encana

Deep Panuke

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02U	2019-03-28	Issued for Use	M. Thillet	D. Morykot	J Hurley
01R	2019-03-11	Issued for Review	M. Thillet	D. Morykot	J Hurley
Rev.	Date	Reason for Issue	Prepared	Checked	Approved

Title

2018 Offshore Environmental Effects Monitoring Annual Report

DM – EN – X00 – RP – EH – 90 – 0039. 02U							
Proj	Orig	Loc	Info	Disc	Sys	Sheet	Rev

REVISION LIST	
REVISION	DESCRIPTION OF CHANGES
01R	Issued for review
02U	Issued for Use

HOLDS AND INPUT STATUS		
HOLD NO.	ACTION	REMARKS

Executive Summary

The objective of the Environmental Effects Monitoring (EEM) program for the Deep Panuke natural gas field is to address all production operations-related EEM commitments made during the Deep Panuke regulatory process as outlined in the 2007 Comprehensive Study Report (CSR) and environmental effects predictions made during the 2006 Environmental Assessments (EAs). The Deep Panuke EEM Plan (EEMP) builds on results and lessons learned from the Sable Offshore Energy Project (SOEP) EEM program, which has been carried out on Sable Island Bank since 1997. The Deep Panuke EEM program is an adaptive process which incorporates learnings from the previous years of monitoring. Encana permanently ceased production from Deep Panuke on May 7, 2018; therefore, Encana has begun preparing for decommissioning and abandonment activities.

The Deep Panuke offshore EEM program was designed to address the following objectives:

- identify and quantify environmental effects;
- verify predictions made during the EA processes;
- evaluate the effectiveness of mitigation and identify the need for improved or altered mitigation;
- provide an early warning of undesirable change in the environment; and,
- assist in identifying research and development needs.

This document details 2018 findings for the following EEM components:

- Produced water chemistry and toxicity (section 6.1 of the EEMP)
- Fish habitat alteration on the subsea production structures (section 6.4 of the EEMP)
- Marine wildlife observations (section 6.6 of the EEMP)
    - marine mammal and sea turtle observations; and
    - stranded-bird observations; and
- Air quality monitoring (section 6.7 of EEMP)
    - flare plume observations on Deep Panuke.

As mentioned in the 2017 EEM report, the air quality monitoring and the beached bird surveys on Sable Island were discontinued in 2018 due do the reduced production and the lack of effects from production activities demonstrated by several years of data (five years for the air quality monitoring and more than 20 years for the beached bird surveys).

In February 2017, the frequency of the EEM field sampling program for marine water (section 6.2 of the EEMP), sediments (section 6.3 of the EEMP) and fish health (section 6.5 of the EEMP) changed from annual to every two years. As a result, the 2017 EEM report indicated that the next round of field sampling would be conducted in 2018. However, since this report was submitted, Encana permanently ceased production on May 7, 2018. In addition, Deep Panuke only produced intermittently in 2017 and 2018 (no production from June-December 2017 except for a few days between September and December, and only approx. 6 weeks of production in total from January to May 2018). As a result, there was less, and better-quality produced water discharged in 2017-2018 than in 2015-2016, when results from the field sampling program showed no measurable effects. Therefore, the 2018 sampling program was cancelled and a final “as-left” field sampling program for mussels and sediments will be conducted post decommissioning activities (water sampling is no longer relevant since produced water discharges have stopped).

The results of the 2018 EEM program include the following:

Produced water chemistry and toxicity

January 2018 produced water chemistry:

- Except for elevated naphthalene (PAH), benzene and toluene levels, all metal, non-metal, hydrocarbon and nutrient concentrations in the produced water were found to fall below threshold levels as defined by the Canadian EQG (CCME Guidelines) where available.
- 4-Nonylphenol (1240 ng/L) was found to be above the CCME guidelines of 700 ng/L. 4-Nonylphenol monoethoxylates (12.6 ng/L) was detected but well below the CCME guidelines.

January 2018 produced water toxicity:

- The IC50 for the Microtox test was 14.2%.
- The IC25 for the sea urchin fertilization test was 3.38%.
- The LC50 for the Threespine Stickleback toxicity test was 11.5%.

Fish habitat alteration

- Epifauna colonization of WHPS at all well site locations observed varied in numbers for some species from the 2018 survey. Several sections of the WHPS were cleaned in 2017 and these sections were slowly starting to recolonize in the 2018 survey.
- Seasonal differences in the timing or surveys could account for differences in fish species at the WHPS. For example, at WHPS H-08 pollock were present in the 2016 fall video survey compared to the spring 2018 video survey where no pollock were present.
- Zonation observed in previous years was not as evident in 2018. During the 2018 survey, the tops and bottoms of many of the WHPS legs were covered with 100% marine growth. The main sections of many subsea structure legs had minimal marine growth due to cleaning in 2017. Hydroids, frilled anemones, and blue mussels were noted to be slowly recolonizing the previously cleaned locations on each leg.
- Zonation of the PFC legs was consistent to past survey results. Marine growth was sparse (<10% coverage) near the base of the legs with some hydroids, frilled anemones, and sea stars. Cunner were also seen swimming around the base of both legs (PFC-2 and PFC-4) surveyed in 2018.
- Wellheads and protective structures appear to continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures, as predicted in the 2006 EA. The structures are attracting fish from the surrounding areas and providing shelter in an otherwise relatively featureless seafloor.
- Video quality and the distance from the ROV to PFC legs made identification difficult at times. The ROV operator recorded the video in black and white to improve the clarity.
- The GEP continues to act as an artificial reef to provide shelter and protection for many species of fish (i.e., redfish and Atlantic wolffish) and invertebrates.

- Commercial finfish species recorded from the video analysis included Atlantic cod and redfish. Abundance of these commercial species increased starting around KP 60.
- The most abundant commercial crustaceans observed in the analyzed video were Jonah crabs, consistent with the same video sections in 2016.
- One American lobster was observed in 2018 (in the nine video clips analyzed).
- Other commercial invertebrates observed include the orange-footed sea cucumber, which were occasionally observed on top of the GEP.
- SARA-listed Atlantic wolffish were observed near the GEP, beginning at KP 20 and appear to be using the pipeline as a refuge burrow.
- As in past survey years, crustaceans were observed on video sitting on top of the pipe and climbing on it. Lobsters have not been observed climbing the pipeline or sitting on top of it in this project; however, as the GEP is not a physical barrier for other crustaceans, it is unlikely that it is a physical barrier for lobsters. Studies have also shown that lobsters are capable of climbing over a pipeline (Martec 2004).
- As in 2014 and 2016, dead crustaceans or possible exoskeletons from molting were found along the GEP in 2018.
- Garbage and debris continue to collect at the GEP, due to it being a physical barrier. The most common items were plastic, netting, rope and metal.
- Habitat/substrate types along buried sections of the GEP and flowlines were consistent with previous years. Sand buried sections showed no difference to the adjacent sand seafloor with very little marine life/growth and periodic shells. Flowline rock berms installed were predominately covered with sea cucumbers with some starfish.

Marine wildlife observations

- There were two stranded birds in 2018. A spotted sandpiper was found dead (no oil) on the PFC on June 3 and was sent to ECCC for necropsy (results pending). A great black-backed gull (no oil) was found on March 10 on the Atlantic Condor entangled in fishing gillnet. The bird was freed from the net and released. Non-stranded ospreys and peregrine falcon (PFC) as well as a brown booby (Atlantic Tern) were also sighted.

- Both the supply vessels the M/V Atlantic Condor and the M/V Atlantic Tern reported wildlife sightings in 2018, including gulls and seals.

Air Quality Monitoring:

- Using the Ringelmann chart, in 2018, the flare smoke shade was a “1” (light smoke) until production shut down on May 7, 2018.

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All appendices follow the main body of the report

LIST OF DIGITAL APPENDICES

Digital appendices are submitted separately.

GLOSSARY OF TERMS

APs	Alkyl Phenols
BC	Black Carbon
BC	British Columbia
BTEX	Benzene, Toluene, Ethylbenzene, Xylene(s)
C	Celsius
CCME	Canadian Council of Ministers of the Environment
CEQG	Canadian Environmental Quality Guidelines
CH_4	Methane
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPAN	Cohasset and Panuke
CSR	Comprehensive Study Report
CWS	Canadian Wildlife Service
DIC	Dissolved Inorganic Carbon
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DS	Downstream
EA	Environmental Assessment
EEM	Environmental Effects Monitoring
EEMP	Environmental Effects Monitoring Plan
EPCMP	Environment Protection and Compliance Monitoring Plan
EQG	Environmental Quality Guidelines
ESRF	Environmental Studies Research Fund
GC	Gas Chromatography
GEP	Gas Export Pipeline
GHG	Greenhouse Gases
GVI	General Visual Inspection
H_2S	Hydrogen Sulphide
IC	Ion Chromatography
ICP	Inductively Coupled Plasma

ISE	Ion Selective Electrode
KP	Kilometre Point
LC49	Bioassay Acute Toxicity Analysis
LAT	Lowest Astronomical Tide
LRMS	Low Resolution Mass Spectrometry
MOPU	Mobile Offshore Production Unit
M&NP	Maritimes & Northeast Pipeline
MS	Mass Spectrometry
MV	Motor Vessel
NB	New Brunswick
ND	Not Detected
NEB	National Energy Board
NMHC	Non-methane hydrocarbons
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Nitrogen Oxides
OES	Optical Emission Spectroscopy
O&G	Oil and Gas
O_3	Ozone
OWTG	Offshore Waste Treatment Guidelines
PAH	Polynuclear Aromatic Hydrocarbons
PFC	Production Field Centre
pH	Power of Hydrogen
$PM_{2.5}$	Fine airborne particulate matter with a median aerodynamic diameter ≤ 2.5 microns
ppb	Parts per billion
PPMW	Parts per million by weight
PSU	Practical Salinity Units
PTGC	Programmed Temperature Gas Chromatography
ROV	Remotely Operated Vehicle
QA	Quality Assurance
QC	Quality Control
RDL	Reportable Detection Limit
S^{2-}	Sulphide

SACFOR	Abundance Scale; S-superabundant, A-abundant, C-common, F-frequent, O-occasional, R-rare
SBM	Single Buoy Moorings Inc.
SO_2	Sulphur Dioxide
SOEP	Sable Offshore Energy Project
SSIV	Subsea Isolation Valve
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
US	United States
US	Upstream
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VECs	Valued Environmental Components
VOCs	Volatile Organic Compounds
WBM	Water-based Mud
WGS84	World Geodetic System 1984
WHPS	Wellhead Protection Structure

1 INTRODUCTION

The environmental effects monitoring (EEM) program for the Deep Panuke natural gas field started in 2011 (post drilling and pre-production activities). This 2018 report represents the eighth annual EEM report submitted by Encana as per the approved Deep Panuke Offshore Production EEM Plan (Encana, 2011: DMEN-X00-RP-EH-90-0003).

The 2018 EEMP project team consisted of the following:

- lab services from Maxxam Analytics (produced water, including subcontract to AXYS Analytical Services Ltd for alkylphenol testing) and Harris Industrial Testing Service (produced water toxicity, including subcontract to Aquatox for Microtox and sea urchin fertilization testing);
- Stantec for subsea video data analysis;
- SBM/Encana personnel from the production field centre (PFC) and support vessels, MV Atlantic Condor and MV Atlantic Tern, for sampling operations, bird monitoring, wildlife observations and flare plume monitoring; and
- Encana for coordination and reporting.

Table 1.1 below provides an overview of the 2018 EEM program including relevant EEM components and survey timing.

Table 1.1 - Overview of 2018 EEM Program

EEM Component(s)	*2018 EEM Program*	*Survey Timing*
Produced water chemistry and toxicity Section 6.1 of EEMP	Produced water collected on Deep Panuke for chemical characterization and toxicity testing.	Jan 2018
Fish habitat alteration Section 6.4 of EEMP	Inspection of ROV video data to determine development of benthic communities at the wellheads, PFC legs and pipelines.	Feb to Sep 2018
PFC marine wildlife observations Section 6.6 of EEMP	Summarize PFC and vessels wildlife observations, including stranded birds.	Continuous
Flare plume observations Section 6.7 of EEMP	Systematic flare smoke monitoring (twice a day) using the Ringelmann smoke chart.	Throughout 2018

1.1 DEEP PANUKE BACKGROUND

The Deep Panuke natural gas field is located offshore, 250 km southeast of Halifax, Nova Scotia, approximately 45 km to the west of Sable Island in water depths ranging from 42 m to 50 m (**Figure 1.1**).

Deep Panuke involved offshore production, processing and transport via a nominal 559 mm (22 inch) pipeline to an interconnection with the Maritimes & Northeast Pipeline (M&NP) facilities near Goldboro, Nova Scotia. The M&NP main transmission pipeline delivered to markets in Canada and the Northeast United States. The condensate produced offshore was treated and used as fuel on the PFC. The Deep Panuke facilities consist of a PFC which includes a hull and topsides facilities, four subsea production wells (H-08, M-79A, F-70, and D-41) (**Figures 1.2 and 1.3**), a disposal well (E-70) and associated subsea flowlines and control umbilicals, and a gas export pipeline (GEP) to shore. Encana permanently ceased production from Deep Panuke on May 7, 2018; therefore, Encana has begun preparing for decommissioning and abandonment activities.

Deep Panuke is a sour gas reserve with raw gas containing approximately 0.18 mol % hydrogen sulphide (H2S). The offshore processing system consisted of separation, compression (inlet and export), gas sweetening, gas dehydration, gas dewpointing (via Joule-Thompson), condensate sweetening and stabilization, and produced water treatment and disposal. Once H2S and carbon dioxide (acid gas) had been removed from the raw gas stream to acceptable levels, the acid gas was injected into a dedicated underground disposal well.

Significant milestones for Deep Panuke in 2018 are as follows:

- 2018 was the sixth year of production operations at Deep Panuke (the field started producing in August 2013 and “First Gas”, or start of steady state production, was announced on December 17, 2013). Depending on operational status, production rate varied, with maximum production capability reaching approximately 38 million cubic feet per day in April. Produced water volumes varied greatly depending on wells producing and peaked at 3,492 m^3/day in January.

- Deep Panuke only produced intermittently in 2018 (only approx. 6 weeks of production in total from January to May 2018) and Encana permanently ceased production from Deep Panuke on May 7, 2018.
- The annual ROV subsea survey took place over the GEP, flowlines, wellheads and PFC legs from February to September.
- No acid or foam treatments were conducted in 2018.

The general location of the Deep Panuke EEMP is shown in **Figure 1.1**. Rendering of the production platform and the wellheads are shown in **Figure 1.2** and schematic of the Deep Panuke subsea production structures referenced in this report can be seen on **Figure 1.3**.

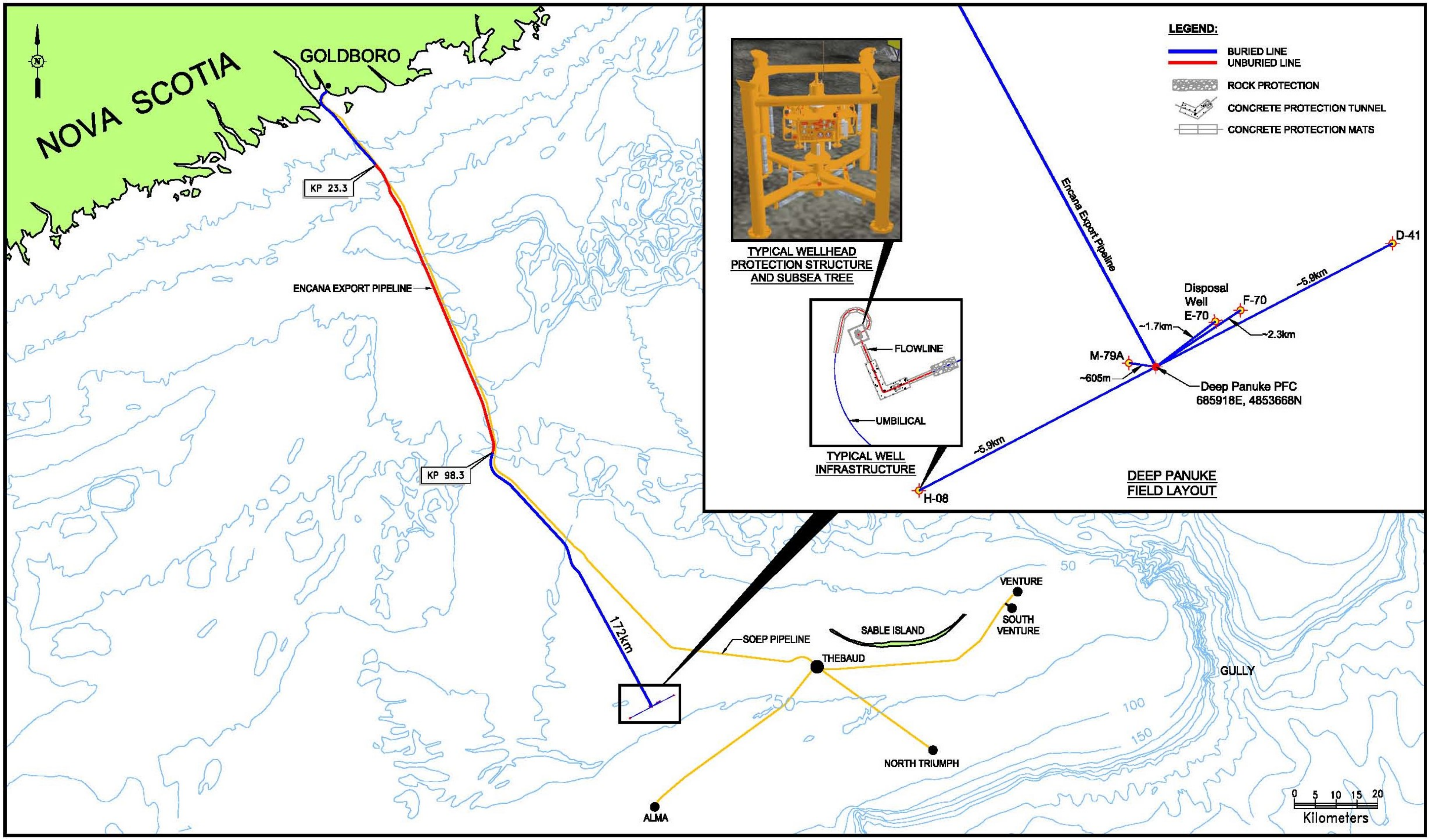


Figure 1.1 Deep Panuke Subsea Production Structures - General Overview (From Offshore Production EEMP - May 21, 2011)

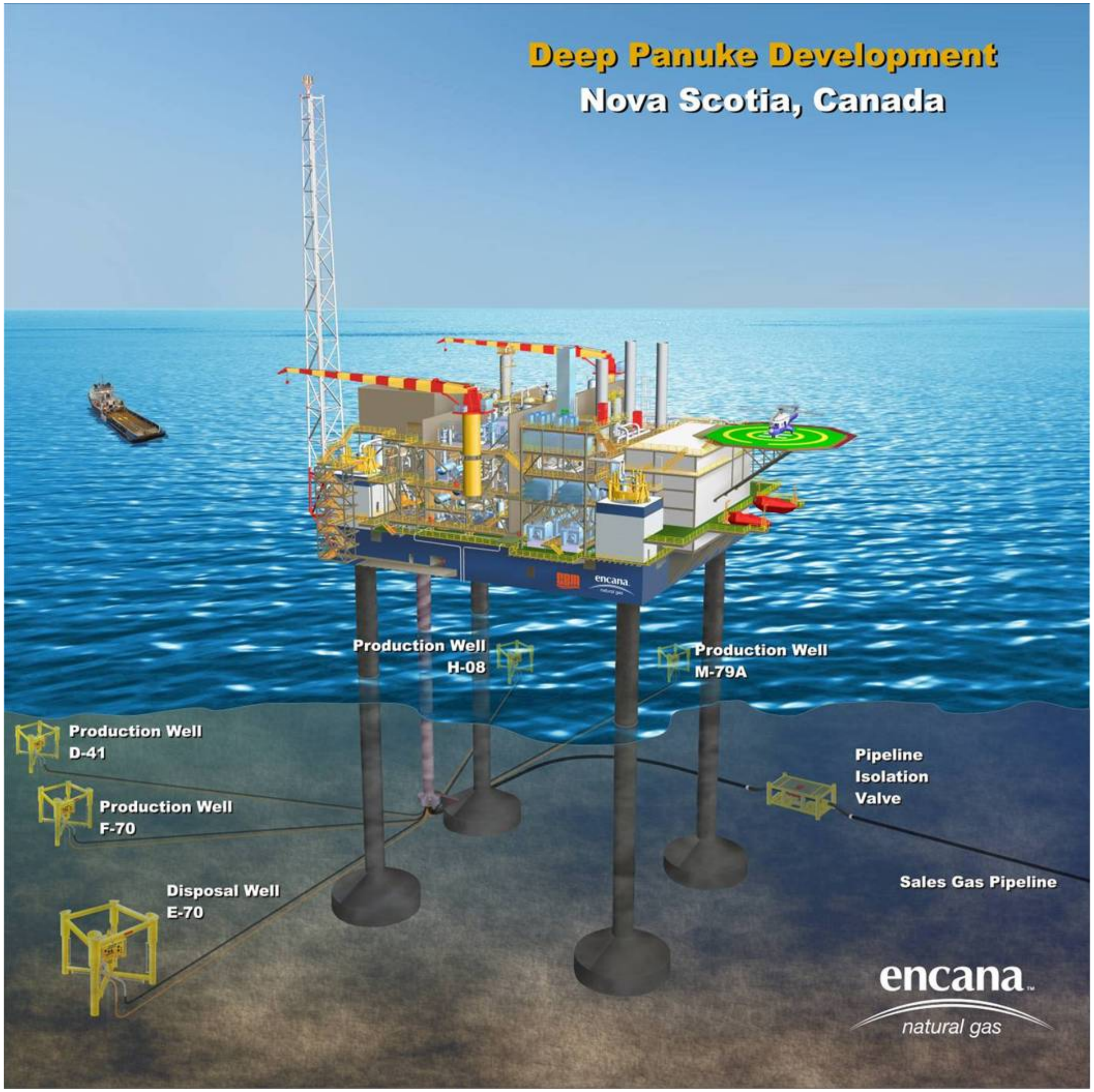


Figure 1.2 Deep Panuke Production Field Centre Rendering (From Offshore Production EEMP - May 21, 2011)

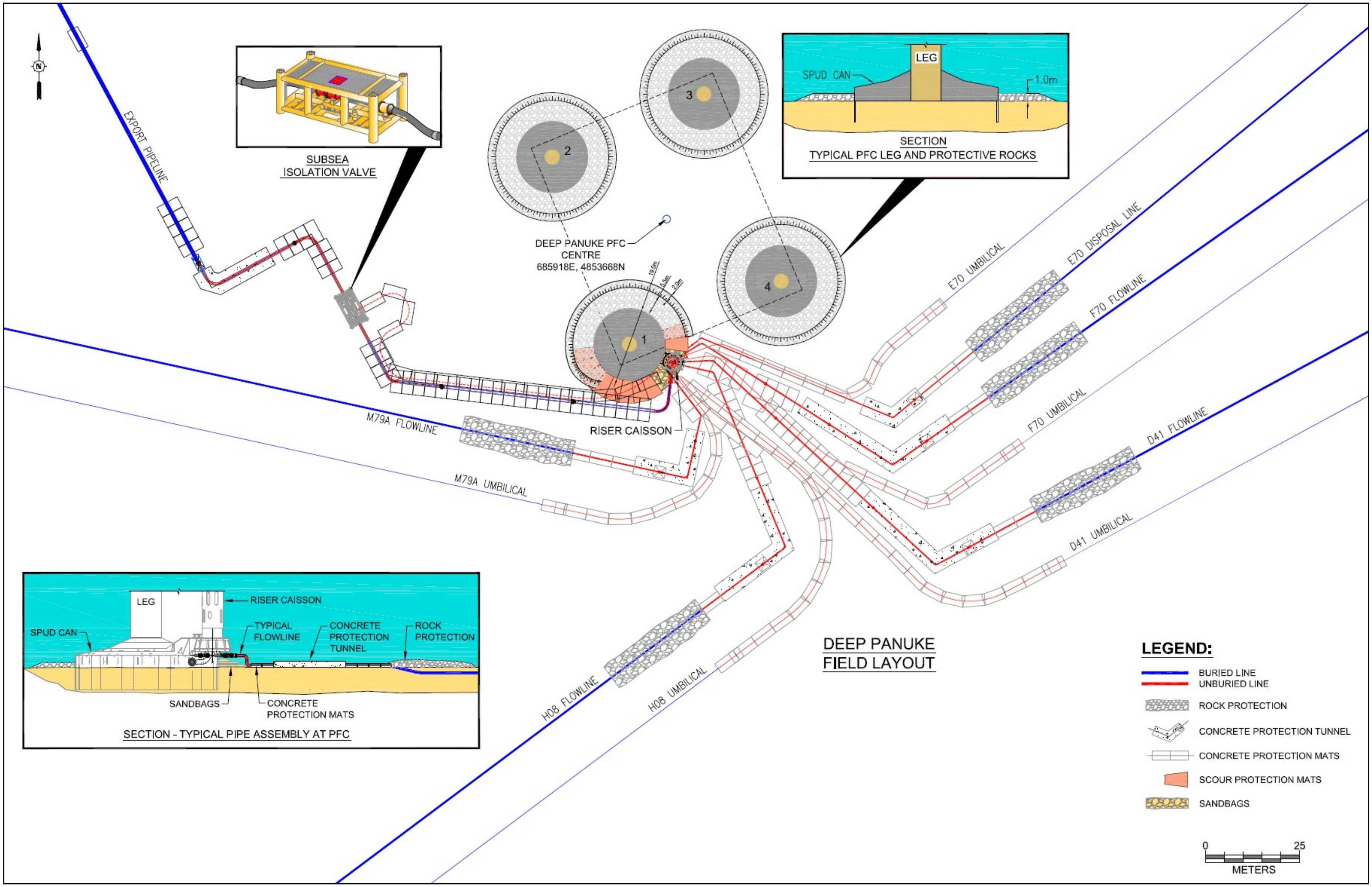


Figure 1.3 Deep Panuke Subsea Production Structures - PFC Area (From Offshore Production EEMP, May 21 2011)

2 EEM COMPONENTS

2.1 PRODUCED WATER CHEMISTRY AND TOXICITY

2.1.1 Background

Produced waters, which are generated during the production of oil and gas, represent a complex mixture of dissolved and particulate organic and inorganic chemicals varying in salinity from freshwater to concentrated saline brine (Lee & Neff, 2011). The physical and chemical properties of produced water vary widely depending on the geological age, depth, geochemistry of the hydrogen-bearing formation as well as the chemical composition of the oil and gas phases in the reservoir and processes added during production. On most offshore platforms, these waters represent the largest volume waste stream in oil and gas exploration and production operations (Stephenson, 1992).

