APPENDIX C

Produced Formation Water Modelling Study

SUSTAINABILITY
FUTURE GROWTH

ENI-JPDA-06-105 PTY LTD

KITAN DEVELOPMENT PRODUCED FORMATION WATER MODELLING

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EXECUTIVE SUMMARY

ENI-JPDA-06-105 PTY LTD is planning to develop the Kitan oilfield, which is located in the region of the Sahul Banks in the Timor Sea, approximately 170km south of the coast of Timor-Leste and 360km north of the coast of Australia. It is located on an area of the Australian continental shelf known as the Sahul Banks, in water depths of approximately 300m. The main environmentally sensitive areas in the vicinity of Kitan are the Big Bank Shoals, which stretch approximately 50 km in a NE-SW direction along the edge of the Sahul Shelf. This report presents the findings of a modelling study aimed at assessing the likely environmental impact from Produced Formation Water (PFW) discharge from the proposed Kitan Oilfield Development.

PFW is the water mixed in well fluids extracted from oil and gas production wells. It originates from fossil water found inside the geological reservoir with the oil and gas (formation water) and water that condenses in pipes due to the pressure drop between the reservoir and surface (condensed water). It is common practice throughout the offshore industry to physically separate the PFW from the well fluids and then dispose of the water directly to the ocean. This separation is not 100% effective and the PFW often contains small amounts of contaminants including dispersed oil, dissolved organic compounds (aliphatic and aromatic hydrocarbons, organic acids and phenols), inorganic compounds (metals and salt ions) and residual process chemicals. The field basis of design (BOD) is to treat PFW to an oil in water content ≤ 15ppm by volume and discharge it to the sea at a maximum rate of 250m^3/hour.

Once PFW is discharged to sea, it is subject to dilution, dispersion and physical, chemical and biological degradation. After discharge, the PFW stream rises to the surface under its own buoyancy and spreads laterally. The plume is then advected away from the discharge point by ambient currents whilst mixing both horizontally and vertically into the receiving waters. Modelling of the PFW plume predicted that it would extend up to 6km from the FPSO albeit as discontiguous patches and at the low concentrations of 0.01% – 0.1% of the initial concentration i.e. 1,000 times to 10,000 times dilution. The plume was also predicted to remain in the top 7m of the water column.

Records of maximum PFW concentrations occurring around the FPSO location during the 25 day simulation period indicated that the PFW plume would be advected predominantly towards the east-northeast (away from the Big Bank Shoals). The maximum concentration at 200m from the FPSO was predicted to be 1.64%PFW. Using a conservative PNEC of ≥0.1%PFW, PFW at potentially toxic concentrations could occur at up to 7km from the FPSO and down to a depth of 7m at sometime during the life of the field. Thus, whilst the maximum PFW concentration was 1.64%, the mean and 95th percentile concentrations were predicted to be 0.03% and 0.19%, respectively, highlighting that PFW would generally be expected to occur at very low concentrations beyond 200m of the FPSO.

The model predicted that a PEC/PNEC ratio >1 (where the PEC exceeds the PNEC) would only occur within 250m of the FPSO and only within the top 1m of the water column. Beyond 250m and deeper than 1m, the PEC/PNEC ratio was predicted to be <1 so no adverse effects would be expected to occur. This means, with a PNEC set at 0.1% PFW, that dilutions of over 1000 times of the initial PFW concentration would be expected to occur by the time the plume has travelled 250m from its discharge point and also at depths greater than 1m.

Importantly, the model simulation indicated that PFW would not reach the Big Bank Shoals, either laterally or vertically, at concentrations that would be toxic to marine biota. The maximum PFW concentration in the vicinity of the Big Bank Shoals was predicted to be 0.01% — 0.05% i.e. a dilution of between 2,000 and 10,000 times of its initial concentration. Consequently, the PFW is predicted to represent little risk to the marine environment in general and in particular, pose no risk to the marine biota inhabiting the Big Bank Shoals.

1. INTRODUCTION

1.1 BACKGROUND

Eni-JPDA-06-105 Pty Ltd (Eni) is developing the Kitan oil field in the Timor Sea (Figure 1.1 and Figure 1.2). The Kitan Development will consist of a Floating Production Storage and Offloading (FPSO) facility in conjunction with a sub-sea production facility. This report presents the findings of a hydrodynamic modelling study of produced formation water (PFW) to be discharged from the development. The results from this work will form part of Eni's Environment Impact Statement (EIS) for submission to the Timor Leste Regulatory Authority.

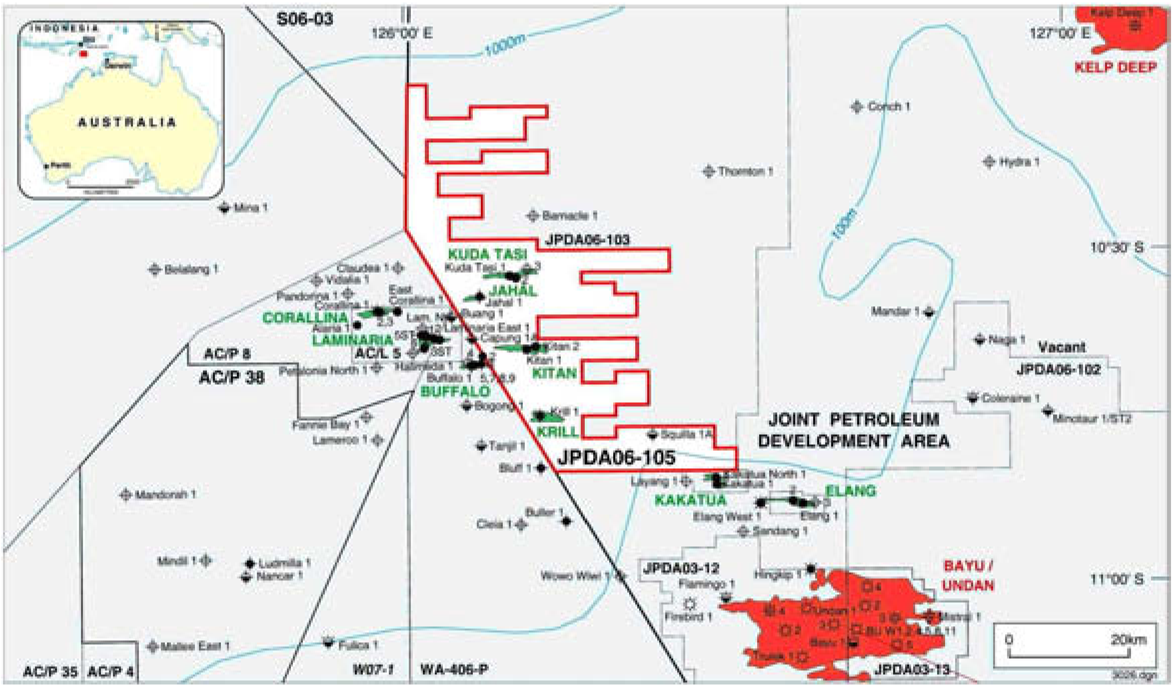


Figure 1.1 Location of Kitan in relation to other production facilities

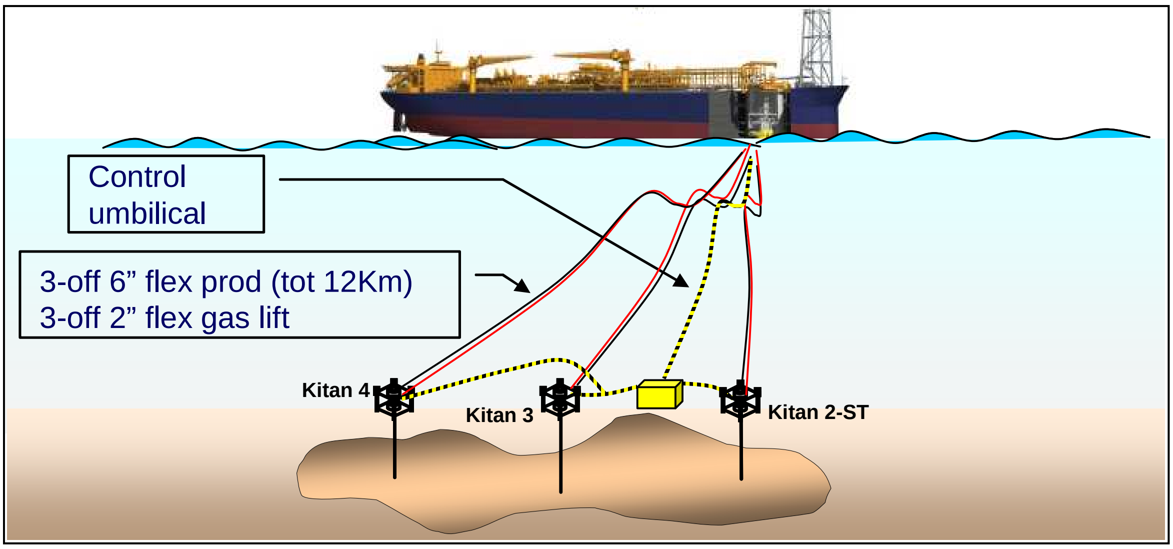


Figure 1.2 Kitan FPSO and field layout

1.2 KITAN LOCATION

The Kitan oilfield is situated in Joint Production Development Area (JPDA) in the Timor Sea, approximately 170km south of the coast of Timor-Leste and 360km north of the coast of Australia. It is located on an area of the Australian continental shelf known as the Sahul Banks, in water depths of approximately 300m. The coordinates of the Kitan FPSO are shown in Table 1.1.

Table 1.1 Coordinates of the Kitan FPSO

Location	Easting	Northing
FPSO	191815	8825599

The coordinates are provided in reference to the UTM system (GDA94/MGA Zone 52 (EPSG 28352), GRS 1980 spheroid.

Shallow shoals and small sea mounts occur along the edge of the shelf including:

- Big Bank, 6km to the southwest of the FPSO location;
- Karmt, 50km to the southwest;
- Echo, 90km to the northeast; and
- Pea Shoals, 200km to the southwest.

Most of these shoals and reefs support extensive areas of coral, and some of the islands and large reefs support endangered turtles and seabirds. The nearest emergent reefs, Ashmore, Cartier and Hibernia, are located on the southwest end of Sahul Shelf. The nearest, Hibernia reef, is more than 300 km to the southwest of the Kitan oilfield.

1.3 OBJECTIVE

The objective of the study is to determine the potential ecotoxicological risks that Kitan PFW poses to marine biota likely to inhabit the area.

1.4 SCOPE OF THE STUDY

The scope of work for this study is to:

- simulate the discharge of PFW from the Kitan Development at Basis of Design (BOD) maximum discharge rate of 250 m^3/hour;
- determine the vertical and horizontal dispersal and dilution of PFW; and
- evaluate the risks to marine biota based on predicted effect concentrations (PEC), predicted no effect concentration (PNEC) with distance from the discharge point.

2. PRODUCED FORMATION WATER SYSTEM

2.1 GENERAL

PFW is the water mixed in well fluids extracted from oil and gas production wells. It originates from:

- fossil water found inside the geological reservoir with the oil and gas (formation water); and
- water that condenses in pipes due to the pressure drop between the reservoir and surface (condensed water).

