GESAMP (1993).

Body burden data provides information on bioavailability of contaminants in discharges and reflects a process (bioaccumulation) rather than an effect. Bioaccumulation represents a pathway to an effect, such as taint, health or change in some aspect of life history (e.g., fecundity, growth).

Icelandic scallop is a suitable species for measuring body burden due to life history and probability for persistent and continual exposure to project discharges. These conditions maximize the potential for uptake of project-related contaminants. Body burden provides information that is useful in the interpretation of results for other monitoring variables such as taint and health. Body burden data are important as well from a human health perspective, in terms of acceptable limits for human consumption under the federal *Food and Drug Act.*

Body burden analysis was demonstrated to be feasible for Icelandic scallops in the baseline characterization program. No polycyclic aromatic hydrocarbons (PAH) were detected in adductor muscle or viscera samples from scallops (Suncor Energy 1997). Therefore, bioaccumulation of PAH should be readily detectable in post-operational monitoring. Some metals were detected, notably in viscera samples. There were significant differences in metal concentrations in adductor muscle between study and control areas. Both tissue types should be used for an EEM program. Edible tissue (adductor muscle) is important from a human consumption perspective, while viscera is important for animal health considerations. Contaminant concentrations will be higher in viscera than in adductor muscle.

Cost of analysis is considered to be moderate, in comparison with other monitoring variables. As a result of this evaluation, body burden analysis is considered a suitable supporting monitoring variable for use in the Terra Nova EEM program.

HEALTH

Fish health is a broad term that applies to a number of variables, including examination of tissues for pathological changes (histopathology), blood analysis (haematology), enzymatic indicators of exposure to pollutants or stress (e.g., Mixed-Function Oxygenase; MFO), and life history measures (e.g., age, size, growth and fecundity).

Histopathology is usually carried out on liver and gill tissues. The liver plays a major role in metabolism, excretion, digestion, and storage of various substances, including those toxic to the organism. Common liver disorders that result when fish are exposed to toxins are hepatocyte regenerative foci, hydropic vacualization, neoplasia, and necrosis. The gill epithelium of fish is the major site of gas exchange, acid-base balance, ionic regulations, and excretion of nitrogenous waste. Fish exposed to contaminants may show gill histological changes such as epithelium hyperplasia, fusion of gill lamellae, separation of respiratory epithelium from underlying tissue, and other lamellar lesions.

Histopathology is a measure of long-term changes whereas haematology is a short-term indicator of health. Haematological assessment involves morphological analysis of blood samples for several different types of blood components such as neutrophils, lymphocytes, thromocytes, and polychromatocytes. Examining the cellular components of the blood to determine whether they are within normal range is a quick method to assess the general health of a fish.

MFO enzyme induction is an indicator of recent exposure to stress or pollutants. MFOs play an important role in detoxification by transforming foreign components into derivatives that are more easily eliminated from the organism. A series of oxidation reactions converts relatively insoluble inorganic components into water-soluble metabolites that may be further conjugated and excreted in urine or bile. Measurement of MFO activity is economical and sensitive, while at the same time relatively insensitive to any stress associated with animal collection. A number of field and laboratory studies have demonstrated that MFO enzyme induction is a useful index for assessing recent exposure to organic pollution. Flatfish have been used to assess fish health in EEM programs in the North Sea.

Due to the mobility to American plaice, caution must be used in interpreting the data as health effects may or may not be attributable to the Terra Nova Development. As the project develops, consideration should be given to using health effects in a "regional monitoring plan" as opposed to the site-specific Terra Nova EEM program. However, the cost of assessing fish health indicators is moderate in relation to information return. As a result of this overall evaluation, fish health indicators are considered to be appropriate monitoring variables to include in the Terra Nova EEM program.

3. WATER QUALITY

Water will serve as the primary receiving environment for discharges during drilling and operations of the Terra Nova field, and as a pathway to the sediment receiving environment and biological effects. As a result, a commitment was made in the Terra Nova Environmental Impact Statement (Suncor Energy 1996) to monitor water quality. Monitoring this variable will allow testing of impact predictions made in the Environmental Impact Statement relative to produced water and drill cuttings. The EIS predicted that the potential effects of oily water discharges (drilling muds and cuttings, other drilling fluids, deck drainage, and hydrostatic testing fluids) on water quality would be negative, minor, sublocal to local, and short-term. However, the impact of produced water on water quality was predicted to be negative, minor, sublocal and long-term.

Monitoring water quality near discharge sources may prove useful in indicating whether there are detectable impacts to the water column within the initial dilution zone. However, it should be recognized that the utility of using water quality as a routine

monitoring variable for offshore oil EEM programs is limited, due to rapid dilution and the difficulty in tracking movement of contaminants in a fluid medium (Boesch and Rabelais 1987).

Persistent discharges may be measurable in the water column using chemical and physical analysis, particularly in the immediate vicinity of discharge. Measuring phytoplankton density may provide an indication of biological changes in the water column resulting from project inputs.

Results of the baseline characterization study indicate that no PAH and few metals were detected in water column samples. Therefore, false positives are not a concern and post-operational increases in concentrations of contaminants should be readily detectable in an EEM program. Differences in concentrations of copper and arsenic, the only two frequently detected contaminants among depths and stations, were relatively small and should not create problems for post-operational effects assessment. Formation of two water layers with warmer water overlying a colder layer is a commonly observed seasonal structure in the study area. Lack of variation in water column profiles between stations is normal for this type of open ocean environment. Deeper water temperatures will be less variable over time than the upper layer, which is more heavily influenced by overlying weather systems and seasonal isolation. Seasonal variations may occur in the structure of the water column, however, there is no reason to expect large differences in water column structure between control and study areas.

Analysis of water quality is moderate in relation to information return. As a result of this evaluation, and commitments made in the Environmental Impact Statement, water quality is included as a monitoring variable in the Terra Nova EEM program.

4. SEDIMENT QUALITY

Two primary contaminants associated with offshore oil platforms are hydrocarbons and metals. These chemicals will ultimately accumulate in sediments to higher concentrations than found in the water column. Sediments will act as a sink for persistent chemicals present in project discharges and are the major pathway and route of exposure of project-related contaminants to benthic organisms. Chemical contaminants in sediments can affect environmental quality in two ways:

- adversely affect natural productive capacity of sediments; and
- adversely affect other components of the environment, such as the water column and biota, through potential release contaminants from the sediments.

In addition to chemicals, discharge of particulate matter will also occur during drilling and operations phases of the Terra Nova field development. Particulates alter physical characteristics of sediments and may have a slight and temporary smothering effect on benthos.

Sediment quality may serve as an indicator of effects to habitat of commercial fish species which is a VEC in the Environmental Impact Statement. In addition, using sediment quality as a monitoring variable would fulfil the commitment in the EIS to monitor oils in sediments and their effects on benthos. The EIS predicted a positive, minor, local and long-term effect on the benthos resulting from the safety zone around the offshore structures together with lifting of the fishery moratorium. Other project impacts were rated as negligible, with the exception of the predicted negative, minor, sublocal and long-term impact resulting from the discharge of drilling muds and cuttings to the benthos. The objective of sediment quality analyses is to determine if there is deterioration of sediment quality within the study area and to determine whether a relationship exists between sediment quality and distance from source.

Reliance on any single test as a descriptor of sediment quality is not a recommended approach (Chapman et al. 1991) and will not be used in the EEM program. An integrated approach such as the Sediment Quality Triad (SQT; See Box 1) relies on measurement of a number of variables to assess sediment quality, such as sediment chemistry and physical description, toxicity testing and benthic community structure (e.g., Long and Chapman 1985; Chapman et al. 1987; Chapman 1992). Integration of results from these three variables greatly increases the value of the overall study results. The SQT approach has recently been applied to assess the pollution status of sediments near offshore oil platforms in the North Sea (Chapman 1992) and in the Gulf of Mexico (Chapman and Power 1990; Chapman et al. 1991; Green and Montagna 1996).

Components of the SQT are discussed in the following sections.

CHEMICAL AND PHYSICAL CHARACTERISTICS

Analysis of sediment chemistry and physical characteristics provides information on change in the sediment receiving environment and changes to benthic habitat. Included are factors that can influence the bioavailability of contaminants and the distribution of benthic infauna, such as carbon content and particle size (i.e., sand, silt, clay size fractions).

Sediments were analyzed for chemical and physical characteristics as part of the baseline characterization. Based on this information, sediment chemical and physical characteristics should be very useful in the Terra Nova EEM program since sediments were spatially homogeneous with low or non-detectable concentrations of PAH and

metals. Fine sediments were virtually absent, therefore any addition of fine particles or "smothering" resulting from drilling activities will be easy to detect using measurements of sediment particle size. Physical and chemical alteration of the sediments, if they occur, will be easy to detect in post-operational sampling years.

Analysis of sediment chemistry and physical characteristics is moderately expensive, but information return relative to cost is high. This, coupled with proven utility in previous offshore oil monitoring programs and baseline characterization information, indicate that sediment chemistry and physical characteristics is an important variable to include in the Terra Nova EEM program.

Box 1 The Sediment Quality Triad

The Sediment Quality Triad approach integrates sediment chemistry (C), toxicity (T), and biology (B) data or variables. The Triad was initially used for assessing sediment quality, via comparison of sediments from potentially impacted sites to reference sediments (Chapman 1996). More recently, the Triad has been used as a conceptual cause → effect and dose-response model in gradient designs (e.g., Green et al. 1993; Chapman et al. 1996; Green and Montagna 1996).