There is concern about ocean disposal of produced water because of the potential for chronic ecological impact. In particular, aromatic hydrocarbons, some alkylated phenols and some metals, if present in high enough concentrations, can lead to bioaccumulation and toxicity in marine organisms.

The Deep Panuke produced water compliance monitoring program is designed to meet testing and reporting requirements from the *Offshore Waste Treatment Guidelines* (*OWTG*) (CNSOPB, C-NLOPB, NEB, December 2010) and is outlined in the Deep Panuke Production Environment Protection and Compliance Monitoring Plan (EPCMP) (DMEN-X00-RP-EH-90-0002). Produced water chemistry and toxicity testing are considered environmental compliance monitoring since they are a requirement under the *OWTG*. They are included together in the EEMP report as they assess the potential impact of contaminants discharged in the marine environment.

The *OWTG* specify a maximum limit of 30 mg/L (30-day volume-weighted average) and 44 mg/L (24-hour volume-weighted average) of oil in produced water discharged to the marine environment. Encana's design target for Deep Panuke is 25 mg/L (30-day volume-weighted average). The concentration of oil in produced water is measured at least every 12 hours and rolling 24-hr and 30-day volume-averages are calculated for each sample.

The chemical composition of produced water is typically analyzed twice yearly; however, it was only analyzed once in 2018 (in January, concurrently with toxicity testing) since the field produced for less than six months. The following parameters are analyzed for produced water chemistry (see **Table 2.2** for details):

- hydrocarbons: total petroleum hydrocarbons (TPH), BTEX, poly-aromatic hydrocarbons (PAHs) and alkyl phenols (APs);
- metals;
- non-metals (nitrogen, phosphorus, sulphur, oxygen);
- nutrients (nitrate, phosphate, ammonia, organic acids);
- sulphide;
- salinity;
- pH; and
- temperature.

This list of chemical parameters to test for in produced water has been developed to be consistent with the EEM marine water quality sampling program in order to allow for comparisons between concentrations of the same parameters prior to and after discharge of produced water to the marine environment. As such, the list is expected to evolve based on the results from the marine water quality monitoring program.

Produced water is tested for toxicity annually. The marine toxicity testing typically includes the sea urchin fertilization test and at least two other bioassay tests (e.g., early life stage of fish, bacteria, algal species, etc.). The tests are conducted contemporaneously with one of the twice-yearly chemical characterization tests. Besides the Sea Urchin Fertilization test, Dr. Ken Doe of the Environment Canada Toxicology Laboratory in Moncton, NB recommended the Threespine Stickleback Test for the SOEP EEM Program as an indicator of fish toxicity and the Microtox test as an indicator of toxicity at the cellular level.

2.1.2 EEMP Goal

The potential toxicity of produced water from the Deep Panuke PFC will be examined using indicator species and to perform chemical characterization test as per the Deep Panuke Production EPCMP (DMEN-X00-RP-EH-90-0002) [Deep Panuke EA predictions #1, 3, 4, 5 & 6 in **Table 3.1**].

2.1.3 Objectives

Produced water collected on the Deep Panuke PFC will be analyzed for marine toxicity testing and chemical composition as per the Deep Panuke Production EPCMP (DMEN-X00-RP-EH-90-0002, refer to Section 6.1.1).

Produced water samples are taken on the PFC (i.e., prior to mixing with seawater system discharge before overboard discharge) to be analyzed for chemistry (semi-annual) and toxicity (annually). If feasible, one of the twice-yearly produced water chemistry samples is collected the same day as the EEM water quality samples to allow for comparison between concentrations of the tested parameters prior to and after discharge of produced water to the marine environment. If feasible, this sampling is scheduled during steady state of production operations, such that the samples are representative of average conditions. Production data and produced water equipment performance are recorded at the time of sampling.

2.1.4 Sampling

In 2018, the field only produced for less than six months; therefore, only one round of produced water chemistry testing was conducted, in January 2018, concurrently with the toxicity testing (See **Table 2.1** for details).

Table 2.1 - Produced Water Sampling Details - January

<table>
<tr><td>Sample Date:</td><td>Jan 17, 2018 at 06:30 local time (chemistry and toxicity)</td></tr>
<tr><td>Type of Sample:</td><td>Produced water samples</td></tr>
<tr><td>Test Sample Locations:</td><td><table><tr><th>Station</th><th>Water Depth(m)</th><th>Easting</th><th>Northing</th></tr><tr><td>PFC, produced water discharge line sampling point</td><td>NA</td><td>685918</td><td>4853668</td></tr><tr><td colspan="4">WGS84 UTM Zone 20N</td></tr></table></td></tr>
<tr><td>Number of Samples/Locations:</td><td>Water was collected on the platform by PFC laboratory personnel.</td></tr>
<tr><td>Equipment:</td><td>Water was collected directly from a produced water outlet located on the PFC and transferred to sampling containers. Containers were put on ice in a cooler and shipped to Halifax via the MV Atlantic Condor.</td></tr>
<tr><td>Sample Preparation:</td><td><table><tr><th>Parameter</th><th>Preservative</th></tr><tr><td>Organic acids</td><td>no preservative</td></tr><tr><td>Mercury</td><td>Potassium dichromate</td></tr><tr><td>BTEX/TPH</td><td>Sodium Bisulphate</td></tr><tr><td>Metal scan</td><td>Nitric acid</td></tr><tr><td>BTEX/TPH - volatile</td><td>Sodium Bisulphate</td></tr><tr><td>Alkylated Phenols</td><td>no preservative</td></tr><tr><td>PAHs</td><td>no preservative</td></tr><tr><td>Nitrate/ortho-P/Total Nitrogen</td><td>no preservative</td></tr><tr><td>Sulphide</td><td>Zn Acetate + NaOH</td></tr><tr><td>Total P/Ammonia</td><td>Sulphuric Acid</td></tr><tr><td>Microtox</td><td>no preservative</td></tr><tr><td>Sea Urchin Fertilization Test</td><td>no preservative</td></tr><tr><td>Threespine Stickleback LC50</td><td>no preservative</td></tr></table></td></tr>
</table>

2.1.5 Analyses

2.1.5.1 Produced Water Chemistry Analysis

Produced water was analyzed for parameters summarized in **Table 2.2**. Major ions were determined using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES), while trace elements were determined using Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) was used, except for mercury, which was analyzed using Cold Vapour AA method. Nutrients were determined by a variety of instruments including chromatographs, colorimeters, and spectrophotometers. DIC was measured on an

Elemental Analyzer. DOC was measured with a carbon analyzer after high temperature catalytic oxidation.

Water samples were also analyzed for total petroleum hydrocarbons (TPH) including benzene, toluene, ethylbenzene, and xylene(s) (BTEX), gasoline range organics (C6 to C10), and analysis of extractable hydrocarbons – fuel oil (>C10 to C16), fuel oil (>C16 to C21) and lube oil (>C21 to C32) range organics. BTEX and gasoline range organics were analyzed by purge and trap-gas chromatography/ mass spectrometry or headspace – gas chromatography (MS/flame ionization detectors). Extractible hydrocarbons, including diesel and lube range organics were analyzed using capillary column gas chromatography (flame ionization detector).

Alkylated phenols were analyzed by AXYS Analytical Services Ltd. for Maxxam Analytics. AXYS method MLA-004 describes the determination of 4-n-octylphenol, nonylphenol and nonylphenol ethoxylates in aqueous samples, and in extracts from water sampling columns (XAD-2 columns). Concentrations in XAD-2 resin and filters are reported on a per sample basis or a per volume basis.

Sulphides in water were analyzed using the ion selective Electrode (ISE). The sulphide may be in the form of S^{2-}, HS- or H_2S.

Produced water chemistry analysis QA/QC parameters are described in the labs report found in **Digital Appendix A1**.

Table 2.2 - Produced Water Chemistry Parameters Measured

Parameter	Units	RDL Jan 2018	CCME Guidelines	Analysis Method
Nutrients				
Nitrate + Nitrite	mg/L	0.050	N/A	colorimetry
Nitrate (N)	mg/L	0.050	1500	colorimetry
Nitrite (N)	mg/L	0.010	N/A	colorimetry
Nitrogen (Ammonia)	mg/L	2.5	N/A	colorimetry
Orthophosphate (P)	mg/L	0.010	N/A	colorimetry
Major Ions				
Phosphorus	mg/L	0.020	N/A	AC
Salinity	N/A	10	N/A	
Sulphide	mg/L	0.020	N/A	ISE
Organic Acids				
Formic Acid	mg/L	100	N/A	IC

Parameter	Units	RDL Jan 2018	CCME Guidelines	Analysis Method
Acetic Acid	mg/L	200	N/A	IC
Propionic Acid	mg/L	200	N/A	IC
Butyric Acid	mg/L	400	N/A	IC
Trace Metals				
Aluminum (Al)	µg/L	500	N/A	ICP-MS
Antimony (Sb)	µg/L	100	N/A	ICP-MS
Arsenic (As)	µg/L	100	12.5	ICP-MS
Barium (Ba)	µg/L	100	N/A	ICP-MS
Beryllium (Be)	µg/L	100	N/A	ICP-MS
Bismuth (Bi)	µg/L	200	N/A	ICP-MS
Boron (B)	µg/L	5000	N/A	ICP-MS
Cadmium (Cd)	µg/L	1.0	0.12	ICP-MS
Calcium (Ca)	µg/L	10000	N/A	ICP-MS
Chromium (Cr)	µg/L	100	Hex = 1.5, Tri = 56	ICP-MS
Cobalt (Co)	µg/L	40	N/A	ICP-MS
Copper (Cu)	µg/L	200	N/A	ICP-MS
Iron (Fe)	µg/L	5000	N/A	ICP-MS
Lead (Pb)	µg/L	50	N/A	ICP-MS
Magnesium (Mg)	µg/L	10000	N/A	ICP-MS
Manganese (Mn)	µg/L	200	N/A	ICP-MS
Mercury (Hg)	µg/L	0.13	0.016	Cold Vapour AA
Molybdenum (Mo)	µg/L	200	N/A	ICP-MS
Nickel (Ni)	µg/L	200	N/A	ICP-MS
Phosphorus (P)	µg/L	10000		
Potassium (K)	µg/L	10000	N/A	ICP-MS
Selenium (Se)	µg/L	100	N/A	ICP-MS
Silver (Ag)	µg/L	10	N/A	ICP-MS
Sodium (Na)	µg/L	10000	N/A	ICP-MS
Strontium (Sr)	µg/L	2000	N/A	ICP-MS
Thallium (Tl)	µg/L	10	N/A	ICP-MS
Tin (Sn)	µg/L	200	N/A	ICP-MS
Titanium (Ti)	µg/L	200	N/A	ICP-MS
Uranium (U)	µg/L	10	NRG	ICP-MS
Vanadium (V)	µg/L	200	N/A	ICP-MS
Zinc (Zn)	µg/L	500	N/A	ICP-MS
PAH				
1-Methylnaphthalene	µg/L	1.0	N/A	GC/MS
2-Methylnaphthalene	µg/L	1.0	N/A	GC/MS
Acenaphthene	µg/L	0.01	N/A	GC/MS
Acenaphthylene	µg/L	4.0	N/A	GC/MS
Anthracene	µg/L	0.80	N/A	GC/MS
Benzo(a)anthracene	µg/L	0.13	N/A	GC/MS
Benzo(a)pyrene	µg/L	0.01	N/A	GC/MS
Benzo(b)fluoranthene	µg/L	0.01	N/A	GC/MS
Benzo(g,h,i)perylene	µg/L	0.01	N/A	GC/MS
Benzo(j)fluoranthene	µg/L	0.01	N/A	GC/MS
Benzo(k)fluoranthene	µg/L	0.01	N/A	GC/MS
Chrysene	µg/L	0.01	N/A	GC/MS

Parameter	Units	RDL Jan 2018	CCME Guidelines	Analysis Method
Dibenz(a,h)anthracene	µg/L	0.01	N/A	GC/MS
Fluoranthene	µg/L	0.01	N/A	GC/MS
Fluorene	µg/L	0.20	N/A	GC/MS
Indeno(1,2,3-cd)pyrene	µg/L	0.01	N/A	GC/MS
Naphthalene	µg/L	4.0	1.4	GC/MS
Perylene	µg/L	0.01	N/A	GC/MS
Phenanthrene	µg/L	0.20	N/A	GC/MS
Pyrene	µg/L	0.01	N/A	GC/MS
Petroleum Hydrocarbons				
Benzene	mg/L	0.05	110	PTGC
Toluene	mg/L	0.05	215	PTGC
Ethylbenzene	mg/L	0.05	25	PTGC
Xylene (Total)	mg/L	0.10	N/A	PTGC
C_6 - C_{10} (less BTEX)	mg/L	0.50	N/A	PTGC
>C_{10}-C_{16} Hydrocarbons	mg/L	0.05	N/A	PTGC
>C_{16}-C_{21} Hydrocarbons	mg/L	0.05	N/A	PTGC
>C_{21}-<C_{32} Hydrocarbons	mg/L	0.10	N/A	PTGC
Modified TPH (Tier1)	mg/L	0.50	N/A	PTGC
Reached Baseline at C_{32}	mg/L	N/A	N/A	PTGC
Alkylated Phenols				
4-Nonylphenols (NP)	ng/L	6.31	700	LR GC/MS
4-Nonylphenol monoethoxylates (NP1EO)	ng/L	5.73	700	LR GC/MS
4-Nonylphenol diethoxylates (NP2EO)	ng/L	6.37	700	LR GC/MS
4-n-Octylphenol (OP)	ng/L	2.12	N/A	LR GC/MS
Field Measurements				
pH (field)	pH units	-	7.0-8.7	PFC lab data
Temperature	˚C	-	N/A	Field meter
Salinity	mg/L	-	N/A	PFC lab data

2.1.5.2 Produced Water Toxicity Analysis

Toxicity test for produced water were coordinated by Harris Industrial Testing Service (HITS) and completed as follows:

- Sea Urchin Fertilization Test by Aquatox;
- Microtox Test by Aquatox; and
- Threespine Stickleback LC50 Test by HITS.

2.1.6 Results

2.1.6.1 Produced Water Chemical Characterization Results

Produced water was collected in January 2018. Results for nutrients, major ions, organic acids, trace metals, PAHs, BTEX-TPH and alkylated phenols carried out by Maxxam and Axys laboratories are summarized in the tables below. CEQG for marine water quality are included in **Appendix A** and reported in **Table 2.3** below for all detectable chemical parameters. The labs produced water chemistry report can be found in **Digital Appendix A1**. Results from all tested produced water parameters from 2014 to 2018 are compiled in **Table 2.3** and results from the Jan 2018 testing are summarized below.

- Nitrogen, total phosphorus and sulphide were all above the RDL. The pH of the produced water was 7.18, which is within the CCME guidelines of 7.0-8.7. The organic acids analyzed were not detected. All results were compared with CCME guidelines where available. It should be noted that CCME guidelines are for marine water quality and are not available for outfalls.
- No metals were found in concentrations above CCME guidelines where available. Barium, boron, calcium, magnesium, potassium, sodium and strontium were all detected well above RDL, and no CCME guidelines were available for these elements. Thallium was measured slightly above the RDL. All other metals were not detected.
- Naphthalene was found to have elevated levels of 460 μg/L, which is well above the CCME guideline of 1.4 μg/L. All other PAH parameters measured were not detected or did not have CCME guidelines to be compared to.
- Toluene and benzene results were found to be above CCME guidelines. Ethylbenzene and C6-C10 less BTEX were not detectable. The other BTEX-TPH results were found to be well above RDLs, but no CCME guidelines were available.
- 4-Nonylphenol (1240 ng/L) was found to be above the CCME guidelines of 700 ng/L. 4-Nonylphenol monoethoxylates (12.6 ng/L) was detected but well below the CCME guidelines.

Table 2.3 - Produced Water Quality Results Summary (2014 to 2018)

Parameter	Units	10-Jun-2014 07:00	24-Mar-2015 07:00	30-Dec-2015 08:15	12-Mar-2016 07:30	29-Nov-2016 10:10	07-Mar-2017 16:15	17-Jan-2018 06:30	CCME Guidelines*
		M-79A, F-70, D-41, H-08 wells	M-79A, F-70, D-41, H-08 wells	M-79A, D-41 wells	D-41 well	D-41 well	F-70, D-41 wells	M-79A well	
		Formation water	Formation water	Formation water	Condensed water	90% formation / 10% condensed	Formation water	Formation water	
Nutrients, Major Ions and Organic Acids									
Nitrate (N)	mg/L	ND	ND	ND	0.22	ND	ND	ND	200
Nitrate + Nitrite	mg/L	ND	ND (1)	ND (2)	0.23	ND	ND	ND	No data
Nitrite (N)	mg/L	ND	0.11 (2)	ND (2)	0.012	0.012	ND	ND	-
Nitrogen (Ammonia Nitrogen)	mg/L	46	73	74	7.9	68	94	90	No data
Orthophosphate (P)	mg/L	1.4	0.31 (2)	0.49 (2)	0.52	0.099	0.023	ND	No data
pH	pH	6.95	6.79	7.10	7.21	7.17	7.20	7.18	7.0-8.7
Total Phosphorus	mg/L	4.3	1.2	0.73	0.81	0.56	0.029	0.022	No data
Salinity	PSU	71	160	150	7.0	93	170	120	-
Sulphide	mg/L	2.6	0.63	1.5	4.6	0.27	0.52	0.29	No data
Formic Acid	mg/L	ND	ND	ND	ND	ND	ND	ND	-
Acetic Acid	mg/L	ND	ND	ND	ND	ND	ND	ND	-
Propionic Acid	mg/L	ND	ND	ND	ND	ND	ND	ND	-
Butyric Acid	mg/L	ND	ND	ND	ND	ND	ND	ND	-
Metals									
Total Aluminum (Al)	µg/L	210	ND	690	320	ND	ND	ND	No data
Total Antimony (Sb)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Arsenic (As)	µg/L	ND	ND	ND	ND	ND	ND	ND	12.5
Total Barium (Ba)	µg/L	3800	19000	25000	690	12000	22000	30000	No data
Total Beryllium (Be)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Bismuth (Bi)	µg/L	ND	ND	ND	ND	ND	ND	ND	-
Total Boron (B)	µg/L	49000	89000	87000	5500	76000	98000	100000	NRG
Total Cadmium (Cd)	µg/L	ND	ND	**4.4**	0.014	ND	ND	ND	0.12
Total Calcium (Ca)	µg/L	4200000	8000000	7100000	450000	5900000	8500000	9100000	No data
Total Chromium (Cr)	µg/L	ND	ND	**320**	33	ND	ND	ND	Hex=1.5, Tri=56
Total Cobalt (Co)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Copper (Cu)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Iron (Fe)	µg/L	ND	ND	ND	1000	ND	ND	ND	No data
Total Lead (Pb)	µg/L	ND	ND	220	ND	ND	ND	ND	No data
Total Magnesium (Mg)	µg/L	510000	850000	790000	68000	660000	900000	1000000	-
Total Manganese (Mn)	µg/L	510	270	730	150	490	ND	ND	No data
Total Mercury (Hg)	µg/L	Not tested	ND	ND	ND (1)	ND (1)	ND (1)	ND (1)	0.016
Total Molybdenum (Mo)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Nickel (Ni)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Phosphorus (P)	µg/L	5000	ND	ND	1000	ND	ND	ND	No data
Total Potassium (K)	µg/L	280000	380000	360000	38000	350000	420000	440000	-
Total Selenium (Se)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Silver (Ag)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Sodium (Na)	µg/L	18000000	31000000	28000000	1900000	24000000	33000000	36000000	No data
Total Strontium (Sr)	µg/L	310000	730000	600000	37000	540000	730000	730000	-
Total Thallium (Tl)	µg/L	2.0	14	ND	ND	ND	16	17	No data
Total Tin (Sn)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Titanium (Ti)	µg/L	ND	ND	ND	ND	ND	ND	ND	-
Total Uranium (U)	µg/L	ND	ND	ND	ND	ND	ND	ND	NRG
Total Vanadium (V)	µg/L	ND	ND	ND	ND	ND	ND	ND	No data
Total Zinc (Zn)	µg/L	170	ND	590	590	1100	ND	ND	No data

Parameter	Units	10-Jun-2014 07:00	24-Mar-2015 07:00	30-Dec-2015 08:15	12-Mar-2016 07:30	29-Nov-2016 10:10	07-Mar-2017 16:15	17-Jan-2018 06:30	CCME Guidelines*
		M-79A, F-70, D-41, H-08 wells	M-79A, F-70, D-41, H-08 wells	M-79A, D-41 wells	D-41 well	D-41 well	F-70, D-41 wells	M-79A well	
		Formation water	Formation water	Formation water	Condensed water	90% formation / 10% condensed	Formation water	Formation water	
Polyaromatic Hydrocarbons									
1-Methylnaphthalene	µg/L	200 (3)	410 (3)	220 (3)	100 (3)	28	730	270 (3)	-
2-Methylnaphthalene	µg/L	230 (3)	470 (3)	300 (3)	120 (3)	34	900	310 (3)	No data
Acenaphthene	µg/L	3.3	3.0	2.5	ND (4)	0.39	16	2.2	Insufficient data
Acenaphthylene	µg/L	ND (4)	4.1	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	No data
Anthracene	µg/L	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	ND (4)	Insufficient data
Benzo(a)anthracene	µg/L	ND (4)	1.0	0.073	0.036	ND (4)	0.64	ND (4)	Insufficient data
Benzo(a)pyrene	µg/L	0.012	0.014	ND	ND	ND	0.85	0.018	Insufficient data
Benzo(b)fluoranthene	µg/L	0.17	0.080	0.048	0.042	0.069	1.4	0.099	No data
Benzo(g,h,i)perylene	µg/L	0.022	ND	ND	ND	ND	1.1	0.014	-
Benzo(j)fluoranthene	µg/L	0.015	0.017	ND	ND	0.010	1.1	0.017	-
Benzo(k)fluoranthene	µg/L	ND	ND	ND	ND	ND	1.0	0.011	No data
Chrysene	µg/L	1.7	0.93	0.63	0.49	0.82	2.3	1.0	Insufficient data
Dibenz(a,h)anthracene	µg/L	ND	ND	ND	ND	ND	0.96	ND	No data
Fluoranthene	µg/L	2.7	2.0	1.6	0.67	1.4	4.4	1.9	Insufficient data
Fluorene	µg/L	55 (3)	76 (3)	55 (3)	28	13	250	82 (3)	Insufficient data
Indeno(1,2,3-cd)pyrene	µg/L	ND	ND	ND	ND	ND	1.0	ND	No data
Naphthalene	µg/L	**310** (3)	**660** (3)	**470** (3)	**83** (3)	**79** (3)	**1000**	**460** (3)	1.4
Perylene	µg/L	0.036	0.023	ND	0.015	0.033	0.90	0.024	-
Phenanthrene	µg/L	56 (3)	48 (3)	38	25	22	140	60 (3)	Insufficient data
Pyrene	µg/L	1.5	0.97	0.86	0.55	1.1	3.0	1.1	Insufficient data
Petroleum Hydrocarbons									
Benzene	mg/L	**3.2**	**3.5**	**3.6**	**8.0**	**1.4**	**2.0**	**1.2**	0.110
Toluene	mg/L	**1.3**	**1.6**	**1.7**	**2.9**	**0.52**	**1.4**	**0.58**	0.215
Ethylbenzene	mg/L	**0.049**	**0.058**	**0.069**	**0.084**	0.023	**0.048**	ND	0.025
Total Xylenes	mg/L	0.39	0.53	0.57	0.55	0.18	0.39	0.21	No data
C6 - C10 (less BTEX)	mg/L		ND	ND	ND	ND	0.29	ND	-
>C10-C16 Hydrocarbons	mg/L	5.9	15 (5)	6.5 (5)	6.4	1.0	24 (5)	3.5	-
>C16-C21 Hydrocarbons	mg/L	8.3	7.6	3.3 (5)	4.2	3.2	27 (5)	2.7	-
>C21-<C32 Hydrocarbons	mg/L	5.3	4.5	1.8 (5)	2.9	2.2	15 (5)	1.4	-
Modified TPH (Tier1)	mg/L	20	27	12	14	6.4	66	7.8	-
Reached Baseline at C32	mg/L	Yes	Yes	Yes	Yes	No	Yes	Yes	-
Alkylphenols									
4-Nonylphenols	ng/L	122	ND	ND	ND	24.7	ND	**1240**	700
4-Nonylphenols monoethoxylates	ng/L	ND	ND	ND	ND	226	128	12.6	700
4-Nonylphenols diethoxylates	ng/L	ND	ND	ND	ND	ND	ND	ND	700
4-n-Octylphenol	ng/L	ND	145	ND	ND	2.3	16.2	ND	N/A
Field Measurements									
pH (field)	pH	3-4	3-4	3-4	3-4	3-4	3-4	~5	7.0-8.7
Temperature	˚C	75	90	81	~70	71	94	103	N/A
Salinity (Cl)	mg/L	>70,000	>70,000	>70,000	<1,000	59,400	60,000	~70,000	N/A

*CCME Guidelines only for detected parameters only using Water Quality Guidelines for the Protection of Aquatic Life.
RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
ND = Not detected
N/A = Not Applicable
NRG = No Recommended Guideline
(1) Elevated RDL due to sample matrix
(2) Elevated reporting limit due to sample matrix
(3) Elevated PAH RDL(s) due to sample dilution
(4) Elevated PAH RDL(s) due to matrix / co-extractive interference
(5) Elevated TEH RDL(s) due to sample dilution / limited sample

2.1.6.2 Produced Water Toxicity Test Results

To assess the toxicity of the produced water, a Microtox test, a sea urchin fertilization test and a Threespine Stickleback toxicity test were performed on water collected at the PFC on January 17, 2018.

2.1.6.2.1 Microtox Toxicity Results

The Microtox test consists in exposing and measuring light levels of bioluminescent bacteria *Vibrio fischeri* at various concentrations of the sampled produced water. The toxicity of the sample is presumed to have an effect on the metabolic processes of the bacteria, and the measured bioluminescence is inhibited in proportion to the metabolic effect. Inhibition is measured after a set amount of exposure time and expressed as the IC50 (Inhibitory Concentration 50%), *i.e.* the concentration that causes 50% inhibition (Environment Canada, Biological Test Method EPS 1/RM/24, 1992). The IC50 for the produced water was 14.2% (**Table 2.4).** Complete results can be found in **Appendix B**.