It is common practice throughout the offshore industry to physically separate the PFW from the well fluids and then dispose of the water directly to the ocean. This separation is not 100% effective and the PFW often contains small amounts of contaminants including dispersed oil, dissolved organic compounds (aliphatic and aromatic hydrocarbons, organic acids and phenols), inorganic compounds (metals and salt ions) and residual process chemicals. Although only small concentrations of these compounds are released, the continuous discharge of large PFW volumes gives rise to environmental concern. Accordingly, most of the world's national or regional regulatory authorities set limits on the concentration of petroleum hydrocarbons (or total oil and grease) that can remain in produced water for ocean disposal. Many regulators also require that environmental impact assessments be undertaken to fully evaluate the risk.

The chemical composition of produced formation water varies from field to field and depends mainly on attributes of the reservoir geology. The composition of produced water may also change slightly through the production lifetime of the reservoir. Compared to oil production fields, produced water from gas/condensate fields generally have higher hydrocarbon contents due to technical difficulties in separating condensate and water and also due to the higher aromatic content of condensate. However, the total volume of water produced from gas fields is much smaller than from oil production fields. Many gas fields discharge less than 10 cubic metres of produced water per day whilst most oil fields discharge hundreds or even thousands of cubic metres per day.

2.2 KITAN PFW TREATMENT

The Kitan production process is shown in Figure 2.1 and the PFW production curve over the life of the field is shown in Figure 2.2. The PFW treatment system for Kitan includes:

- a flash vessel;
- hydrocyclone units;
- gas induced flotation vessel; and

- produced formation water cooler.

After treatment the PFW will have:

- Oil content in water: ≤ 15 ppm by volume (Less than 30 ppm by volume required by JPDA Draft Rules); and
- Discharge Temperature: max 3°C sea water temperature increase @ 100m from discharge point.

The maximum basis of design PFW discharge flow rate is given as 250 m^3/hour (Tecnomare 2009).

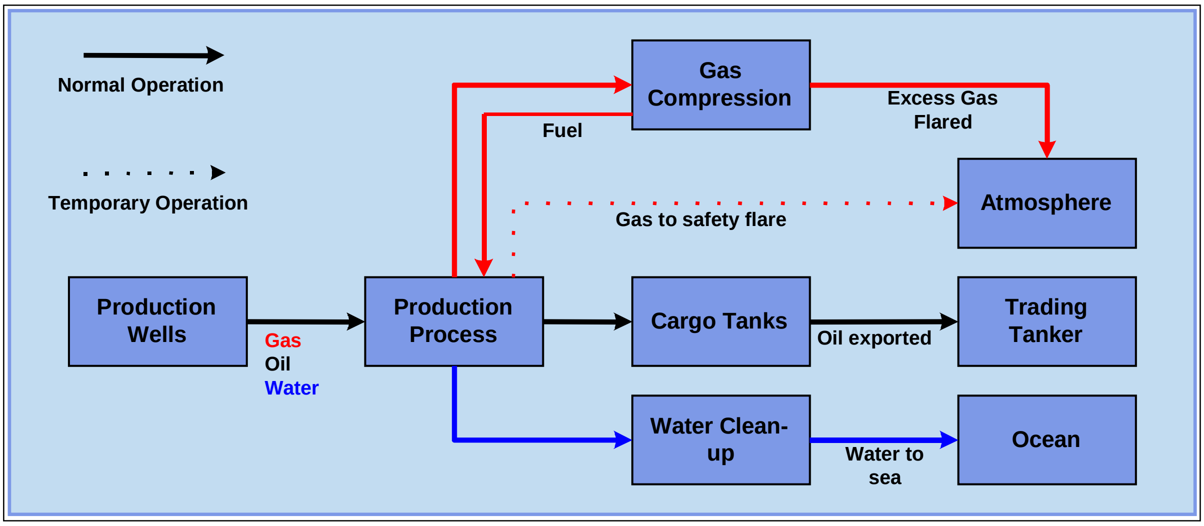


Figure 2.1 Kitan production process (PFW discharge is indicated with a blue arrow)

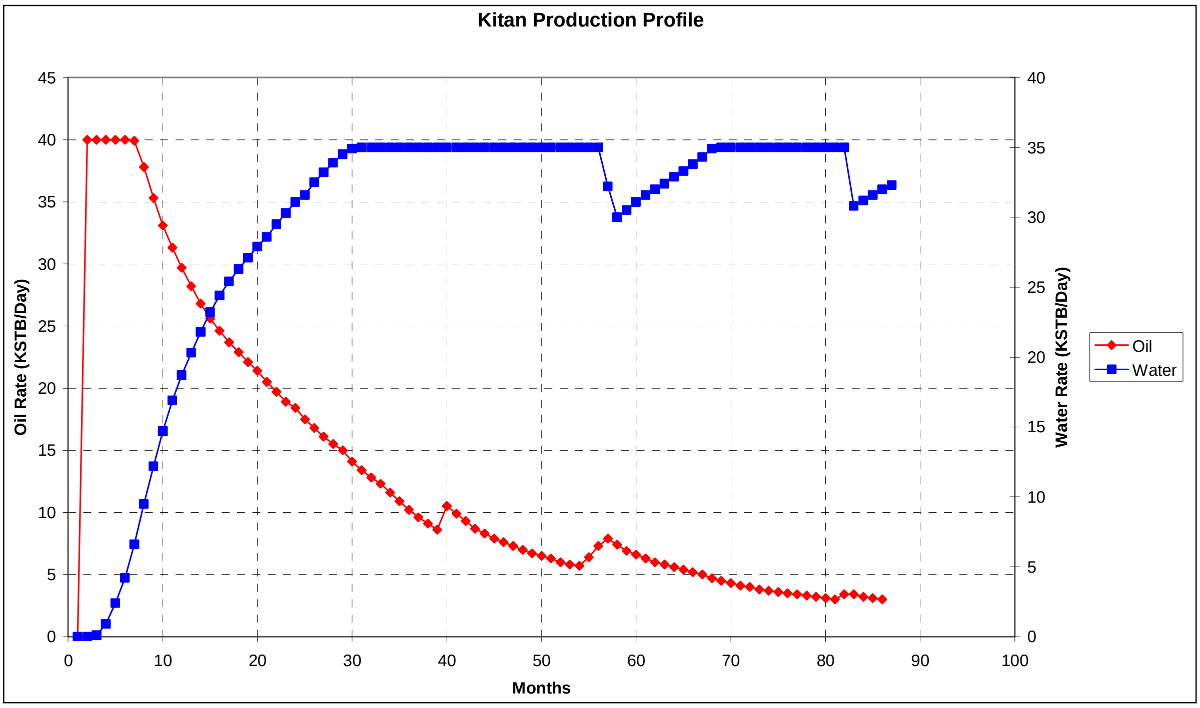


Figure 2.2 Indicative production profile for the Kitan Project (PFW is shown in blue)

3. DESCRIPTION OF RECEIVING ENVIRONMENT

3.1 CLIMATE

The Timor Sea has two distinct seasons: "winter" from April to September and "summer" from October to March. The short period between the two seasons is termed the transition season. During this period, either winter or summer regimes could dominate.

3.1.1 Winter

The "winter" dry season (April to September) is characterised by steady easterly (northeast to southeast) winds of $5ms^{-1}$ to $13ms^{-1}$ driven by the South East Trade Winds over Australia.

3.1.2 Summer

The "summer" season (October to March) is the period of the predominant North West Monsoon. It is characterised by mostly westerly (west-southwest) winds of $5ms^{-1}$ for periods of 5 to 10 days with surges in the airflow of $10ms^{-1}$ to $18ms^{-1}$ for the period of 1 to 3 days. Tropical cyclones can develop between November and April resulting in short lived, severe storm events often with strong but variable winds.

3.2 WINDS

Joint frequency distributions were calculated from 10 complete years (July 1997 – Jun 2007) of verified ambient modelled data for the Kitan location (data sourced from the National Center for Environmental Protection). Wind roses for the winter, summer and transitional seasons are presented in Figure 3.1. These display the expected seasonal variation in prevailing wind direction, with westerly winds (southwest-northwest) persisting from October to March, and a fairly rapid shift to easterlies (northeast – southeast) in late March or early April that then persist until late October or early November before the return to the westerlies.

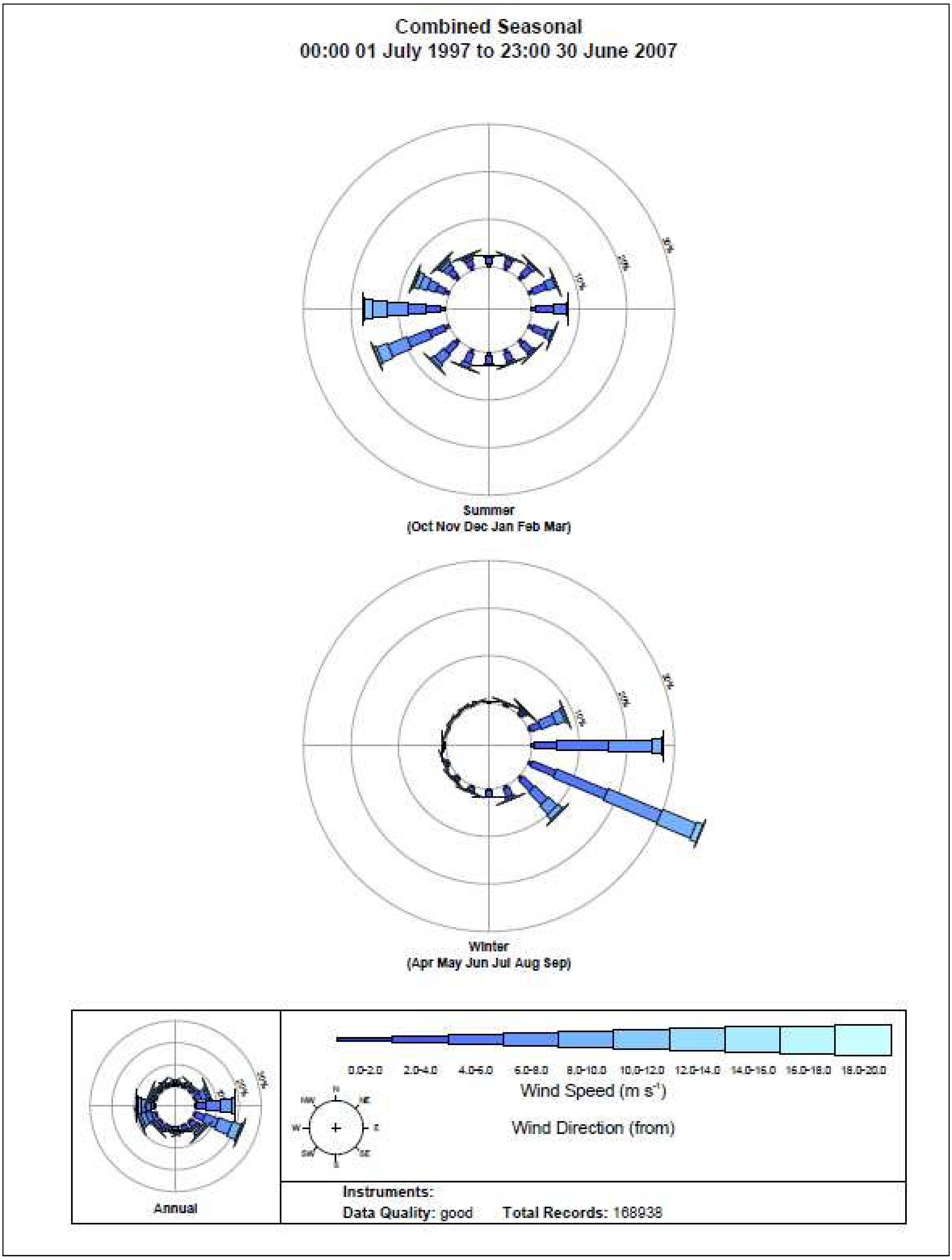


Figure 3.1 Seasonal wind roses for the Timor Sea (Saipem Energy Services 2009).