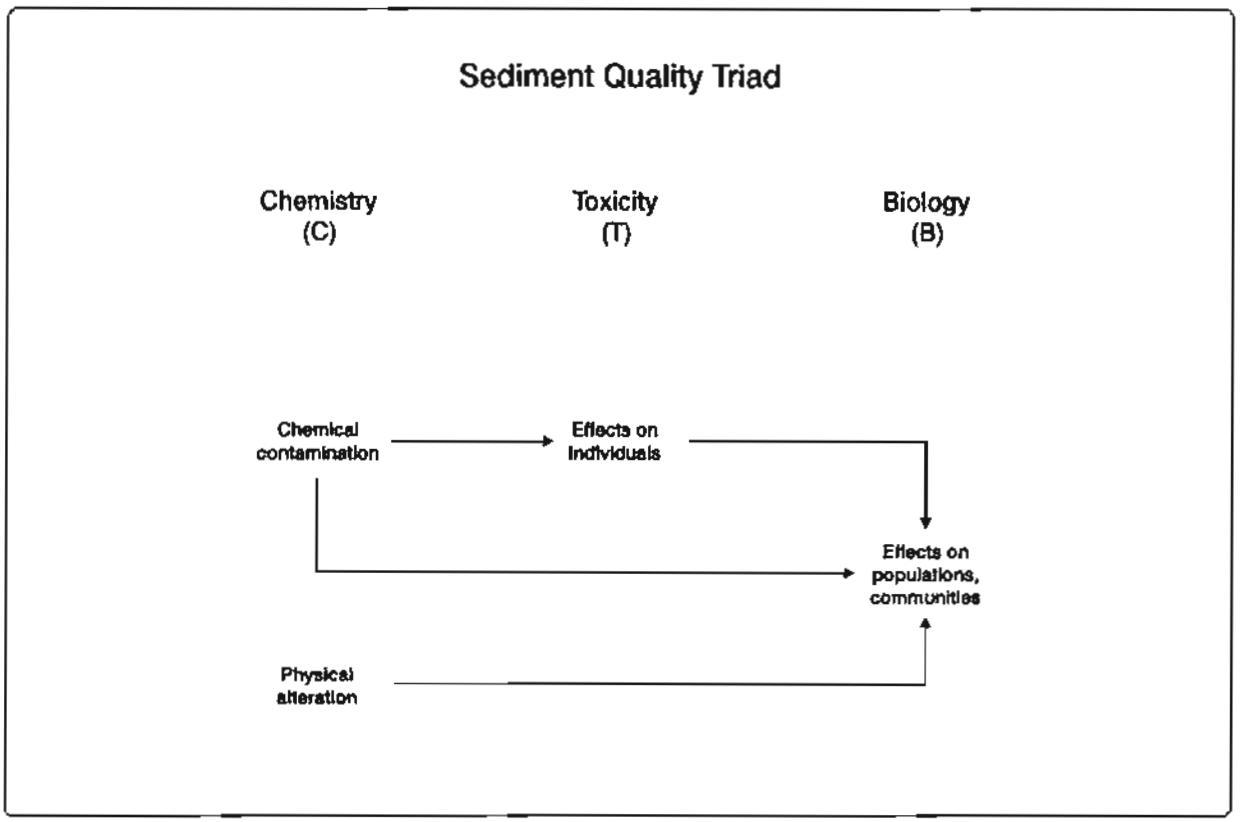
Figure 2.1 provides the underlying conceptual model for the Triad. The existence and strength of the links or arrows in this model are assessed using correlations between the Triad components. The C → T link indicates whether chemicals are available for uptake and present in concentrations sufficient to cause toxic effects. The T → B link indicates whether toxic effects on individuals in laboratory experiments are translated into higher-level effects on resident biota. The C → B link may indicate the presence of non-toxic effects, such as nutrient enrichment, or physical effects (e.g., smothering from fine particles discharged during drilling) if physical variables are included among the C variables (bottom of Figure 2.1). The correlations between C and either B or T variables are effectively dose-response relationships.

The Triad approach provides a convenient framework for study design, data analysis and interpretation. The Triad is also flexible (Chapman 1996). For example, the approach is easily adapted to monitor water column contamination and its effects. The list of C variables can be expanded to include physical as well as chemical variables; the T variables could include endpoints from *in situ* as well as laboratory toxicity tests.

Benthic invertebrate communities are usually used as the biological component of the Triad because these invertebrates are in intimate contact with the contaminated sediment. Presumably, these communities are the biological resources at greatest risk. In some cases, benthic fish populations or communities may be more suitable as the biology component. Another link between the invertebrates and their predators could also be added to the basic model to reflect direct effects on predators from dietary uptake or indirect effects from altered prey abundances.

The strengths and limitations of the Sediment Quality Triad are discussed further in Chapman (1996).

Figure 2.1 Conceptual Model for Sediment Quality Triad as it Applies to Terra Nova EEM Program



TOXICITY

Sediment toxicity testing puts environmental chemical and physical data into perspective by acting as a measure of bioavailability to sediment-dwelling (infaunal) animals. It is a well-recognized tool that is included in regulatory programs such as *Canadian Environmental Protection Act Ocean Dumping Regulations* administered by Environment Canada, and monitoring programs such as Puget Sound Estuary Program.

Testing involves exposing animals to sediment under controlled conditions to determine if exposure causes adverse effects on the animals. Because there is no organism for toxicity testing that represents all animals, a suite of organisms representing different trophic levels and taxonomic groups is used in standardized tests. Environment Canada has developed standardized methods that include both lethal and sublethal endpoints and use of appropriate controls (e.g., negative and positive controls).

Sediment toxicity measures the bioavailability of chemical and physical characteristics of sediments that may be influenced by project discharges, as indicated in measurement of these characteristics. Toxicity testing is one of the SQT tools used to indicate whether habitat quality has deteriorated as a result of project discharges and activities.

Sediment toxicity test results for the baseline characterization program indicate that sediment in the study area was generally non-toxic. There was some natural spatial variance in toxicity; however, these spatial differences are unlikely to persist over time. Some low incidence of natural toxicity or false positives can also be expected in post-operational monitoring. Therefore, there will be a lower limit to the magnitude of toxic effects that can be confidently attributed to the Terra Nova development. Baseline spatial differences in toxicity were relatively small and did not follow a pattern that could be misinterpreted as an impact. Consequently, assessing effects based on spatial patterns, such as relationships between toxicity and distance from drill centres, should not be affected or confounded by natural spatial differences. Using two or more tests to define toxicity will also reduce the already very low risk of false positives.

Analysis of sediment toxicity is moderately expensive, but information return relative to cost is high. This, coupled with proven utility in previous offshore oil monitoring programs and baseline characterization information, indicate that sediment toxicity is an important variable to include in the Terra Nova EEM program.

BENTHIC COMMUNITIES

Benthic community status is the third component of the SQT and provides information on in situ effects of contaminant exposure. Benthic communities are important to marine ecosystems, particularly as the link in energy and contaminant transfer from the water column to benthos and subsequently within the food web to pelagic organisms such as fish (Steel 1974; Rees et al. 1991). Benthic species are predominately sessile or have limited mobility and are therefore likely to be exposed to persistent project-related discharges that reach sediments.

The Hibernia baseline characterization program and EEM design did not include benthic community sampling due to its apparent sparseness and patchiness in the vicinity of the production platform (HMDC 1995). At the time, variability in benthic community parameters made detection and interpretation of change problematic within the context of an EEM program. However, more recent field studies applying multivariate data analyses have demonstrated that substantial change to benthic communities associated with offshore oil platforms is detectable to considerable distances (Gray et al. 1990; Olsgård and Gray 1995; Peterson et al. 1996). An in-house workshop involving regional and international scientists and representatives of the regulatory community convened in June 1997 to consider the use of benthic community analysis in monitoring programs (Suncor Energy 1997). Participants agreed that benthic community analysis should be used in the baseline characterization program and subsequent EEM program.

Results of the baseline characterization program demonstrated that benthic infauna community variables varied more among stations than chemistry or toxicity variables, as is typical. A limited number of organisms were collected per sample which inflates

variances and makes only large effects detectable for some measures. However, variances for measures of bio-diversity were low and making changes to sampling design can reduce variances of most or all variables.

Analytical costs associated with benthic communities tend to be low when compared to analytical costs of other sediment quality variables. On balance, benthic community status is suitable for inclusion in the Terra Nova EEM program and a component of the SQT for measuring sediment quality in the Terra Nova EEM Program.

5. SEABIRDS

Seabirds are indicated as a Valued Environmental Component in the Terra Nova EIS (Suncor Energy 1996). The EIS predicted negligible potential impacts on seabirds resulting from drilling and operations of the Terra Nova development. The exceptions were the predicted negative, minor to major, local and long-term potential effects resulting from project-related noise from supply vessels and aircrafts. These potential impacts changed to negligible residual impacts after mitigation. Seabird mitigation and monitoring procedures are specified in the following Suncor Procedures: Environmental Protection Plan - Production (IM-EV03-X00-011), Environmental Protection Plan - Drilling, Completions and Intervention (TN-IM-EV03-X00-009) and Seabird Procedures (TN-PE-ER03-X00-006).

There is no doubt that the offshore Grand Banks supports a large number and variety of seabirds and seabirds may be expected to pass through the Terra Nova field area. However, seabirds are not recommended for inclusion as a monitoring variable in the site-specific Terra Nova EEM program. Seabirds are not considered suitable for inclusion in EEM programs for offshore oil activities due to their wide-ranging movement patterns (Dunnet and Clark 1994). This was recognized by the Environmental Assessment Panel and cited by C-NLOPB in Decision 97-02. However, it is recognized that monitoring of seabirds may be more appropriate for a regional monitoring program addressing regional effects of offshore oil development on the Grand Banks. C-NLOPB has committed to determining the feasibility of developing a seabird-monitoring program (C-NLOPB 1997).

To contribute to the knowledge base of seabird interactions with offshore structure, Terra Nova will commit to the following:

- monitor landings on and collisions with project structures during operations;
- develop an action plan for recovering and releasing birds following collisions;
- develop a feasible monitoring program for seabirds in the case of a large spill, as part of the Emergency Response Plan;

- support an observer program for seabirds by:
  - ✓ providing space for observers aboard Terra Nova project platforms and vessels;
  - ✓ assign Terra Nova staff to participate in the observer program; and
  - ✓ consult with regulatory agencies with respect to appropriate observer procedures.
- provide funding support for a study examining seabird attraction to light and seabird monitoring in the Atlantic Region.

These commitments are separate initiatives from the EEM program.

6. MARINE MAMMALS

Marine mammals are recognized as a Valued Environmental Component in the Terra Nova EIS (Suncor Energy 1996). The EIS predicted negligible potential impacts on marine mammals from drilling and operations of the Terra Nova development. The exceptions were the predicted negative, negligible to minor, sublocal to local and long-term potential effects resulting from project-related noise from the drilling rigs, supply vessels, aircrafts and floatation platform. However, marine mammals are not suitable for inclusion in a site-specific offshore oil EEM program due to their transient residence within the area (Dunnet and Clark 1994). The exclusion of marine mammals is supported by C-NLOPB in Decision 97-02.

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APPENDIX F

Potential Survey Designs and Analysis Models

CONTENTS

The following text from the original design document has been combined into an appendix dealing with design (originally submitted in the main body of the report) and statistical power/ cost-benefit (originally submitted separately, as an appendix). A literature cited section specific to this appendix has been added.

1. INTRODUCTION

Statistical design includes:

- selection of statistical models - used to develop sampling designs and analyze data;
- sampling layout - sample locations, times; and
- optimization - statistical power and cost-benefit analysis.

Statistical designs for the Terra Nova EEM program should be:

- practical and cost-effective;
- flexible - drilling locations, schedules and technology, and C-NLOPB monitoring requirements may change over 20 years;
- scientifically and statistically defensible; and
- statistically powerful.

The basic statistical designs recommended for the Terra Nova EEM program are discussed below.

2. STATISTICAL MODELS FOR EEM

Two basic statistical models can be used for EEM:

- regression (i.e., gradient or trend); and
- ANOVA.