Table 2.4 - Produced Water Microtox Results

Substance	Data Collected	Date Tested	Species/Test	15 Minute IC50	95% Confidence Limits
Deep Panuke Produced Water	17/01/2018	19/01/2018	Microtox IC50	14.2%	11.7 – 17.2

2.1.6.2.2 Sea Urchin Fertilization Test Results

The sea urchin fertilization test is a sub-lethal marine toxicity test that uses sea urchin gametes. Sperm is first exposed to the substance being tested, and then eggs are added. The test is conducted at various concentrations. The endpoint of the test is decreased fertilization success (in this case, a reduction of 25% from the control), and the concentration at which it occurs is calculated using the various concentrations tested and linear interpolation. The fertilization process and cells at the gamete stage are highly sensitive, so this test is one of the most sensitive marine sub-lethal toxicity tests. The test also has a quick turnaround time (Environment Canada, 2011).

The Echinoid Fertilization test was conducted at AquaTox according to the protocol EPS 1/RM/27, 2nd Edition (Environment Canada, 2011) on January 23, 2018, using Lytechinus pictus (White sea urchins).

There were two deviations from the protocol. First, the salinity of the 100% sample as measured at AquaTox was 122‰. The salinity of the 100%, 30%, and 9% exposure concentrations exceeded the maximum salinity of 32‰ allowed by the test method cited above. Second, the three-day holding time as specified by the test method was exceeded.

At a concentration of 3.38% produced water, 25% of the eggs are inhibited from being fertilized. See **Table 2.5** and **Table 2.6** for a summary of results, and **Appendix B** for full results.

Table 2.5 - Produced Water Sea Urchin Fertilization Results

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	3.38%	2.65 – 3.99	Linear Interpolation

Table 2.6 - Produced Water Sea Urchin Fertilization Data

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
Control	A	89	11	89	84.25	3.77
	B	85	15	85		
	C	83	17	83		
	D	80	20	80		
Blank	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
0.02	A	-	-	-	-	-
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.07	A	-	-	-	-	-
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.24	A	-	-	-	-	-
	B	-	-	-		
	C	-	-	-		
	D	-	-	-		
0.81	A	83	17	83	84.75	2.63
	B	87	13	87		
	C	87	13	87		
	D	82	18	82		

Concentration (%)	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean Fertilization (%)	Standard Deviation
2.7	A	74	26	74	74.5	3.32
	B	77	23	77		
	C	70	30	70		
	D	77	23	77		
9	A	12	88	12	10.75	0.96
	B	11	89	11		
	C	10	90	10		
	D	10	90	10		
30	A	8	92	8	9.75	1.26
	B	10	90	10		
	C	11	89	11		
	D	10	90	10		
100	A	0	100	0	0	0.00
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		

2.1.6.2.3 Threespine Stickleback Toxicity Test Results

The 96-hour LC50 results for the produced water with the Threespine Stickleback toxicity test was 11.5% (**Table 2.7).** Complete results can be found in **Appendix B**.

Table 2.7 - Produced Water Threespine Stickleback Toxicity Test Results

Substance	Data Collected	Date Tested	Species/Test	96 Hour LC50	95% Confidence Limits
Deep Panuke Produced Water	17/01/2018	18-22/01/2018	Threespine Stickleback	11.5%	8.59 – 15.4

2.1.7 Summary and Conclusions

January 2018 produced water chemistry:

- Except for elevated naphthalene (PAH), benzene and toluene levels, all metal, non-metal, hydrocarbon and nutrient concentrations in the produced water were found to fall below threshold levels as defined by the Canadian EQG (CCME Guidelines) where available.
- 4-Nonylphenol (1240 ng/L) was found to be above the CCME guidelines of 700 ng/L. 4-Nonylphenol monoethoxylates (12.6 ng/L) was detected but well below the CCME guidelines.

January 2018 produced water toxicity:

- The IC50 for the Microtox test was 14.2%.
- The IC25 for the sea urchin fertilization test was 3.38%.
- The LC50 for the Threespine Stickleback toxicity test was 11.5%.

2.2 MARINE WATER QUALITY MONITORING

2.2.1 Background

The 2006 Deep Panuke EA (p. 8-38) made the following specific predictions with respect to water quality dispersion:

- the maximum discharge rate of produced water will be 6,400 m^3/day (266.7 m^3/hr) and 2,400 m^3/hr for cooling water giving a dilution rate of 9:1;
- the produced water treatment facilities are expected to treat produced water so that H_2S concentration prior to mixing with cooling water does not exceed 1 to 2 ppmw; and
- produced water will be mixed with cooling water prior to discharge. Upon being released to the marine environment, discharged water will be rapidly diluted by ambient currents and background oceanic mixing as per **Table 2.8** below (Table 8.18 from the 2006 Deep Panuke EA).

Table 2.8 – Summary of 2006 Discharged Water Far-Field Dispersion Modelling Results

Distance from Discharge Site	Dilution (Discharge/Background Waters)	Temperature Anomaly (°C)	Salinity Anomaly (PSU)	Hydrocarbon Concentration (mg/L)	H_2S Concentration (PPMW)	Oxygen Concentration Relative to Background (%)
End of Pipe*	No dilution	25	6.25	.8	0.2	0
Site (seafloor)	10:1	2.5	0.6	0.28	0.02	90
500m	70:1	0.4	0.1	0.04	0.003	98
1km	100:1	0.25	0.06	0.03	0.002	99
2km	400:1	0.06	0.02	0.007	0.0005	100
End of discharge caisson at a depth of 10m						

Note: discharge water consists of produced water mixed with cooling water (9:1 mixing ration)

The Deep Panuke Production EPCMP (DMEN-X00-RP-EH-90-0002) provides more recent information on the design of the PFC produced water system. The current system is designed for a produced water rate of 6,400 m^3/d (266.7 m^3/hr). After treatment and sampling, the treated produced water goes down the seawater discharge caisson located in the PFC southeast leg and is mixed with the spent 3,340 m^3/hr cooling water inside the leg prior to discharge into the ocean environment at a depth of approximately 26 m below Lowest Astronomical Tide (LAT). Therefore, the dilution ratio for a maximum produced water rate has increased from 1:9 to 1:13, with the discharge depth changed from 10 m to 26 m below LAT.

In July 2015, the produced water dispersion modeling completed in the 2006 EA was revised with updated parameters (e.g. lower dilution of produced water in cooling water prior to discharge and increased produced water temperature, hydrocarbon concentration and H_2S concentration). The re-modelling demonstrated similar plume behaviour to that described in the 2006 modelling with respect to plume buoyancy and interaction with the sea floor. Slight differences were observed in the anomaly in temperature and salinity, hydrocarbon concentration, and dissolved oxygen concentration (see **Table 2.9**). A greater difference was observed between the 2006 and 2015 results for H_2S concentrations. However, analysis of the modeling results concluded that the environmental effect assessment and significance determinations presented in the 2006 EA report remain valid for the updated 2015 cooling water and produced water discharge data. No significant adverse environmental effects are predicted to occur as a result of routine operational discharges with the updated parameters.

Table 2.9 - Summary of 2015 Discharged Water Far-Field Dispersion Modeling Results

From Discharge Site	Centerline Dilution (Background/ Discharge Waters)		Temperature Anomaly (°C)		Salinity Anomaly (PSU)		Hydrocarbon Concentration (mg/L)		H_2S Concentration (ppm)		Oxygen Concentration Relative to Background (%)	
	2006	2015	2006	2015	2006	2015	2006	2015	2006	2015	2006	2015
End of Pipe	1:1	1:1	25	38	6.25	7	2.8	6.67	0.2	2.22	0	0
Site (seabed)	10:1	8:1	2.5	4.75	0.6	0.88	0.28	0.83	0.02	0.28	90	87.5
500m	70:1	56:1	0.4	0.68	0.1	0.12	0.04	0.12	0.003	0.04	98	98
1km	100:1	80:1	0.25	0.48	0.08	0.09	0.03	0.08	0.002	0.03	99	99
2km	400:1	320:1	0.06	0.12	0.02	0.02	0.007	0.02	0.0005	0.007	100	100

Represents worst case scenario: cooling water flow rate = 1500 m^3/hr in winter; cooling water temp = 25°C

In February 2017, the frequency of the EEM field sampling program for marine water, sediments and fish health changed from annual to every two years. As a result, the 2017 EEM report indicated that the next round of field sampling would be conducted in 2018. However, since this report was submitted, Encana permanently ceased production on May 7, 2018. As a result, the 2018 water sampling program was canceled (produced water discharges have stopped).

2.3 SEDIMENT CHEMISTRY

2.3.1 Background

Chemical contamination of sediments in the vicinity of offshore gas platforms can be the result of discharges of mud/cuttings during drilling and completion, produced water during production operations and/or accidental releases (*i.e.*, spills). While effects are anticipated to be localized, such contamination can be potentially toxic, especially to bottom-dwelling fauna. Bioassay analysis using a suitable indicator species is a useful technique for evaluation of the toxicology of sediments collected at various distances from the source of contamination.

Analytical parameters for sediment chemistry initially used in the SOEP EEM program were the following: full metal (24 parameters) scan, grain size analysis, C6-C32 hydrocarbon scan, benzene, ethylbenzene, toluene, xylene, polycyclic aromatic hydrocarbons, organic and inorganic carbon, ammonia and sulphide. With the exception of barium and TPH concentrations in the near-field area (within 1,000 m of a discharge site) along the direction of the prevailing current, all other parameters showed no significant differences from levels measured during baseline surveys and from other near-field and far-field reference stations. Consequently, the number of stations and parameters for recent sediment samples taken for the SOEP EEM program was first reduced to three near-field stations (at 250 m, 500 m and 1,000 m) downstream of the main production platform at Thebaud and a few key parameters and finally discontinued from the program because of non-detectable/background levels for measured parameters.

A variety of laboratory-based sediment toxicity bioassays were originally used in the SOEP EEM program to evaluate potential lethal and sublethal effects on organisms representing several different trophic levels - amphipod (*Rhepoxynius abronius*) survival, echinoderm (*Lytechinus pictus*) fertilization and bacterial luminescence of *Vibrio fischeri* (Microtox). Within a relatively short period (two to three years of sampling), the echinoderm fertilization and Microtox tests were discontinued as the results did not correlate with trends in sediment chemistry results. However, the marine amphipod survival test has proved to be the most reliable indicator of sediment contamination and was a valuable monitoring parameter in the SOEP EEM program until this EEM component was discontinued after 2007.

At the Deep Panuke site, produced water and hydrocarbon spills are the only potential sources of TPH in sediments since only water-based mud (WBM) was used during drilling and completion activities. While barium was a component of WBM used to drill the production wells in 2000 (M-79A and H-08) and 2003 (F-70 and D-41), it was not a component of WBM used for the 2010 drilling and completion program (drilling of the new E-70 disposal well and recompletion of the four production wells), which instead used brine as a weighting agent.

The 2008 Baseline Benthic Study provided comparative data on sediment quality for the 2011 EEM program. Results from the 2008 Baseline Benthic Study indicated that the concentrations of metals in offshore sediments collected at the Deep Panuke site (pipeline route and PFC area) in 2008 (before the 2010 drilling and completion program but post drilling of the four production wells) were within background ranges found in other offshore studies on Scotian Shelf sediments. (In particular, mercury levels were non-detectable.)

The Deep Panuke 2011 sediment chemistry and toxicity testing (after the 2010 drilling and completion program) confirmed that all metal, non-metal, hydrocarbon and nutrient concentrations were below Canadian EQG threshold levels and that all collected sediments were non-toxic. Therefore, sediment sampling at the wellsites was discontinued and sediment sampling was focused downstream of the PFC to monitor potential impact from production discharges.

2.3.2 EEMP Goal

Predictions regarding sediment toxicity made in the 2006 Deep Panuke EA [EA predictions #1, 2, 3, 4, 5, 6, 7 & 8 in **Table 3.1**] are to be validated.

2.3.3 Objectives

The dispersion of key production chemical parameters at the production site is to be determined.

2.3.4 Sampling

In February 2017, the frequency of the EEM field sampling program for marine water, sediments and fish health changed from annual to every two years. As a result, the 2017 EEM report indicated that the next round of field sampling would be conducted in 2018. However, since this report was submitted, Encana permanently ceased production on May 7, 2018. In addition, Deep Panuke only produced intermittently in 2017 and 2018 (no production from June-December 2017 except for a few days between September and December, and only approx. 6 weeks of production in total from January to May 2018). As a result, there was less, and better-quality produced water discharged in 2017-2018 than in 2015-2016, when results from the field sampling program showed no measurable effects. Therefore, the 2018 sampling program was cancelled and a final “as-left” field sampling program for sediments (and mussels) will be conducted post decommissioning activities.

2.4 SEDIMENT TOXICITY

2.4.1 Background

A variety of laboratory-based sediment toxicity bioassays were originally used in the SOEP EEM program to evaluate potential lethal and sublethal effects on organisms representing several different trophic levels - amphipod (*Rhepoxynius abronius*) survival, echinoderm (*Lytechinus pictus*) fertilization and bacterial luminescence of *Vibrio fischeri* (Microtox). Within a relatively short period (two to three years of sampling), the echinoderm fertilization and Microtox tests were discontinued as the results did not correlate with trends in sediment chemistry results. However, the marine amphipod survival test has proved to be the most reliable indicator of sediment contamination in the SOEP EEM program.

In 2011 and in 2015, laboratory-based toxicity bioassays were conducted with Deep Panuke sediments samples in accordance with Environment Canada's "Biological Test Method: Reference Method for Determining Acute Lethality of Sediment to Marine or Estuarine Amphipods", EPS 1/RM/35, December 1998, using *Eohaustorius estuarius* as the test species. All sediments were found to be non-toxic.

Sediment samples at the drill sites were discontinued after the 2011 sediment chemistry and toxicity program confirmed that chemical parameters were below Canadian EQG threshold levels and that all collected sediments were non-toxic (see Section 2.3.1). Sediment sampling was focused downstream of the PFC to monitor potential impact from production discharges.

2.4.2 EEMP Goal

Predictions regarding sediment toxicity made in the 2006 Deep Panuke EA [EA predictions #1, 2, 3, 4, 5, 6, 7 & 8 in **Table 3.1** from the Offshore EEMP] are to be validated.

2.4.3 Objectives

A suitable indicator species to evaluate acute toxicity of sediments collected at the production site is to be used.

2.4.4 Sampling

In February 2017, the frequency of the EEM field sampling program for marine water, sediments and fish health changed from annual to every two years. As a result, the 2017 EEM report indicated that the next round of field sampling would be conducted in 2018. However, since this report was submitted, Encana permanently ceased production on May 7, 2018. In addition, Deep Panuke only produced intermittently in 2017 and 2018 (no production from June-December 2017 except for a few days between September and December, and only approx. 6 weeks of production in total from January to May 2018). As a result, there was less, and better-quality produced water discharged in 2017-2018 than in 2015-2016, when results from the field sampling program showed no measurable effects. Therefore, the 2018 sampling program was cancelled and a final "as-left" field sampling program for sediments (and mussels) will be conducted post decommissioning activities.

2.5 FISH HABITAT ALTERATION

2.5.1 Background

Fish habitat is predicted to be enhanced to a minor extent from a "reef" effect due to additional habitat created by the Deep Panuke subsea production structures (*i.e.* PFC legs, spool pieces, protective mattresses, subsea isolation valve (SSIV) valve, subsea wellheads and exposed sections of the subsea export pipeline to shore) and possibly a "refuge" effect associated with the creation of a safety (no fishing) zone around PFC facilities.

Underwater ROV video camera surveys at the SOEP and Cohasset-Panuke platform areas have shown that exposed subsea structures on Sable Bank were colonized predominantly by blue mussels, starfish, sea cucumbers, sea anemones and some fish species (most likely cunners), and occasionally by crustaceans (*e.g.* Jonah crabs). Sea stars, sea anemones and hydroids were also commonly observed on subsea platform/wellhead structures in association of mussel aggregations. It is well known that mussels are a preferred prey species of sea stars. Concentrations of small redfish have been observed at most span locations along the SOEP subsea pipeline to shore and snow crabs are frequently encountered on many exposed sections of the pipeline.

It is highly unlikely that the proposed subsea pipeline, where unburied, would constitute a significant concern as a physical barrier to the migration of most crustacean species (Martec Ltd. *et al*. 2004). Snow crab is the main commercial-sized crustacean species commonly observed near/on exposed sections of the SOEP subsea pipeline to shore. Cunners and pollock were the most commonly observed fish species at SOEP platforms. Hurley and Ellis (2004), in their review of EEM results of drilling, concluded that the spatial and temporal extent of discharged drill wastes appears to be related to mud type, differences in the number of wells/volume of discharges, oceanic and environmental conditions such as current speed and direction, water depth or sediment mobility at the drilling location.

Changes in the diversity and abundance of benthic organisms were detected within 1,000 m of drill sites, most commonly within the 50 m to 500 m range of drill sites. Benthic impacts in the Deep Panuke production field are anticipated to be negligible given the low biological diversity and highly mobile sand bottom characteristic of shallower areas of Sable Island Bank.

Based on the results of dispersion modeling carried out for the 2006 Deep Panuke EA, discharged mud/cuttings were predicted to have smothering effects over a relatively small area (cone with a base radius of 20 m from the drill site for subsea release of cuttings and with a base radius of between 30-160 m depending on the particle settling rate for surface release of cuttings). Such effects (if any) are likely to be relatively transient (less than one year) with the marine benthic community rapidly colonizing affected areas (*i.e.*, returning them to baseline conditions). One new well (disposal well E-70) was drilled as part of the 2010 drilling and completion program; the other Deep Panuke wells were drilled in 2000 (M-79A and H-08) and 2003 (F-70 and D-41) and were re-completed in 2010 (*i.e.* no cuttings piles involved) so no cuttings piles remain at these locations. The 2011 EEM work confirmed that there was no cutting pile at the E-70 location or any of the other well sites. The 2008 Baseline Benthic Study provides comparative data on benthic mega-faunal diversity as a basis for assessing potential impacts on fish habitat from the 2010 drilling and completion program and the Deep Panuke production subsea structures.

2.5.2 EEMP Goal

Predictions made in the 2006 Deep Panuke EA regarding fish habitat alteration from subsea production structures [EA predictions #1, 2, 3, 4, 5, 6, 7, 8, 9 & 10 in **Table 3.1**] are to be validated**.**

2.5.3 Objectives

The extent of fish habitat created by new hard substrate provided by subsea production structures installed for the Deep Panuke natural gas field are to be assessed. Species found and coverage of structures to previous years are to be compared.

2.5.4 Sampling

2.5.4.1 Subsea Structures

Annual ROV video-camera imagery of epibenthic community near subsea production structures (*i.e.* PFC legs, spool pieces, protective rocks and mattresses, subsea wellheads and exposed sections of the export pipeline to shore) were collected during planned activities such as routine inspection surveys, storm scour surveys, etc.

2.5.5 Analysis

2.5.5.1 Subsea Structures

Subsea inspection videos of the wellhead areas (May, June, and July 2018; D-41 and H-08 were used as representative samples) and of the PFC area (June 2018) were provided electronically and viewed with a generic video software (e.g., VLC media player). A marine technician experienced with underwater videography analyzed the general visual inspection (GVI) with the aid of the commentary and inspection drawings to identify all mega-fauna associated with each structure. Detailed notes were kept on the colonization for parts of each structure, and abundance values (SACFOR scale; Joint Nature Conservation Committee, 2011) calculated for all epifauna encountered.

Fish abundance was calculated for the subsea structures. Each species encountered was identified and given approximate estimates for abundance. Data from 2018 were compared to the 2017 video data.

2.5.5.2 GEP and Flowlines

Videos of the GEP subsea inspection survey (May 2018) were provided on external hard drive and viewed with a generic video software (e.g., VLC media player). An experienced marine technician analyzed the video with the aid of the commentary and inspection drawings to identify all fish and mega-fauna associated with each section. The GEP is exposed from KP 23.3 to KP 98.3. Video clips for nine representative segments of the exposed pipeline, each approximately 500 m in length and spaced out at approximately 10 km intervals, were analyzed. Quantitative values were recorded for all fish and epifauna encountered and compared with data obtained from the 2014-2016 surveys. A survey of the GEP was not conducted in 2017. Eight of the nine representative segments in 2018 were approximately the same segments as surveyed in previous years; the ninth segment was added and began at KP 10.62. It should be noted that not all the GEP from KP 23 to KP 98 was inspected in 2016; therefore, not all sections in 2018 could be compared to the 2016 data. Colonial species were given abundance values (e.g., encrusting algae and encrusting sponges) as they are not easily quantifiable.

A qualitative review of the buried GEP and flowline areas was performed.

2.5.6 Results

2.5.6.1 Subsea Structures

- Species present in 2018 were analogous to those observed during the 2017 survey of the WHPS at each location **(Table 2-10** and **Table 2-11)**. Similar to 2017, the common species observed include blue mussel *Mytilus edulis*, the hydroid *Tubularia* spp., the frilled anemone *Metridium dianthus*, and the sea star *Asterias vulgaris*.
- Zonation was consistent with that observed in previous years. During the 2018 survey, the tops and bottoms of many of the WHPS legs were covered with 100% marine growth consisting mainly of the species mentioned above. The main sections of many subsea structure legs had minimal marine growth due to cleaning in 2017. Hydroids, frilled anemones, and blue mussels were noted to be slowly recolonizing the previously cleaned locations on each leg. Total fouling of the WHPS was estimated to be between 70% to 80% for all structures (**Figure 2.1**). Percentage of marine growth coverage was 100% in some areas of the WHPS, except for areas that were cleaned in 2017. This generally high percentage of marine growth on structures in 2018 is consistent with observations made in previous years (**Figure 2.2**).
- Analysis of the bases of PFC legs #2 and #4 were conducted in 2018. Zonation of the PFC legs was consistent with past survey results. Marine growth was sparse (<10% coverage) near the base of the legs with some hydroids, frilled anemones, and sea stars. Cunner (*Tautogolabrus adspersus*) were also seen swimming around the base of both legs analyzed (**Table 2-12; Figure 2.3**).

Table 2.10 - May 2018 Survey of D-41 WHPS Compared to June 2017 Survey

Wellhead Site	Structure	Fauna	June 2017 Abundance	May 2018 Abundance	May 2018 Number	Description
D-41	WHPS	Porifera	-	-	-	Majority of WHPS has not been recently cleaned and has a high percentage of marine growth coverage. There was low visibility in portions of the video due to high suspended particulate matter. Video collection was quick, with the dive being aborted due to inclement weather during survey.
		Metridium dianthus	A	A	-	
		Tubularia? spp.	A	-	-	
		Mytilus edulis	O	O	-	
		Cancer sp.	-	-	-	
		Cucumaria frondosa	-	-	-	
		Asterias vulgaris	-	-	-	
		Ophiuroidea	-	-	-	
		Myoxocephalus sp.	-	-	-	
		Tautogolabrus adspersus	A	A	> 100	
		Ctneophora	R	R	-	
		Tunicate sp.	R	-	-	

* Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2-11 - May 2018 Survey of H-08 WHPS Compared to April 2017 Survey

Wellhead Site	Structure	Fauna	April 2017 Abundance	May 2018 Abundance	May 2018 Number	Description
H-08	WHPS	*Metridium dianthus*	O	O	-	Portions of WHPS were cleaned in 2017. As a result, there was minimal marine growth in previously cleaned areas. High Levels of marine growth located on remaining portions of WHPS. There was low visibility in the majority of the video inspection due to high levels of suspended particulate matter and 'marine snow'.
		Tubularia? spp.	A	A	-	
		Mytilus edulis	A	A	-	
		Cucumaria frondosa	-	-	-	
		Asterias vulgaris	O	O	-	
		Myoxocephalus sp.	-	-	-	
		Pollachius sp.	-	-	-	
		Tautogolabrus adspersus	-	-	-	
		Urophysis sp.	-	-	-	
		Cancer so.	-	-	-	
		Ophiuroidea	-	-	-	
		Henricia sp.	-	-	-	
		Gadus morhua	-	-	-	
		Ctneophora	R	R	-	
	Subsea Tree	*Mytilus edulis*	A	-	-	Subsea Tree not included in 2018 video.
		Tubularia? spp.	C	-	-	
		Henricia sp.	-	-	-	
		Asterias vulgaris	O	-	-	
		Metridium dianthus	C	-	-	
		Tautogolabrus adspersus	O	-	-	
		Ophiuroidea	R	-	-	
		Pollachius sp.	R	-	-	

* Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table 2-12 - June 2018 Survey of PFC Legs Compared to July 2017 Survey