3.3 TIDAL RANGES

The tides in the vicinity of the Kitan Development are semidiurnal (two highs and lows each day) with a slight diurnal inequality (difference in heights between successive highs and low). There is a well defined spring-neap lunar cycle, with spring tides occurring 2 days after the new and full moon. Table 3.1 provides the standard tidal levels for the Kitan Field. Highest Astronomical Tide (HAT) is 3.46m and the mean ranges for spring and neap tides are 2.07m and 0.29m, respectively.

Table 3.1 Standard tide levels for Kitan (Saipem Energy Services 2009).

Northern Endeavour	Level (m)
Highest Astronomic Tide (HAT)	3.46
Mean High Water Springs (MHWS)	3.12
Mean High Water Neaps (MHWN)	1.97
Mean Sea Level (MSL)	1.82
Mean Low Water Neaps (MLWN)	1.68
Mean Low Water Springs (MLWS)	0.39

3.4 CURRENTS

The main forces contributing to surface water motions in the Kitan Development location are:

- general oceanic circulation
- astronomical tides; and
- wind stress.

The Pacific – Indian Throughflow flows south through the Indonesian Archipelago and into the Eastern Indian Ocean bathing the Browse Basin in warm, relatively low salinity seawater. At the Kitan location, this may add a small westerly component to the current regime. Current speeds vary depending on the season. Lowest speeds would occur in April at the end of the northwest monsoon when winds blow towards the Pacific whilst highest speeds would occur in September associated with the southeast monsoon (Wijffels *et. al*. 1996).

Near-surface tidal currents in the region are anti-clockwise rotational, flooding towards the NE and ebbing towards the SW. Speeds range from about 0.2ms^{-1} on neap tides to 0.4 ms^{-1} on springs.

For wind driven surface currents, the typical "rule of thumb" is 2% to 4% of the wind speed. Surface currents are expected to reflect seasonal wind regimes. Local wind-driven surface currents may attain maximum speeds of 0.7ms^{-1} during extreme monsoonal or Trade Wind surges. More typically speeds would be in the range of 0.2ms^{-1} to 0.4 ms^{-1}.

3.5 WAVES

Waves at the Kitan Development location will comprise contributions from:

- Southern Ocean swells;
- summer monsoonal swells;
- winter easterly swells; and
- locally generated seas.

The most persistent swell will arrive from the south and southwest with typical heights of 2m in winter and 1m in summer. Since longer period swell suffer less dissipation, periods of long-travelled swell commonly reach 18 seconds and occasionally exceed 20 seconds.

Shorter period swell (6 to 10 seconds), may result from tropical cyclone, winter easterlies over the Arafura Sea and the eastern portions of the Timor Sea, and summer westerlies over the western portions of the Timor Sea. Local wind generated sea is highly variable but typically range in period from 2 to 6 seconds with heights of up to 6m in strong persistent forcing at some locations.

3.6 WATER TEMPERATURES

Surface sea temperatures in the vicinity of Kitan are expected to range from about 30°C in summer to 27°C in winter.

3.7 SENSITIVE ENVIRONMENTAL AREAS

The main environmentally sensitive areas in the region are the shoals and banks of the Sahul Shelf. The major shoals and banks in the region (Figure 3.2) include:

- Karmt Shoals, approximately 45km to the southwest of the Kitan Development;
- Big Bank Shoals, approximately 6km southwest of the Kitan Development; and
- Echo Shoals, approximately 85km to the northeast of the Kitan Development.

The submerged banks of the region vary in their habitat and species composition, but are generally characterised by mixed *Halimeda* algae, sponge and soft coral communities with some hard corals on the more consolidated sediments.

The nearest shoals to the Kitan Development are the Big Bank Shoals (Figure 3.2). They comprise some 13 significant submerged banks, ranging in size from 0.05km^2 to 40 km^2. The banks emerge from a water-depth of 200m to 300m and rise steeply to within 20m below the water surface.

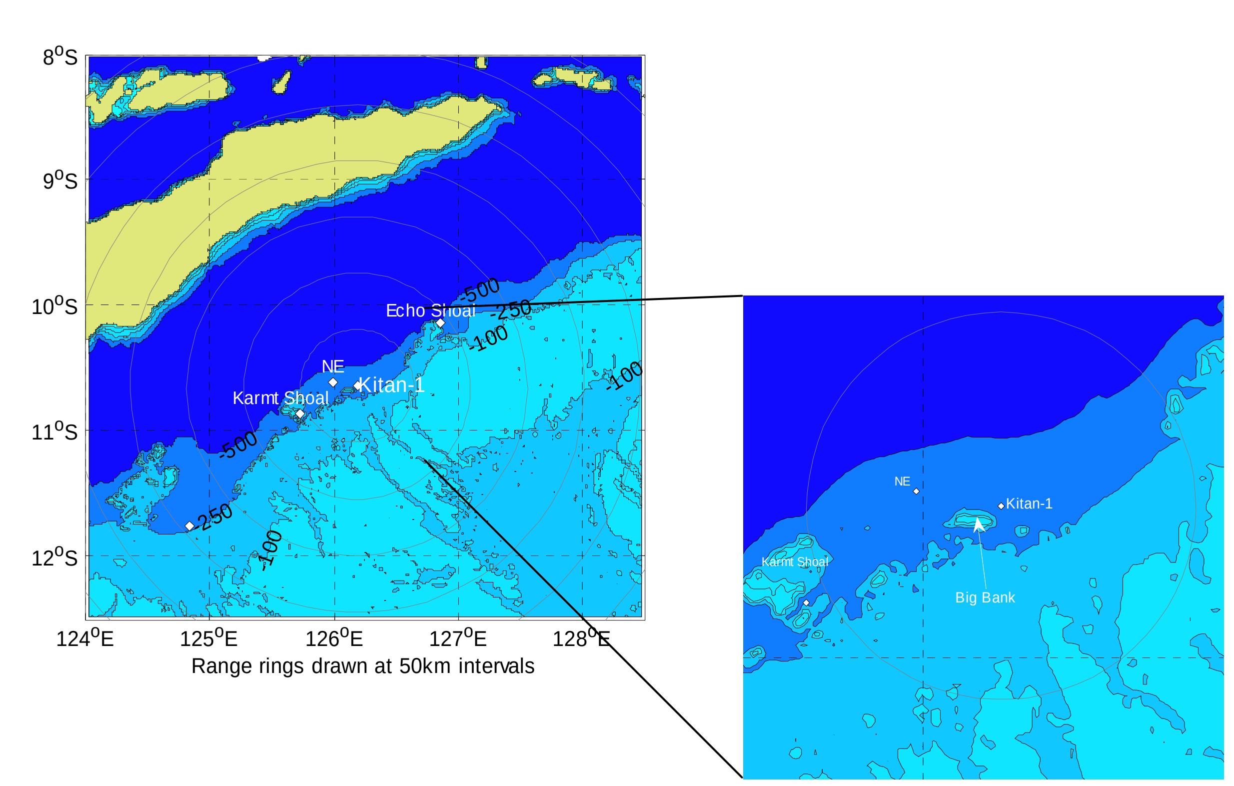


Figure 3.2 Major shoals and banks of the Sahul Shelf in the region of the Kitan Development

Considerable work has been undertaken on the Big Bank Shoals. Heyward *et al.* (1997) recognised three important ecosystems on the Big Bank Shoals: *Halimeda* dominated and coral dominated ecosystems on the shallower shoals and filter-feeding ecosystems which dominate deeper banks (Figure 3.3).

The largest of the Big Bank Shoals, Big Bank, is situated 6km southwest of the proposed Kitan Development location. Benthic communities on the top of the Big Bank (Figure 3.4) are dominated by large areas of calcareous sand and rubble with a low percentage cover of algae, isolated sponges and isolated small coral bommies. Areas of high live coral coverage have been identified in approximately 25m to 30m depth on the northern and western sides of Big Bank. The bank slopes are characterised by large erect sponges, gorgonians, bryozoans, ascidians and feather stars. This habitat is typical of a relatively nutrient rich and strong current environment.

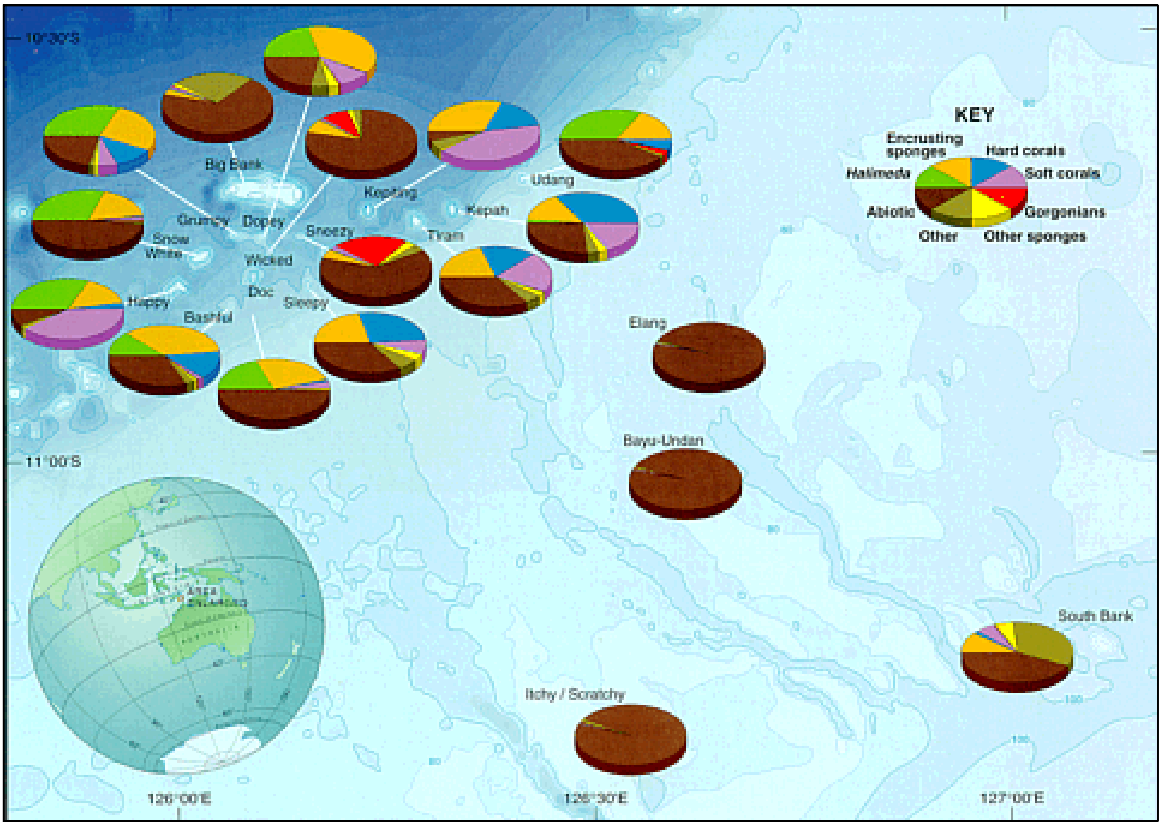


Figure 3.3 **Dominant epibenthic communities on the Big Bank Shoals (from Heyward *et. al.* 1997)**