Regression models test for relationships between chemical, physical or biological y variables, and x variables such as distances or directions from one or more sources (e.g., drill centres). ANOVA models compare y variables among two or more areas (or times) differing in exposure or distance from a source. Regression models will usually be superior to ANOVA models when a wide range of x values can be sampled. However, an ANOVA model must be used when only a few discrete, and often qualitative or semi-quantitative, levels of x can be sampled.

The models used for the Terra Nova EEM program will consider time, as well as space, because the program will span ~20 years.

2.1 Spatial Models

Two spatial models will be used for the Terra Nova EEM program: a regression or gradient design, and an ANOVA or Control-Impact (CI) design. The gradient design will be used on a micro-scale (within 10 km of sources) to monitor sediment chemistry, sediment toxicity, and benthic invertebrate communities. These variables vary over relatively small spatial scales, either naturally or in response to project activities, and are expected to develop radial gradients away from point of contaminant release. The CI design will be used on a macro-scale to

monitor larger and more mobile fish or shellfish. Differences in exposure for these organisms will be more qualitative (i.e., exposed versus not exposed) than quantitative.

GRADIENT DESIGN (ATTENUATION BY DISTANCE)

In gradient designs, samples are collected at various distances from one or more sources (Ellis and Schneider 1997). Sampling is typically conducted along transects or at points in concentric circles at increasing distances from the source(s). These distances are the x variables. The null hypothesis tested is that there is no attenuation of physical or chemical alterations or biological effects with distance. The null hypothesis is rejected if there is a significant regression slope or correlation between the y variable(s) and distance (Figure 1).

Gradient designs have been used to monitor the effects of offshore oil developments in the North Sea (Ellis and Schneider 1997) and in the Gulf of Mexico (Kennicutt et al. 1996). However, these designs included a relatively limited number of distances (x values) with replication within stations. In gradient and other regression designs, replication within stations or distances is unnecessary. This sub-sampling is rarely cost-effective unless the samples are composited or can be processed and analyzed at no cost (Cuff and Coleman 1979). In the Terra Nova EEM program, only one sample will be collected per station and the number of stations or distances sampled will be maximized.

A gradient design was used for the Terra Nova EEM baseline program, with samples collected at 54 stations along three transects (Suncor Energy 1998). The same sampling layout, with some minor modifications to accommodate changes in drill centre locations, will be used for the EEM program. Potential x variables include:

- distance from the nearest drill centre;
- distances from other drill centres (i.e., the second closest, the third closest, etc.);
- distance from the FPSO;
- direction relative to these sources;
- time since drilling started or stopped; and
- the cumulative volume of cuttings produced.

Not all of these x variables are likely to be important or significant. Models of the dispersion of FPSO discharges and drill cuttings (Seaconsult 1998) indicate that:

- only the nearest source(s) are likely to be important; and
- directional biases should be minor given the weak residual current.

Relationships between physical, chemical and biological variables and distances from drilling platforms in the North Sea reach positive or negative asymptotes or thresholds at ~1 km (Ellis and Schneider 1997).

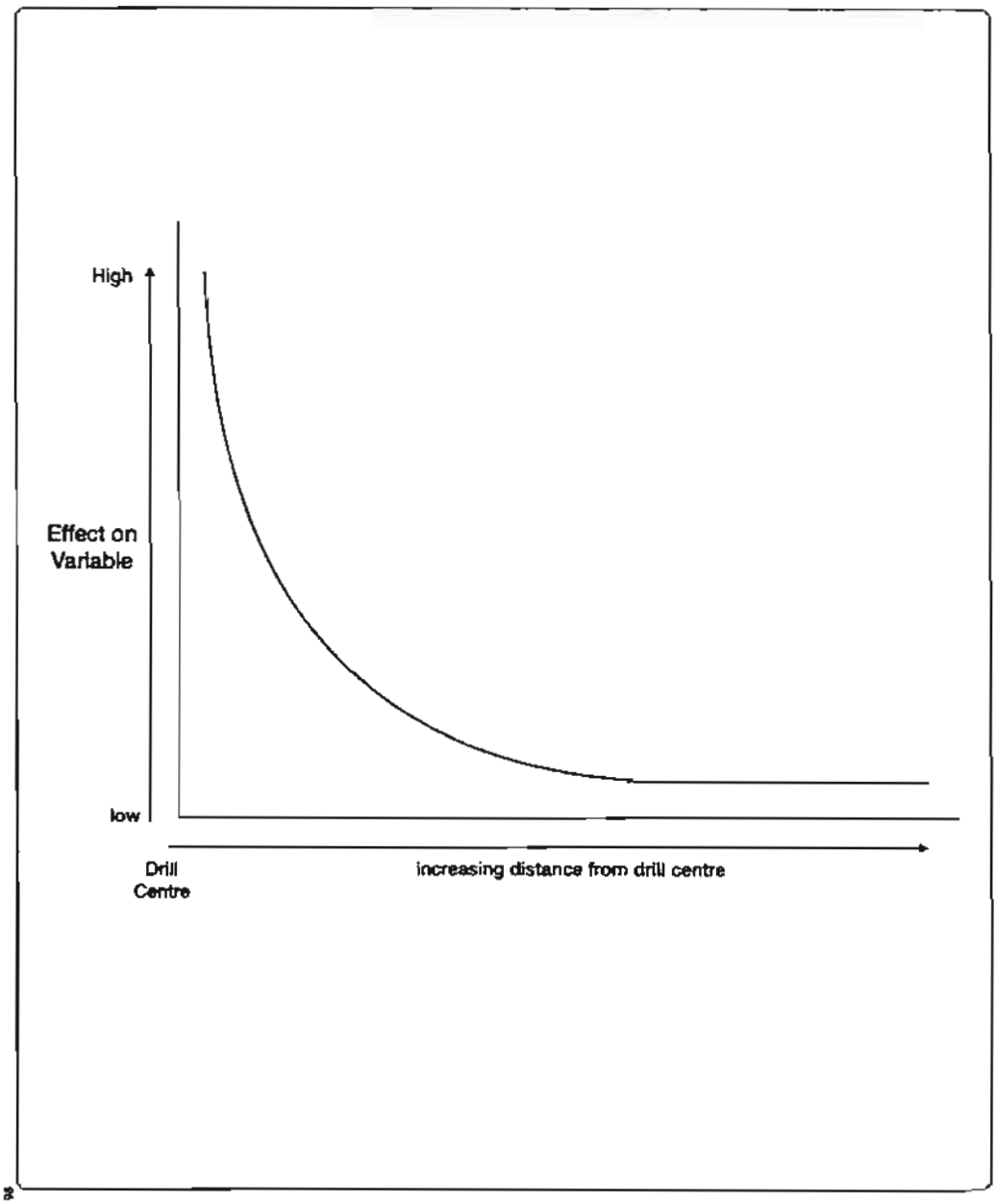


Figure 1 Attenuation by Distance

If regression models become too complex, with many x variables, they can be unreliable. In those cases, it may be better to replace many distance, direction, and other x variables with one or a few physical or chemical variables to provide dose-response relationships. Alternatively, geostatistical methods could be used (Kitinidis 1993).

The Terra Nova EEM gradient design has several advantages relative to the designs used to monitor other offshore oil developments. Gradient designs, if many stations are sampled, minimize the risk that differences in exposure or effects will be confounded with natural spatial differences. The Terra Nova baseline program indicated that natural spatial differences were limited in the study area and did not follow patterns that would be misinterpreted as alterations or effects (i.e., false positives). Gradient designs, and regression models in general, are also more flexible and usually more powerful than ANOVA models and designs (Ellis and Schneider 1997). In the Terra Nova EEM program, all possible combinations of distance and direction from each source cannot be tested separately in an ANOVA design. The Terra Nova gradient design can be used to examine the effects of individual sources, as well as the combined effects of all sources. The design can also accommodate changes in the numbers and locations of drill centres.

CONTROL-IMPACT DESIGN

A CI model will be used to determine if there are differences in biological variables between samples collected within the study (i.e., Impact) area and those collected in a reference (i.e., Control) area. This design will be used to assess abundances, contamination, taint and health of fish and/or shellfish. A gradient design is not feasible for large and/or mobile organisms; they cannot be sampled as intensively as sedentary benthic invertebrates or with the same spatial resolution.

The CI design was used in the baseline program to collect fish and shellfish. Five replicate scallop dredge tows were conducted in the Impact area and nine tows were conducted in the Control area. The same approach will be used in the post-operational EEM program, although the numbers and locations of tows may change.

CONTROL-IMPACT DESIGN FOR REGIONAL MONITORING PROGRAMS

Modified CI designs could also be used for regional assessments of the cumulative effects of all offshore oil developments in the Grand Banks. Gradient designs would be impractical on a regional scale. The entire development area could be treated as a single Impact site for monitoring large, mobile fish or marine mammals, although a comparable reference area might be difficult to find.

Alternatively, each development site could be treated as a separate Impact area. Reference or Control areas could be paired with each Impact area, if those Impact areas differed in depth, substrate, current, etc. If the Impact areas were relatively similar, only one or a few reference areas would be required. In these regional CI designs, the different developments are treated as different levels of one factor (i.e., Site). If references are paired with each Impact area, the CI differences among developments can be compared. If the CI differences do not differ among developments, the null hypothesis that the overall difference is zero (i.e., no regional effects) can be tested. Similar tests can be conducted if reference areas are shared or common to all

developments. Note that EEM programs for each development are likely to use CI designs for monitoring fish and shellfish. All that is required to implement a regional program is some coordination in terms of the target organisms sampled and the variables measured.

2.2 Temporal Models

Trend designs, in which time is the x variable, are the temporal counterparts of spatial gradient designs. Trend monitoring designs are most useful for assessing effects on a regional scale and on large, long-lived organisms such as seabirds and marine mammals. However, trend designs can also be used on a micro-scale for monitoring recovery from any alterations or effects that occur. For example, attenuation of sediment contamination from drill cuttings over time could be monitored at one or more stations after drilling ceases, or after extraction ceases. As in spatial designs, chemical or physical variables can replace time as x variables.

Before-After (BA) designs are the temporal counterparts of spatial CI designs. The simplest BA designs compare periods before and after some activity or stressor begins (or ends). More than two periods can be compared when stressors or activities change over time. For example, the Terra Nova project could be divided into baseline, drilling, post-drilling, and de-commissioning and recovery periods.

Temporal designs are more problematic, and usually less effective, than spatial designs. Sample sizes, in terms of the number of sample years, are limited by the lifespan of the project. As in most EEM programs, there will be only one baseline year in the Terra Nova program, so the Before period is unreplicated and potentially unrepresentative of natural conditions. In a spatial design, a set of similar sample locations can be selected; in a temporal design, investigators have little or no control over the characteristics of sample years. The future cannot be predicted and the past cannot be re-sampled. Consequently, the risk that effects will be confounded with natural changes or differences is much greater in temporal designs than in spatial designs.