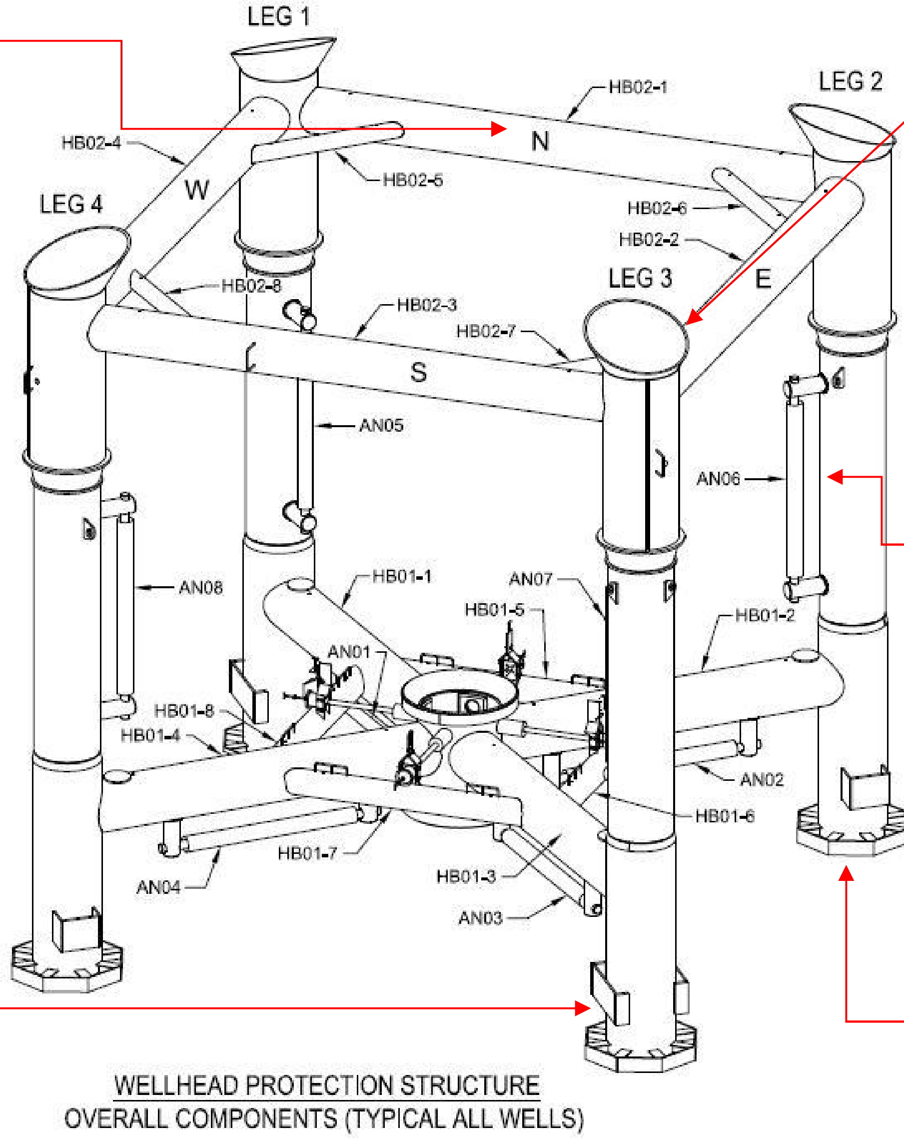
Wellhead Site	Structure	Fauna	July 2017 Abundance	June 2018 Abundance	June 2018 Number	Description
PFC	PFC (Leg 1 -SW)	*Metridium dianthus*	O	-	-	PFC Leg 1-SW was not included in 2018 video.
		Tubularia? spp.	R	-	-	
		Mytilus edulis	S	-	-	
		Asterias vulgaris	C	-	-	
		Ophiuroidea	-	-	-	
		Cancer sp.	-	-	-	
		Tautogolabrus adspersus	A	-	-	
		Pollachius sp.	-	-	-	
		Unidentified fish	-	-	-	
		Ctenophora	R	-	-	
		Henricia sp.	-	-	-	
		Semibalanus balanoides	R	-	-	
	PFC (Leg 2 - NW)	*Metridium dianthus*	C	C	-	Base of PFC Leg 2 was inspected and surrounding rock berm in 2018. Video was taken in black and white and at an increased distance from the PFC leg due to high current and swell in the area. This led to poor video quality in sections in both 2017 and 2018.
		Tautogolabrus adspersus	O	F	> 25	
		Tubularia? spp.	C	C	-	
		Mytilus edulis	S	A	-	
		Ophiuroidea	-	-	-	
		Cucumaria frondosa	-	-	-	
		Asterias vulgaris	O	O	-	
		Henricia sp.	-	F	-	
		Ctenophora	-	-	-	
		Cyanea capillata	-	-	-	
		Semibalanus balanoides	O	-	-	
	PFC (Leg 3 - NE)	*Metridium dianthus*	C	-	-	PFC Leg 3-NE was not included in 2018 video
		Tautogolabrus adspersus	O	-	-	
		Ophiuroidea	-	-	-	
		Tubularia? spp.	C	-	-	
		Henricia sp.	-	-	-	
		Mytilus edulis	S	-	-	
		Solaster endeca	-	-	-	
		Asterias vulgaris	C	-	-	
		Pollachius sp.	-	-	-	
		Cyanea capillata	-	-	-	

Wellhead Site	Structure	Fauna	July 2017 Abundance	June 2018 Abundance	June 2018 Number	Description
		Semibalanus balanoides	R	-	-	
	PFC (Leg 4 - SE)	*Metridium dianthus*	O	F	-	Base of PFC Leg 4 and its surrounding rock berm were inspected in 2018. Video was taken in black and white and at an increased distance from the PFC leg due to high current and swell in the area. This led to poor video quality in sections in both 2017 and 2018.
		Tubularia? spp.	C	C	-	
		Mytilus edulis	S	A	-	
		Ophiuroidea	-	-	-	
		Asterias vulgaris	C	F	-	
		Tautogolabrus adspersus	R	C	-	
		Pollachius sp.	-	-	-	
		Cucumaria frondosa	-	-	-	
		Semibalanus balanoides	R	-	-	
	PFC - Riser Caisson	*Metridium dianthus*	C	-	-	PFC - Riser Caisson was not included in 2018 video
		Tubularia? spp.	C	-	-	
		Mytilus edulis	S	-	-	
		Asterias vulgaris	C	-	-	
		Tautogolabrus adspersus	A	-	-	
		Pollachius sp.	R	-	-	
		Semibalanus balanoides	R	-	-	
		Ctenophora	R	-	-	

* Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Minimal marine growth on northern top bar.

Marine growth is starting to recolonize at the top of Leg 3 where it was cleaned in 2017.



Heavy marine coverage of hydroids on the AN-06 anode.

Mussels at the base of Leg 3.

Dense hydroids, and sea star at the base of Leg 2.

Figure 2.1 Wellhead Protection Structure and Associated Fauna at H-08 in 2018

2011

Moderate marine growth on East horizontal brackets at WHPS M-79A in the 2011 survey.

2012

Significant growth of marine fauna on East horizontal bracket at WHPS M-79A in 2012.

2013

Significant growth, and 100% coverage of marine fauna on the East horizontal bracket at WHPS M-79A in 2013.

2014

100% coverage of marine fauna on the East horizontal bracket at WHPS M-79A in 2014. Appears to have changed little since the 2013 survey.

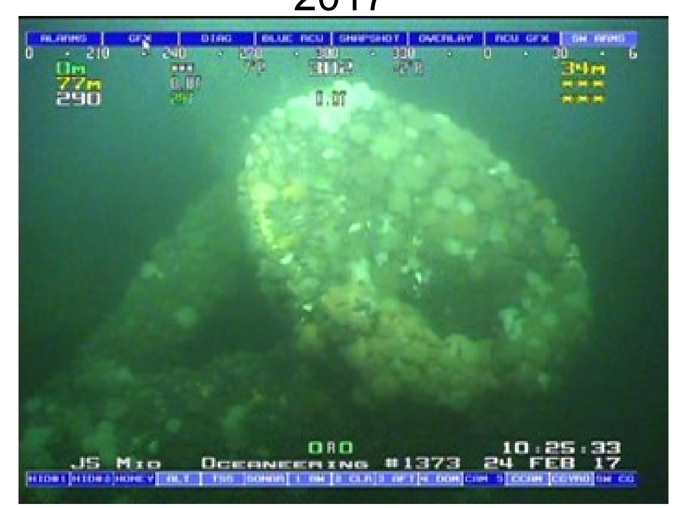
2015

100% coverage of marine fauna. Hydroids appear to have colonized on top of blue mussel since 2014.

2016

Minimal marine growth at MG-14 between Legs 2 and 3 which were cleaned in August 2016. Cunner are present.

2017



100% coverage of marine fauna at the top of Leg 2. Coverage consists of frilled anemones, hydroids, and blue mussels.

2018

100% coverage of marine fauna at the top of Leg 2. Coverage consists of frilled anemones, hydroids, and blue mussels.

Figure 2.2 Comparison of benthic fauna from 2011 to 2018 surveys at WHPS M-79A

2013 Survey | **2014 Survey** | **2015 Survey** | **2016 Survey** | **2017 Survey**

2013 Survey

Dense mussel patches near the top of the leg, with some possible *Metridium senile*.

Some mussel and sea star coverage mid leg, similar to the base of the leg.

Base of PFC leg 1 with some mussel and sea star coverage.

2014 Survey

Increased mussel coverage (almost 100%) near the top of the leg with some possible *Metridium senile*.

Dense mussel colonization mid leg, with dense patches of sea stars.

Less marine growth than 2013, possibly due to cleaning.

2015 Survey

Similar mussel coverage to 2014 near the top of the leg with some possible *Metridium senile*.

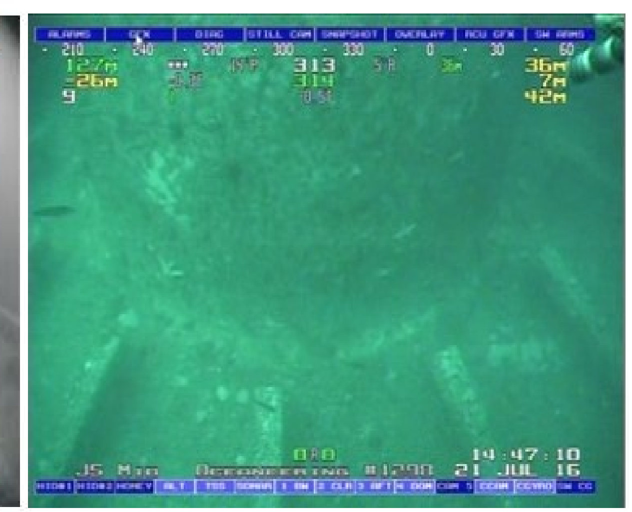
Dense mussel colonization mid leg, with dense patches of sea stars.

Similar marine growth to 2014, with cunner swimming around the base.

2016 Survey

Mussel coverage near the top of the leg with sea stars.

Dense mussel colonization mid leg, with occasional sea stars.



Similar marine growth to 2015, including cunner swimming around the base.

2017 Survey

Mussel coverage near the top of the leg with sea stars.

Dense mussel colonization mid leg, with occasional sea stars.

Similar marine growth to 2016, including cunner swimming around the base.

Figure 2.3 Comparison of PFC Legs from 2013 to 2018 Surveys

2018 Survey

Base of PFC Leg 2 with minimal marine growth and cunner swimming around base

Figure 2.3 Comparison of PFC Legs from 2013, 2014, 2015, 2016, 2017 and 2018 Surveys

2.5.6.2 GEP and Flowlines

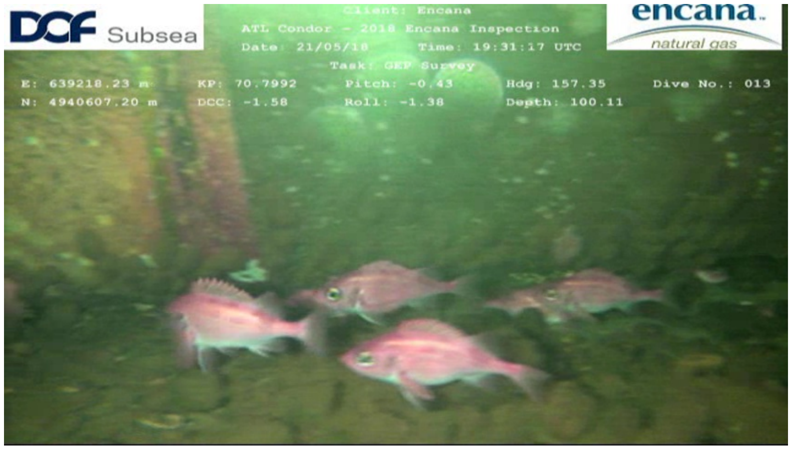
- In all videos analyzed, marine life continues to be abundant and diverse around the GEP in relation to the surrounding ocean floor (see **Table A-1 from Appendix D** for raw 2018 data; and **Figures 2.4 and 2.5**).
- The pipeline is exposed from KP 13.5 to 98.3 (85 km). Nine representative video clips were analyzed in 2018, starting at approximately KP 10. The video segment starting at approximately KP 10 was in addition to eight similar segments reviewed in 2014 and 2016, and therefore abundance comparisons in this report were made between those three sampling years. Of the nine clips captured in 2018, only four similar segments of video were surveyed/analyzed in 2015. Where relevant, 2015 results are discussed for particular segments.
- Comparison of faunal diversity by major group among the 2014, 2015, 2016 and 2018 surveys is presented in **Table A-2 from Appendix D**. Some species were categorized based on the SACFOR scale and therefore could not be quantified. Generally, for each of the categorized groups (Pisces, Crustacea, Echinodermata, Anthozoa, Mollusca, and Porifera) the highest observations were generally noted in 2014 for each of the KP segments. The exception was for Pisces, which generally had similar or greater numbers observed in 2016 starting at KP 52.48. The species below are discussed in greater detail based on their commercial value, higher number of observations, or because they are listed under the *Species at Risk Act* (SARA).
- Approximately 4500 redfish (*Sebastes sp.*) were observed in the nine videos analyzed in 2018. Previously, there were a total of 4655 redfish in 2014 and 5500 redfish in 2016 observed for the same segments of the GEP. This species was commonly found wherever the pipeline created a shallow excavation in the seafloor (**Figure 2.4**). It should also be noted that redfish numbers are likely higher than reported, as they are primarily found at the base of the pipe where a shadow is often created. Depending on how the lights are adjusted on the ROV, the base of the pipe is not always visible on video, making fish and other species difficult to see and identify.
- Thirty-one Atlantic cod (*Gadus morhua*) were observed in the nine videos analyzed in 2018. This was lower than the 51 individuals observed in 2014, but higher than the four observed in 2016 over the same segments of the GEP. In comparison, of

the four segments from 2015 that were analyzed for the same segments as in 2016 and 2018, only six Atlantic cod were observed. Similar to redfish, cod are primarily found at the base of the pipe, and the same lighting issues may be a factor in the number observed.

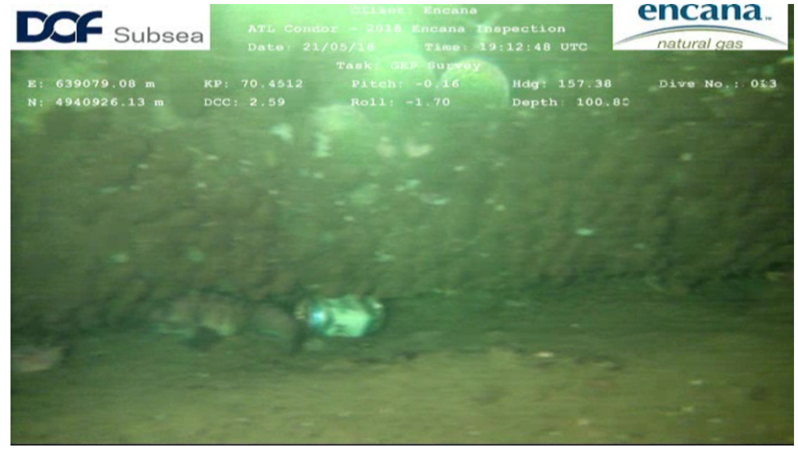
- It is also notable that it is often difficult to distinguish gadoids (the family Gadidae which includes cod, haddock and pollock) on video. There were 89 gadoids (in addition to identifiable Atlantic cod) observed in the nine videos analyzed in 2018.
- Flatfish (Pleuronectidae) were not observed in the nine video clips in 2018. There were seven flatfish observed along the same segments in 2016, and 10 in 2014. No flatfish were observed in 2015 video clips. As flatfish typically cover themselves with sand to blend in with the surrounding substrate, video quality could be a factor in reported numbers from year to year.
- The number of observed Atlantic wolffish (*Anarhichas lupus*) decreased from 2016 to 2018. A total of 10 Atlantic wolfish were noted in the nine video clips in 2018, compared to seven individuals observed in 2014 and 17 individuals observed in 2016 along the eight segments of the GEP surveyed. In 2015 there were a total of eight Atlantic wolfish observed in only four segments analyzed. The Atlantic wolffish is notable, as it is considered a species of special concern under SARA. In many of the Atlantic wolffish video sightings they appeared to have a burrow at the base of the pipe, or to be swimming along the protected area at the base of the pipe (**Figure 2.4**).
- Approximately 1043 commonly observed sea stars (*Asterias* sp. and *Henricia* sp.) were present in the nine video clips analyzed in 2018. This number was higher than the approximate 848 individuals present in the eight video clips in 2016, but much lower than the 8877 observed in 2014. The small size of many of the sea stars inhabiting the pipeline makes it difficult to obtain exact numbers. Video quality has varied between years, making comparison between the annual surveys difficult to interpret.
- Sea anemones, including tube anemones (*Cerianthus* sp.) (**Figure 2.4**) were observed in eight of the nine segment videos analyzed in 2018 (no sea anemones were observed along the pipeline video segment beginning at 10.61 KP), totalling approximately 295 individuals sighted. The number of sightings appeared to increase the further along the GEP, with the highest number recorded at approximately the mid-point along the KP segments analyzed. In 2014 and 2016,

1102 and 211 sea anemones, respectively, were reported in the same video clips for the same eight KP segments.

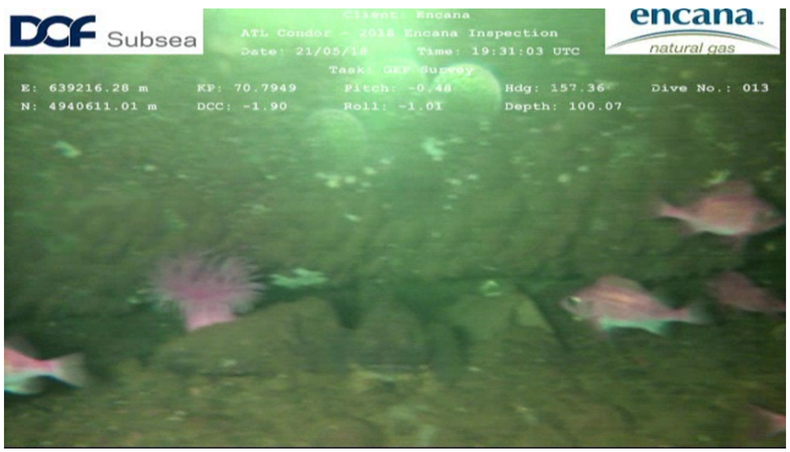
- Snow crab (*Chionoecetes opilio*) were not observed in any of the nine segments analyzed in 2018. Snow crab were observed in three of the eight videos analyzed in 2016, totalling 42 individuals sighted. In 2014, snow crab were observed in all eight segments analyzed, totalling 261 individuals. In comparison, in 2015 there were 31 snow crabs observed in the four representative GEP segments.
- In 2018, 92 Jonah crabs (*Cancer borealis*) (**Figure 2.4**) were observed in the nine videos analyzed. In 2016, over 177 Jonah crabs were observed in the eight videos analyzed. In 2014 of the same eight video clips analyzed, 340 Jonah crabs were observed. No hermit crabs (*Pagurus sp*.) were observed in 2018, 2016 or 2015 videos analyzed. This may be due to video quality, as many hermit crabs are small in size, compared to other macrofauna present. In 2014 there was only one hermit crab observed. Five northern stone crabs (*Lithodes maja*) (**Figure 2.5**) were observed in 2018, which is lower than the 10 observed in 2016 and in 2014 in the eight segments surveyed those years.
- In 2018, one American lobster (*Homarus* americanus) (**Figure 2.5**) was observed on rocky substrate at KP 10.8. One American lobster was also observed on rocky substrate at KP 17.4 in 2016. There were no observations of lobster along the same segments of the GEP in 2014 or 2015.
- Dead crabs or crab exoskeletons from molting were observed near the GEP. In 2018, only three dead crabs or exoskeletons were observed in total for all nine video clips analyzed. In 2016, only three dead crabs or exoskeletons were observed in total for all eight video clips analyzed that year. In comparison, 39 dead or exoskeletons were observed in 2014.
- The sand buried sections of the GEP show no difference to the adjacent sand seafloor, with very little marine life/growth and periodic shells observed. The flowline rock berms are predominately covered with sea cucumbers with some starfish (see **Figure 2.6**).
- 87 debris items located within 1 m from the GEP were identified during the 2018 subsea survey. The most common item found were plastic (20), netting (16), rope (14), and metal (13) (**Figure 2.7**).



Redfish (*Sebastes* sp.) at KP 70.79



Atlantic wolffish (*Anarhichas lupus*) and hard debris at KP 70.45



Sea raven (*Hemitripterus americanus) [centre]* amongst rocky debris and Tube anemone (*Cerianthus sp.*) and redfish at KP 70.79

Tube anemone affixed to side of pipeline at KP 50.72

Figure 2.4 Some Marine Fauna Observed along the GEP in 2018

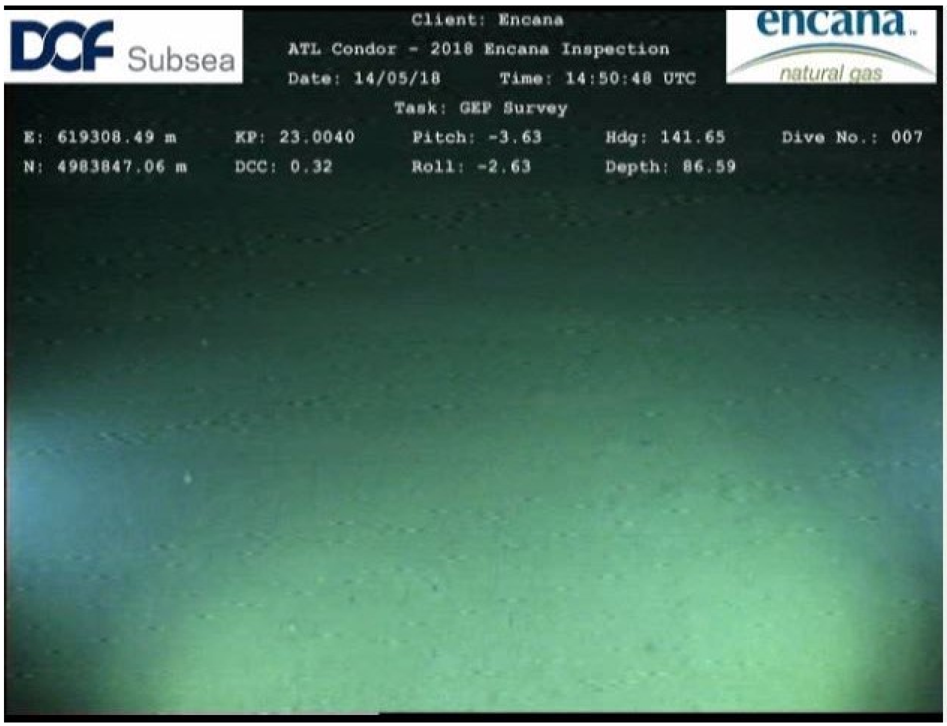
American lobster (*Homarus americanus*) in rocky substrate at KP 10.83

Jonah Crab (*Cancer borealis*) in soft substrate at KP 81.16

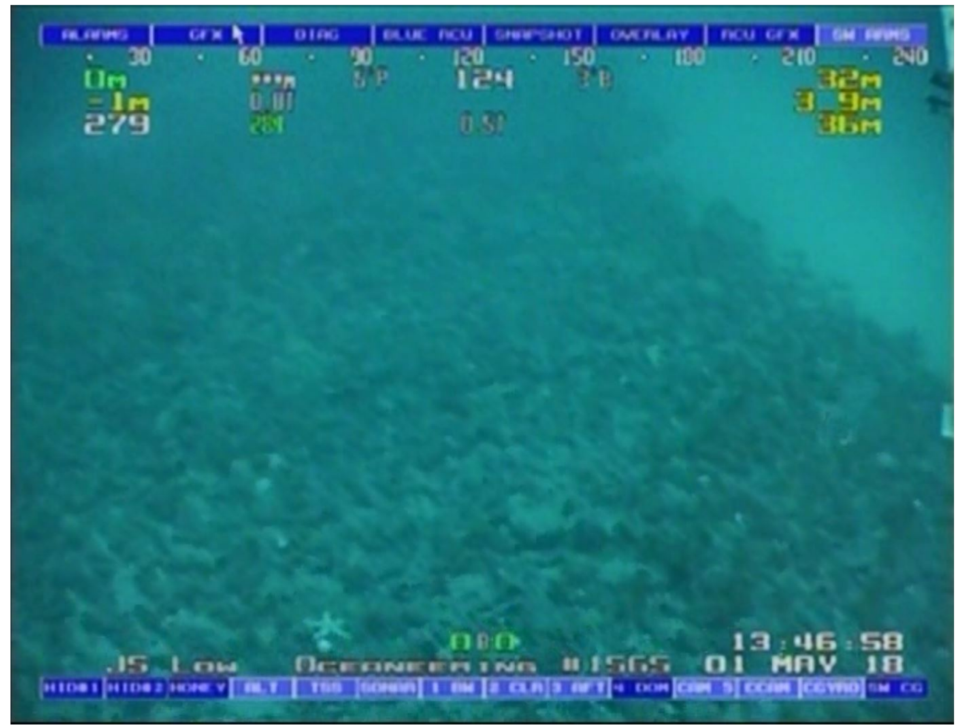
Northern stone crab (*Lithodes* maja) in soft substrate at KP 90.55

Toad crab (*Hyas sp.*) on rocky substrate at KP 30.85

Figure 2.5 Crustaceans Observed along the GEP in 2018



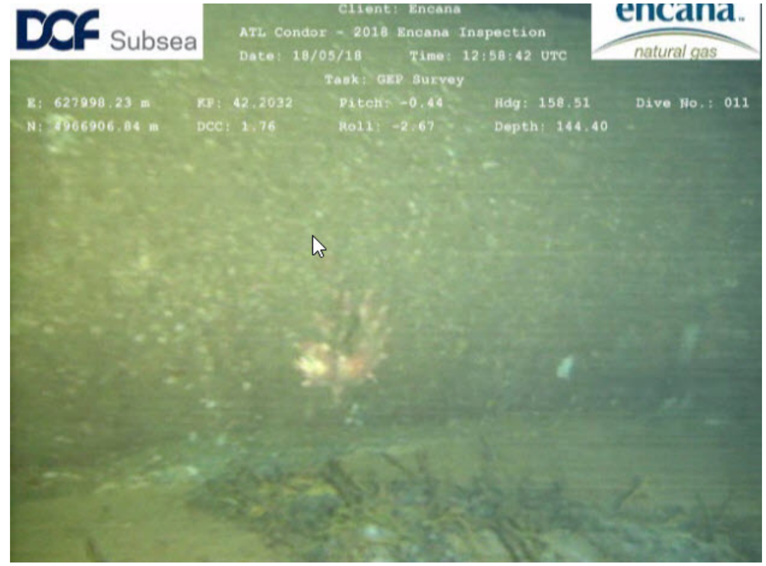
Buried GEP section [KP 134.3] (very little marine life, periodic shells observed)



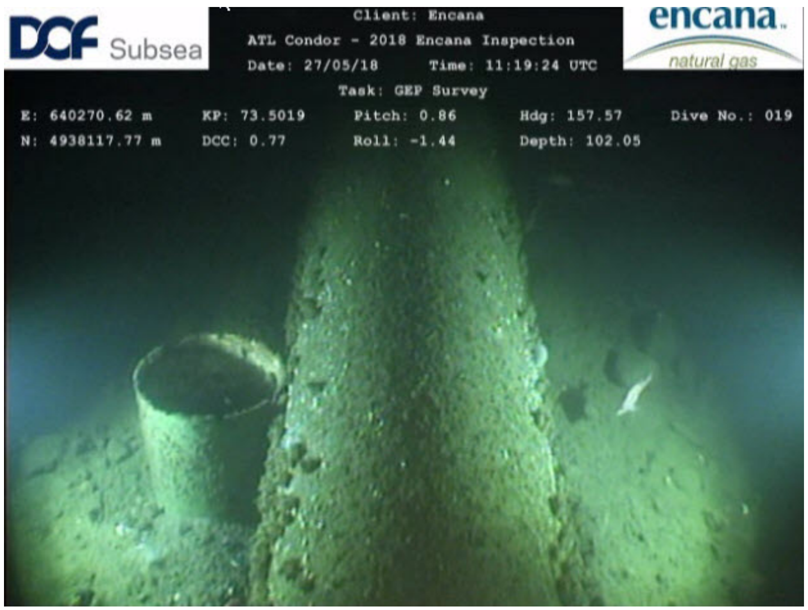
H-08 flowline rock berm (predominant sea cucumbers with some starfish)