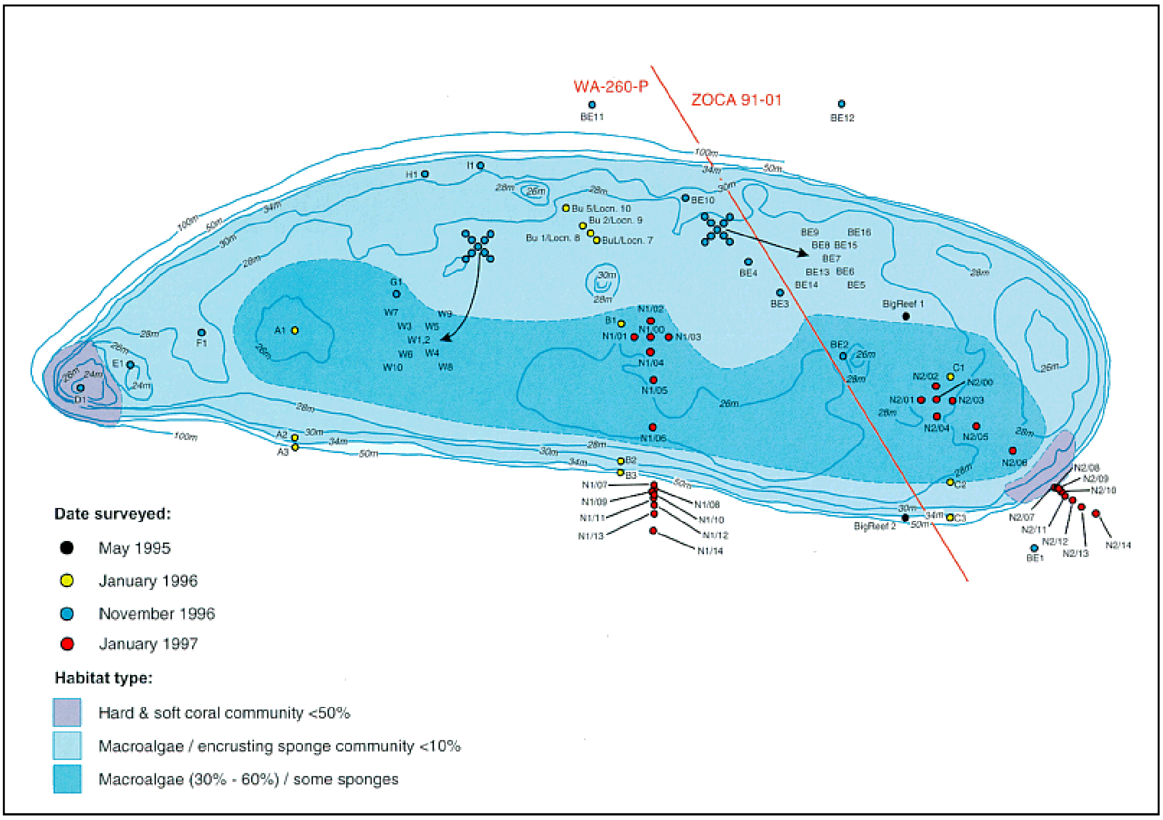


Figure 3.4 **Big Bank Shoal (from Heyward et. al. 1997)**

4. METHODS

4.1 MODEL OVERVIEW

4.1.1 Far Field Dispersion Modelling

The dispersion module applied in this study is based on the classic random walk particle tracking method (Elliot 1992) and assumes that the discharge can be idealised as a large number of particles that move independently under the action of tide and wind.

The motion of the particles is the sum of two effects:

- advection by the tidal currents; and
- dispersion due to turbulence and current shear effects.

Advection is calculated by stepping through the variations in the current field in time. Dispersion is included by subjecting each particle to a random displacement at each time step. The dispersive displacement (random step) of each particle at each time step (dt) is scaled by the square root of the increment in the variance of the effluent plume which is given by the product:

$$\text{(increment in variance)} = 2Kdt$$

where K is the horizontal (Kxy) or vertical (Kz) diffusion coefficient. The actual step length taken by each particle is also determined by a random number selected from a normal distribution with zero mean and unit variance which is scaled by the product (2Kdt). Steps in the x, y and z co-ordinate directions are made independently. Steps in the vertical plane allow for reflection of the particle from the seabed and surface. The current velocity applied to each particle is corrected according to its level in the water column using a power law relationship. Full details of the model are provided in RPC (2007). The model has been verified against a dye dispersion study from the North Rankin platform on the North West Shelf of Australia (RPC 2007).

4.1.2 Hydrodynamic Model

The hydrodynamics applied in the present study were computed using a combination of HYbrid Coordinate Ocean Model (HYCOM) and QUODDY. HYCOM is a data-compiled hybrid generalised coordinate ocean model, sponsored by the National Ocean Partnership Program as part of the U. S. Global Ocean Data Assimilation Experiment. Computations are carried out on a cylindrical map projection grid between 78°S and 47°N (1/12° equatorial resolution), where the horizontal dimensions of the global grid are 4500 x 3298 grid points resulting in ~7 km spacing on average. Daily hindcast values are available from 3 November 2003 to the present day.

QUODDY solves the time dependent, free surface circulation problems in three dimensions (Ip and Lynch 1995). The algorithms that comprise QUODDY utilise the finite element method in space and the model can be applied to computational domains encompassing the Deep Ocean, continental shelves, coastal seas and estuarine systems.

Model grid and bathymetry are shown in Figure 4.1 and Figure 4.2, respectively. The bathymetry was interpolated from the Australian Geological Survey Office database. The model was forced from the open boundary by tidal elevations calculated from the M2, S2, N2, O1 and K1 tidal constituents. Amplitudes and phases for these were taken from the FES-95.2 global ocean model (Le Provost *et. al.* 1998). The model has undergone extensive validation and found to compare favourably against measured currents and tidal elevations in the Timor Sea.

Table 4.1 summarises the discharge parameters for the model scenario. The model was run for 25 days using transitional season hydrodynamics.

Table 4.1 Discharge parameters.

Parameter	Value
Flow (m^3/hr)	250
Temp (°C)	40
Salinity (psu)	20
Discharge Depth (m below sea surface)	5
Discharge Conc. (%PFW)	100

4.2 RISK ASSESSMENT

The ratio of the Predicted Environmental Concentration (PEC) to the Predicted No Effect Concentration (PNEC) (PEC/PNEC ratio) was used to provide a measure of the toxicological risk of the PFW. This is an established technique used to screen chemicals in offshore discharges (EC 1996) and forms the basis of the OSPAR Harmonised Notification Scheme (OSPAR, 2000). It is also used in the Environmental Impact Factor (EIF) tool (Johnsen *et. al.* 2000) applied in the North Sea to assess the effect of PFW discharge.

The PNEC is derived from ecotoxicity data and is the concentration below which it is believed there will be no detrimental effect on the environment. It relies upon the assumption that a single value captures the concentration at which no toxic response (acute or chronic) is expected in the target population of marine biota. Dispersion models, such as that used in the present study, provide spatially and temporally varying PECs for either the whole effluent or individual compounds.

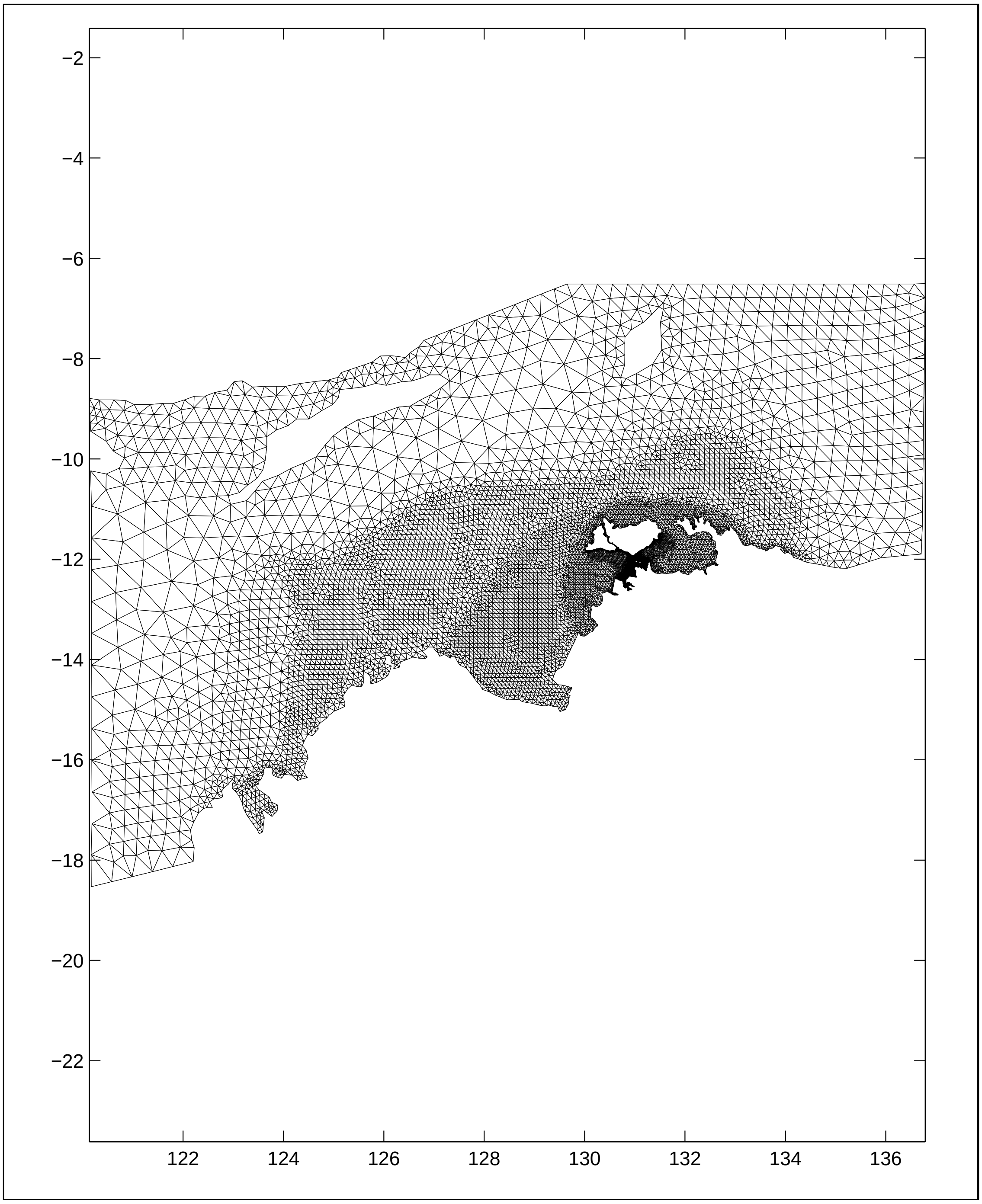


Figure 4.1: Timor Sea model grid.