Given the nature of the Terra Nova project and the limitations of temporal designs:

1. Temporal effects assessments should be combined with, and secondary to, spatial effects assessment.
2. Emphasis should not be on testing the standard Before versus After (BA) contrast. With several different activities and potential stressors occurring at different times, and often gradually, there probably will be no single overall BA contrast or step change. Furthermore, the Terra Nova monitoring program design, with only a single Before or baseline year versus multiple and potentially heterogeneous After years, will be an unbalanced and inefficient design for testing an overall BA contrast.

3. Emphasis should be on testing temporal contrasts or trends in the After years, which will account for the bulk of the EEM database. For example, 'mini' BA contrasts could be used for each phase (drilling, post-drilling, de-commissioning) or trends could be assessed over all phases.

2.3 Spatial-Temporal Designs

OVERVIEW

Spatial and temporal EEM designs can be combined to create spatial-temporal models. The basic spatial-temporal model is a Before-After Control-Impact or BACI ANOVA, which compares Control and Impact sites before and after some intervention or activity. In statistical terms, Site (or Area) and Period (i.e., Before and After) are factors in a two-way ANOVA. More than two sites or periods can be sampled. Either or both the spatial and temporal components can be based on regression rather than ANOVA models. Schmitt and Osenberg (1996) and Paine (1998a) provide recent reviews of spatial-temporal models.

Spatial-temporal designs reduce the risk of confounding natural changes with effects. Effects are interactions between time and space, although the mechanics of testing those interactions vary widely among models. For example, a BACI design provides both temporal (Before or baseline period) and spatial (Control or reference sites) controls. An effect would be defined as a change in the CI difference between the Before and After periods (i.e., an Area × Period interaction). In gradient designs, effects are differences in the slopes of regressions of y on distance(s) among periods. In either design, it does not matter if there are natural spatial differences or relationships in the Before period; only changes in those differences or relationships are relevant for effects assessment. There were few or no potentially confounding baseline spatial patterns in the gradient design, but there were some biological differences between the Control and Impact areas (Suncor Energy 1998). As Box 1 illustrates, even when there are no baseline spatial patterns or differences, including Before data in analysis can be more powerful than analyzing After data only.

Spatial-temporal designs and analysis also protect against false positives and negatives in another way. When spatial EEM designs are repeated, separate tests for effects are often conducted on the data from each year. If an effect is defined as some correlation or difference significant at $p \leq 0.05$, there is a 5% probability of a false positive or Type I error (i.e., declaring there is an effect when there is none). The probability of making at least one Type I error increases with the number of years analyzed. For example, if effects assessments are conducted for 10 different years, the probability of a false positive occurring in at least one year is 1–(1–0.05)10 or ~0.4 (i.e., 40%). In contrast, if all ten years are analyzed simultaneously in a spatial-temporal model, the risk of false positives is still 0.05 or 5%. Furthermore, the larger sample sizes from multiple years increase power, or the ability of tests to detect effects that do occur. The risk of false negatives or Type II errors (failure to detect real effects) is reduced.

The spatial components of the Terra Nova EEM spatial-temporal design will be gradient and CI designs. The temporal component is largely outside investigator control, assuming that the spatial surveys will be repeated annually or less frequently over the next two decades. The only remaining design issue is whether the same locations should be re-sampled every year. The alternative is to select a new set of sample locations every sample year (i.e., re-allocation, or re-randomization if the locations are randomly selected).

RE-SAMPLING VERSUS RE-ALLOCATION

In the CI design, the same Control area should be re-sampled every sample year. If different Control areas are sampled each year, natural spatial differences among the Controls will lead to changes in the CI difference that could be misinterpreted as effects. The Control area sampled in 1997 is also the only Control area for which baseline or Before data is available. The same Impact area must be re-sampled, because there are no alternatives.

There can be advantages to re-sampling the same replicates within areas in CI and related designs (Green 1993, Paine 1996). However, it will not be feasible to re-sample the same tow locations or transects within areas. Some of these transects will run through or near active drill centres or even the FPSO and will have to be moved. The number of tows required to provide sufficient numbers of organisms, and sufficient tissue for taint and bioaccumulation testing, will vary among years. In the taint tests, re-sampling is impossible. The tasters are the replicates and the same set of tasters cannot be used every year.

Box 1 discusses the merits of re-sampling the same stations versus sampling a different set of stations every year for the gradient design. Re-sampling is more powerful than re-allocation whenever there are natural differences among stations that persist over time (i.e., carry-over effect or correlation between times). Even when those natural differences vary over time, re-sampling is more appropriate than re-allocation (Box 1; Green 1993). Finally, re-sampling designs can always be treated as re-allocation designs if there are no carry-over effects. Therefore, re-sampling is recommended for the gradient design. Designs in which the same locations are re-sampled are referred to as repeated-measures designs. Green (1993) and Paine (1996, 1998a) review the application of repeated-measures designs to environmental monitoring programs (see also Section 7).

There are some potential disadvantages to re-sampling. Adjusting for Before or baseline values is only valuable if those values are representative of natural conditions. Re-sampling is effective in the gradient design only if the original set of sample stations is representative and suitable for regression approaches. Even in the first After year, some stations will have to be replaced because drill centre locations have changed. If stations are added or deleted, missing values occur (i.e., all stations are not sampled in all years). There are ways to accommodate those missing values, but a data set with no missing values is always preferable in repeated-measures designs.

Box 1. Re-sampling versus Re-allocation.

Real and simulated data were used to illustrate the advantages of re-sampling the same stations in a gradient design when there is a carry-over effect, or correlation between measurements made at different times.

1. Data

Baseline sediment barium concentrations at 12 stations along the East-West transect (Figure 2) were used as Before data. After data, with no carry-over effect, were simulated using:

ln (Ba After) =mean ln (Ba Before) – 0.4 × (distance in km – 8 km) + ε

The equation set Ba concentrations at stations furthest (8 km) from the drill centre at the Before mean. The concentrations increased towards the drill centre at the same rate observed off the Ekofisk oil platform in the North Sea (slope=0.4; Ellis and Schneider 1997). Then a random error term (ε) with a mean of 0 and a variance equal to the Before variance was added.

After data with a strong carry-over effect were simulated using the following equation:

ln (Ba After) = ln (Ba Before) – 0.4 × (distance in km – 8 km) + ε

In this case, the After value for each station was a function of the Before value for that station. To account for the correlation, the error variance (ε) was reduced to 25% of the Before variance (i.e., the Before-After r^2 was ~0.75 before distance effects were added).

Box 1, Figures 1 and 2 plot the Before and After values, and After/Before, versus distance from the FE drill centre for each data set. After/Before was used as the BA difference because data were log-transformed: ln After – ln Before = ln (After/Before).

2. Analyses

The most common methods for analyzing the data would be:

- comparisons of regression slopes of ln (Ba) on distance between the Before and After periods
- regression of the BA differences (ln After – ln Before) on distance
- regression of ln (Ba) for the After period on distance, with ln (Ba) for the Before period as an additional *x* variable

The first method would be used with re-allocation (sampling a different set of stations in each period). The last two methods would be used with re-sampling. *F* and *p* values for these tests, and for regressions of After values on distance, were:

Test	Error df	No carry-over effect		Carry-over effect	
		F	*p*	F	*p*
Regression of A on distance	10	95	2×10^{-6}	86	3×10^{-6}
Comparison of slopes between B and A	20	49	0.9×10^{-5}	51	0.6×10^{-5}
Regression of BA on distance	10	36	130×10^{-6}	698	$<0.001\times10^{-6}$
Regression of A on distance, B	9	98	4×10^{-8}	733	0.001×10^{-5}

NOTE: A = After; B = Before; BA = After – Before; all on a log scale

All *F* values were highly significant because the error variances of Ba concentrations were low (≈CV of 40%), and the decreases in concentration with distance were large (~30%/km). Numerator degrees of freedom (df) for all tests were 1. However, the error df differed among tests. Pairing or matching times when stations are re-sampled always reduces error df relative to treating values at each time as independent observations. Consequently, statistical power will always be reduced by pairing unless there is some carry-over effect or correlation between times.

Box 1. Re-sampling versus Re-allocation (continued).

Significance (i.e., p) for regressions of After concentrations on distance for both data sets were similar; with r^2=0.90 (versus r^2=0.79 for the North Sea data). Therefore, p were also similar when the After regression slopes were compared to the Before slopes (≈0, and the same for both data sets). Even though F were lower for the comparisons of slopes than for the After regressions, p were lower because error df doubled. Thus, there can be some advantage to comparing to baseline or Before slopes, even when those slopes are 0.

For the data set with no carry-over effect, the comparison of slopes was the most powerful test (lowest p). Subtracting the Before value (i.e., differencing) and regressing the BA difference on distance was equivalent to subtracting a random number. Error df were reduced, and the error variance doubled (the variance of a sum or difference of two independent variables is equal to the sum of their variances). Consequently, F and p are reduced, and the test is not powerful. The fit of the regression equation is worse than for the regression based only on After values (Box 1, Figure 1; on a log scale, the scatter or variance of points around the regression line is greater for the bottom plot). Using Before values as an additional x variable in a regression of After values on distance provides more power than differencing, which will usually be the case when carry-over effects are weak or absent (Cohen 1988). This approach reproduces results for the regression based only on After values, except that 1 error df is lost for including the Before values. The slope for the Before values as x was, of course, not significantly different from 0 (p=0.30) because there was no correlation between After and Before values.

In the data set with a strong carry-over effect, differencing or using Before values as an additional x dramatically increased power (much higher F; lower p) relative to comparing slopes between periods. The regression slope for the Before values as x was highly significant ($p=1\times10^{-5}$). Differencing was slightly more powerful than using Before values as x, only because there was one more error df. Both approaches reduced error variances by ~75%, as one might expect when r^2=0.75 between times. The scatter of points about the regression line based on differencing (Box 1, Figure 2; bottom plot) was much less than the scatter about the After regression (top plot).

Implications for the Terra Nova EEM Program

Carry-over effects for most or all monitoring variables in the Terra Nova EEM program will be between the two extremes used in this simulation. The variance of most chemical and physical variables among stations in the baseline study was not markedly greater than analytical error. Consequently, there must be little added variance among stations, and carry-over effects will be weak (i.e., there are no differences between stations to carry over into the After period). There was significant added variance among stations for some benthic community and toxicity test variables. Assuming that the differences or variances among stations are reasonably consistent over time, which may not be the case, carry-over effects can be expected.