Figure 2.6 Representative Photos of Buried GEP / Flowline Sections during the 2018 Survey

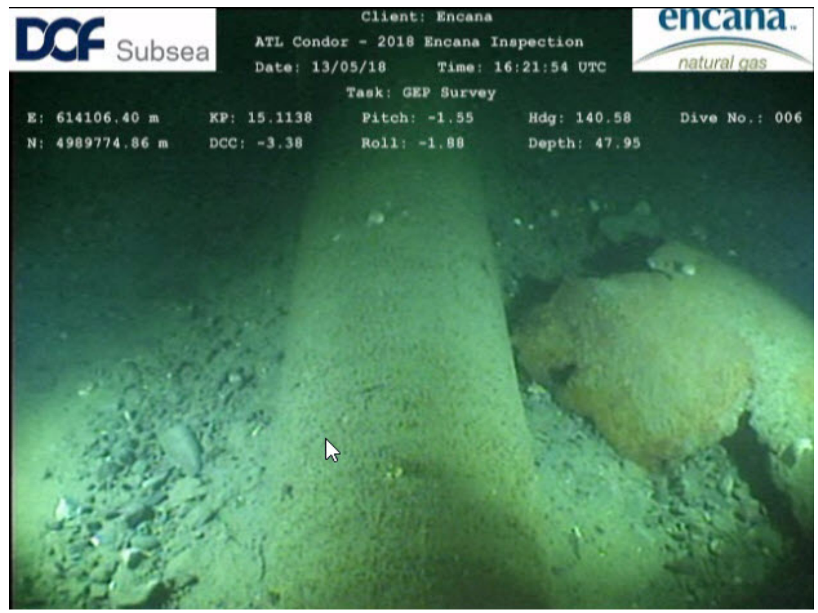
Soft debris (plastic) at KP 54.055



Soft debris (netting) at KP 42.203



Hard debris (drum) at KP 73.502



Hard debris (metal) at KP 15.114

Figure 2.7 Debris at the GEP during the 2018 Survey

Hard debris (wood) at KP 42.183

Soft debris (rigging soft) at KP 56.363

Hard debris (cable or wire) at KP 79.105

Figure 2.7 Debris at the GEP during the 2018 Survey

2.5.7 Summary and Conclusions

2.5.7.1 Subsea Structures

- Epifauna colonization of WHPS at all well site locations observed varied in numbers for some species from the 2018 survey. Several sections of the WHPS were cleaned in 2017 and these sections were slowly starting to recolonize in the 2018 survey.
- Seasonal differences in the timing or surveys could account for differences in fish species at the WHPS. For example, at WHPS H-08 pollock were present in the 2016 fall video survey compared to the spring 2018 video survey where no pollock were present.
- Zonation observed in previous years was not as evident in 2018. During the 2018 survey, the tops and bottoms of many of the WHPS legs were covered with 100% marine growth. The main sections of many subsea structure legs had minimal marine growth due to cleaning in 2017. Hydroids, frilled anemones, and blue mussels were noted to be slowly recolonizing the previously cleaned locations on each leg.
- Zonation of the PFC legs was consistent to past survey results. Marine growth was sparse (<10% coverage) near the base of the legs with some hydroids, frilled anemones, and sea stars. Cunner were also seen swimming around the base of both legs (PFC-2 and PFC-4) surveyed in 2018.
- Wellheads and protective structures appear to continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures, as predicted in the 2006 EA. The structures are attracting fish from the surrounding areas and providing shelter in an otherwise relatively featureless seafloor.
- Video quality and the distance from the ROV to PFC legs made identification difficult at times. The ROV operator recorded the video in black and white to improve the clarity.

2.5.7.2 GEP and Flowlines

- The GEP continues to act as an artificial reef to provide shelter and protection for many species of fish (*i.e.,* redfish and Atlantic wolffish) and invertebrates.
- Commercial finfish species recorded from the video analysis included Atlantic cod and redfish. Abundance of these commercial species increased starting around KP 60.

- The most abundant commercial crustaceans observed in the analyzed video were Jonah crabs, consistent with the same video sections in 2016.
- One American lobster was observed in 2018 (in the nine video clips analyzed).
- Other commercial invertebrates observed include the orange-footed sea cucumber, which were occasionally observed on top of the GEP.
- SARA-listed Atlantic wolffish were observed near the GEP, beginning at KP 20 and appear to be using the pipeline as a refuge burrow.
- As in past survey years, crustaceans were observed on video sitting on top of the pipe and climbing on it. Lobsters have not been observed climbing the pipeline or sitting on top of it in this project; however, as the GEP is not a physical barrier for other crustaceans, it is unlikely that it is a physical barrier for lobsters. Studies have also shown that lobsters are capable of climbing over a pipeline (Martec 2004).
- As in 2014 and 2016, dead crustaceans or possible exoskeletons from molting were found along the GEP in 2018.
- Garbage and debris continue to collect at the GEP, due to it being a physical barrier. The most common items were plastic, netting, rope and metal.
- Habitat/substrate types along buried sections of the GEP and flowlines were consistent with previous years. Sand buried sections showed no difference to the adjacent sand seafloor with very little marine life/growth and periodic shells. Flowline rock berms installed were predominately covered with sea cucumbers with some starfish.

2.6 FISH HEALTH ASSESSMENT

2.6.1 Background

The effects of environmental contamination can be viewed at different levels of biological organization, extending from the molecular or biochemical level to effects on organ physiology and histology at the individual animal level and ultimately to the population or community level. Over the past few years, there has been increasing emphasis on the use of individual-level indicators of chemical stress to obtain an appreciation of the degree, extent and severity of potential health effects in populations. These indicators are commonly referred to as bio-indicators or health effect indicators. Use of such indicators at the individual level has the potential to identify adverse conditions in advance of responses at the population level and, as such, can provide an early warning of potential problems and adverse health effects. Thus they are of special value for use in EEM programs around development sites in the open ocean where population level effects or for instance any site-induced changes in various condition indices could be very difficult to detect in the absence of major impacts since exposure levels are typically well below those that would pose a health risk (Lee and Neff, 2009, in press).

It is important to have background knowledge on selected bio-indicators for selected adult fish and shellfish species in order to provide perspective on any future changes which may arise over the life of Deep Panuke. In this regard it is also important to note that bio-indicators can be a powerful tool for "disproving" as well as "proving" whether or to what extent effects may be occurring. The typical bio-indicators used in EEM programs, including the SOEP EEM program, have been shellfish (taint and body burden) and fish (body burden and health parameters). The shellfish monitoring program was initiated at Deep Panuke in 2015 and the fish program started in 2016.

The low concentrations of hydrocarbons in produced water stipulated by relevant offshore guidelines, the rapid dilution of hydrocarbon fractions and the physiological ability of marine organisms to depurate hydrocarbons mitigate the potential for significant effects of hydrocarbon fractions in produced water on marine benthos. In the case of Deep Panuke, treating the produced water at several levels (including polishing as required) prior to discharge and the rapid dilution of the plume implies that marine organisms will be exposed to very low concentrations of contaminants that are unlikely to elicit measurable effects. The trace amounts of toxic contaminants likely to be in the discharged produced water, the rapid dilution of produced water, and the transient exposure of organisms mitigates against measurable, long-lasting effects. Of the organic constituents, PAH and alkylated phenols (APs) often contribute significantly to the environmental risk, exhibiting both toxic and sub-lethal effects. Experimental data pertinent to the toxicity of H_2S on invertebrates suggest that the concentrations of H_2S that benthic organisms will likely be exposed to are less than the concentrations required to cause chronic or acute effects. However, the potential for taint exists particularly in filter-feeders, such as mussels which can concentrate contaminants in body tissues. Potential H_2S contamination is not an issue at SOEP facilities since the gas/condensate is considered sweet.

Summary of Lessons Learned from SOEP EEM Program

- Hydrocarbons found in blue mussels collected from Thebaud jacket legs were shown to be non-petrogenic (i.e., derived from phytoplankton);
- Aliphatic hydrocarbons in mussels collected from platform legs (and in suspended cages as close as 250 m from the platform) have consistently been shown to have a biogenic origin (i.e., derived from natural sources).

2.6.2 EEMP Goal

Predictions made in the 2006 Deep Panuke EA regarding fish health [EA predictions #1, 3, 4, 5, 6, and 7] in **Table 3.1** are to be validated**.**

2.6.3 Objectives

The tissues of shellfish species collected on PFC legs (i.e., blue mussels) are to be examined for possible body burden due to petroleum contamination. Fish health is to be assessing using suitable bio-indicators for selected fish species collected near the Deep Panuke PFC.

2.6.4 Sampling

In February 2017, the frequency of the EEM field sampling program for marine water, sediments and fish health changed from annual to every two years. As a result, the 2017 EEM report indicated that the next round of field sampling would be conducted in 2018. However, since this report was submitted, Encana permanently ceased production on May 7, 2018. In addition, Deep Panuke only produced intermittently in 2017 and 2018 (no production from June-December 2017 except for a few days between September and December, and only approx. 6 weeks of production in total from January to May 2018). As a result, there was less, and better-quality produced water discharged in 2017-2018 than in 2015-2016, when results from the field sampling program showed no measurable effects. Therefore, the 2018 sampling program was cancelled and a final “as-left” field sampling program for mussels (and sediments) will be conducted post decommissioning activities.

2.7 MARINE WILDLIFE OBSERVATIONS

2.7.1 Background

As mentioned in the 2017 EEM report, the beached bird surveys on Sable Island were discontinued in 2018 due do the reduced production and the lack of effects from production activities demonstrated by more than 20 years of data.

2.7.1.1 Stranded Birds Handling

Encana's stranded bird protocol is outlined in the EPCMP and includes dedicated personnel responsible for implementing the protocol, directions on how to handle different types of stranded birds, offshore personnel awareness/training, reference material, etc. A stranded bird report Is submitted to Canadian Wildlife Service (CWS) every year.

2.7.1.2 Visual Monitoring of Wildlife around the PFC / Vessels

In recent studies, baleen whales, toothed whales, seals and sea turtles have been observed in the vicinity of production platforms and drill rigs, but the animals provided no evidence of avoidance or attraction to platform operations (Encana, 2011: DMEN-X00-RP-EH-90-0003). Cetacean species, including their young, have also been seen feeding close to platform operations.

2.7.2 EEMP Goal

The goal is to detect effects on marine wildlife in the vicinity of Deep Panuke PFC [EA predictions #11, 12 and 13 in **Table 3.1**].

2.7.3 Objectives

The following information is to be recorded/identified:

- any stranded (live or dead) birds on the Deep Panuke PFC and vessels; and
- the behaviour of any birds, marine mammals and sea turtles observed in the vicinity of the Deep Panuke PFC and vessels.

2.7.4 Sampling

The following samples were recorded/identified:

- any stranded (live or dead) birds on the Deep Panuke PFC and vessels; and

- the behaviour of any birds, marine mammals and sea turtles observed in the vicinity of the Deep Panuke PFC and vessels.

2.7.5 Analysis

- Stranded birds were identified by PFC and support vessels (**Appendix C**).
- Wildlife seen from the PFC and support vessels was recorded daily.

2.7.6 Parameters Analyzed

Table 2.11 - Marine Wildlife Observations in 2018

	Sampling		Analysis	
Location	**Type/Method**	**Frequency/Duration**	**Type/Method**	**Parameters**
PFC/vessels	Implementation of Encana's EPCMP stranded bird protocol	As required	Yearly stranded bird report submitted to CWS	Species; condition; action taken; fate of bird
PFC/vessels	Visual monitoring of seabirds, marine mammals and sea turtles around PFC / vessels	Opportunistic observations from PFC /vessels	Direct observation	Species, counts and behavioural observations (*e.g.* any congregation of wildlife will be reported)

2.7.7 Results

2.7.7.1 Marine Wildlife Observations

2.7.7.1.1 Stranded Seabird Summary

- On-going monitoring for stranded birds was conducted in 2018 on the PFC and support vessels Atlantic Tern and the Atlantic Condor.
- Two stranded birds were found in 2018. A spotted sandpiper was found dead (no oil) on the PFC on June 3 and was sent to ECCC for necropsy (results pending). A great black-backed gull (no oil) was found on March 10 on the Atlantic Condor entangled in fishing gillnet. The bird was freed from the net and released.
- In addition, several non-stranded birds were observed: two ospreys (April) and a peregrine falcon (September) on the PFC; and a brown booby (September) on the Atlantic Tern.

For complete description and photos of these bird events, refer to the report "2018 Stranded Bird Report", **Appendix C**.

2.7.7.1.2 Visual Monitoring of Wildlife around the PFC / Vessels Summary

- Both the supply vessels the Atlantic Condor and the Atlantic Tern reported wildlife sightings from January to December of 2018.
- The Atlantic Condor observed various gulls throughout the year.
- The Atlantic Tern observed gulls, other seabirds, and seals from April to December.
- There were no unusual wildlife sightings from the PFC or supply vessels in 2018.

2.7.8 Summary and Conclusions

- There were two stranded birds in 2018. A spotted sandpiper was found dead (no oil) on the PFC on June 3 and was sent to ECCC for necropsy (results pending). A great black-backed gull (no oil) was found on March 10 on the Atlantic Condor entangled in fishing gillnet. The bird was freed from the net and released. Non-stranded ospreys and peregrine falcon (PFC) as well as a brown booby (Atlantic Tern) were also sighted.
- Both the supply vessels the M/V Atlantic Condor and the M/V Atlantic Tern reported wildlife sightings in 2018, including gulls and seals.

2.8 AIR QUALITY MONITORING

2.8.1 Background

Sable Island is uniquely located in the Atlantic Ocean off the east coast of North America. Despite its remote location, Sable Island receives significant trans-boundary pollutant flows from industrial and urban areas along the Great Lakes and US eastern seaboard. The local air-shed around Sable Island also receives contributions of contaminants from local sources of emissions on Sable Island itself, passing marine traffic, and from activities associated with nearby offshore hydrocarbon developments.

The Sable Island Air Monitoring Station, which has been operating since mid-2003, was installed to provide baseline information on the ambient air quality on Sable Island and to monitor trends in air quality as development of the Nova Scotia offshore oil and gas exploration expanded. Data collected serves as a basis for a comprehensive air quality management system to identify and address any potential impacts attributable to contaminant emissions from offshore activities. Monitoring is targeted at potential pollutants that could be associated with offshore oil and gas activity such as nitrogen oxides (NOx), sulphur dioxide (SO_2), fine particulate matter ($PM_{2.5}$), hydrogen sulphide (H_2S) and greenhouse gases (GHG) such as methane (CH_4), carbon monoxide (CO), and carbon dioxide (CO_2). If the station detects a pollutant spike, researchers are able to generate a back-trajectory indicating the origin of the pollutant based on flare characteristics and analysis of meteorological conditions at the time of the event.

A new study focusing on gaseous pollutants (in particular VOCs) and particulate speciation (for fine and ultra-fine particles) associated with the offshore oil and gas industry and marine emissions has been carried out by Dr. Mark Gibson, Dalhousie University, Department of Community Health and Epidemiology on Sable Island since 2011. The study was funded principally by the Environmental Studies Research Fund (ESRF) with in-kind logistical and technical support from various government agencies, stakeholder groups and offshore oil and gas companies.

Starting in 2013, Mark Gibson was contracted by Encana and ExxonMobil through Kingfisher Environmental Health Consultants to conduct Sable Island air contaminant spike monitoring as well as data analysis of air quality and meteorological data to identify potential correlation with O&G operations. As mentioned in the 2017 EEM report, air quality monitoring on Sable Island for Deep Panuke was discontinued in 2018 due do the reduced production and the lack of effects from production activities demonstrated by five years of data. Flare smoke monitoring at the PFC was conducted in 2018.

2.8.2 EEMP Goal

The goal of air quality monitoring is to provide feedback for continuous improvement in reducing flare and other emissions from the Deep Panuke natural gas field [EA prediction #14 in **Table 3.1**].

2.8.3 Objectives

Investigate the possible relationship of production operations and flaring patterns on the PFC.

2.8.4 Sampling

Systematic flare smoke monitoring on the PFC was conducted twice daily (morning and afternoon), assessing smoke shade using the Ringelmann chart.

2.8.5 Analysis

Assess presence (percentage) of various flare smoke shades during the year.

2.8.6 Results

Using the Ringelmann chart, in 2018, the flare smoke shade was a “1” (light smoke) until production shut down on May 7, 2018.

2.8.7 Summary and Conclusions

Using the Ringelmann chart, in 2018, the flare smoke shade was a “1” (light smoke) until production shut down on May 7, 2018.

3 ENVIRONMENTAL ASSESSMENT (EA) PREDICTIONS

Table 3.1 - EEM Related Environment Assessment (EA) Predictions and 2018 Results

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2018 Plan	2018 Results
1	No significant adverse effects are predicted on marine receptors that are linked to water quality due to various levels of treatment of produced water on the PFC platform and rapid dilution of discharged water.	8.2.4 8.3.4 8.4.4 8.5.4	- Marine Water Quality - Marine Benthos - Marine Fish - Marine Mammals and Sea Turtles	- Produced Water Chemistry and Toxicity - Marine Water Quality - Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	The field produced for less than six months and was permanently shut down on May 7, 2018; therefore, only one round of produced water chemistry testing was conducted, in January 2018, concurrently with the toxicity testing. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene and toluene. Some APs were detected. Subsea structures continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures.
2	Mortality of benthic organisms due to exposure of the diluted brine plume is unlikely due to the short duration of exposure coupled with the high dilution factor. In the case of limited mortality of benthic organisms, habitat would be re-colonized from adjacent areas.	8.3.4.1	- Marine Benthos	- Sediment Chemistry and Toxicity - Fish Habitat Alteration	Discontinue E-70 cuttings pile monitoring. Continue fish habitat analysis near subsea production structures into with annual ROV footage of wellsite structures and pipeline.	Benthic communities were well developed and continue to thrive at each of the wellheads, with a dense and diverse epifaunal fouling community on the wellhead protection structures. Some fish aggregations were also observed, suggesting no negative impacts, and possible "reef" effects attracting mobile organisms into the vicinity of the subsea structures. EA prediction has been confirmed.

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2018 Plan*	*2018 Results*
3	The discharged water will have a maximum "end of pipe" temperature anomaly of 25°C. The temperature anomaly will be a maximum of a 2.5°C upon contact with the seafloor. Beyond 130 m, the temperature anomaly will be less than that 1°C and will fall below 0.4°C at a distance of 500m. The temperature anomalies are not predicted to exceed temperature tolerance thresholds of fish species except in the immediate area (*i.e.*, tens of metres) from the end of pipe discharge. The benthic organisms of the study area are capable of withstanding variable temperatures and the predicted 2.5°C temperature anomaly in unlikely to exceed tolerance thresholds of benthic species present.	8.4.4.2 8.3.4.2	- Marine Fish - Marine Benthos	- Produced Water Chemistry and Toxicity - Marine Water Quality Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	The field produced for less than six months and was permanently shut down on May 7, 2018; therefore, only one round of produced water chemistry testing was conducted, in January 2018, concurrently with the toxicity testing. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene and toluene. Some APs were detected. Subsea structures continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures.
4	The maximum salinity anomaly of the plume upon contact with the seafloor will be about 0.7 PSU. Upon spreading of the plume, the maximum salinity anomaly will fall below 0.6 PSU within 100 m of the site (seafloor) and 0.1 with 500 m. Similar to the effects of the bulk discharge of completion fluid, the predicted salinity anomaly of the plume upon contact with the bottom is minor and is unlikely to exceed tolerance thresholds of benthic organisms or fish.	8.3.4.2 8.4.4.2	- Marine Benthos - Marine Fish	- Produced Water Chemistry and Toxicity - Marine Water Quality - Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	The field produced for less than six months and was permanently shut down on May 7, 2018; therefore, only one round of produced water chemistry testing was conducted, in January 2018, concurrently with the toxicity testing. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene and toluene. Some APs were detected. Subsea structures continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2018 Plan	2018 Results
5	Treating the produced water at several levels (including continuous polishing) prior to discharge and the rapid dilution of the plume implies that benthic organisms will be exposed to very low concentrations of contaminants that are unlikely to elicit measurable effects.	8.3.4.2	- Marine Benthos	- Produced Water - Chemistry and Toxicity - Marine Water Quality Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	The field produced for less than six months and was permanently shut down on May 7, 2018; therefore, only one round of produced water chemistry testing was conducted, in January 2018, concurrently with the toxicity testing. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene and toluene. Some APs were detected. Subsea structures continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures.
6	Experimental data pertinent to the toxicity of H2S on fish suggest that the concentrations of H2S that fish will likely be exposed to at Deep Panuke are much less than the concentrations required to cause chronic or acute effects, including at the point of discharge. The full-time "polishing" of produced water on the MOPU and the rapid dilution of the plume will result in fish being exposed to extremely low concentrations of Alkylated phenols that are unlikely to elicit measurable effects.	8.4.4.2	- Marine Fish	- Produced Water - Chemistry and - Toxicity - Marine Water Quality Monitoring - Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Produced water to be collected twice a year. Chemical characterization to be done twice a year and toxicity testing to be done once a year. Continue monitoring PFC and WHPS with ROV footage to assess fish habitat.	The field produced for less than six months and was permanently shut down on May 7, 2018; therefore, only one round of produced water chemistry testing was conducted, in January 2018, concurrently with the toxicity testing. Chemical parameters measured were all below CCME guidelines, except for PAH-naphthalene, benzene and toluene. Some APs were detected. Subsea structures continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures.

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2018 Plan*	*2018 Results*
7	The effects of cuttings and WBM are most likely to affect demersal fishes as drilling wastes will fall out of suspension and settle on the seafloor or be held in the benthic boundary layer.	4.4.4.1	- Marine Fish	- Sediment Chemistry and Toxicity - Fish Habitat Alteration - Fish Health Assessment	Sediment sampling to continue in 2013. Discontinue E-70 cuttings pile monitoring.	N/A - Sediment sampling at wellsite locations to be discontinued in 2014 based on results from 2011 chemistry and toxicity survey (no surveys conducted in 2012 and 2013), which concluded that all metal, non-metal, hydrocarbon and nutrient concentrations were below Canadian EQG threshold levels and that all collected sediments were non-toxic ("therefore, there is negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of the ecosystem and the designated resource uses they support"). – EA prediction no longer applicable. The sediment chemistry and toxicity program will focus on the sampling locations downstream and upstream of the PFC site (i.e. 4 near-field and 2 far-field reference sites).
8	Overall, cuttings piles are not expected to persist for more than a year due to the dynamic and energetic environment (*i.e.* currents and storm events) of Sable Island Bank. Following dissipation of the cuttings pile, the benthic community is expected to recover within 2 to 3 years through recruitment from adjacent areas.	8.3.4 8.4.4	- Marine Benthos - Marine Fish	- Sediment Chemistry - and Toxicity - Fish Habitat Alteration	Discontinue E-70 cuttings pile monitoring.	N/A – EA prediction has been confirmed.
9	Marine life will benefit to a minor extent from a "reef" effect due to additional habitat created by PFC facilities and exposed sections of the subsea pipeline to shore and a "refuge" effect associated with the creation of a safety (no fishing) zone around PFC facilities.	8.2.4 8.3.4 8.4.4 8.5.4	- Marine Benthos - Marine Fish - Marine Mammals and Turtles	- Fish Habitat Alteration	ROV video data to be inspected in order to determine and interpret the development of benthic communities at the wellheads, wellhead protection structures, pipelines etc.	Subsea structures continue to act as an artificial reef/refuge as evidenced by the continued colonization of the structures.

#	EA Predictions	Relevant Section of 2006 EA	VEC(s)	EEM Component(s)	2018 Plan	2018 Results
10	It is highly unlikely that the proposed subsea pipeline, where unburied, would constitute a significant concern as a physical barrier to crustacean movement.	8.3.4 8.4.4	- Marine Benthos - Marine Fish	- Fish Habitat Alteration	ROV video data to be inspected in order to determine and interpret the development of benthic communities along the pipeline. Continue observation of crustaceans, particularly American lobster if present.	The subsea pipeline does not constitute a physical barrier to crustacean movement as evidenced by multiple species of crabs on top and on the sides of the exposed structure. EA prediction has been confirmed for all types of crabs found along the GEP. Lobsters have not been observed climbing the pipeline in this project; however, as the GEP is not a physical barrier for other crustaceans, it is unlikely that it is a physical barrier for lobsters. Studies have also shown that lobsters are capable of climbing over a pipeline (Martec 2004)
11	Marine Mammals and Sea Turtles may be attracted to the PFC area due to the availability of increased prey species ("reef/refuge" effects) or thermal plume (in winter).	8.2.4 8.4.4 8.5.4	- Marine Water - Quality - Marine Fish - Marine Mammals and Turtles	- Marine Water Quality - Monitoring - Marine Wildlife Observations	Marine Mammal and Sea Turtle observations to continue.	Presence of wildlife near the PFC has been observed sporadically, but these observations cannot affirm the presence or nature of an attraction (*i.e.* noise, heat, food, shelter/refuge, curiosity, etc.).
12	Birds, such as gulls and tubenoses, can be attracted by macerated sewage and food waste, although this was not observed at the Cohasset Project. Overall, the potential effects of the presence of project related lighting and flares will be low.	6.3.6.4 (2002 CSR)	- Marine Related - Birds	- Marine Wildlife Observations	Bird observations from vessel and platform to continue.	Two bird strandings were reported in 2018. A spotted sandpiper was found dead (no oil) on the PFC and sent to ECCC for necropsy (results pending). A great black-backed gull (no oil) was found on the Atlantic Condor entangled in fishing gillnet and was freed and released. Non-stranded ospreys and peregrine falcon (PFC) as well as a brown booby (Atlantic Tern) were also sighted.
13	The potential for oiling of birds and/or contamination of their food sources from discharged produced water is unlikely since a sheen, if it did occur, would be very short lived and would be unlikely to produce any oiling of bird plumage.	8.2.4 8.6.4	- Marine Water - Quality - Marine Related - Birds	- Marine Water Quality - Monitoring - Marine Wildlife Observations	Sable Island Beach Surveys discontinued in 2018 do the reduced production and the lack of effects from production activities demonstrated by more than 20 years of data	N/A

#	*EA Predictions*	*Relevant Section of 2006 EA*	*VEC(s)*	*EEM Component(s)*	*2018 Plan*	*2018 Results*
14	Routine operations can be conducted with sufficient mitigation to ensure that effects on air quality are not significant.	8.1.4	- Air Quality	- Air Quality Monitoring	Air quality data monitoring on Sable Island discontinued in 2018 due do the reduced production and the lack of effects from production activities demonstrated by five years of data Flare smoke monitoring was conducted at the PFC.	Using the Ringelmann chart, the flare smoke shade was a "1" (light smoke) until production shut down on May 7, 2018.
15	Air quality modeling for accidental events indicates exposure levels to receptors on Sable Island remain not significant.	8.1.4	- Air Quality - Sable Island	- Air Quality Monitoring	Air quality data monitoring on Sable Island discontinued in 2018 due do the reduced production and the lack of effects from production activities demonstrated by five years of data	N/A

4 RECOMMENDED EEM PROGRAM FOR 2019

Table 4.1 provides a summary of Deep Panuke's 2018 offshore EEM sampling activities, analysis, and recommendations for the 2019 EEM program.