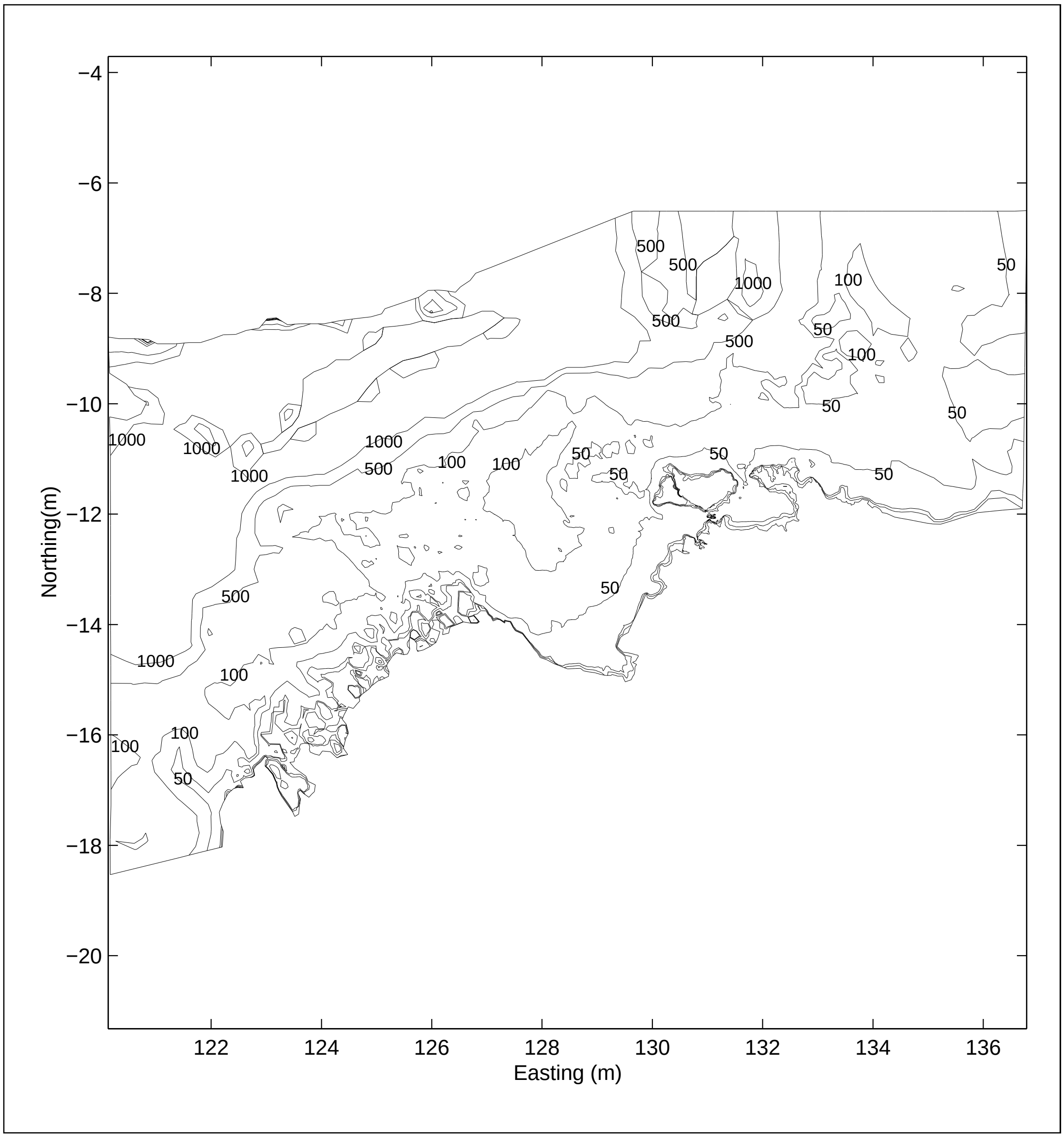


Figure 4.2 Model Bathymetry

If the spatial scale of the effect is limited to the immediate area around an offshore facility and the significance of the effect is considered to be low, then the risk is likely to be acceptable (Terrens and Tait 1996). Conversely, if the spatial scale of the effect is widespread and the survival or reproductive capacity of marine organisms is significantly reduced then the risk is likely to be considered unacceptable. Where risks are unacceptable, management actions are required to reduce risk to an acceptable level.

As the Kitan field is not yet producing it is not possible to directly undertake ecotoxicological tests on Kitan PFW. Thus, a conservative PNEC value of 0.1%PFW (1:1000 dilution) has been used in the modelling. This is based on knowledge of ecotoxicological results from PFW discharges on the North West Shelf and in the Timor Sea.

4.3 MODEL OUTPUT

Model results were presented as:

- plan views of PFW concentrations in the discharge plume;
- time series of PFW concentrations and excess temperature at 200m from the discharge in any direction; and
- maximum and averaged predicted PFW concentrations and associated ratio of the Predicted Environmental Concentration to the Predicted No Effect Concentration (PEC/PNEC ratio) over the duration of the simulation.

Plan views of PFW concentrations were plotted for various stages of the tidal cycle. As plume concentrations vary through the water column, the maximum temperature from each layer in the model was plotted rather than results from one particular layer or a depth averaged value. A time series of the maximum predicted concentration and temperature at 200m and in any direction from the discharge was also plotted.

To identify the highest PFW concentration occurring over the duration of the simulation, the model recorded the maximum instantaneous values occurring in each cell. These values were plotted to present surface and vertical distributions through a transect along the length of the plume. Similar plots were presented for time averaged values over the duration of the simulation.

PEC/PNEC ratios were calculated using the average concentration over the duration of the simulation. The PEC/PNEC ratio is an established technique to screen chemicals in offshore discharges (EC 1996). A chemical is assessed to be environmentally compatible if the PEC i.e. the concentration predicted to occur in the environment is lower than the PNEC, which is the concentration at which no adverse environment effects occur. If the PEC/PNEC ratio is greater than 1 i.e. PEC>PNEC, then the chemical is assessed to potentially cause adverse environmental effects. Sublethal ecotoxicological test data from tests conducted over durations of at least 24 hours were used to calculate PNEC.

5. RESULTS

Once PFW is discharged to sea, it is subject to dilution, dispersion and physical, chemical and biological degradation. Figure 5.1 shows the predicted PFW concentrations at various stages of the tidal cycle for the chosen period. The location of the Big Bank Shoals in relation to the FPSO and the PFW plume is shown in the bottom left hand corner of each figure. After discharge, the PFW stream rises to the surface under its own buoyancy and spreads laterally. The plume is then advected away from the discharge point by ambient currents whilst mixing both horizontally and vertically into the receiving waters. The PFW plume is predicted to extend up to 6km from the FPSO albeit as discontiguous patches and at the low concentrations of 0.01% – 0.1% of the initial concentration i.e. 1,000 times to 10,000 times dilution. Figure 5.1 also indicates that during the course of this particular model simulation, the PFW was constrained to within the top 7m of the water column.

Figure 5.2 shows the time series of PFW concentrations at 16 compass points, 200m from the discharge point. Concentrations are highly variable in time and space as a result of ambient currents. Ambient currents fluctuate with tide and prevailing wind conditions: during low current speeds, the plume pools and concentrations increase; conversely during strong currents, concentrations decrease as dilution of the plume is enhanced.

The maximum, mean and 95th percentile predicted PFW concentrations at 200m from the FPSO along 16 compass points are summarised in Table 5.1. Maximum concentrations are predicted to the east-northeast. Whilst the maximum concentration in this direction was predicted to be 1.64%PFW, the mean and 95th percentile concentrations were predicted to be 0.03% and 0.19%, respectively, highlighting that PFW would generally be expected to occur at very low concentrations beyond 200m of the FPSO.

Table 5.1 Maximum, mean and 95th percentile concentration at 200m from the discharge point

	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
Max	0.95	0.99	1.64	1.11	1.11	0.85	0.79	0.61	0.61	0.41	0.72	0.60	0.60	0.68	0.73	0.95
Mean	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.04	0.03	0.03	0.02
95%ile	0.17	0.10	0.19	0.08	0.08	0.03	0.04	0.07	0.07	0.06	0.14	0.17	0.17	0.16	0.18	0.17