Therefore, re-sampling should be used for the gradient design. If carry-over effects are weak, values at different times can always be treated as independent observations, and slopes compared among times or periods. There will be no loss of power relative to sampling a different set of stations each time (i.e., re-allocation). A re-sampling design can always be analyzed as a re-allocation design, but a re-allocation design can never be analyzed as a re-sampling design (i.e., by differencing or pairing). The simulated data illustrate one other important point:

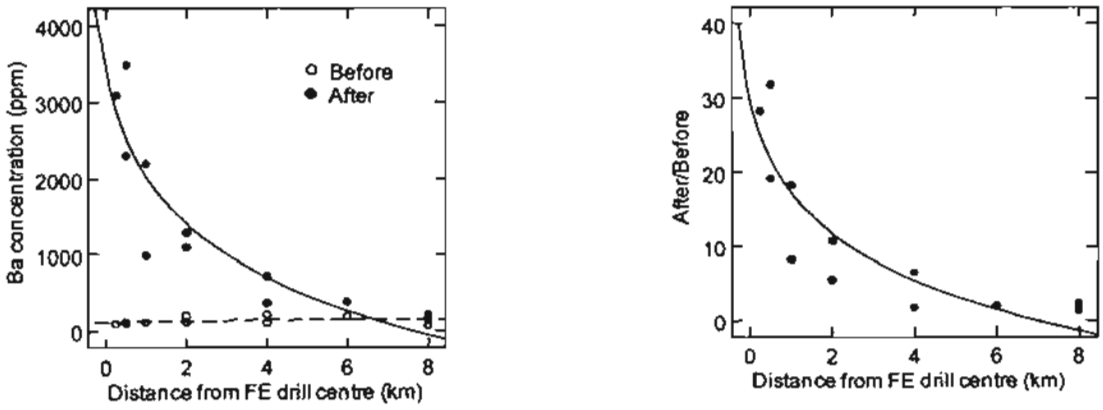
> Even when there is no relationship between y variables and distance for the Before period, including the Before values in analysis can still increase power, relative to analyzing only the After values.

When carry-over effects occur, the Before data must be included to increase power by differencing or regression on Before values. The Before data must also be included when there is a baseline relationship, to avoid false positives. However, including the Before data and comparing slopes between periods may still increase power relative to analyzing only the After data even when there are no carry-over effects. This conclusion presumably applies to the CI design, which must use re-allocation (i.e., differencing or regression on before values is impossible). Testing the Area × Period interaction in a two-way ANOVA may be more powerful than testing only the After CI difference, even when there is no Before CI difference. The increased power associated with including Before values is a sample size effect-error df double.

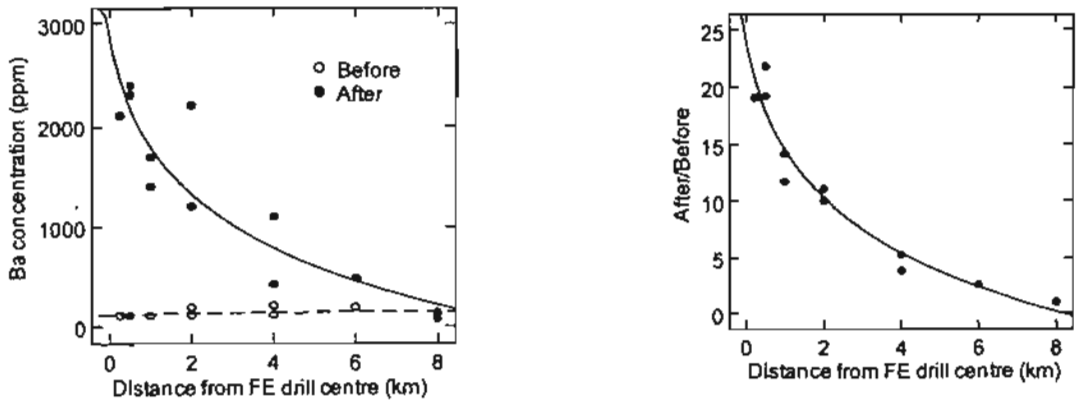
Box 1. Re-sampling versus Re-allocation (continued).

Finally, if re-sampling is used, the appropriate and more powerful differencing or regression adjustment methods must be used for data analysis. Methods suitable for re-allocation designs should only be used if the carry-over effect is weak (e.g., if Before is not significant when used as *x*). One must also be careful when differences among stations are large but vary naturally over time (i.e., natural spatial-temporal variance). In those cases, differencing or regression adjustment may not be as powerful as comparing slopes among periods. However, differencing or regression adjustment should still be used, because the natural spatial-temporal variance is the error term. This natural spatial-temporal variance is the appropriate error term for testing for effects, which are spatial-temporal interactions. Comparisons of slopes between periods use natural spatial variance as the error term, which is not appropriate when natural spatial-temporal variance is present (see Green 1993, for more discussion of this issue).

Surveys of the primary literature indicate that most investigators *do not* use the appropriate methods for analyzing more complex data sets based on re-sampling (Maceina et al. 1995; Paine 1996). For the simulated data, any test would identify a significant relationship between Ba concentrations and distance. However, in other cases, false negatives or positives may occur if an inappropriate test is used.



Box 1, Figure 1 Relationships between sediment barium concentration and distance from the FE drill centre. The Before data are real baseline data; the After data were simulated, with no carry-over effect or correlation between Before and After values.



Box 1, Figure 2 Relationships between sediment barium concentration and distance from the FE drill centre. The Before data are real baseline data; the After data were simulated, with a carry-over effect or correlation between Before and After values (compare with Box 1, Figure 1).

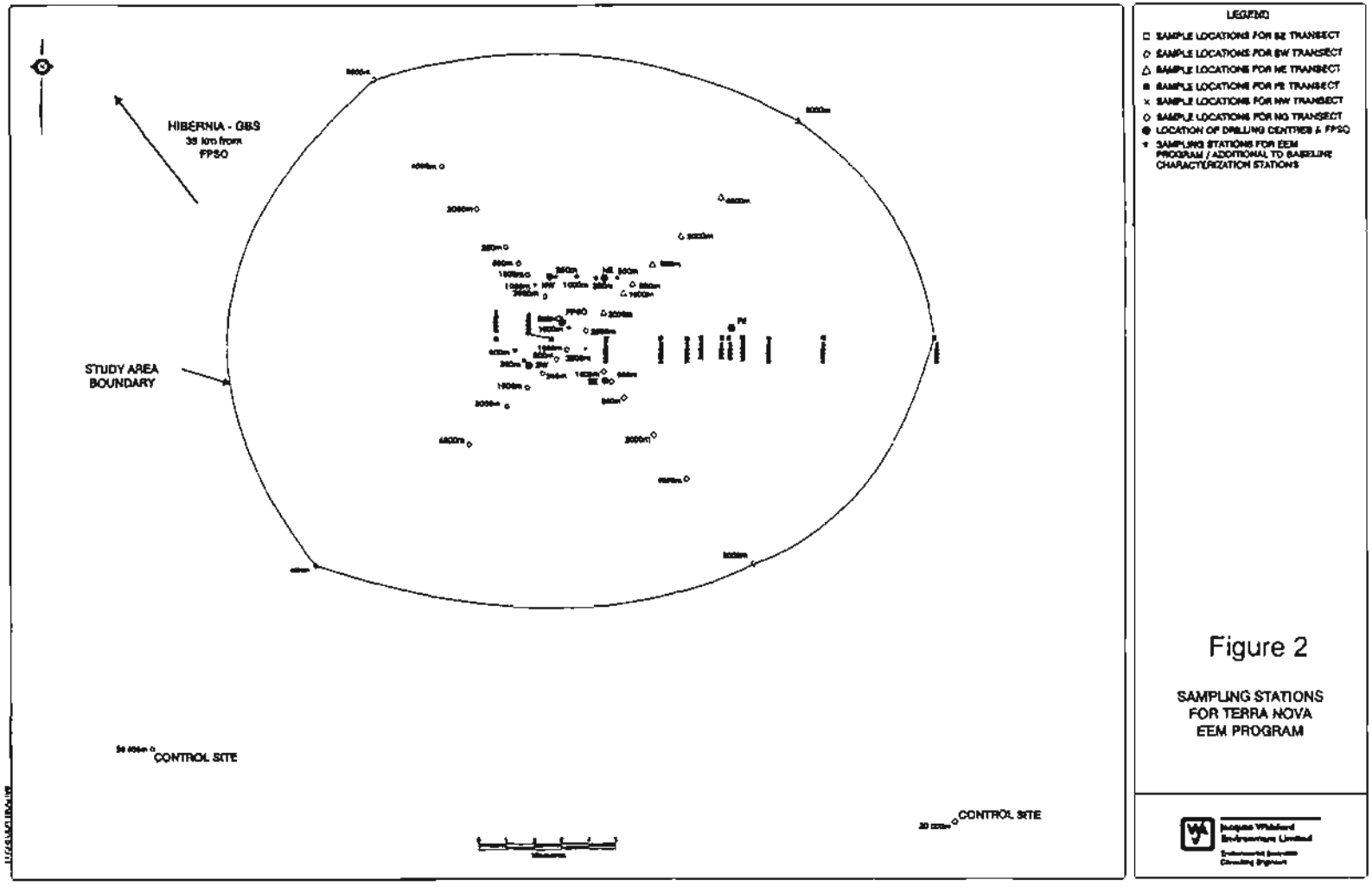


Figure 2 Sampling Stations for Terra Nova EEM Program

3. SAMPLING DESIGN

Sampling design involves selecting sample locations and times. Replicate locations and times can be selected randomly or systematically, depending on the statistical model used. One must also consider whether subsampling or compositing will be cost-effective.

3.1 Spatial (Sample Locations)

Important aspects of spatial sampling include:

- general approach;
- scale; and
- replication.

These aspects were reviewed in the baseline proposal, design and data reports (Suncor Energy 1997a, b; 1998). Sampling locations in the Terra Nova program do not need to be substantially altered from those used in the baseline program.

GRADIENT DESIGN

In the baseline program, 54 stations along three transects were sampled. The stations were located along three transects; each transect passed through one or more proposed drill centre locations. Stations were initially placed 250, 500, 1000, 2000, 4000, and 8000 m from the drill centres in two directions: inbound (towards the centre of the development) and outbound. A log series of distances was used because alterations and effects typically decrease exponentially with distance from sources. Some redundant stations were then eliminated for reasons outlined in Suncor Energy (1997b, 1998). Two reference stations 20 km to the southeast and southwest were added. Reference stations could not be added to the north because they would be too close to other developments.

The sampling stations are indicated in Figure 2. The proposed drill centre locations have changed slightly since the baseline sampling was conducted. These changes had little effect on distances from sources for stations ≥2 km from the previous locations. However, some of the stations closer to sources, especially the 250 and 500 m stations, were no longer near drill centres. These near-field stations are important for the EEM program. Therefore, to provide the same number of near-field stations as in the baseline program, several new stations were added close to the new drill centre locations. Several other stations, primarily former 250 and 500 m stations, were deleted as redundant. These changes in the sampling grid, which were considered necessary, may create some complications for data analysis.