Table 4.1 - Summary of Deep Panuke 2018 Offshore EEMP Sampling Activities, Analysis, and 2019 Recommendations

EEMP Component	2018 Sampling			2018 Analysis		2019 Recommendations
	Location	Type/Method	Frequency/Duration	Type/Method	Parameters	
Produced Water Chemistry and Toxicity	PFC (prior to mixing with seawater system discharge)	Sampled on the PFC directly from outlet.	Twice annually after First Gas Produced water sampled in January 2018 only due to less than 6 months of production	Water quality composition	Trace metals; BTEX, TPH, PAHs; APs; nutrients; organic acids; major ions and physical parameters	Discontinued – production shutdown (no produced water discharges)
			Annually after First Gas Conducted in January 2018	Microtox Sea urchin fertilization Threespine stickleback	15 min IC50 bioassay IC25 (Fertilization) 96-hr LC50	Discontinued – production shutdown (no produced water discharges)
Marine Water Quality Monitoring	Tri-level seawater samples (surface, mid and bottom depths) at 5 near-field downstream sites and 2 upstream sites along tide direction	Niskin Bottle	In 2011 (prior to First Gas), then 2015, 2016 and every two years after that. *No sampling in 2018.*	Water quality composition	Trace metals; BTEX, TPH, PAHs; APs; nutrients; organic acids; major ions and physical parameters	Discontinued – production shutdown (no produced water discharges)
Sediment Chemistry and Toxicity	4 near-field benthic sampling locations and 2 far-field reference sites (5 wellsite sampling locations discontinued in 2015)	Grab Sample - Van Veen	In 2011 (prior to First Gas and post 2010 drilling and completion activities), then 2015, 2016 and every two years after that. *No sampling in 2018.*	Chemical composition	Sediment grain size and TOC; suite of metals and hydrocarbons measured in 2008 Benthic Baseline Study; TPH, PAHs and APs; and sulphides	Conduct final "as-left" sediment sampling program post decommissioning activities
				LC49 bioassay acute toxicity analysis	Suitable marine amphipod species such as *Rhepoxynius abronius* or *Eohaustoriux estuaries*	Conduct final "as-left" sediment sampling program post decommissioning activities
Fish Habitat	Subsea production structures	ROV video- camera survey	Annually (using planned activities, *e.g.* routine inspection and storm scour surveys) Conducted Feb-Sep 2018	Video analysis	Subsea production structures: evaluate the extent of marine colonization and compare to previous years.	Continue fish habitat analysis near subsea production structures into 2019 with ROV footage of wellsites, SSIV and PFC structures

EEMP Component	2018 Sampling			2018 Analysis		2019 Recommendations
	Location	Type/Method	Frequency/Duration	Type/Method	Parameters	
Fish Health Assessment	Mussels: PFC SW leg Fish: immediate vicinity of PFC and suitable far-field reference sites	Mussels: scraping Fish: angling	Mussels: 2015, 2016, then every two years after that. *No sampling in 2018.* Fish: every 3 years after First Gas (start 2016). *No sampling in 2018.*	Mussels: body burden Fish: body burden; pathology	Mussels: PAH and AP Fish: PAH and AP; standard characteristics (*e.g.* length, weight, sex, etc.); gross pathology and histopathology	Conduct final "as-left" mussel sampling program post decommissioning activities
Marine Wildlife Observations	PFC / vessels	Implementation of Williams and Chardine protocol for stranded birds	As required	Yearly stranded bird report to be submitted to CWS	Species; condition; action taken; fate of bird	Continue into 2019 for all vessels involved in decommissioning and abandonment activities
		Visual monitoring of seabirds, marine mammals and sea turtles around PFC	Opportunistic observations from PFC / vessels	Direct observations	Species, counts and behavioural observations (*e.g.* any congregation of wildlife will be reported)	Continue into 2019 for all vessels involved in decommissioning and abandonment activities
	Sable Island	Beached bird surveys	Approx. 10 surveys/year *Discontinued in 2018 due to reduced production and lack of effects from production activities demonstrated by more than 20 years of data.*	Based on CWS protocol	Oiling rate (standardized approach)	Discontinued
Air Quality Monitoring	Sable Island Air Quality Monitoring Station	Air quality monitoring instrumentation	Continuous *Discontinued in 2018 due to reduced production and lack of effects from production activities demonstrated by five years of data.*	Compare Sable Island air contaminant spikes with O&G production activities using meteorological records	$PM_{2.5}$; VOCs, SO_2; H_2S; NO; NO_2; NOx; O_3; CH_4; and NMHC	Discontinued
	PFC	Visual observations of flare plume	Continuous during walk-arounds on deck and from video camera looking at the flare	Flare smoke monitoring using Ringelmann chart	Flare smoke shades	No longer applicable as only cold venting is planned in 2019 (no flaring)

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APPENDIX A
CEQG for Marine Water Quality

INTRODUCTION

The aquatic ecosystem is composed of the biological community (producers, consumers, and decomposers), the physical and chemical (abiotic) components, and their interactions. Within the aquatic ecosystem, a complex interaction of physical and biochemical cycles exists, and changes do not occur in isolation. Aquatic systems undergo constant change. However, an ecosystem has usually developed over a long period of time and the organisms have become adapted to their environment. In addition, ecosystems have the inherent capacity to withstand and assimilate stress based on their unique physical, chemical, and biological properties. Nonetheless, systems may become unbalanced by natural factors, which include drastic climatic variations or disease, or by factors due to human activities. Any changes, especially rapid ones, could have detrimental or disastrous effects. Adverse effects due to human activity, such as the presence of toxic chemicals in industrial effluents, may affect many components of the aquatic ecosystem, the magnitude of which will depend on both biotic and abiotic site-specific characteristics.

Canadian water quality guidelines are intended to provide protection of freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical components (e.g., pH, temperature, and debris). Guidelines are numerical limits or narrative statements based on the most current, scientifically defensible toxicological data available for the parameter of interest. Guideline values are meant to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term. Ambient water quality guidelines developed for the protection of aquatic life provide the science-based benchmark for a nationally consistent level of protection for aquatic life in Canada.

Canadian water quality guidelines for aquatic life are not restricted to a particular (biotic) species, but species-specific information is provided in the respective fact sheets, and, more detailed, in the supporting documents, so that the water quality manager and other users may determine the appropriateness of the guideline for the protection and enhancement of local species. A consistent approach according to the nationally approved, scientifically defensible protocol for the development of water quality guidelines (freshwater and marine) for the protection of aquatic life was maintained. It is important to note that the national protocol emphasizes best scientific judgment in all cases, so the nature of the parameter and the variation in the quality and quantity of supporting information necessitates modifications to the derivation procedures from time to time.

This chapter contains (a) a summary table of the guidelines, listing the ones that either have been carried over from the original *Canadian Water Quality Guidelines* (CCREM 1987), revised since then, or newly developed; (b) the protocol (originally published in 1991); and (c) fact sheets for the respective substances and parameters of concern. These guidelines, therefore, replace the former recommendations published in CCREM (1987) and its appendixes. The fact sheets, and, more extensively, the supporting documents on which they are based, provide details for the derivation of the guidelines, physical-chemical properties, fate in the aquatic environment, use patterns, environmental concentrations, and toxicological data. Effects diagrams give a graphical summary of the relevant toxicity information, i.e., the most sensitive effects thresholds for the different taxonomic groups. The recommended guideline values are expressed to two significant figures, unless otherwise required or indicated by the original toxicity study. The guideline values apply to the total element or substance in an unfiltered sample, unless otherwise specified. It should be noted, however, that certain information about a parameter changes over time, and that the data presented in the fact sheets may not reflect current use patterns. The guidelines and their supporting documents will be reviewed and updated following national priorities and as further relevant information becomes available.

Information on the implementation of guidelines for the protection of aquatic life can be found in the Appendix IV of CCREM (1987). The CCME Task Group recognizes the importance of providing the most up-to-date scientific and technical guidance on implementing national environmental quality guidelines. For this reason, an update of Appendix IV, entitled "Scientific and Technical Guidance on Canadian Water Quality Guideline Implementation", is currently being written and will be released shortly.

For waters of superior quality or that support valuable biological resources, the CCME nondegradation policy states that the degradation of the existing water quality should always be avoided. The natural background concentrations of parameters and their range should also be taken into account in the design of monitoring programs and the interpretation of the resulting data.

In order to apply this scientific information, for example to recommend site-specific water quality objectives, many factors such as the local water quality, resident biotic species, local water demands, and other elements have to be considered. When developing or using guidelines and site-specific objectives for aquatic life, the aquatic ecosystem should be viewed as a whole unit, not as isolated organisms affected by one or a few pollutants. The aquatic ecosystem is part of a complex system with aquatic and terrestrial components and should not be studied in isolation.

Since the release of *Canadian Water Quality Guidelines* (CCREM 1987), it has been recognized that water quality guidelines for highly persistent, bioaccumulative substances such as polychlorinated biphenyls (PCBs), toxaphene, and DDT have a high level of scientific uncertainty and limited practical management value, and are, therefore, no longer recommended. For these substances, it is more appropriate to use the respective tissue residue guidelines and/or sediment quality guidelines.

It has been recognized that the definition of the terms criteria, guidelines, objectives, and standards varies widely among jurisdictions and users. For the purpose of this chapter, these terms will be defined as follows:

- **Criteria:** scientific data evaluated to derive the recommended limits for water uses.
- **Water quality guideline:** numerical concentration or narrative statement recommended to support and maintain a designated water use.
- **Water quality objective:** a numerical concentration or narrative statement that has been established to support and protect the designated uses of water at a specified site.
- **Water quality standard:** an objective that is recognized in enforceable environmental control laws of a level of government.

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Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Introduction. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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Excerpt from Publication No. 1299; ISBN 1-896997-34-1

Aussi disponible en français.

Canadian Council of Ministers of the Environment

CCME

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Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,1,1-Trichloroethane **CASRN** 71556	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2,2- Tetrachloroethene PCE (Tetrachloroethylene) **CASRN** 127184	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	110	1993	*No data*	Insufficient data	1993
1,1,2,2-Tetrachlorethane **CASRN** 79345	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2-Trichloroethene TCE (Trichloroethylene) **CASRN** 79-01-6	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	21	1991	*No data*	Insufficient data	1991

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3,4-Tetrachlorobenzene **CASRN** 634662	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	1.8	1997	*No data*	Insufficient data	1997
1,2,3,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3-Trichlorobenzene **CASRN** 87616	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	8	1997	*No data*	Insufficient data	1997

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,4,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
1,2,4-Trichlorobenzene **CASRN** 120801	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	24	1997	*No data*	5.4	1997
1,2-Dichlorobenzene **CASRN** 95501	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	0.7	1997	*No data*	42	1997
1,2-Dichloroethane **CASRN** 1070602	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	100	1991	*No data*	Insufficient data	1991
1,3,5-Trichlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
1,3-Dichlorobenzene **CASRN** 541731	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	150	1997	*No data*	Insufficient data	1997

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,4-Dichlorobenzene **CASRN** 106467	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	26	1997	*No data*	Insufficient data	1997
1,4-Dioxane		NRG	NRG	2008	NRG	NRG	2008
3-Iodo-2-propynyl butyl carbamate IPBC **CASRN** 55406-53-6	Organic Pesticides Carbamate pesticides	*No data*	1.9	1999	*No data*	*No data*	*No data*
Acenaphthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	5.8	1999	*No data*	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Acenaphthylene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	*No data*	1999	*No data*	*No data*	1999
Acridine PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	4.4	1999	*No data*	Insufficient data	1999
Aldicarb **CASRN** 116063	Organic Pesticides Carbamate pesticides	*No data*	1	1993	*No data*	0.15	1993
Aldrin	Organic Pesticides Organochlorine compounds	*No data*	~~0.004~~	1987	*No data*	*No data*	*No data*
Aluminium	Inorganic	*No data*	Variable	1987	*No data*	*No data*	*No data*
Ammonia (total)	Inorganic Inorganic nitrogen compounds	*No data*	Table	2001	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Ammonia (un-ionized) **CASRN** 7664417	Inorganic Inorganic nitrogen compounds	*No data*	19	2001	*No data*	*No data*	*No data*
Aniline **CASRN** 62533	Organic	*No data*	2.2	1993	*No data*	Insufficient data	1993
Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.012	1999	*No data*	Insufficient data	1999
Arsenic **CASRN** none	Inorganic	*No data*	5	1997	*No data*	12.5	1997
Atrazine **CASRN** 1912249	Organic Pesticides Triazine compounds	*No data*	1.8	1989	*No data*	*No data*	*No data*
Benz(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.018	1999	*No data*	Insufficient data	1999

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzene **CASRN** 71432	Organic Monocyclic aromatic compounds	*No data*	370	1999	*No data*	110	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.015	1999	*No data*	Insufficient data	1999
Beryllium	Inorganic	No data	No data	2015-02-23	No data	No data	2015-02-23
Boron	Inorganic	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	NRG	NRG	2009

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Bromacil **CASRN** 314409	Organic Pesticides	*No data*	5	1997	*No data*	Insufficient data	1997
Bromoxynil	Organic Pesticides Benzonitrile compounds	*No data*	5	1993	*No data*	Insufficient data	1993
Cadmium **CASRN** 7440439	Inorganic	1.0	0.09	2014	NRG	0.12	2014
Captan **CASRN** 133062	Organic Pesticides	*No data*	1.3	1991	*No data*	*No data*	*No data*
Carbaryl **CASRN** 63252	Organic Pesticides Carbamate pesticides	3.3	0.2	2009	5.7	0.29	2009
Carbofuran **CASRN** 1564662	Organic Pesticides Carbamate pesticides	*No data*	1.8	1989	*No data*	*No data*	*No data*
Chlordane	Organic Pesticides Organochlorine compounds	*No data*	~~0.006~~	1987	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Chloride	Inorganic	640,000 µg/L or 640 mg/L	120,000 µg/L or 120 mg/L	2011	NRG	NRG	2011
Chlorothalonil **CASRN** 1897456	Organic Pesticides	*No data*	0.18	1994	*No data*	0.36	1994
Chlorpyrifos **CASRN** 2921882	Organic Pesticides Organophosphorus compounds	0.02	0.002	2008	NRG	0.002	2008
Chromium, hexavalent (Cr(VI)) **CASRN** 7440473	Inorganic	*No data*	1	1997	*No data*	1.5	1997
Chromium, trivalent (Cr(III)) **CASRN** 7440473	Inorganic	*No data*	8.9	1997	*No data*	56	1997
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	Insufficient data	1999	*No data*	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Colour **CASRN** N/A	Physical	*No data*	Narrative	1999	*No data*	Narrative	1999
Copper	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Cyanazine **CASRN** 2175462	Organic Pesticides Triazine compounds	*No data*	2	1990	*No data*	*No data*	*No data*
Cyanide	Inorganic	*No data*	5 (as free CN)	1987	*No data*	*No data*	*No data*
Debris **CASRN** N/A	Physical	*No data*	*No data*	*No data*	*No data*	Narrative	1996
Deltamethrin **CASRN** 52918635	Organic Pesticides	*No data*	0.0004	1997	*No data*	Insufficient data	1997
Deposited bedload sediment	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Insufficient data	1999	*No data*	Insufficient data	1999
Di(2-ethylhexyl) phthalate **CASRN** 117817	Organic Phthalate esters	*No data*	16	1993	*No data*	Insufficient data	1993

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Di-n-butyl phthalate **CASRN** 84742	Organic Phthalate esters	*No data*	19	1993	*No data*	Insufficient data	1993
Di-n-octyl phthalate **CASRN** 117840	Organic Phthalate esters	*No data*	Insufficient data	1993	*No data*	Insufficient data	1993
Dibromochloromethane	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Dicamba **CASRN** 1918009	Organic Pesticides Aromatic Carboxylic Acid	*No data*	10	1993	*No data*	*No data*	*No data*
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	*No data*	~~0.001~~	1987	*No data*	*No data*	*No data*
Dichlorobromomethane	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichloromethane Methylene chloride **CASRN** 75092	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	98.1	1992	*No data*	Insufficient data	1992

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	0.2	1987	*No data*	*No data*	*No data*
Diclofop-methyl **CASRN** 51338273	Organic Pesticides	*No data*	6.1	1993	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Didecyl dimethyl ammonium chloride DDAC **CASRN** 7173515	Organic Pesticides	*No data*	1.5	1999	*No data*	Insufficient data	1999
Diethylene glycol **CASRN** 111466	Organic Glycols	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
Diisopropanolamine DIPA **CASRN** 110974	Organic	*No data*	1600	2005	*No data*	Insufficient data	2005
Dimethoate **CASRN** 60515	Organic Pesticides Organophosphorus compounds	*No data*	6.2	1993	*No data*	Insufficient data	1993
Dinoseb **CASRN** 88857	Organic Pesticides	*No data*	0.05	1992	*No data*	*No data*	*No data*
Dissolved gas supersaturation **CASRN** N/A	Physical	*No data*	Narrative	1999	*No data*	Narrative	1999
Dissolved oxygen DO **CASRN** N/A	Inorganic	*No data*	Variable	1999	*No data*	>8000 & Narrative	1996

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Endosulfan	Organic Pesticides Organochlorine compounds	0.06	0.003	2010	0.09	0.002	2010
Endrin	Organic Pesticides Organochlorine compounds	*No data*	~~0.0023~~	1987	*No data*	No data	*No data*
Ethylbenzene **CASRN** 100414	Organic Monocyclic aromatic compounds	*No data*	90	1996	*No data*	25	1996
Ethylene glycol **CASRN** 107211	Organic Glycols	*No data*	192 000	1997	*No data*	Insufficient data	1997
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.04	1999	*No data*	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	3	1999	*No data*	Insufficient data	1999
Fluoride	Inorganic	*No data*	120	2002	*No data*	NRG	2002
Glyphosate **CASRN** 1071836	Organic Pesticides Organophosphorus compounds	27,000	800	2012	NRG	NRG	2012
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	*No data*	~~0.01~~	1987	*No data*	*No data*	*No data*
Hexachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	Insufficient data	1997	*No data*	Insufficient data	1997
Hexachlorobutadiene HCBD **CASRN** 87683	Organic Halogenated aliphatic compounds	*No data*	1.3	1999	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	*No data*	0.01	1987	*No data*	*No data*	*No data*
Imidacloprid **CASRN** 13826413		*No data*	0.23	2007	*No data*	0.65	2007
Iron	Inorganic	*No data*	300	1987	*No data*	*No data*	*No data*
Lead	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Linuron **CASRN** 41205214	Organic Pesticides	*No data*	7	1995	*No data*	*No data*	1995
Mercury **CASRN** 7439976	Inorganic	*No data*	0.026	2003	*No data*	0.016	2003
Methoprene **CASRN** 40596698		*No data*	0.09 (Target Organism Management value: 0.53)	2007	*No data*	Insufficient data	2007

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methyl tertiary-butyl ether MTBE **CASRN** 1634044	Organic Non-halogenated aliphatic compounds Aliphatic ether	*No data*	10 000	2003	*No data*	5 000	2003

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) MCPA **CASRN** 94746	Organic Pesticides	*No data*	2.6	1995	*No data*	4.2	1995
Methylmercury	Organic	*No data*	0.004	2003	*No data*	NRG	2003
Metolachlor **CASRN** 51218452	Organic Pesticides Organochlorine compounds	*No data*	7.8	1991	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Metribuzin **CASRN** 21087649	Organic Pesticides Triazine compounds	*No data*	1	1990	*No data*	*No data*	*No data*
Molybdenum	Inorganic	*No data*	73	1999	*No data*	*No data*	*No data*
Monobromomethane Methyl bromide	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Monochlorobenzene **CASRN** 108907	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	1.3	1997	*No data*	25	1997
Monochloromethane Methyl chloride	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Monochlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	7	1987	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	1.1	1999	*No data*	1.4	1999
Nickel	Inorganic	*No data*	Equation	1987	*No data*	*No data*	*No data*
Nitrate **CASRN** 14797-55-8	Inorganic Inorganic nitrogen compounds	550,000 µg/L or 550 mg/L	13,000 µg/L or 13 mg/L	2012	1,500,000 µg/L or 1500 mg/L	200,000 µg/L or 200 mg/L	2012

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nitrite	Inorganic Inorganic nitrogen compounds	*No data*	60 NO_2-N	1987	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	*No data*	1	2002	*No data*	0.7	2002
Nutrients		*No data*	Guidance Framework	2004	*No data*	Guidance framework	2007
Pentachlorobenzene **CASRN** 608935	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	6	1997	*No data*	Insufficient data	1997
Pentachlorophenol PCP	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	0.5	1987	*No data*	*No data*	*No data*
Permethrin **CASRN** 52645531	Organic Pesticides Organochlorine compounds	*No data*	0.004	2006	*No data*	0.001	2006
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.4	1999	*No data*	Insufficient data	1999

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Phenols (mono- & dihydric) **CASRN** 108952	Organic Aromatic hydroxy compounds	*No data*	4	1999	*No data*	*No data*	*No data*
Phenoxy herbicides 2,4 D; 2,4-Dichlorophenoxyacetic acid	Organic Pesticides	*No data*	4	1987	*No data*	*No data*	*No data*
Phosphorus	Inorganic	*No data*	Guidance Framework	2004	*No data*	Guidance Framework	2007
Picloram **CASRN** 1918021	Organic Pesticides	*No data*	29	1990	*No data*	*No data*	*No data*
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	*No data*	~~0.001~~	1987	*No data*	~~0.01~~	1991
Propylene glycol **CASRN** 57556	Organic Glycols	*No data*	500 000	1997	*No data*	Insufficient data	1997

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	0.025	1999	*No data*	Insufficient data	1999

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
pH	Inorganic Acidity, alkalinity and pH	*No data*	6.5 to 9.0	1987	*No data*	7.0 to 8.7 & Narrative	1996
Quinoline PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	3.4	1999	*No data*	Insufficient data	1999

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Reactive Chlorine Species total residual chlorine, combined residual chlorine, total available chlorine, hypochlorous acid, chloramine, combined available chlorine, free residual chlorine, free available chlorine, chlorine-produced oxidants	Inorganic Reactive chlorine compunds	*No data*	0.5	1999	*No data*	0.5	1999
Salinity	Physical	*No data*	*No data*	*No data*	*No data*	Narrative	1996
Selenium	Inorganic	*No data*	1	1987	*No data*	*No data*	*No data*
Silver	Inorganic	*No data*	0.1	1987	*No data*	*No data*	*No data*
Simazine **CASRN** 122349	Organic Pesticides Triazine compounds	*No data*	10	1991	*No data*	No data	*No data*
		Concentration	Concentration	Date	Concentration	Concentration	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Sodium adsorption ratio SAR		*No data*	*No data*	*No data*	*No data*	*No data*	*No data*
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Streambed substrate	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Styrene **CASRN** 100425	Organic Monocyclic aromatic compounds	*No data*	72	1999	*No data*	*No data*	*No data*
Sulfolane Bondelane **CASRN** 126330	Organic Organic sulphur compound	*No data*	50 000	2005	*No data*	Insufficient data	2005
Suspended sediments TSS	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Tebuthiuron **CASRN** 34014181	Organic Pesticides	*No data*	1.6	1995	*No data*	Insufficient data	1995

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Temperature	Physical Temperature	*No data*	Narrative	1987	*No data*	Narrative	1996
Tetrachloromethane Carbon tetrachloride **CASRN** 56235	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	13.3	1992	*No data*	Insufficient data	1992
Tetrachlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	1	1987	*No data*	*No data*	*No data*
Thallium	Inorganic	*No data*	0.8	1999	*No data*	*No data*	*No data*
Toluene **CASRN** 108883	Organic Monocyclic aromatic compounds	*No data*	2	1996	*No data*	215	1996
Toxaphene	Organic Pesticides Organochlorine compounds	*No data*	~~0.008~~	1987	*No data*	*No data*	*No data*
Triallate **CASRN** 2303175	Organic Pesticides Carbamate pesticides	*No data*	0.24	1992	*No data*	*No data*	*No data*

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Tribromomethane Bromoform	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992
Tributyltin	Organic Organotin compounds	*No data*	0.008	1992	*No data*	0.001	1992
Trichlorfon **CASRN** 52-68-6		1.1	0.009	2012	NRG	NRG	2012
Trichloromethane Chloroform **CASRN** 67663	Organic Halogenated aliphatic compounds Halogenated methanes	*No data*	1.8	1992	*No data*	Insufficient data	1992
Trichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	*No data*	18	1987	*No data*	*No data*	*No data*
Tricyclohexyltin	Organic Organotin compounds	*No data*	Insufficient data	1992	*No data*	Insufficient data	1992

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

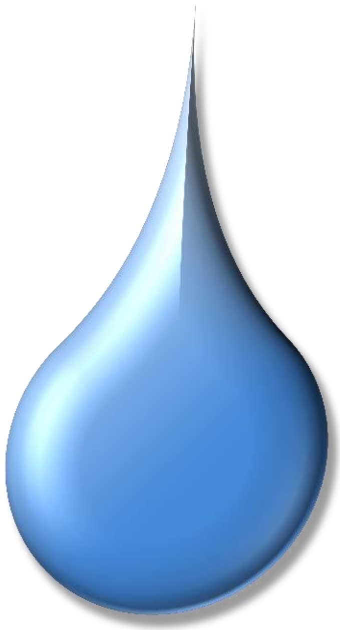
		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Trifluralin **CASRN** 1582098	Organic Pesticides Dinitroaniline pesticides	*No data*	0.2	1993	*No data*	*No data*	*No data*
Triphenyltin	Organic Organotin compounds	*No data*	0.022	1992	*No data*	*No data*	1992
Turbidity	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	Narrative	1999	*No data*	Narrative	1999
Uranium **CASRN** 7440-61-1	Inorganic	33	15	2011	NRG	NRG	2011
Zinc	Inorganic	*No data*	30	1987	*No data*	*No data*	*No data*

Chemical name	Chemical groups

Chemical name	Chemical groups
Sodium adsorption ratio SAR	

APPENDIX B

2018 Produced Water Toxicity Results (Microtox, Sea Urchin Fertilization and Threespine Stickleback Toxicity) (HITS)



Encana Deep Panuke Produced Water 2018 Toxicity Testing

Final Discussion

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1.0 Background and Introduction

Harris Industrial Testing Service Ltd. (HITS) is a privately owned and operated testing facility in South Rawdon, Nova Scotia. HITS has been collecting, culturing and testing *Gasterosteus aculeatus* (commonly known as Threespine Stickleback or TSS) since 1997 and its CALA accredited (ISO 17025) scope of testing includes the acute toxicity testing of this species.