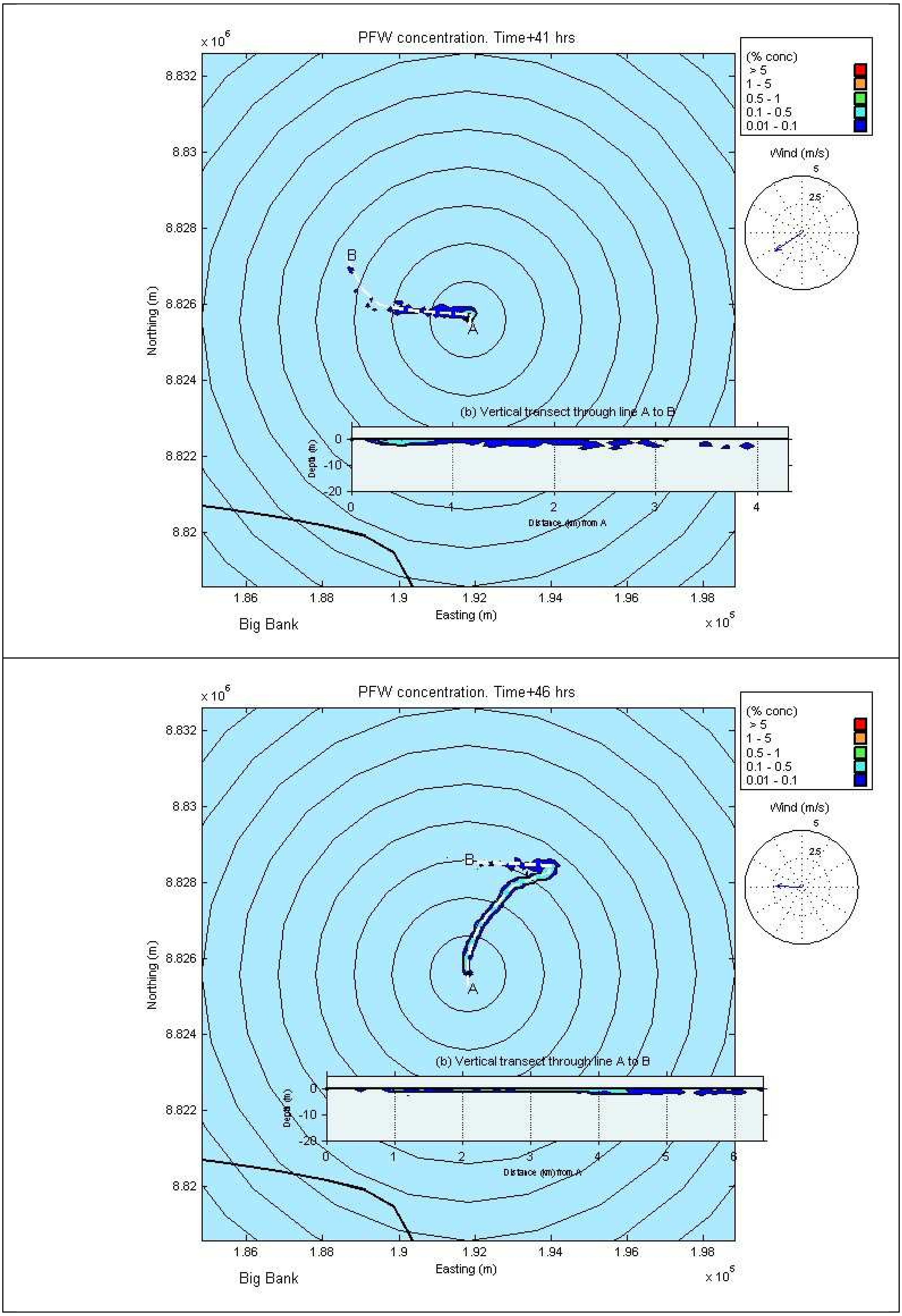
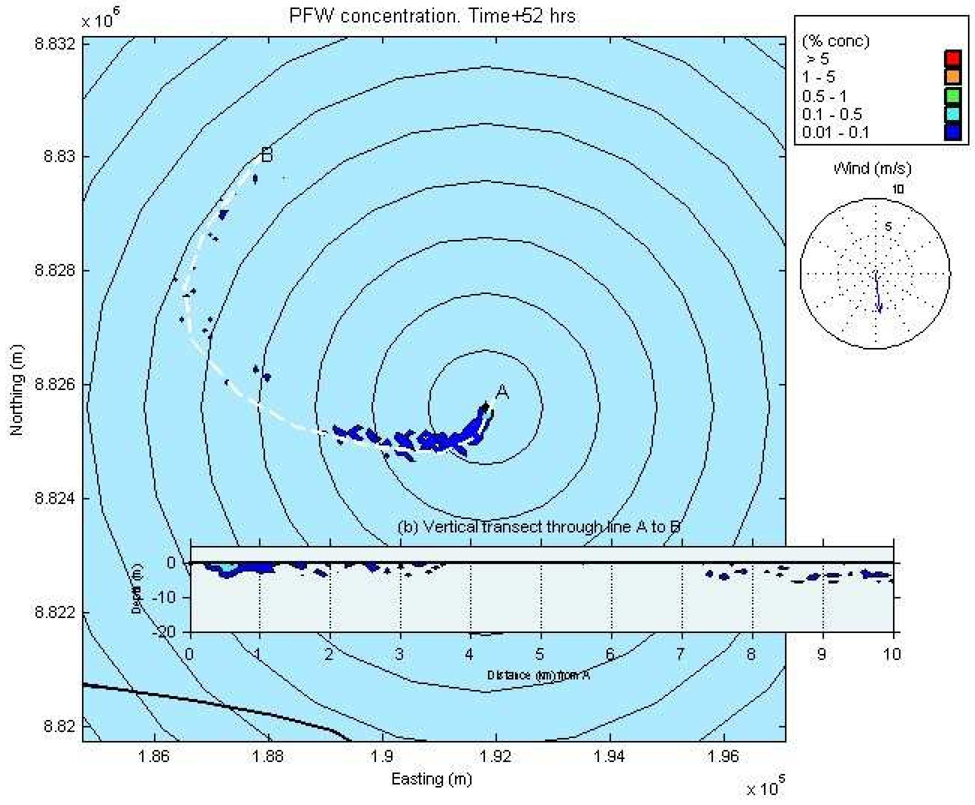


Figure 5.1 Predicted PFW concentrations for maximum design discharge rates (250m^3) at various times of the tide cycle



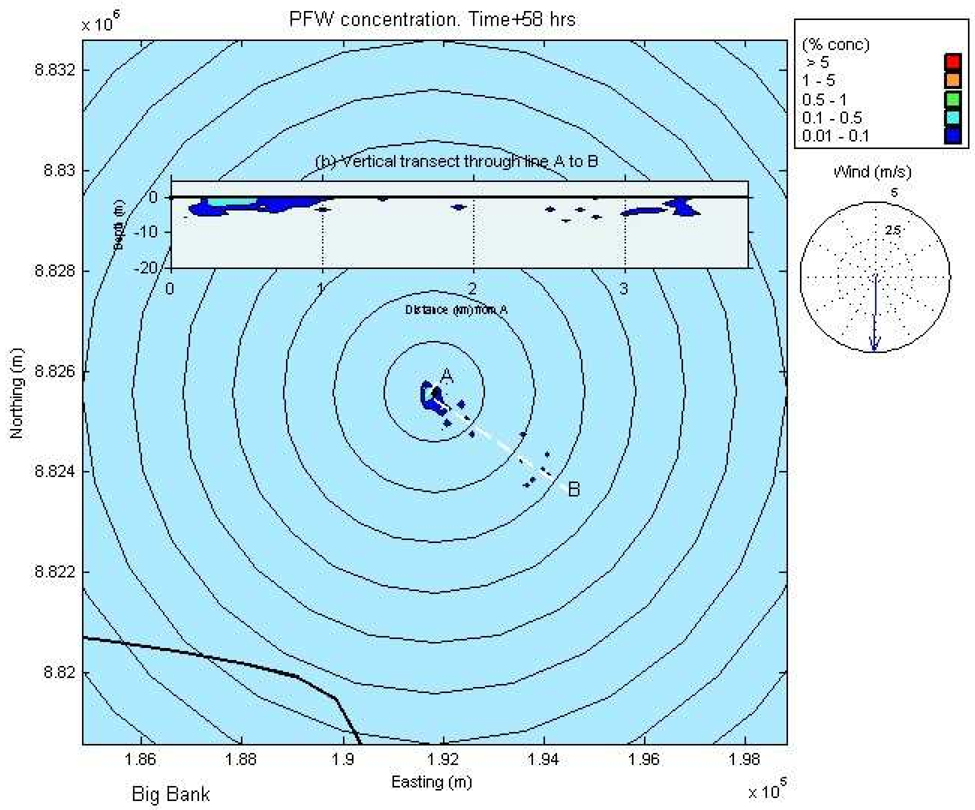
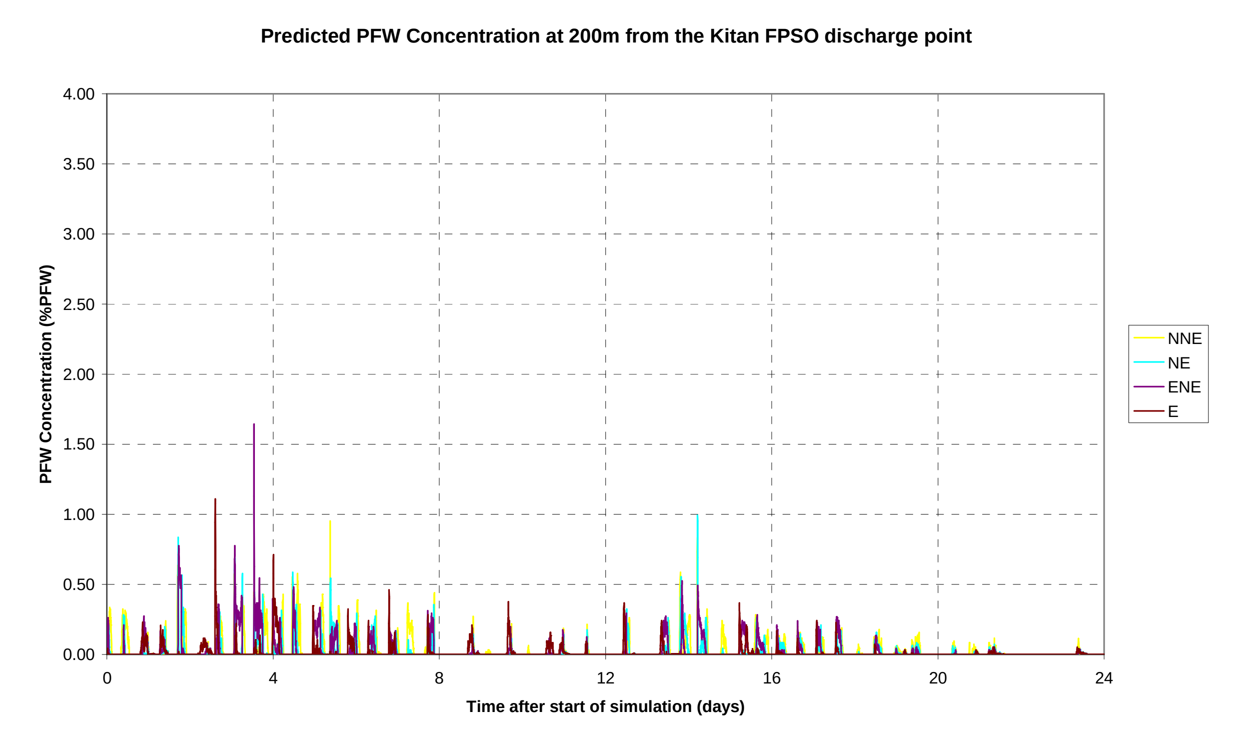


Figure 5.1 (continued) **Predicted PFW concentrations for maximum design discharge rates (250m3) at various times of the tide cycle**