In gradient designs, the optimal strategy is to sample an evenly spaced series of x values (i.e., systematic or regular sampling) (Gilbert 1987). For each drill centre, the sampling grid provides a subset of stations representing an evenly spaced log series of distances. Consequently, over the entire set of stations, there is a reasonably evenly spaced log series of distances to the

nearest drill centre, the primary x variable. However, distances to the second nearest, third nearest, etc. sources are almost all >1 km and most are 5-10 km. Therefore, the design is sub-optimal for detecting effects from sources other than the nearest. That may be a moot point, if effects do not extend far from the drill centres or if there are few locations that are within 1-2 km of more than one source. The present design was developed to address concerns about far-field effects 1-10 km from sources. If those effects cease to be a concern, near-field effects from multiple sources could be examined more intensively by sampling primarily within the centre of the development.

CONTROL-IMPACT DESIGN

The Control-Impact (CI) design should use the same Control and Impact areas sampled in the baseline program. Ideally, replicate tows within each area should be randomly selected and re-sampled. Re-sampling is not feasible. Tow locations could be randomly selected from the set of all possible transects. In practice, haphazard or more systematic selection of sample locations, which can be altered in the field to accommodate boat traffic and other activity, are probably adequate. Over the long term, data should be examined to determine if there are systematic spatial biases and serious departures from randomness present.

There is no optimal strategy for selecting sample locations within areas, other than to ensure that they are as similar and representative as possible.

SUBSAMPLING AND COMPOSITING

Subsampling within stations is unnecessary for the gradient design and rarely cost-effective. This issue was discussed in more detail in the baseline report, with respect to sampling benthic invertebrates (Suncor Energy 1998). Two box cores were collected per station because of concerns that few organisms would be collected in only one core. Abundances and richness (number of taxa) per core were higher than expected but still relatively low. Thus, there could be some advantage to collecting two cores, if (Cuff and Coleman 1979):

- there were no added variance among stations
- there were significant added costs associated with sampling another station as opposed to sampling within a station.

However, there was significant added variance among stations for most variables. The only added costs for sampling another station as opposed to sampling within a station are associated with the small amount of time required to travel to that station. Those costs are trivial relative to the costs of collecting and processing the sample and especially the base costs of the cruise.

Compositing subsamples is useful when:

- the composite can be analyzed for the same cost as a subsample (e.g., chemical analysis)
- large volumes of sediment or tissue are required for analyses or tests.

Compositing was used in the baseline program and will be used in the EEM program for both of the above reasons. Unfortunately, compositing is not useful for benthic invertebrate samples because processing and identification costs are typically based on sample volume.

3.2 Temporal (Sample Times)

Sampling at regularly spaced time intervals is optimal (and convenient) for detecting monotonic (i.e., unidirectional) trends, simple cycles, and simple non-linear trends (Gilbert 1987). If abrupt or step changes are expected, sample sizes within periods Before and After those changes should be equal (Hirsch 1988). Stratified sampling can be used if the magnitude or types of stressors or effects vary over time. For the Terra Nova project, strata could be the initial drilling phase, the longer post-drilling phase, and the de-commissioning and recovery phase. The optimal sampling allocation is to make sample sizes (i.e., number of sample years) within strata or phases proportional to the expected magnitude or variance of stress or impacts (Gilbert 1987).

The proposed sample schedule for the offshore cruises calls for annual sampling beginning in 2000 and continuing for at least the first three years, after which the frequency will be reviewed. That schedule provides more sample years during the drilling phase and early post-drilling phases when alterations and effects are likely to vary most. The years 2000-2002 will provide a semi-quantitative "dose" series in terms of the cumulative volume of cuttings produced. During the post-drilling phase, regularly scheduled sample cruises will be suitable for trend monitoring. It is also more prudent and proactive to sample intensively early in EEM programs and to reduce sampling when frequency alterations and effects are minimal. The alternative of increasing sampling frequency only when effects are detected or suspected is a reactive approach.

SUBSAMPLING

In water quality monitoring programs, samples are typically collected within years (e.g., monthly or weekly), usually to examine seasonal cycles. However, the within-year sample times (usually referred to as seasons) are also commonly used as blocks for analysis of long-term trends or step changes (Gilbert 1987). Alden et al. (1997) provide an example, in which trends for benthic invertebrate communities in Chesapeake Bay were compared among seasons. Blocking by season is another form of subsampling. In the Chesapeake Bay study, eight-year.trends were calculated for each of the four seasons. Since the trends were homogeneous among seasons, the seasons effectively provided four "trials" or replications of the same "experiment" (i.e., the trend). Thus, using seasons as blocks can increase power, especially for analysis of short time series.

In the absence of cost considerations, within-year subsampling and blocking by season could be an effective approach for increasing power in the Terra Nova program, especially within

shorter time intervals (i.e., the drilling phase). However, within-year sampling would be prohibitively costly. The major costs for the sample cruises are associated with the base costs of the vessel and crew and travel to the Grand Banks. In other words, simply mounting a cruise accounts for a significant part of the costs for each sample year, regardless of how many stations are sampled.

Seasons are also pseudoreplicates, especially for trend monitoring. In the Chesapeake Bay study, the eight-year trend, even if highly significant and homogeneous among seasons, applies only to the eight years in which samples were collected. There is no guarantee that the trend extended beyond those eight years, and sampling monthly or even daily within the eight-year period would not alter that fact. In the Terra Nova program, there might be some interest in increasing sampling frequency in the de-commissioning phase, if effects occur, to document recovery as soon as possible. However, recovery will almost certainly be defined as some minimum number of years in which effects are no longer evident. Sampling daily within the first year after oil extraction ceases would be of little or no value for assessing recovery. Similarly, daily sampling in the baseline year (1997) would not substantially expand our knowledge of conditions prior to the development.

Stations are also commonly used as blocks for examining trends and step changes (Gilbert 1987). Re-sampling the same stations in a spatial-temporal EEM design is a form of blocking. A test for effects (i.e., a spatial-temporal interaction) is really a test of the null hypothesis that time trends or step changes are homogeneous among stations differing in exposure. Stations are relatively inexpensive, given the high base costs of sample cruises (i.e., once you are out there, you might as well sample as many stations as possible). Therefore, increasing the number of stations sampled is an effective way to increase power. However, stations (or even areas in a CI design) can also be pseudoreplicates if temporal or spatial-temporal variances are large or if effects vary over time. This issue is important in any long-term EEM program.

4. DESIGN OPTIMIZATION

Cohen (1988) reviews power analysis for most relevant statistical models. Underwood (1996) and Paine (1998a, b) review power and cost-benefit analysis for environmental studies. Millard and Lettenmaier (1986), Green (1993), Underwood (1994), Keough and Mapstone (1995), Osenberg et al. (1996) and Ellis and Schneider (1997) provide power or cost-benefit analysis for specific spatial or spatial-temporal EEM models. Berryman et al (1988), Nicholson et al. (1997) and several papers in Ecological Applications (1998; Volume 8{2}; Invited Feature on Measuring Trends in Ecological Resources) discuss power and optimization of long-term monitoring programs.

The absence of data on temporal and spatial-temporal variances limits the quantitative statistical power and cost-benefit analysis that can be conducted for spatial-temporal EEM

models. However, some qualitative recommendations and "rules of thumb" are noted in Sections 4.1 and 4.2

4.1 Power Analysis

Statistical power analysis is used to minimize, or at least balance, the risks of false positives (Type I errors) and false negatives (Type II errors). Typically, one calculates the sample size (n) necessary to provide some stated probability or power (P) of detecting an effects size (ES) in a statistical test. The Type II error rate or β is equal to 1-P; the Type I error rate or α for the test is usually set at the standard 0.05 used to define statistical significance. ES can usually be expressed as differences (δ) or correlations (ρ), even in relatively complex models (Cohen 1988). Some estimate of variance (σ^2) is also required. Power or P is directly related to n, ES, and α, and inversely related to σ^2. For any given P and α, required n is roughly proportional to σ^2/ES2.

Calculating required n is a useful exercise when proposed sample sizes are small, since many environmental studies are under-replicated. However, whenever sample sizes exceed some minimum requirements (see below), increasing n is often a brute force and costly way to increase power. Figure 3 provides the differences (δ; standardized by dividing by the SD or σ) and correlations (ρ) that can be detected, given $\alpha=\beta=0.05$ (i.e., equal probability of Type I and II errors). The curves would have identical shapes if ρ^2 were used instead of ρ; differences can always be expressed as correlations (Cohen 1988; that is why ANOVA comparing means are really regression models). At small sample sizes (e.g., n<20 and especially <10) the ES that can be detected (i.e., sensitivity) decrease rapidly with increasing sample size. Adding a few more replicates is not too costly, and substantially increases power and sensitivity. However, beyond that, the curves flatten considerably, and increasing sample sizes produces diminishing returns. Prohibitively large sample sizes (i.e., >100) are required to detect δ<0.75 SD and ρ<0.3. Doubling sample sizes from 50 to 100 accomplishes little other than doubling costs—the first 50 replicates are far more effective than the last 50, and cost the same.

Some basic minimum sample size requirements or "rules of thumb" should be met in any monitoring program:

1. Most statistical tests are not robust unless error degrees of freedom (df) are ≥10 (Harris 1985). Non-parametric tests, especially, gain power as df increase beyond 10. In a CI design, increasing sample size to n_i=6 per area (df=$\sum(n_i-1)$=10) is almost always cost-effective.

2. At least 10, and preferably 20, replicates should be used for detecting correlations in gradient designs. With n=20-30, P is >0.80 for detecting ρ>0.5, with α=0.05. Weaker correlations (i.e., ρ<0.50), with less than 25% of the variance of one variable explained by another, have limited predictive or descriptive power.

3. If gradient designs are used to develop predictive or descriptive regression equations, a good rule of thumb is n=10-20k, where k is the number of x variables originally considered for inclusion in the regression model (Tabachnick and Fidell 1989). The same rule should be used for multivariate analysis, unless correlations among variables are high (e.g., >0.5 and preferably >0.75).

4. Long-term trends are usually defined as intervals of ≥10 years (e.g., Dixon et al. 1998). A three-year "trend" is not a long-term trend even if it occurs at an infinite number of stations, or for every day of the year. Sample sizes of $n \geq 10$ sample years are recommended for analysis of trends (Berryman et al. 1988), which are effectively analysis of correlations between y and time.

5. For small sample sizes (i.e., <20 overall), equal sample sizes for any comparison are always better than unequal sample sizes, except when variances are greater for the larger sample (Paine 1997). This is particularly true when overall sample sizes are small. A good rule of thumb is that the effective n or n^* is for a comparison of several means is the harmonic mean (HM) of the sample sizes (n_i) used to calculate each mean. HM = $1/\sum(1/n_i)/a$, where a is the number of means compared. The HM of n_i will always be less than the arithmetic mean.