HITS was contracted by Encana Corporation to coordinate and conduct aquatic toxicity testing on Deep Panuke Produced Water. Selected tests were TSS acute toxicity testing, Microtox toxicity testing, and Echinoid Fertilization testing. This report summarizes and provides basic interpretation of the results from this testing which was conducted at HITS and AquaTox Testing and Consulting Inc. (AquaTox) in Puslinch, ON in January 2018.

2.0 Methods

The Deep Panuke platform was sampled on January 17, 2018 by Isaac Fraser at 0630 hrs. Sampling took place on the produced water discharge line. Three 20 L jerry cans were delivered to HITS lab on January 18, 2018 by Bluewater. The sample was assigned the Lab ID number of 18-29. The sample was homogenized and a sub-sample was taken, packaged and delivered to the Purolator Depot in Dartmouth for air shipment to AquaTox on January 18, 2018. It was received January 19, 2018.

2.1 TSS Acute Toxicity Testing

The TSS test was conducted at HITS lab according to Environment Canada's test protocol EPS 1/RM/10 (Environment Canada, 1990) within the five days allowed between sampling and test commencement.

HITS Lab Method "Tox 9B" is held on file in the lab. This method describes the following:

- holding of test organisms;
- preparation of test concentrations;
- preparation of reference toxicant;
- conduct of testing;
- statistical analyses.

One six concentration test was conducted on the sample with one replicate per concentration. Concentrations were determined after initial measurement of the sample salinity (140‰). Since the salinity was higher than normal salinity values (~ 30‰), one additional concentration was tested. The test was run from January 18 – 22, 2018.

At termination, the 96 hour LC50 result was calculated using the Comprehensive Environmental Toxicity Information System (CETIS, 2001 – 2014). A test for statistical significance between two LC50s was run to compare the two LC50 endpoints from 2017 and 2018 (Environment Canada, 2002).

2.2 Microtox Toxicity Testing

The Microtox test was conducted at AquaTox according to the protocol EPS 1/RM/24 (Environment Canada, 1992) on January 19, 2018, within the maximum three day holding time allowed. There were no deviations from the protocol.

A test for statistical significance between two IC50s was run to compare the two IC50 endpoints from 2017 and 2018 (Environment Canada, 2002).

2.3 Echinoid Fertilization Testing

The Echinoid Fertilization test was conducted at AquaTox according to the protocol EPS 1/RM/27, 2nd Edition (Environment Canada, 2011) on January 23, 2018.

There were two deviations from the protocol. First, the salinity of the 100% sample as measured at AquaTox was 122‰. The salinity of the 100%, 30%, and 9% exposure concentrations exceeded the maximum salinity of 32‰ allowed by the test method cited above. Second, the three day holding time as specified by the test method was exceeded. Testing was conducted with the consent of the client.

Since a different test species was used in 2017 the toxicity results for the 2018 sample were not statistically compared between 2017 and 2018.

3.0 Results

Table 1 summarizes the results for toxicity testing from March 2015 to January 2018. Note that TSS testing was not conducted in 2015.

Table 1. Deep Panuke Toxicity Results (2015 – 2018).

	TSS		Microtox		Echinoid Fertilization		Salinity
Date	LC_{50} Value	95% C.L.	IC_{50} Value	95% C.L.	IC_{25} Value	95% C.L.	**(‰)**
Mar. 24 2015	Not conducted		5.65%	(4.80 – 6.64%)	34.3%	(28.0 – 39.4%)	116
Mar. 12 2016	12.5%	(10.0 – 15.6%)	1.02%	(0.93 – 1.12%)	1.86%	(1.82 – 1.91%)	14
Mar. 07 2017	16.5%	(14.5 – 18.8%)	29.8%	(28.6 – 31.2%)	2.18%	(1.93 – 2.42%)	115
Jan. 17 2018	11.5%	(8.59 – 15.4%)	14.2%	(11.7 – 17.2%)	3.38%	(2.65 – 3.99%)	140

4.0 Discussion

Current local offshore waste treatment guidelines do not have pass/fail criteria (Canada-Newfoundland Offshore Petroleum Board *et al*, 2002), however most effluent discharge regulations stipulate that if an effluent has greater than 50% mortality at the 100% concentration it should be considered a failure. Based on this industry standard, the Deep Panuke Produced Water should be considered toxic to TSS. There are no pass/fail criteria available for Microtox and Echinoid fertilization toxicity tests.

Normal seawater salinity values range from 28 – 32‰. The salinity value for this platform (140‰) is much higher than normal seawater. Based on the results of the above testing, the sensitivity of TSS, Microtox and Echinoids to the Deep Panuke Produced Water may be influenced by high salinity, toxicity of petroleum hydrocarbons, or by a combination of both. This is discussed in more detail below.

4.1 TSS Acute Toxicity Testing

HITS tested one additional concentration in the TSS LC50 test at the low end (3.13%) in order to better assess the sample's toxicity at lower salinity levels. Salinity remained slightly higher than normal at the 3.13% concentration (32‰). Similar to 2017 TSS testing, 100% mortality occurred in the 100, 50, and 25% concentrations, with additional mortality in the 12.5% and 6.25% concentrations of 50% and 10% in 2018, respectively. All validity criteria for this test were met.

From these results, mortality may have occurred at the higher concentrations due to high salinity, toxicity from petroleum hydrocarbons, or a combination of both. The LC50 result for the 2018 Deep Panuke produced water is statistically lower than the LC50 result for 2017, and therefore the sample may be considered significantly more toxic to TSS than in 2017. In other words, the result of the statistical comparison shows that the increased toxicity of the sample to TSS is likely not attributable to chance alone.

4.2 Microtox Toxicity Testing

Based on the salinity values reported in the Echinoid Fertilization test, it can be extrapolated that normal salinity levels were reached at the 3.13% concentration. Significant inhibition occurred in the Microtox test at the statistically estimated concentration of 14.2%. Therefore, it would appear that significant inhibition occurred in concentrations with higher than normal salinity values. From these results, inhibition likely occurred due to high salinity, toxicity from petroleum hydrocarbons, or a combination of both.

The reference toxicant test run in conjunction with this sample produced an IC50 result that exceeded the 95% warning limits for historical data. Due to the expectation that up to 5% of reference toxicant IC50 results may fall outside these warning limits, as well as no other unusual circumstances being observed in association with the testing, the test result as reported should be considered acceptable.

The IC50 result for the 2018 Deep Panuke produced water is statistically lower than the IC50 result for 2017, and therefore the 2018 sample may be considered significantly more toxic to Microtox than in 2017.

4.3 Echinoid Fertilization Testing

The salinity level of this sample fell within the normal range at the 2.7% dilution concentration. Test toxicity (*i.e.* fertilization inhibition) occurred at the statistically estimated concentration of 3.38% and therefore inhibition likely occurred due to high salinity, toxicity from petroleum hydrocarbons, or a combination of both.

Since a different test species was used in 2017 the toxicity results for this platform cannot be compared statistically with those from 2018.

5.0 References

Canada-Newfoundland Offshore Petroleum Board, Canada-Nova Scotia Offshore Petroleum Board & National Energy Board, "Offshore Waste Treatment Guidelines, BACKGROUNDER, August, 2002. https://www.cnsopb.ns.ca/sites/default/files/pdfs/owtg_backgrounder.pdf

Environment Canada, "Biological Test Method: Toxicity Test Using Luminescent Bacteria", Report EPS 1/RM/24, 1992.

Environment Canada, "Biological Test Method: Acute Lethality Test Using Threespine Stickleback, *Gasterosteus aculeatus*", Report EPS 1/RM/10, 1990 with 2000 amendments.

Environment Canada, "Biological Test Method: Fertilization Assay Using Echinoids (Sea Urchins and Sand Dollars), Report EPS 1/RM/27, 2nd Edition, 2011.

Environment Canada, "Test for Statistical Significance between Two LC50's", Excel application, created 2002.

Tidepool Scientific Software, 2001 - 2014. Comprehensive Environmental Toxicity Information System – CETIS v1.8.7.20.

FISH TOXICITY REPORT (LC_{50})

CLIENT INFORMATION

Encana Corporation
Suite 701, 1700 Hollis St.
Halifax, N.S. B3J 3M8
Contact: Marielle Thillet

TEST FACILITY INFORMATION

Harris Industrial Testing Service Ltd.
1320 Ashdale Rd., South Rawdon
Nova Scotia B0N 1Z0
Ph : 902 757-0232 Fax: 902 757-2839 office@harrisindustrial.info

SAMPLE INFORMATION

Lab Identification #: 18-29
Sample Name/Location: Deep Panuke 2018-01-17 PW Toxicity
Sampling Method: Grab
Sampler Name: I. Fraser
Date & Time Sampled: Jan. 17 2018 0630 Hrs
Date & Time Received: Jan. 18 2018 1300 Hrs
Sample Description: Light grey, translucent liquid.

GENERAL TEST INFORMATION

Reference Method:
EPS 1/RM/10 July 1990 with 2000 Amendments
Type: LC50 Tox 9B
General Test Procedures held on file
Test Organism: *Gasterosteus aculeatus*
(Threespine stickleback)

PRE-TEST PARAMETERS

Pre-test Temp. (°C): 14.0
Pre-test D.O. (mg/L): 4.8
Pre-test pH: 7.0
Sample Conductivity (µS/cm): 143,700
Sample Salinity (‰): 140
Control Salinity (‰): 30

SAMPLE PRE-TREATMENT

Sample Homogenized: Yes
pH Adjusted: No
Mandatory Pre-aeration: Yes
Duration: 30 minutes Rate: 6.5 $\pm$ 1 ml/min/L
Time: 1345 hrs D.O. (mg/L): 4.0
Continued: Yes Duration: 90 min. @ 1415 hrs
D.O. (mg/L): 5.0

TEST CONDITIONS

Date & Time Test Initiated: Jan. 18 2018 1545 Hrs
Date & Time Test Terminated: Jan. 22 2018 1545 Hrs

Fish Batch #: 57
% Mortality over 7 days prior to test: 3.5
Test Volume (L): 20
Depth (cm): 36.2
Replicates: No
Number of fish per vessel: 10

Loading Density (g/L): 0.39
Mean Fork Length (mm): 48 $\pm$ 4.8 SD
Range (mm): 38 - 55
Mean Wet Weight (g): 0.77 $\pm$ 0.31 SD
Range (g): 0.31 – 1.32

Temperature: 15 ± 1°C
Photoperiod: 16L/8D
Lux: 100 – 500
Static Test, Duration: 96 hours
Control/Dilution Water: Natural Seawater
Deviations from Test Method: No
Description: N/A

TEST PARAMETERS

	INITIAL (0 hrs)				FINAL (96 hrs)		
CONC. %	TEMP. °C	D.O. mg/L	pH	SALINITY ‰	TEMP. °C	D.O. mg/L	pH
100	14.0	5.0	7.2	140	14.5	7.4	7.1
50	14.5	7.2	7.5	74	15.0	7.7	7.5
25	14.0	8.0	7.7	56	14.5	7.7	7.6
12.5	14.0	8.0	7.8	40	14.0	8.3	7.7
6.25	14.0	8.1	7.8	35	14.5	8.2	7.7
3.13	14.0	8.0	7.8	34	14.5	8.4	7.8
Control	14.0	8.0	7.9	30	14.5	8.2	7.8

TEST RESULTS

CONC. %	TOTAL MORTALITY # 24 hrs	48 hrs	72 hrs	96 hrs	PERCENT MORTALITY % 24 hrs	48 hrs	72 hrs	96 hrs
100	10/10	10/10	10/10	10/10	100	100	100	100
50	10/10	10/10	10/10	10/10	100	100	100	100
25	10/10	10/10	10/10	10/10	100	100	100	100
12.5	3/10	5/10	5/10	5/10	30	50	50	50
6.25	0/10	0/10	1/10	1/10	0	0	10	10
3.13	0/10	0/10	0/10	0/10	0	0	0	0
Control	0/10	0/10	0/10	0/10	0	0	0	0

CONC. %	TOTAL STRESS # 24 hrs	48 hrs	72 hrs	96 hrs	PERCENT STRESS % 24 hrs	48 hrs	72 hrs	96 hrs
100	0/10	0/10	0/10	0/10	0	0	0	0
50	0/10	0/10	0/10	0/10	0	0	0	0
25	0/10	0/10	0/10	0/10	0	0	0	0
12.5	0/10	0/10	0/10	0/10	0	0	0	0
6.25	0/10	0/10	0/10	0/10	0	0	0	0
3.13	0/10	0/10	0/10	0/10	0	0	0	0
Control	0/10	0/10	0/10	0/10	0	0	0	0

96 HR LC_{50} RESULTS

LC_{50} Value: 11.5%
95% Confidence Limits: 8.59 – 15.4%
Statistical Method: Untrimmed Spearman Karber - CETIS

REFERENCE TOXICANT DATA

Performed under laboratory conditions as above, no deviations
Batch: 57 Test Date: Jan. 18 – 22 2018
Reference Substance: Phenol

LC_{50} Value: 15.4 mg/L
95% Confidence Limits: 12.9 – 18.3 mg/L
Historical Mean: 15.7 mg/L
Warning Limits ± 2 SD: 12.0 – 20.6 mg/L

COMMENTS

Test meets all conditions for test validity.
D.O. meter was set to maximum salinity setting of 40 ‰. As salinity increases, D.O. value decreases, therefore reported D.O. measurements for 100, 50 & 25% sample concentrations are higher than true values.
Sample dissolved oxygen level remained below 70% of saturation value after maximum allowable 2 hours pre-aeration.

TEST AUTHORIZATION AND VERIFICATION

Analyst(s): K. Marks, G. Harris & A. Huybers
Verified by: K. Marks
Date: Jan. 22 2018
Signed: K Marks

REFERENCES

Tidepool Scientific Software, 2001 - 2014. Comprehensive Environmental Toxicity Information System – CETIS v1.8.7.20

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Rd.
Puslinch ON N0B 2J0
Tel: (519) 763-4412 Fax: (519) 763-4419

TOXICITY TEST REPORT

MICROTOX®

EPS 1/RM/24

Work Order :	235223
Sample Number :	53565

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.	Time Collected :	06:30
Location :	South Rawden NS	Date Collected :	2018-01-17
Substance :	2018-01-17 PW Toxicity	Sample Volume :	1 x 1 L jar
Sampling Method :	Grab	Date Received :	2018-01-19
Sampled By :	I. Fraser	Date Tested :	2018-01-19
Sample Description :	Clear, colourless, strong odour	Temp. on arrival :	7.0°C

Test Method : Toxicity Test Using Luminescent Bacteria, Protocol EPS 1/RM/24, Environment Canada, 1992.

TEST RESULTS

Test Endpoint	Value	95% Confidence Limits	Calculation Method
15 minute IC50	14.2%	11.7-17.2	Least Square Regression

The results reported relate only to the sample tested.

REFERENCE TOXICANT DATA

Reagent Batch :	16M4144A	15 minute IC50 :	1.09 mg/L*
Expiry Date :	12/2018	95% Confidence Limits :	0.88-1.35 mg/L
Date Tested (yyyy-mm-dd) :	2018-01-19	Historical Mean IC50 :	0.82 mg/L
Reference Substance :	Zinc (as zinc sulphate)	Warning Limits (± 2SD) :	0.62-1.07 mg/L
Statistical Method :	Least Square Regression	Analyst(s):	AW

CONDITIONS OF ACUTE MICROTOX TEST

Test Organism :	*Vibrio fischeri*	Test Initiation Time :	14:45
Reagent Batch :	16M4144A	Observation Time(s) :	15 minutes
Date Reagent Received :	2017-03-07	Sample Pre-aeration/Aeration :	None
Reagent Holding Temperature :	-24 °C	Sample pH :	7.2
Analyzer Model Number :	M500	pH Adjustment :	None
Test Well Temperature :	15.0 ± 0.3 °C	Salinity Adjustment :	Not required
Highest Concentration Tested :	50 %	Final Salinity :	≥ 2 %
Number of Controls :	2	Dilution Water :	AquaTox Diluent
Number of Concentrations Tested :	8	Sample Storage :	4 ± 2 °C
Number of Replicates :	2	Colour Correction :	No
Appearance of Test Solutions :	No changes noted.	Analyst(s):	AW
		Test Method Deviation(s) :	None

*Note: The reference toxicant test result exceeded the 95% warning limits for historical data. Approximately 5% of the results would be expected to fall outside the warning limits. No other unusual circumstances were observed and therefore the test result is considered acceptable.

Date: 2018-02-16
yyyy-mm-dd

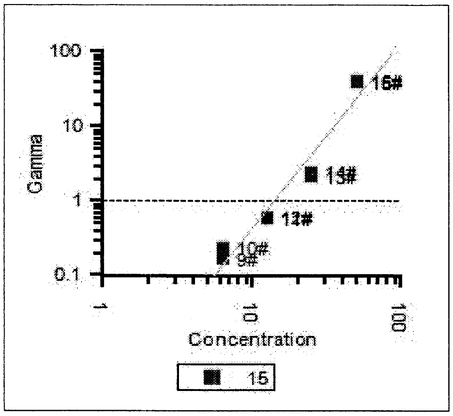
Approved by: [signature]
Project Manager

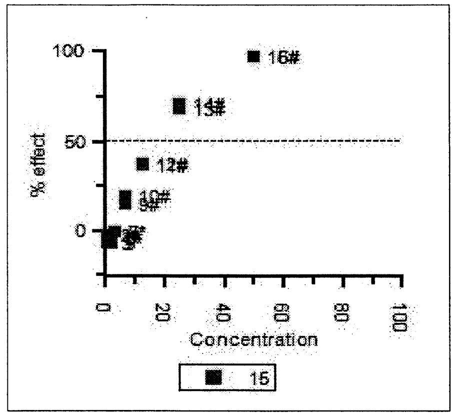
AQUATOX

TOXICITY TEST REPORT

MICROTOX®
EPS 1/RM/24

Work Order : 235223
Sample Number : 53565





Time	Sample	Conc. (%)	I0	It	Gamma	% Effect
15 Mins						
	Control	0.00	92	84	0.9101#	
	Control	0.00	92	84	0.9071#	
	Control	0.00	91	84	0.9289#	
	Control	0.00	91	80	0.8838#	
	1	0.39	89	83	-0.0349*	-3.62%
	2	0.39	90	83	-0.0203*	-2.07%
	3	0.78	92	89	-0.0651*	-6.96%
	4	0.78	91	85	-0.0364*	-3.78%
	5	1.56	89	86	-0.0606*	-6.45%
	6	1.56	92	87	-0.0387*	-4.02%
	7	3.13	91	83	-0.0010*	-0.10%
	8	3.13	94	86	-0.0070*	-0.70%
	9	6.25	93	72	0.1686#	14.43%
	10	6.25	96	70	0.2381#	19.23%
	11	12.50	96	55	0.5748#	36.50%
	12	12.50	89	51	0.5931#	37.23%
	13	25.00	91	26	2.122#	67.97%
	14	25.00	95	25	2.404#	70.62%
	15	50.00	93	2	38.56#	97.47%
	16	50.00	95	2	40.46#	97.59%

- included, * - invalid

Statistics:

Data: 15 Mins

EC50 Concentration: 14.15%
(95% Confidence Range: 11.65 to 17.19)
95% Confidence Factor: 1.215
Estimating Equation: LOG C = 0.3795 x LOG G +1.151
Correction Factor: 0.9075
Slope: 2.482
Coeff of Determination (R^2): 0.9419

Test Data Reviewed By : VC
Date : 2018-01-25

AquaTox Testing & Consulting Inc.
B-11 Nicholas Beaver Rd.
Puslinch ON N0B 2J0
Tel: (519) 763-4412 Fax: (519) 763-4419

TOXICITY TEST REPORT

Lytechinus pictus
EPS 1/RM/27

Work Order : 235223
Sample Number : 53565

SAMPLE IDENTIFICATION

Company :	Harris Industrial Testing Service Ltd.		
Location :	South Rawden NS	Date Collected :	2018-01-17
Substance :	2018-01-17 PW Toxicity	Time Collected :	06:30
Sampling Method :	Grab	Date Received :	2018-01-19
Sampled By :	I. Fraser	Time Received :	10:45
Temp. on arrival :	7.0°C	Date Tested :	2018-01-23
Sample Description :	Clear, colourless, strong odour		

Test Method : Fertilization Assay Using Echinoids (Sea Urchins and Sand Dollars). Environment Canada, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/27, 2nd ed. (February 2011), with deviation(s) as noted below.

TEST RESULTS

Effect	Value	95% Confidence Limits	Statistical Method
IC25 (Fertilization)	3.38%	2.65-3.99	Non Linear Regression* (CETIS) a

The results reported relate only to the sample tested.

COPPER (AS COPPER SULPHATE) REFERENCE TOXICANT DATA

Date Tested :	2018-01-23	Statistical Method :	Non-Linear Regression* (CETIS)[a]
Gamete Batch :	Ur18-01-03	Historical Mean IC25 :	81 µg/L
Test Duration :	20 minutes	Warning Limits (± 2SD) :	22 - 297 µg/L
IC25 Fertilization :	39 µg/L	Analyst(s) :	DK, AS, TL
95% Confidence Limits :	36 - 43 µg/L		

The reference toxicant test was performed under the same experimental conditions as those used with the test sample.

TEST CONDITIONS

Test Vessel :	20 mL glass scintillation vial	Control/Dilution Water :	Natural Sea Water[1]
Volume per Replicate :	10 mL	Sperm Exposure Time [2]:	20 min
Number of Replicates :	4 per treatment	Egg Exposure Time :	10 min
Depth of Test Solution :	Approx. 3 cm	Total Duration of Test :	20 min
Sperm Density :	40000000 per vessel	pH Adjustment :	None
Sperm : Egg Ratio :	20000 : 1	Sample Filtration :	None
Males Used to Pool Sperm :	3	Test Aeration :	None
Females Used to Pool Eggs :	3	Test Method Deviation(s) :	Yes (see 'Comments')

[1]Pointe-du-Chene, Shediac Bay NB, no additional chemicals
[2] 10 min exposure, continued for an additional 10 min after addition of eggs

COMMENTS

Noted Deviation(s):

•The salinity of the 100% sample as submitted was 122‰. The salinity of the 100%, 30%, and 9% test concentrations exceeded the maximum salinity of 32‰ allowed by the test method cited above.

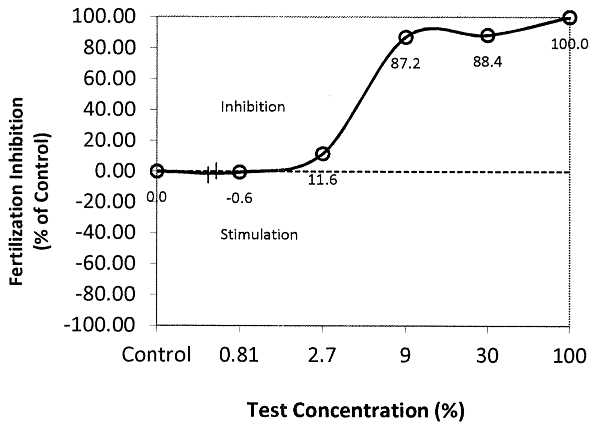
•The maximum 3 day sample holding time as specified by the test method was exceeded. Testing was conducted with the consent of the client.

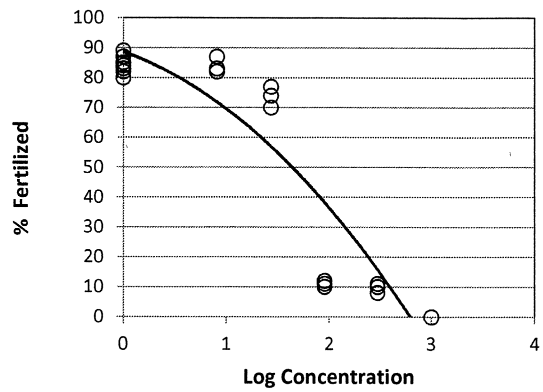
*Binomial weighting (CETIS)[a] was applied.

•All test validity criteria as specified in the test method cited above were satisfied.

Work Order : 235223
Sample Number : 53565

Sea Urchin Fertilization Inhibition





TEST ORGANISM

Adult Test Organism :	*Lytechinus pictus*	Holding Vessel :	Glass aquaria
Adult Organism Source :	Marinus Scientific	Adult Mortality Rate :	0% (previous 7 days)
Source Location :	Garden Grove CA USA	Life Stage Tested :	Gamete (sperm/egg)
Date Received :	2018-03-16	Gamete Batch Tested :	Ur18-01-03
Holding Water :	Artificial Sea Water	Reference :	Environment Canada, September 1999.[e]
Holding Temperature :	12 - 15 °C	Reference Deviation(s) :	None
Holding Salinity :	34 ± 2 ‰		

No organisms or gametes exhibiting unusual appearance, behaviour, or undergoing unusual treatment were used in the test.

REFERENCES

[a] CETIS, © 2000-2013. V.1.8.7.17. Comprehensive Environmental Toxicity Information System. Tidepool Scientific Software, McKinleyville, Calif. 95519[Program on disk and printed User's Guide].

[e]Environment Canada. "Recommended Procedure for the Importation of Test Organisms for Sublethal Toxicity Testing", Unpublished Report,September 1999, 21 p. Method Development and Applications Section, Environmental Technol. Centre, Ottawa, ON (1999).

[f]Environment Canada. 2001. Revised Procedures for Adjusting Salinity of Effluent Samples for Marine Sublethal Toxicity Testing Conducted under Environmental Effects Monitoring (EEM) Programs. Method Development and Applications Section, Environmental Technology Centre, December 2001.