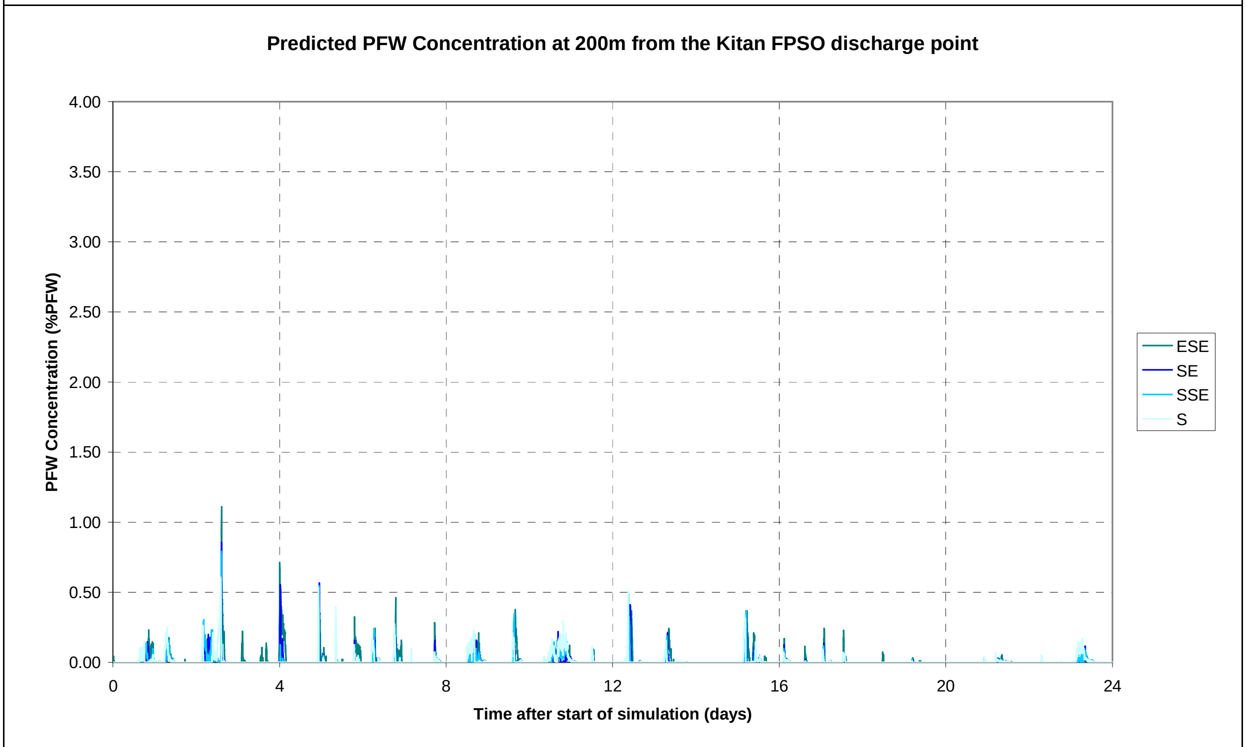
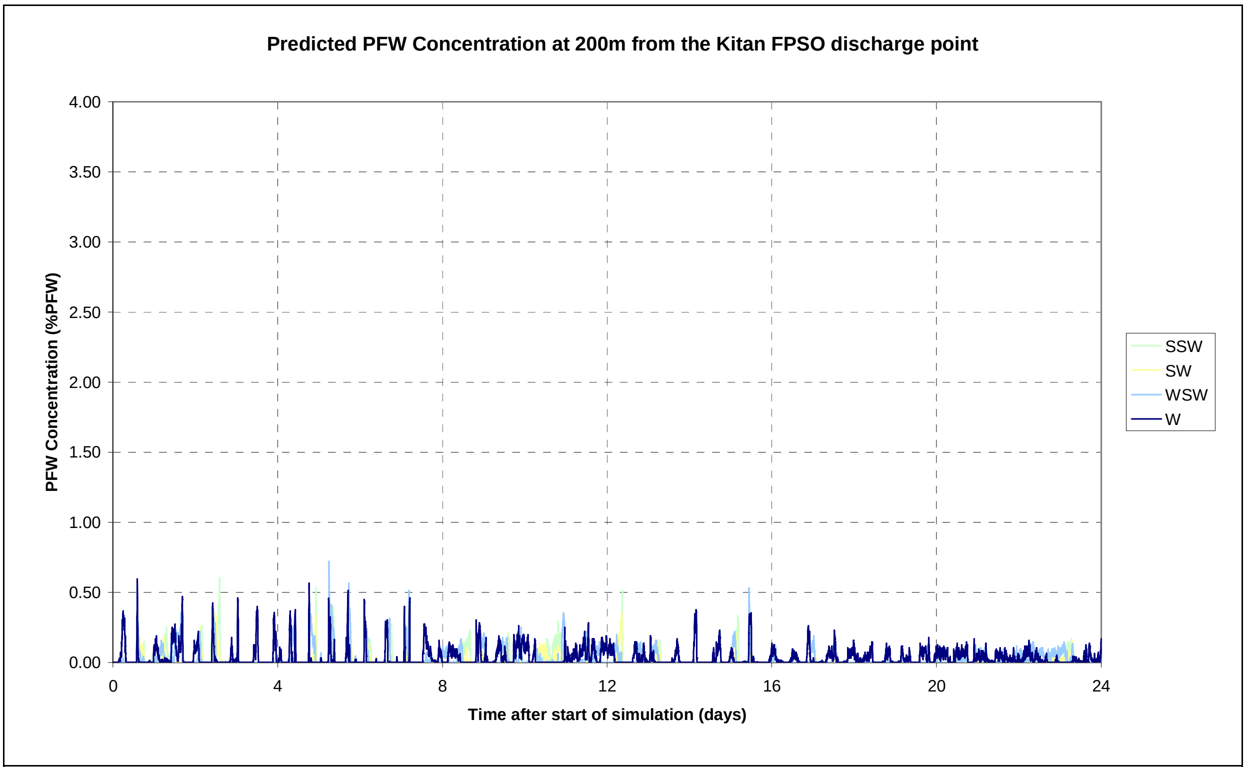


Figure 5.2 Predicted PFW concentrations at 200m from the discharge point for maximum discharge rate (250m^3)



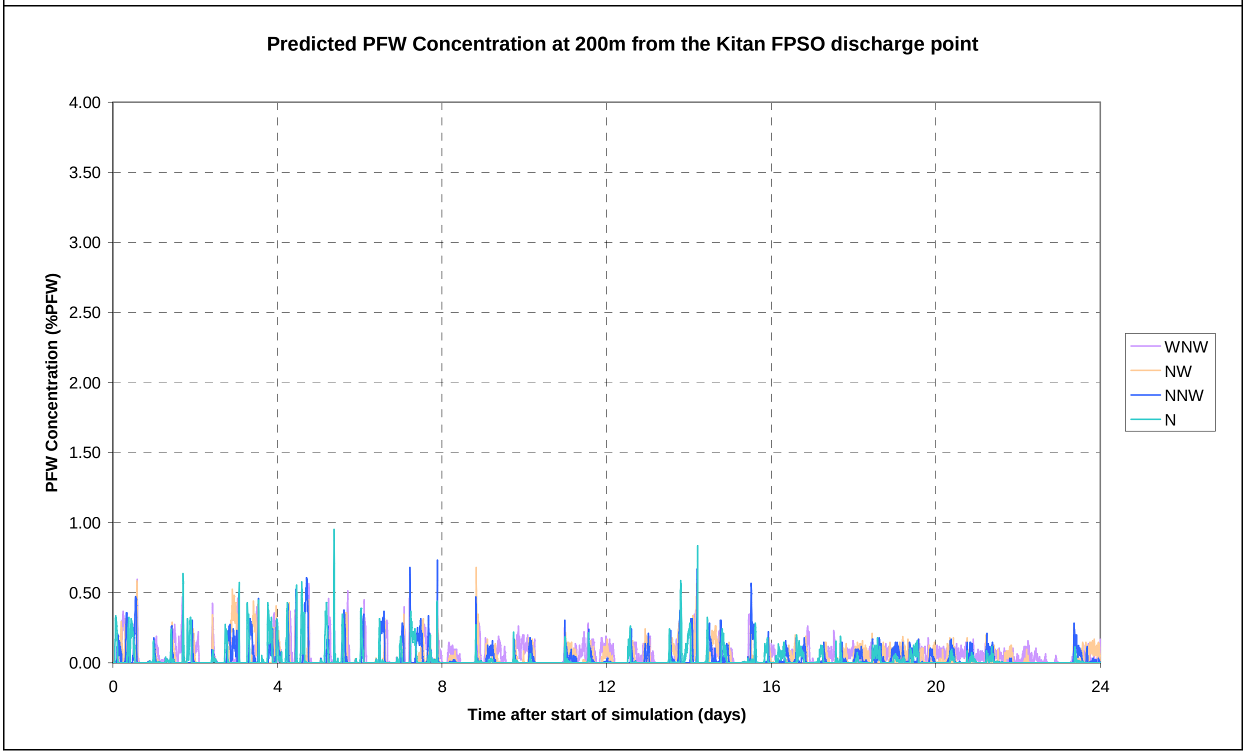


Figure 5.2 (continued) Predicted PFW concentrations at 200m from the discharge point for maximum discharge rate (250m^3)

Figure 5.3 shows the maximum predicted %PFW concentration recorded laterally and vertically around the proposed FPSO location over the 25 days of the model simulation. Using a conservative PNEC of ≥0.1%PFW, indicates that PFW at potentially toxic concentrations could occur at some time at a distance of up to 7km from the FPSO. Figure 5.3 also indicates that potentially toxic concentrations could occur at some time at a depth of up to 7m from the FPSO. The maximum %PFW concentration provides a prediction of the highest PFW that may occur at any given point but is not indicative of the conditions that would generally prevail around the FPSO.

Figure 5.4 shows the predicted PEC/PNEC ratio based on average %PFW concentrations recorded around the FPSO over the 25 days of the model simulation. A PEC/PNEC ratio >1 i.e. where the PEC exceeds the PNEC was only observed to occur within 250m of the FPSO. Beyond 250m, the PEC/PNEC ratio was predicted to be <1 so no adverse effects would be expected to occur. This means, with a PNEC set at 0.1% PFW, that dilutions of over 1000 times of the initial PFW concentration would be expected to occur by the time the plume has travelled 250m from its discharge point.

A PEC/PNEC ratio >1 was predicted to be constrained to within 1m water depth from the surface (Figure 5.4). Thus, with a PNEC set at 0.1% PFW, dilutions of over 1000 times of the initial PFW concentration would be expected to occur within the top 1m of the plume. Importantly, the model simulation indicated that PFW would not reach the Big Bank Shoals, either laterally or vertically, at concentrations that would be toxic to marine biota. The maximum PFW concentration in the vicinity of the Big Bank Shoals was predicted to be 0.01% — 0.05% i.e. a dilution of between 2,000 and 10,000 times of its initial concentration.