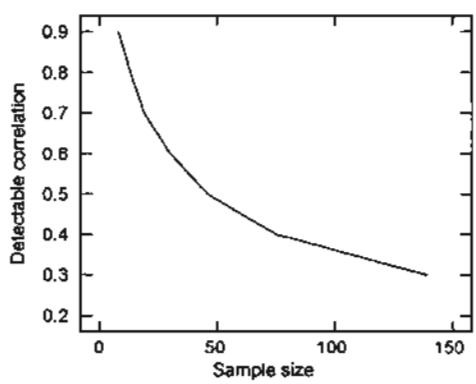


Figure 3 Relationship Between Detectable Differences (δ; standardized by dividing by standard deviation or σ) and correlations (ρ) and sample size for α=β=0.05 (P=0.95).

The gradient and CI designs meet requirements 1-3 in terms of spatial replication, even within a single year. Sample sizes within areas will occasionally be unbalanced in the CI design, as they were in the baseline program, because of the need to collect sufficient animals and tissue from each area. If multiple years are analyzed, all requirements will be met, and the adequacy of spatial replication is a non-issue.

Temporal requirements may be more difficult to meet because there are simply not enough sample years available for some potential tests. To a considerable extent, sampling multiple

locations within years addresses this limitation, *but only for the specific years sampled.* Problems arise mostly at the beginning and end of the program. We have n=1 baseline or Before years; some minimum number of years may also be required to demonstrate recovery if any effects occur.

There are other ways to increase power beyond focusing on sample sizes. Variances (σ^2) can always be reduced by good field and laboratory practice. Power can also be increased, usually by reducing error or nuisance variance, during program design and data analysis. Pairing, blocking, and regression adjustments are powerful techniques (Box 1), and often cost nothing to implement. These and other approaches will be used throughout the Terra Nova EEM program.

4.2 Cost-Benefit Analysis

Cost-benefit analysis is used to compare and evaluate monitoring programs at various levels (variables, sampling designs, statistical models, etc.). Cost-benefit analysis could even be used to evaluate the merits of conducting an EEM program versus not conducting an EEM program, or developing the Terra Nova oilfield versus not developing the Terra Nova oilfield. Statistical cost-benefit analysis is used to maximize power, or minimize variance, per unit cost.

Extensive quantitative cost-benefit analysis has not been used to evaluate the Terra Nova EEM program, because:

- estimates of natural spatial-temporal variance are not available
- some conclusions are obvious without quantitative analysis

As noted above, subsampling within stations or years will rarely, if ever, be cost-effective. As in any spatial-temporal design, the costs and benefits of replication in space versus time must be considered. In the Terra Nova program, years are costly and stations or locations are relatively inexpensive. Therefore, the emphasis has been on spatial replication.

5. MODEL SIMPLIFICATION

As more factors, levels of those factors, and y and x variables are included, statistical models and tests become more complex and less robust. The number of possible interactions increases almost exponentially as the number of factors or x variables increases. Therefore, the models will be simplified when possible, unless that simplification reduces power. Techniques for simplification include:

- analysis of summary statistics (e.g., sums, differences, means, slopes, variances)
- use of one or a few chemical or physical variables to replace many factor levels or x variables
- dropping years or stations.

Multivariate procedures such as Principal Components Analysis (PCA) could also be considered as techniques for simplification when used for variable reduction.

Analysis of summary statistics reduces the number of observations in the data set, and can reduce the number of factors or *x* variables. Summary statistics are also more likely to meet the assumptions of parametric and non-parametric tests than are individual observations. For example, distributions of means will tend to follow a normal distribution even when distributions of individual values used to calculate the means do not. Summary statistics can also be used in simple non-parametric tests when individual observations are not suitable for parametric analysis. Complex parametric models rarely have direct non-parametric counterparts. Finally, stressors can sometimes affect variances rather than means (Green and Montagna 1996). There are tests available for comparing variances, but it is usually more convenient to treat the variances as observations in simple models and tests.

Complex ANOVA or regression models can sometimes be collapsed into simpler dose-response relationships (correlations or regressions). This technique is also useful for removing complex spatial-temporal interactions, if those interactions arise because doses in the same area or station change over time. The Sediment Quality Triad (SQT) is a useful approach for simplifying analysis of large data sets.

Not all years or stations need be included in all analyses. For example, the early years in the drilling phase will be of little interest once drilling has been completed. Only the last year in the phase is relevant for comparisons with post-drilling years (e.g., to test for recovery and other trends).

5.1 Multivariate Techniques

Multivariate analyses will be used primarily for variable reduction. Variable reduction simplifies subsequent analysis, interpretation and presentation. For example, if we measure 20 different metals in tissue, we do not want to conduct 20 separate tests, and then interpret and present the results of each test. It is much easier to conduct one or two tests on composite measures derived using multivariate techniques. The results provide some general conclusions about any patterns of metal contamination, and are certainly easier to present.

Principal Components Analysis (PCA) was used in analysis of the baseline data to reduce many chemical variables to one or two composite measures or Principal Components (PC). This is a common approach for chemistry data that will undoubtedly be used in future analyses. The PC values or scores can be considered weighted sums or means of the original *y* variables (chemical concentrations; usually log-transformed):

$$\text{PC scores} = \sum_{1}^{k} b_i y_i$$

where b_i are the weights for the k variables.

Like sums and means, PC scores are more likely to meet the assumptions of parametric tests than are the original variables. The b_i are usually all positive, because concentrations of chemical compounds are usually positively correlated. However, there can be a balance between positive and negative b_i in other types of data; the PC scores can then be considered differences or contrasts.

PC are calculated so that the first PC (PC1) accounts for the major axis or pattern of variance in the data; PC2 accounts for the next largest axis of variance perpendicular or independent of the first, and so on. Thus, most of the variance is accounted for in the first few PC. If a stressor is an important source of variance, then scores for the first few PC should differ among, or be correlated with, different levels of stress or exposure. Furthermore, scores for different PC are uncorrelated, which has some advantages for analyses.

PCA is not the only multivariate technique available for variable reduction. Non-Metric Multidimensional Scaling (NMDS) was used in the baseline analysis to reduce benthic invertebrate abundance variables to two NMDS axes or composite variables (Suncor Energy 1998). NMDS can be considered a more robust, partly non-parametric, analogue of PCA.

There are also formal multivariate counterparts of most uni- or bivariate models and tests discussed in this document (e.g., MANOVA). There are also multivariate randomization tests that have been used to analyze monitoring data (e.g., Clarke 1993; Green et al. 1993). However, the two-step process of using PCA (or NMDS) for variable reduction, then analyzing the PC scores in uni- or bivariate tests, is usually simpler and often more powerful than these alternatives (Green et al. 1993; Paine 1998b).

5.2 Non-parametric Tests

Most parametric models or tests have non-parametric analogues or counterparts. Summary statistics instead of individual values sometimes have to be analyzed in the non-parametric tests when parametric models are complex, which is not necessarily a drawback. In any event, one can always apply the parametric tests to ranks, instead of the original data, if sample sizes are large. Non-parametric tests are sometimes called distribution-free tests because they can be used when distributions of variable values are non-normal. Most are based on analysis of ranks. Non-parametric tests are particularly useful for analyzing data sets with many chemical concentrations below the laboratory detection limit, which are simply treated as tied values of the lowest rank. With large sample sizes, the power of non-parametric tests approaches that of their parametric counterparts even when data are normally distributed.

Neave and Worthington (1988) review non-parametric counterparts of t-tests, one- and two-way ANOVA, and regression/correlation that can be used to analyze data from a single monitoring year. For multiple-year data, van Belle tests for homogeneity of trends are usually appropriate (van Belle and Hughes 1984; Gilbert 1987; Berryman et al. 1988; Paine 1998a, b). As their name implies, these tests are used widely in water quality monitoring programs to compare

trends among seasons or stations; they are also known as Seasonal Mann-Kendall (MK) tests. However, the tests can be used for many other types of data. Differences or step changes can be analyzed instead of trends (Hirsch 1988; Gurevitch 1993). The standard approach of comparing time trends or differences among stations can be reversed, and spatial differences or trends (e.g., dose-response relationships, correlations of y variables with distance from sources, CI differences) compared among times. There are even multivariate versions of the van Belle tests, which can be used to compare variables or correct for serial correlation over time (Hirsch and Slack 1984; Lettenmaier 1988). However, it is usually simpler to use the standard tests to analyze PC and other multivariate scores (Yu and Zou 1993). The tests make some simplifying assumptions, so they are not universally applicable. However, van Belle tests should be used extensively for analyses of multi-year data from the Terra Nova EEM program.

5.3 Other Universally Applicable Techniques

Several other techniques will be used in many analyses:

- orthogonal contrasts
- removal of nuisance variance by regression adjustment or blocking

Orthogonal contrasts are differences among, or combinations of, means or variables. Different orthogonal contrasts for the same set of means or variables are independent; most statistical texts provide rules for deriving sets of orthogonal contrasts. Using orthogonal contrasts is more powerful than omnibus procedures such as making all possible pair-wise comparisons among means (Day and Quinn 1989). Hoke et al. (1990) and Green (1993) illustrate the use of orthogonal contrasts for analysis of environmental data; Chapman et al. (1996) and Paine et al. (1996) provide other examples. Note that PCA is a method of deriving independent combinations or contrasts for variables.

Nuisance variance is defined as variance that is not of interest (i.e., noise). Nuisance variance can often be removed from error variances to increase the power of tests, often at little or no cost. For example, re-sampling the same stations in the gradient design removes natural spatial variance among stations from error variances in RM models. In these cases, the stations act as blocks for testing differences between times (see Section 7.2.4).

Blocks are experimental units or replicates in which all levels of a factor of interest (i.e., treatment) are tested. Pairing is blocking applied to only two treatment levels. The alternative to blocking is to assign each treatment level to a different replicate (i.e., completely random or CRD designs), which is re-randomization or re-allocation. Blocking removes the variance among blocks from the error variance, and is therefore efficient whenever variance among blocks is large. Almost any factor that occurs in discrete levels can be used as a blocking factor, although times and locations are used more frequently than other factors. Blocking

should usually be identified a priori during the development of statistical designs. However, suitable blocking factors can sometimes become evident after data have been collected.

If nuisance variables are continuous, they can be included as x variables in ANCOVA or regression models to remove nuisance variance. This type of regression adjustment can be even more powerful than blocking and can be implemented after data have been collected. If correlations, rather than regressions are analyzed, partial correlations can be used to remove the influence of nuisance variables on correlations between variables of interest. In the baseline report, partial correlations were used to remove the effects of sediment particle size and organic content on correlations between chemistry (C) and biology (B) variables. In that case, the partial correlation analysis actually reduced or eliminated the B-C correlation. Blocking regression adjustment and partial correlations can all be used to check that apparent effects are not due to some confounding nuisance variable or factor.