Date : 2018-02-16
yyyy-mm-dd

Approved By : [signature]
Project Manager

Work Order : 235223
Sample Number : 53565

FERTILIZATION DATA

Test Conducted By : DK/AS
Enumerated By : DK

Concentration %	Replicate	Fertilized	Unfertilized	% Fertilized	Treatment Mean	Standard Deviation
Control	A	89	11	89	**84.25**	**3.77**
	B	85	15	85		
	C	83	17	83		
	D	80	20	80		
Blank	A	0	100	0	**0**	**0.00**
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		
0.02	A	–	–	–	**–**	**–**
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.07	A	–	–	–	**–**	**–**
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.24	A	–	–	–	**–**	**–**
	B	–	–	–		
	C	–	–	–		
	D	–	–	–		
0.81	A	83	17	83	**84.75**	**2.63**
	B	87	13	87		
	C	87	13	87		
	D	82	18	82		
2.7	A	74	26	74	**74.5**	**3.32**
	B	77	23	77		
	C	70	30	70		
	D	77	23	77		
9	A	12	88	12	**10.75**	**0.96**
	B	11	89	11		
	C	10	90	10		
	D	10	90	10		
30	A	8	92	8	**9.75**	**1.26**
	B	10	90	10		
	C	11	89	11		
	D	10	90	10		
100	A	0	100	0	**0**	**0.00**
	B	0	100	0		
	C	0	100	0		
	D	0	100	0		

"–" = not counted/not required

NOTES :

- Gamete viability test was performed prior to pooling of test gametes.
- A pre-test was not required.
- Preserved eggs were stored for 12 days prior to enumeration.
- No outlying data points were detected according to Grubbs Test (CETIS)[a]

Data Reviewed By : IL
Date : 2018-02-15

Work Order : 235223
Sample Number : 53565

SALINITY ADJUSTMENT

Method :	Not applicable	Salt Used :	Not applicable
Date Adjusted :	Not applicable	Aging Time :	Not applicable
Reference :	Not applicable	Aging Temperature :	Not applicable
Reference Deviation(s):	Not applicable	Aging Conditions :	Not applicable

Note: The 100% sample did not require salinity adjustment since the initial sample salinity was 122‰. Therefore the sample was tested as received.

WATER CHEMISTRY (100% CONCENTRATION)

	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)	Pre-aeration Time (h)[4]
Initial Chemistry (Test Day 0) :	20.0	7.4	6.8	95	122	00:00
Chemistry after Pre-Aeration :	–	–	–	–	–	

WATER CHEMISTRY (CONTROL/DILUTION WATER)

	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)	Pre-aeration Time (h)[3]
Initial Chemistry :	21.0	8.2	7.1	100	30	00:00
Chemistry Before Use :	–	–	–	–	–	

EXPOSURE CONCENTRATIONS WATER CHEMISTRY

Concentration %	Temp.(°C)	pH	Dissolved O_2 (mg/L)	O_2 Sat. (%)*	Salinity (‰)
Control	21.0	8.2	7.1	100	30
Blank	21.0	8.2	7.1	100	30
0.02	21.0	8.1	7.1	100	30
0.07	21.0	–	–	–	–
0.24	21.0	–	–	–	–
0.81	21.0	–	–	–	–
2.7	21.0	8.1	7.1	100	32
9	21.0	8.0	7.1	100	40
30	21.0	7.9	7.0	97	58
100	21.0	7.5	6.7	96	122

* % saturation, adjusted for temperature and barometric pressure
"–" not required/not measured
[4]at <100 bubbles/min

Data Reviewed By : JL
Date : 2018-02-16

CHAIN OF CUSTODY RECORD

AQUATOX

AquaTox Work Order No: 235223

Shipping Address: AquaTox Testing & Consulting Inc.
11B Nicholas Beaver Road, ~~RR #3~~ PUSLINCH
~~Guelph, Ontario Canada N1H 6H9~~ N0B 2J0.

Voice: (519) 763-4412 **Fax:** (519) 763-4419

P.O. Number: PANUKE
Field Sampler Name (print): I. FRASER
Signature: —
Affiliation: ENCANA
Sample Storage (prior to shipping): BY BOAT
Custody Relinquished by: GARY HARRIS
Date/Time Shipped: JAN. 18 2018

Client: HARRIS INDUSTRIAL TESTING SERVICE LTD.
1320 ASHDALE RD. ~~RR#1~~ MT. UNIACKE NS B0N 1Z0
Phone: 902 757-0232
Fax: 902 757-2839
Contact: CAROL HARRIS

Sample Identification					Analyses Requested									Sample Method and Volume		
Date Collected (yyyy-mm-dd)	Time Collected (e.g. 14:30, 24 hr clock)	Sample Name	AquaTox Sample Number	Temp. on arrival	Rainbow Trout Single Concentration	Rainbow Trout LC50	*Daphnia magna* Single Concentration	*Daphnia magna* LC50	Fathead Minnow Survival & Growth	*Ceriodaphnia dubia* Survival & Reproduction	*Lemna minor* Growth	*Pseudokirchneriella subcapitata* Growth	Microtox	Grab	Composite	# of Containers and Volume (eg. 2 x 1L, 3 x 10L, etc.)
2018-01-17	0630	2018-01-17 PW TOXICITY	53565	7.0									✓	✓		1 X 1L

For Lab Use Only
Received By: MR/TL
Date: 2018-01-19
Time: 1045
Storage Location:
Storage Temp.(°C)

Please list any special requests or instructions:
ECHINOID FERTILIZATION AND MICROTOX
PERMISSION TO PROCEED WITH TESTING
IF HOLDING TIME IS EXCEEDED.

Standard COC with Microtox rev 2 2009 07 09 TC

APPENDIX C

2018 Stranded Bird Report

Permit for the Capture and Handling of Migratory Birds – Reporting Form

Permit number: LS 2568	**Actual start and end dates of activities** (*yyyy/mm/dd – yyyy/mm/dd*)**:** 2018/01/01 – 2018/12/31	
Name of permit holder: Marielle Thillet (Sr Environmental Specialist)		
Organization: Encana Corporation		
Phone: (902) 492-5422	**Email:** marielle.thillet@encana.com	**Fax:**

Search effort for live birds

Describe how birds were found. Examples: opportunistically by all staff, daily/nightly (or other interval) rounds by number of observers

Facilities include the Deep Panuke PFC (offshore natural gas production platform) located at 4853668N, 685918E (UTM 20, NAD 83) as well as two support (supply and standby) vessels (Atlantic Tern and Atlantic Condor).

Search effort for birds was opportunistically by all platform / vessel staff at all times.

Number of migratory birds handled

Report on authorized activities by completing the provided template or in an alternative suitable format.

☒ Datasheet attached including the following information:

- Name of facility, vessel, or platform
- General activity of facility, vessel or platform
- Date when migratory bird was found
- Location of stranding (latitude/longitude preferred)
- Migratory bird species name
- Number of migratory birds found dead, alive, and oiled
- Number of migratory birds disposed of at sea, sent shore or released
- Presence of fog and rain

In compliance with the provisions of the *Migratory Birds Convention Act* and Regulations, I am submitting a complete report of the number of specimens of each species of live and dead migratory birds recovered.

Signature of permit holder: ______________________ *(electronic signatures accepted)*

Date ______________________ *(yyyy/mm/dd)*

This Reporting Form must be submitted by mail, fax or email to the regional Canadian Wildlife Service office having issued the original permit by the date specified in the permit conditions

Permits Section, Atlantic Region
Canadian Wildlife Service
PO Box 6227
Sackville NB E4L 1G6

Telephone: 506-364-5068
Fax: 506-364-5062
E-mail: ec.scfatlpermis-cwsatlpermits.ec@canada.ca

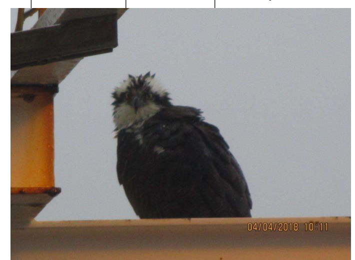
When you find a stranded bird (dead or alive), please take photograph and provide the following information (instructions on following page)

Name of facility, vessel, or platform: Deep Panuke PFC - 4853668N, 685918E (UTM 20, NAD 83)

General activity: Production activities, cessation of production May 7, 2018

Description of search effort: Opportunistically by all platform staff at all times

Grey columns will add up to TOTAL # stranded birds

Date (yyyy/mm/dd)	Location of stranding (Lat/Long, or Name)	Bird species	TOTAL # stranded birds	Found dead			Captured Alive						FOG (yes/no)	RAIN (yes/no)	Comments
					Fate		Oiled**			Not oiled					
				# Oiled**	# disposed of at sea	# sent ashore*	# died in care	# released alive	# sent ashore*	# died in care	# released alive	# sent ashore*			
2018-04-04	PFC	Ospreys	2 (not stranded)	NOT STRANDED, SUBMITTED FOR INFORMATION									yes	yes	Pair of ospreys around the PFC for couple of days, both appeared healthy and active.  
2018-06-03	PFC	Spotted sandpiper	1	0		1							yes	no	Bird found on in Module 1 Level 1 at south end of the facility by the Safety Officer. Dry, good condition, neck appeared to be broken. Bird preserved in refrigerator and sent to ECCC Dartmouth (Carina Gerdrum) for necropsy (arrived at ECCC June 5).   
2018-09-28	PFC	Peregrine falcon	1 (not stranded)	NOT STRANDED, SUBMITTED FOR INFORMATION									yes (Friday evening)	yes (light rain Friday evening)	Arrived evening of Sep 28; stayed until Oct 1.  

***Provide details for situation where bird(s) sent ashore (i.e., sent to CWS, rehabilitation, etc.); **Contact CWS when any bird is found oiled.**

INSTRUCTIONS FOR RECORDING INFORMATION ON STRANDED BIRD ENCOUNTERS

Name of facility, vessel or platform: indicate the name of the facility, vessel, or platform where the stranding occurred.
General activity: indicate the activity of the facility, vessel or platform (i.e., seismic exploration, drilling, refinery, etc.).
Description of search effort: describe general search methods for stranded birds (e.g., opportunistically, systematic searches)
Date: give the date that the bird(s) was encountered (yyyy/mm/dd).
Location: preferably the latitude/logitude of platform when bird(s) was encountered (in decimal degrees), or location name.
Bird Species: document the species of bird encountered. Take a photograph if identification is uncertain and contact CWS.
Total # of stranded birds: indicate the number of birds encountered at that particular time. Use multiple lines if more than one species. This column should be the sum of # disposed of at sea, # released alive, and # sent asl
Found dead: of the birds found dead, indicate the number that were oiled and the number that were disposed of at sea or sent ashore.
Captured Alive: of those birds found stranded but alive, indicate the number found oiled and the number found not oiled that died in care, as well as the numbers released alive or sent ashore.
FOG and **RAIN:** indicate whether there was fog and/or rain at the time of the stranding (yes or no).

When you find a stranded bird (dead or alive), please take photograph and provide the following information (instructions on following page)

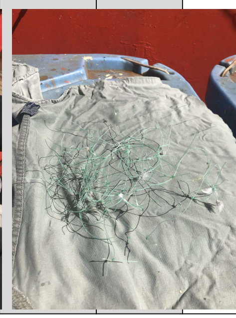
Name of facility, vessel, or platform: Atlantic Condor

General activity: Support (supply/standby) vessel to the Deep Panuke PFC

Description of search effort: Opportunistically by all vessel staff at all times

Grey columns will add up to TOTAL # stranded birds

Date (yyyy/mm/dd)	Location of stranding (Lat/Long, or Name)	Bird species	TOTAL # stranded birds	Found dead			Captured Alive						FOG (yes/no)	RAIN (yes/no)	Comments
					Fate		Oiled**			Not oiled					
				# Oiled**	# disposed of at sea	# sent ashore*	# died in care	# released alive	# sent ashore*	# died in care	# released alive	# sent ashore*			
2018-03-10	43° 47.4'N, 060° 43.4'W	Great black-backed gull	1								1		no	no	Shortly before lunch on March 10 a stranded Great black-backed gull was spotted on the aft deck. The gull was approached and found to be entangled in fishing "gillnet". The net went around its neck, through the beak and around one of its legs. There were no visible signs of injury. The crew secured the bird and untangled it from the net. It was also fed canned tuna and let go freely on the aft deck. It flew away, re-landed on the aft deck and flew off again. It seemed able to fly well and without difficulty. *Note* : *ECCC advised that birds should not be fed.*



***Provide details for situation where bird(s) sent ashore (i.e., sent to CWS, rehabilitation, etc.); **Contact CWS when any bird is found oiled.**

INSTRUCTIONS FOR RECORDING INFORMATION ON STRANDED BIRD ENCOUNTERS

Name of facility, vessel or platform: indicate the name of the facility, vessel, or platform where the stranding occurred.

General activity: indicate the activity of the facility, vessel or platform (i.e., seismic exploration, drilling, refinery, etc.).

Description of search effort: describe general search methods for stranded birds (e.g., opportunistically, systematic searches)

Date: give the date that the bird(s) was encountered (yyyy/mm/dd).

Location: preferably the latitude/logitude of platform when bird(s) was encountered (in decimal degrees), or location name.

Bird Species: document the species of bird encountered. Take a photograph if identification is uncertain and contact CWS.

Total # of stranded birds: indicate the number of birds encountered at that particular time. Use multiple lines if more than one species. This column should be the sum of # disposed o

Found dead: of the birds found dead, indicate the number that were oiled and the number that were disposed of at sea or sent ashore.

Captured Alive: of those birds found stranded but alive, indicate the number found oiled and the number found not oiled that died in care, as well as the numbers released alive or sent ashore.

FOG and **RAIN:** indicate whether there was fog and/or rain at the time of the stranding (yes or no).

When you find a stranded bird (dead or alive), please take photograph and provide the following information (instructions on following page)

Name of facility, vessel, or platform: Atlantic Tern

General activity: Support (supply/standby) vessel to the Deep Panuke PFC

Description of search effort: Opportunistically by all vessel staff at all times

Grey columns will add up to TOTAL # stranded birds

Date (yyyy/mm/dd)	Location of stranding (Lat/Long, or Name)	Bird species	TOTAL # stranded birds	Found dead			Captured Alive						FOG (yes/no)	RAIN (yes/no)	Comments
					Fate		Oiled**			Not oiled					
				# Oiled**	# disposed of at sea	# sent ashore*	# died in care	# released alive	# sent ashore*	# died in care	# released alive	# sent ashore*			
2018-09-06	On standby duties by Deep Panuke PFC	Brown booby	1 (not stranded)					NOT STRANDED, SUBMITTED FOR INFORMATION							Reported Sep 6, had been on the boat for over a week then. Slept on the boat and only left briefly (we assumed to catch food) then returned again. Appeared to be in good health and not afraid of people. The vessel sailed into port in the evening of Sep 9 and the bird did not complete the passage with them.

***Provide details for situation where bird(s) sent ashore (i.e., sent to CWS, rehabilitation, etc.); **Contact CWS when any bird is found oiled.**

INSTRUCTIONS FOR RECORDING INFORMATION ON STRANDED BIRD ENCOUNTERS

Name of facility, vessel or platform: indicate the name of the facility, vessel, or platform where the stranding occurred.

General activity: indicate the activity of the facility, vessel or platform (i.e., seismic exploration, drilling, refinery, etc.).

Description of search effort: describe general search methods for stranded birds (e.g., opportunistically, systematic searches)

Date: give the date that the bird(s) was encountered (yyyy/mm/dd).

Location: preferably the latitude/logitude of platform when bird(s) was encountered (in decimal degrees), or location name.

Bird Species: document the species of bird encountered. Take a photograph if identification is uncertain and contact CWS.

Total # of stranded birds: indicate the number of birds encountered at that particular time. Use multiple lines if more than one species. This column should be the sum of # disp

Found dead: of the birds found dead, indicate the number that were oiled and the number that were disposed of at sea or sent ashore.

Captured Alive: of those birds found stranded but alive, indicate the number found oiled and the number found not oiled that died in care, as well as the numbers released alive or sent ashore.

FOG and **RAIN:** indicate whether there was fog and/or rain at the time of the stranding (yes or no).

APPENDIX D

2018 Fish Habitat Alteration Video Assessments (Stantec)

Table A-1: Marine Fauna Observed During 2018 Survey in Representative GEP Segments

		Start KP								
Fauna	**Fauna (Latin name)**	**10.619**	**20.949**	**30.516**	**40.918**	**50.591**	**60.309**	**70.315**	**80.794**	**90.240**
Comb Jelly	Ctenophore									
Tubularia? Spp.	Tubularia Spp.							91	81	115
Polymastia	*Polymastia sp.*									
Encrusting sponge	Porifera	C								
Sponge	Porifera									
Corymorpha sp.	Corymorpha sp.									
Sea anemone	Actinaria									
Cerianthus sp.	*Cerianthus sp.*		21	12	41	63	57	85	4	12
Soft Coral	Alcyonacea				1		1	1		
Colus sp.	*Colus sp.*					5	2	2		
Jonah crab	*Cancer borealis*	1		1	17	10	5	11	34	14
Snow crab	*Chionoecetes opilio*									
Toad crab	*Hyas sp.*		11	52	67	16				
Portly spider crab	*Libinia emarginata*									
Northern Stone Crab	*Lithodes maja*					1		2	1	1
Shrimp	Pandalidae				92	8		3		
Ceramaster	*Ceremaster sp.*									
Crossaster	*Crossaster sp.*		12		4	7				1
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*	40	28	17	110	475	86	83	94	110
Hippasteria sp	*Hippasteria sp.*			2	3	1	6	4	7	12
Cushion star	*Poriania*									
Solaster	*Solaster sp.*		32			8	4	3	2	3
Basket star	*Gorgoncephalus sp.*		18							
Sand dollar	*Echinarachnius parma*									
Sea urchin	*Strongylocentrotus sp.*									
Sea cucumber	*Cucumaria frondosa*		1			3				1
Feather star	Crinoidea									
Sea potato	*Boltenia ovifera*						1			
Tunicate	Tunicata								1	
Atlantic Wolffish	*Anarhichas lupus*		1				1	6	1	1
Gadoid	Gadidae		4	6	28	13	20	18		
Atlantic Cod	*Gadus morhua*						28	3		
Sea Raven	*Hemitripterus americanus*							1		
Atlantic Hagfish	*Mixine glutinosa*									
Sculpin	*Myoxocephalus sp.*	1	1		2					
Flatfish	Pleuronectiformes									
Pollock	*Pollachius sp.*									
Redfish	*Sebastes sp.*		31	23	20	142	1295	1900	485	605
Eelpout/Ocean pout?	Zoarcidae			2				3	1	3
Haddock	*Melanogrammis aeglefinus*									
American Lobster	*Homarus americanus*	1								
Unidentified Fish					2	1	1	1	1	
Unidentified Worm										
Jonah crab (Dead/exoskeleton)	*Cancer borealis*						2			1
		11.009	**21.398**	**31.070**	**41.415**	**51.143**	**60.857**	**70.972**	**81.337**	**90.798**
		End KP								

Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)

Table A-2: Marine Fauna Observed During 2014-2018 Surveys in Representative GEP Segments

Start KP		10.619				23.222				32.984				42.787				52.48				63.882				73.297				83.016				92.825			
Fauna	Latin Name	2014	2015	2016	2018[1]	2014	2015	2016[2]	2018[3]	2014	2015	2016	2018[4]	2014	2015	2016	2018[5]	2014	2015	2016	2018[6]	2014	2015	2016	2018[7]	2014	2015	2016	2018[8]	2014	2015	2016	2018[9]	2014	2015	2016	2018[10]
Porifera																																					
Polymastia	*Polymastia spp.*													3				23				12	19			14	60			3							
Encrusting sponge	Porifera									O		R						R		O				O						R		O					
Sponge	Porifera							6		46				8				61		1		180	255			26	30			4	3	1		1			
	Sub-total				**0**			**6**	**0**					**11**								**192**	**274**			**40**	**90**				**3**	**1**		**1**			
Anthozoa																																					
Sea anemone	Actinaria					1		1		800		11		32		11		61		12		113	4	22		55	50	27		5	7	2		35		15	
Cerianthus sp	*Cerianthus sp.*						11		21				12				41			3	63		2		57	27	21	36	85	457	284	46	4	13		25	12
Soft Coral	*Alcyonacea*						13			7							1								1				1								
	Sub-total				**0**	**1**	**24**	**1**	**21**	**807**		**11**	**12**	**32**		**11**	**42**	**61**		**15**	**63**	**113**	**6**	**22**	**58**	**82**	**71**	**63**	**86**	**462**	**291**	**48**	**4**	**48**		**40**	**12**
Mollusca																																					
Buccinum sp.	*Buccinum sp.*																	2				1															
Colus sp.	*Colus sp.*												1								5		3		2				2								
Neptunea sp.	*Neptunea sp.*					1								1																							
	Sub-total					**1**								**1**				**2**			**5**	**1**	**3**		**2**				**2**								
Crustacea																																					
Jonah crab	*Cancer borealis*				1			1		10		3		13		9	17	21		35	10	14	18	8	5	38	64	9	11	129	112	22	34	115		90	14
Cancer sp.	*Cancer sp.*																													4							
Snow crab	*Chionoecetes opilio*					24	26			102		27		100		11		19		4		11	6			1	2			2	2			2			
Unid. Decapod	Decapoda									2				1																							
Lobster	*Homarus americanus*				1			1																	`												
Toad Crab	*Hyas sp.*								11				52				67				16		1														
Portly Spider Crab	*Libinia emarginata*																																				
Northern Stone Crab	*Lithodes maja*																			1	1					1	2	2	2	6	2	2	1	3		5	1
Hermit crab	*Pagurus sp.*																																	1			
Shrimp	*Pandalidae*									126		6		29		O	92			R	8							R	3	4						R	
	Sub-total				**2**	**24**	**26**	**2**	**11**	**240**		**36**	**52**	**143**		**20**	**176**	**40**		**40**	**35**	**25**	**25**	**8**	**5**	**40**	**68**	**11**	**16**	**145**	**116**	**24**	**35**	**121**		**95**	**15**
Echinodermata																																					
Ceramaster	*Ceremaster sp.*															9				2				8				10				1		1		19	
Crossaster	*Crossaster sp.*					8	2		12					19		7	4			1	7																1
Henricia sp./Asterias sp.	*Henricia sp./Asterias sp.*				40	3		27	28	102		86	17	64		83	110	617		375	475	762	190	53	86	1525	346	65	83	3694	450	86	94	2110		73	110
Hippasteria sp.	*Hippasteria sp.*									5			2	16			3	1			1	12	4		6	4	7		4	5	3		7	28			12
Pteraster sp.	*Pteraster sp.*																					2								1							
Solaster	*Solaster sp.*					1	3	2	32	3		3		13		2		8		1	8	2			4	2	2	1	3	7	1	5	2				3
Basket star	*Gorgoncephalus sp.*					17	23		18	1		1		2									44								39						
Sand dollar	*Echinarachnius parma*																	7				9										1					
Sea potato	*Boltenia ovifera*																								1												
Sea urchin	*Strongylocentrotus sp.*					51	74			2								487													5			1			
Sea cucumber	*Cucumaria frondosa*					6	1		1					3				17		4	3	9	4	1		2	5			11		1		15		8	1
	Sub-total				**40**	**86**	**103**	**29**	**91**	**113**		**90**	**19**	**117**		**101**	**117**	**1137**		**383**	**494**	**796**	**242**	**62**	**97**	**1533**	**360**	**76**	**90**	**3718**	**498**	**94**	**103**	**2155**		**100**	**127**
Pisces																																					
Atlantic Wolffish	*Anarhichas lupus*								1													5	6	12	1		2	4	6	2		1	1				1
Atlantic Herring	*Clupea harengus*																																	~20			
Gadoid	Gadidae					9			4	2			6	2			28				13				20		13		18								
Atlantic Cod	*Gadus morhua*									1								16		4		26			28	3	6		3	2				3			
Sea Raven	*Hemitripterus americanus*																						2						1	1							
Monkfish	*Lophius sp.*																																	1			
Blenny	*Lumpenus sp.*									3												1								2				1			
Atlantic Hagfish	*Myxine glutinosa*															1		1		1			1					4		6		1					
Sculpin	*Myoxocephalus sp.*				1				1	1						1	2										2				1			2		1	
Flatfish	Pleuronectiformes											1		1		1				1														9		4	
Pollock	*Pollachius sp.*											3								6			47	2						~50	560					1	
Redfish	*Sebastes sp.*					1	1		31	8			23			6	20	209		1125	142	1434	1635	2000	1295	2511	1661	1650	1900	489		700	485	3		4	605
Hake	*Urophycis sp.*									4			2																	19				4			
Eelpout/Ocean pout?	Zoarcidae															2												1	3				1			12	3
Haddock	*Melanogrammis aeglefinus*						1									1							3				2										
Unidentified Fish						1	2	1		2			2	1							1	2			1	2				1	2		1	2			
	Sub-total				**1**	**11**	**4**	**1**	**37**	**21**		**4**	**33**	**4**		**12**	**50**	**226**		**1137**	**156**	**1468**	**1694**	**2014**	**1345**	**2516**	**1686**	**1659**	**1931**	**522**	**563**	**702**	**488**	**25**		**22**	**609**
Miscellaneous																																					
Brachiopod	*Terebratulina sp.*									F																C											
Corymorpha sp.	*Corymorpha sp.*																	1									1							4			
Hydrozoa	Hydrozoa					F																															
Tubularia? Spp.	*Tubularia Spp.*							C				O								R				R				R	R				R			R	C
Tunicate	Tunicata																	C				S	C			S	C			A	2		1	C			
Comb Jelly	Ctenophore							O				R								R																	
Unidentified Worm								1												12				8												3	
Jonah crab (dead/exoskelton)	*Cancer borealis*																	2		1		6	2	2	2	11	11			12	8			3			1
End KP		11.009				23.429				33.497				43.186				52.937				64.474				73.869				83.552				93.349			

Notes:

Segment was not surveyed

[1] KP 10.619 to KP 11.009 surveyed in 2018
[2] KP 17.209 to KP 17.461 surveyed in 2016
[3] KP 20.949 to KP 21.398 surveyed in 2018
[4] KP 30.516 to KP 31.070 surveyed in 2018
[5] KP 40.918 to KP 41.415 surveyed in 2018
[6] KP 50.591 to KP 51.143 surveyed in 2018
[7] KP 60.309 to KP 60.857 surveyed in 2018
[8] KP 70.315 to KP 70.972 surveyed in 2018
[9] KP 80.794 to KP 81.337 surveyed in 2018
[10] KP 90.240 to KP 90.798 surveyed in 2018

Abundance values are based on the SACFOR scale (S = superabundant; A = abundant; C = common; F = frequent; O = occasional; R = rare)