5.4 Repeated Measures (RM) ANCOVA

Repeated measures (RM) approaches are usually ANOVA designs. For example, the same replicate locations within Control and Impact could be re-sampled Before and After some intervention or activity (Green 1993). However, RM approaches used in ANOVA can be applied to gradient designs and regression, although that does not appear to be common.

RM for comparing regressions (i.e., RM ANCOVA) is illustrated in Figure 4a using the barium data in Box 1; the After data used were the data with the string carry-over effect. The "Between Subjects" component of the RM regression model tests for a relationship between the average barium concentration over both times, and distance. Here and elsewhere, the "Subjects" are stations. The Between Subjects test on the average over all times is rarely of interest when the times differ in exposure. Instead, we want to test if the barium-distance relationship changes over time. That test is provided by the Year × Distance term in the "Within Subjects" component of the model. This is an interaction term, testing for a difference in slopes of the barium-distance regression between years or times. The Year term tests for a difference in regression intercepts or elevations between years. This test is of little interest when slopes differ (i.e., the regression lines are not parallel).

Figure 4b provides results of a comparison of regression slopes between years from a standard ANCOVA model. Again, the Year × Distance term tests for equality of regression slopes; F (and p, if enough decimal places were used) for this test were much lower than in the RM model (see also Box 1). Note that Sums-of-Squares (SS), df, and Mean Squares (MS) for Year, Distance, and Year × Distance are the same for both models. However, the RM model splits the error term from the ANCOVA into two parts: the Between Subjects error (Error 1) and the Within Subjects error (Error 2). Error 1 incorporates any systematic differences among stations that persist over time (i.e., the carry-over effect). Error 2 incorporates the remaining, presumably random, lack-of-fit to the regressions, and was much smaller than Error 1. Consequently, the

RM model had much greater power than the ANCOVA for the test of equality of slopes, even though splitting the error term reduces error df in the RM model (see also Box 1). In contrast, Error 2 for the analysis of the data with no carry-over effect from Box 1 was actually larger than Error 1.

(a) Repeated measures (RM) ANCOVA

```
>model beforeba,afterba=constant+distance/repeat name='YEAR' Univariate Repeated
Measures Analysis
Between Subjects
----------------
Source                SS        df        MS              F              P

DISTANCE             1.308      1         1.308       27.143         0.000
Error 1              0.482     10         0.048


Within Subjects
---------------
Source                SS       df          MS          F        P

YEAR                  4.738      1         4.738  2594.566    0.000
YEAR*DISTANCE         1.275      1         1.275   698.437    0.000
Error 2               0.018     10         0.002
```

(b) Standard ANCOVA

```
>model ba=constant+year+distance+year*distance Dep Var: BA   N: 24   Multiple R:
0.964   Squared multiple R: 0.930
Analysis of Variance Source              Sum-of-Squares   df  Mean-Square     F-
ratio       P YEAR                     4.738     1        4.738     189.527
0.000
DISTANCE                  1.308     1        1.308      52.302       0.000
YEAR*DISTANCE             1.275     1        1.275      51.019       0.000

Error          0.500  20    0.025
```

Figure 4 SYSTAT Version 7.0 output for RM and ANCOVA models comparing regressions of barium concentration on distance between Before and After years. The data used were the baseline (Before) data, and the simulated After data with a strong carry-over effect, from Box 1. In both models, the Year × Distance term (bold, italics) provides the test for equality of slopes.

The test for equality of slopes (i.e., Year × Distance) in the RM model is identical to a test of the regression of the BA difference on distance (Box 1; F for the latter test was also 698.437). Therefore, with only two years or times, regressing the difference between the times on distance is a simpler test to conduct and explain. With more than two times, there is no single difference to use as y in regression. The RM model must be used to provide an omnibus test of differences in slope among all times. However, in most RM models, one then proceeds by

testing some specific differences or contrasts of interest (Green 1993). For example, with three After times differing in exposure, and a single Before time, one might test a BA contrast, comparing the Before time with the After average. Then, tests could be conducted on one or more differences or contrasts among the After years, or just on the After mean. The tests of these contrasts in the RM model are identical to tests based on regressing the contrasts or differences on distance. Finally, for any difference $a-b$, using b as an x variable for tests of a (or vice versa) is usually superior to testing $a-b$ (i.e., differencing) (Cohen 1988; Everitt 1994).

6. ANALYSIS

6.1 Sediment Quality Analysis

GENERAL REGRESSION METHODS

The simplest model for analysis of data from gradient designs is linear least-squares regression (LSR): $y=a+bx$. The primary x variable of interest is distance from the nearest drill. There are several different approaches available to decide which x variables should be used or tested in regression models. Our recommendation is that variables other than distances from the nearest drill centre, and from the FPSO, should only be used if there are strong reasons to do so. This will simplify analyses and any predictive or descriptive regression equations produced. This parsimonious approach is preferable to analyzing every possible x variable. Decisions about which variables to include or exclude will be partly subjective, although there are some objective criteria or approaches (Tabachnick and Fidell 1989).

Another important and potentially subjective issue will be to decide which regression model or method to use. Exponential decay models (i.e., log y versus untransformed x) were used by Ellis and Schneider (1997) to fit relationships for the North Sea data. However, other models such as non-linear asymptotic models or threshold "hockey stick" or segmented models (Cox 1987) may provide better fits. Logistic regression could be used to analyze frequencies of detection instead of actual concentrations. There are also non-parametric methods for estimating and testing regression slopes and intercepts (Neave and Worthington 1988). Correlation analysis is adequate to determine if there is a relationship between y and distance. Regression equations are not of much value unless correlations are high (e.g., $r>0.7$, which means that x accounts for ≥50% of the variance in y).

Repeated measures (RM) ANCOVA can be used to compare regressions on distance among years. With only a few years to compare, analysis of regressions of one or a few temporal differences or contrasts on distance may be simpler. Analysis of Before-After differences, or inclusion of Before values as x variables, as in Box 1, will be the method(s) used to analyze the first After data collected in 2000. With many years, analysis of summary statistics such as slopes may be preferable. The non-parametric van Belle tests could be used to compare correlations between y and distance among years.

Some method of dealing with missing values will be required, especially for comparisons of After years to baseline or Before values. Some baseline stations have been replaced, so not all stations sampled in After years will have baseline values. The new stations are near drill centres, and are important for effects assessment. Therefore, they cannot simply be excluded. The best option might be to simply use the mean Before value for missing Before data. This and other options all carry some risks, and those risks should be acknowledged in program reports. On the other hand, results are likely to be the same or similar for most reasonable options.

CHEMISTRY

No special analyses are planned for chemistry variables. PCA will be used for variable reduction. Some method will be required for dealing with values below detection; using half of the limit of quantitation is usually acceptable when few values are below detection. More drastic measures may be required for PAH, which were not detected in the baseline program, and probably will not be detected at far-field and reference stations in After years. Including the baseline values in analyses and PCA would be highly suspect and should be avoided. Therefore, PAH should be analyzed separately from other contaminants.

TOXICITY

Within each year, there are standard comparisons made to either field references or laboratory controls that can be applied to each station. Toxicity assays use industry-developed computer programs for the statistical analyses of toxicity data. These programs facilitate data input with the appropriate statistical methods. Computer programs for statistical analyses of toxicity data are available from Environment Canada and their use is highly recommended.

The amphipod survival assay endpoint is percent mortality. The data for test samples are compared to data from a reference and/or control sample to determine if there is a statistical difference. The statistical analysis used is the student t-test, a common parametric analysis available in most computer spreadsheet packages. A sample is considered toxic if it is statistically different from the reference (or control) sample and there is a 20% (30%) difference in moralities. For a sample to be considered toxic, both of these criteria must be met. In addition to mortality, reburying can be examined using the same guidelines.

The bacteria luminescence assay is conducted by instrumentation developed by Microbics Corporation, which includes a data analysis package. The IC50 (concentration at which 50% inhibition is observed) is calculated. This value is determined by probit analysis and should be verified graphically on a logarithmic-probability plot.

Samples are considered toxic if an IC50 value of less than 98,000 mg/L is obtained for a sandy sample and if an IC50 value of less than 5,000 mg/L is obtained for mud based sample. Terra Nova samples were predominately sand-based and the samples will be considered toxic if a

value of less than 25,000 mg/L are achieved. This values represents the lowest report value observed for toxicity during the baseline study (Suncor Energy 1998) and can be considered to represent a naturally occur toxic response prior to the Terra Nova Development.

The baseline EC50 will be difficult to incorporate into analyses because there was almost no variance (i.e., all but four values were the same, greater than the highest concentrations tested). Results from the Hibernia EEM program suggest that amphipod reburial may be an important variables for assessing effects. PCA can be used to reduce the toxicity variables to a single measure (PC1), if they are correlated. However, with a maximum of three variables, the PCA would only be necessary for the SQT analyses; otherwise, each toxicity variable can be analyzed separately.

BENTHIC INVERTEBRATES

Some specialized techniques used in the baseline report will also be used in future reports for analysis of the benthic invertebrate data. NMDS will be used instead of PCA to reduce abundances of individual taxa to one or two community measures. Regressions on total abundances will be used for analysis of richness, since richness and abundance will undoubtedly be positively correlated.

SEDIMENT QUALITY TRIAD

Green et al. (1993) reviewed methods for analyzing relationships among sets of chemistry (C), toxicity (T) and biology (B) variables in Triad studies. The best approach is that used in the baseline report and by Green and Montagna (1996):

- calculate PC for each set of variables (i.e., C, T and B);
- test pair-wise correlations among the PC

A fourth set of physical variables and "conventionals" such as grain size and organic carbon (OC) should be included. These variables affect the other SQT variables, and can vary both naturally and in response to stressors. Thus, they can be either nuisance variables or variables of interest. It seems reasonable to treat these variables separately rather than pool them with chemistry variables.

The SQT analyses should be kept as simple as possible. Pooling data from all years before calculating PC and correlations is the best approach for analysis of multi-year data. Inclusion of baseline values may be unnecessary, since there was no relationship among the variables in the baseline program. Omitting the baseline data will also remove problems with PAH, bacterial bio luminescence EC50, and other variables with zero or near-zero variance for the baseline year. Approaches such as RM ANCOVA could be used to remove carry-over effects, and to determine if relationships change over time. Natural temporal changes affecting all stations are also likely to be large for the B variables. However, RM ANCOVA and other statistical models can get complicated when there are multiple *y* variables and no obvious *x* variable(s). The

simple relationships among the SQT variables are supposed to explain much of the variance among times and locations. If that does not happen without numerous adjustments and other statistical complexities, then the SQT approach is of questionable value.

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