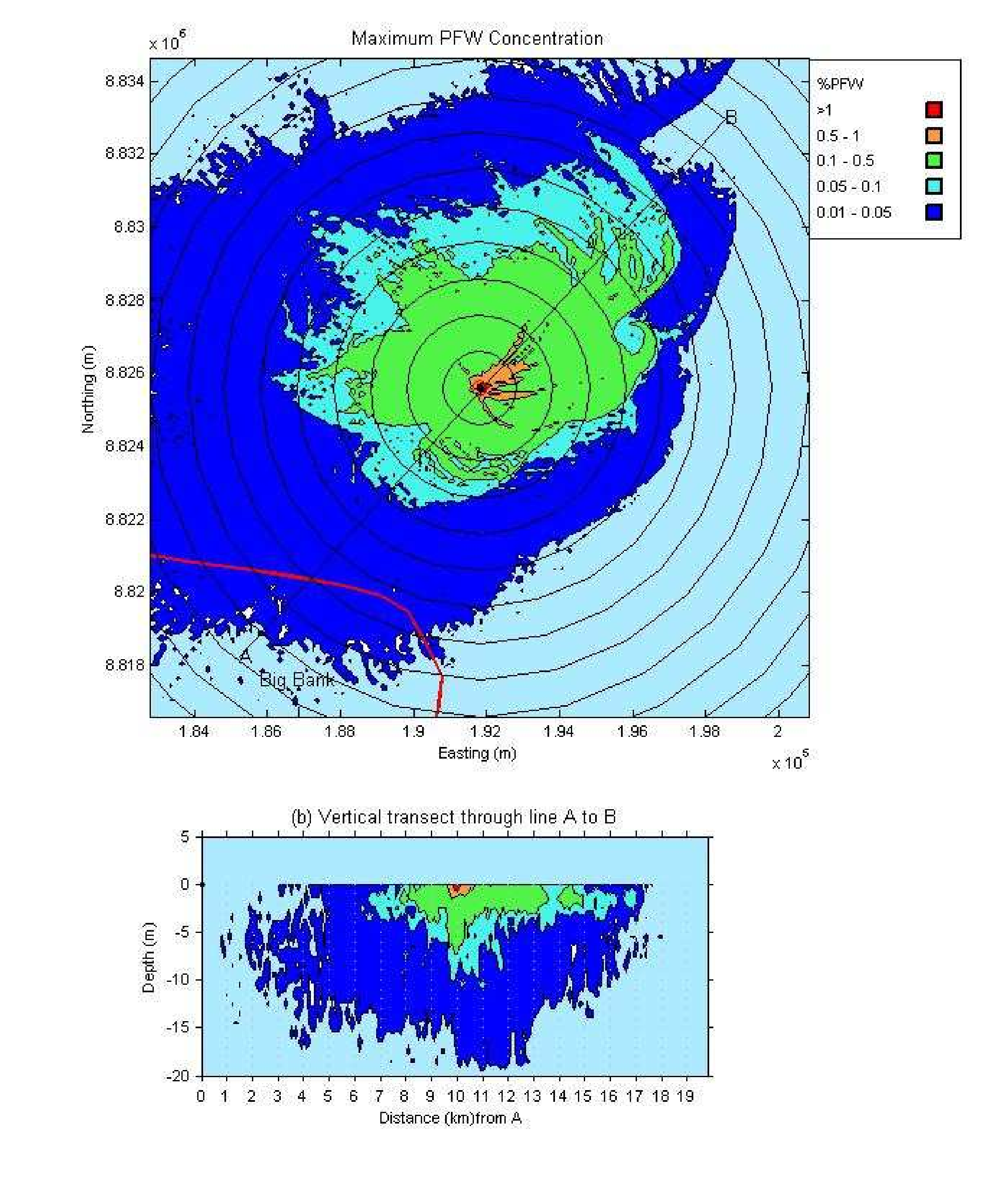


Figure 5.3 Maximum predicted PFW concentrations for the duration of the model run (maximum design discharge rates, 250m3/hr)

Notes: *Discharge flow = 250,m^3/day;*
Discharge temperature (T0) = 45°C;
Discharge depth = 5m below the surface;
Ambient temperature = 30°C
PNEC = 0.1% PFW;
Range rings drawn at 1km intervals

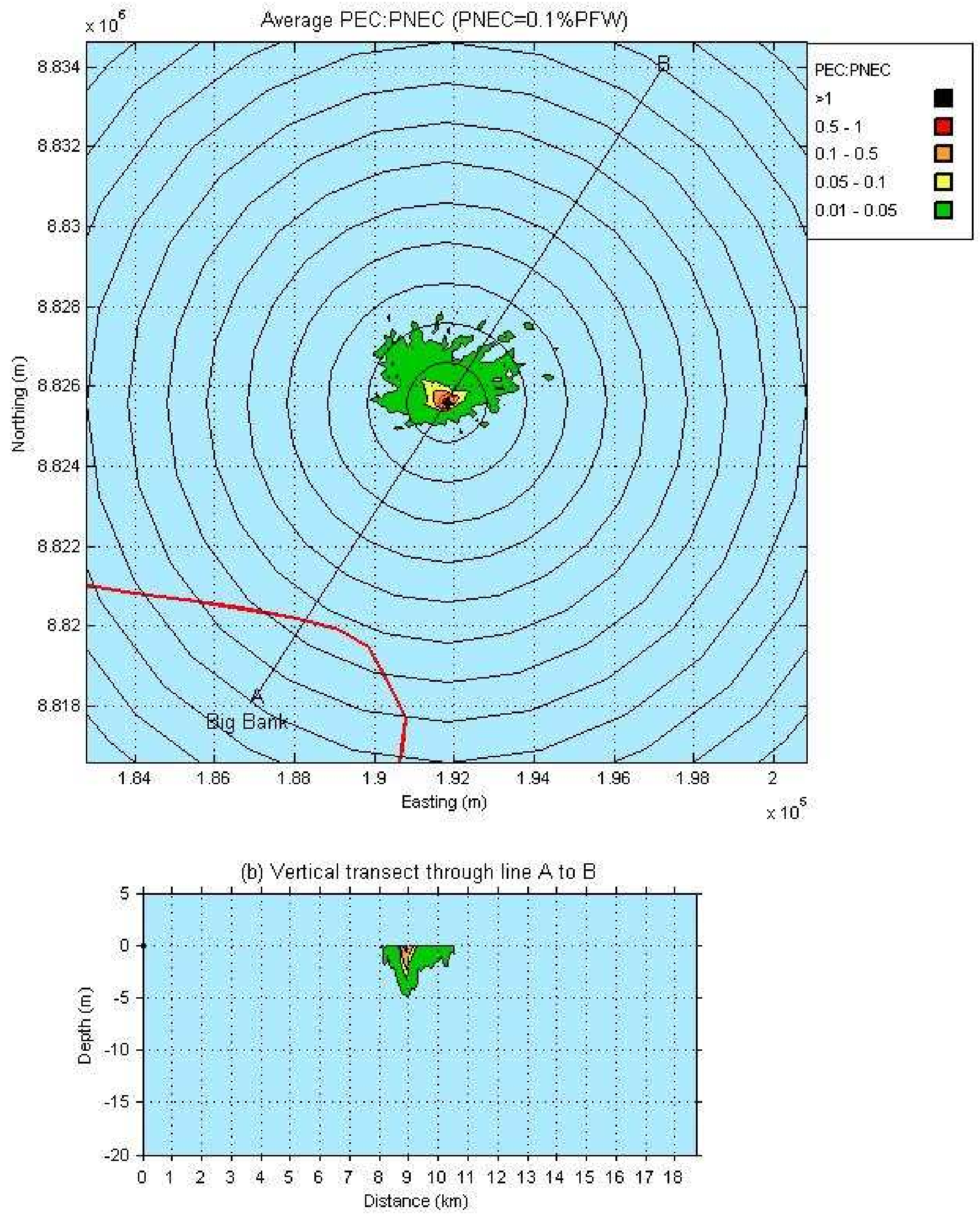


Figure 5.4 PEC/PNEC ratios for average PFW concentration recorded over the duration of the model run

Notes: *Discharge flow = 250,m³/day;*
Discharge temperature (T0) = 45°C;
Discharge depth = 5m below the surface;
Ambient temperature = 30°C
PNEC = 0.1% PFW;
Range rings drawn at 1km intervals

6. EVALUATION OF ENVIRONMENTAL RISK

6.1 ENVIRONMENTAL RISK

To present a more intuitive assessment of the risk posed from the PFW being discharged from the Kitan FPSO, the impact to individual biological communities is examined. These communities include:

- benthos;
- plankton;
- sessile invertebrates (communities attached to the facility);
- fish;
- marine mammals; and
- seabirds.

6.2 BENTHOS

Benthos communities are found in or around the seabed. They are highly unlikely to be affected due to the deep water and the fact that the plume disperses rapidly in the water column and does not impact directly on the seabed. Furthermore adsorption of organic compounds onto suspended sediment particles will be low as the compounds discharged will be low molecular weight, limiting the extent of sedimentation to the seabed.

6.3 PLANKTON

Planktonic organisms live freely in the water column and drift with the water currents. Plankton may also include the early stages (e.g. egg, larva and spores) of non-planktonic species (fish, benthic invertebrates and algae). Figure 6.1 illustrates the typical exposure periods for passive floating organisms. Once discharged to the receiving environment, dilution reduces the concentration of potentially toxic chemicals in the PFW. Under the present discharge rate and configuration, initial dilutions are high. For a "worst-case" scenario, a freely floating organism passing directly beneath the discharge pipe may be exposed to PFW concentrations above the PNEC value for up to 48 hours. There is therefore the potential for impact, however, the exposure concentration will be continually diluting and only organisms residing directly in the plume would be impacted, which constitutes a small proportion of the community.

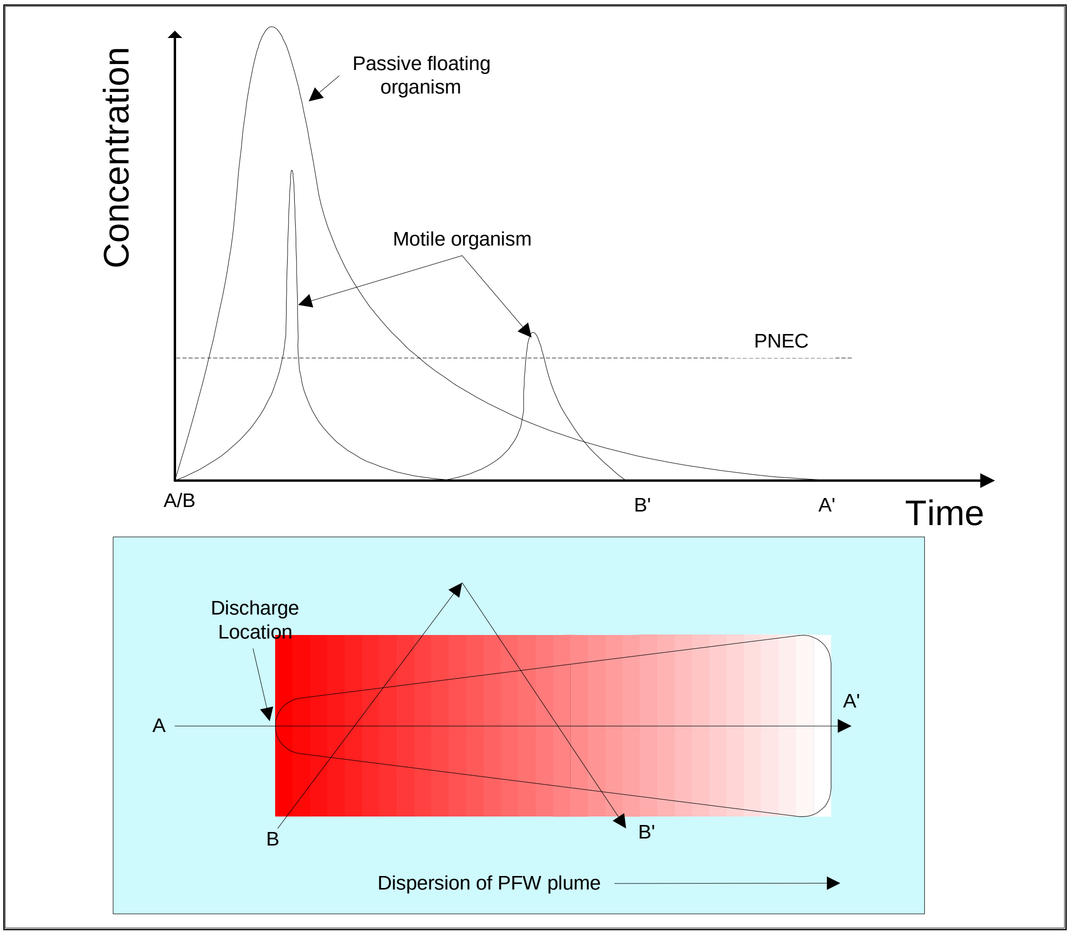


Figure 6.1 Exposure times to the PFW plume for passive and motile organisms

6.4 SESSILE MARINE INVERTEBRATES

Sessile marine invertebrates are those that are attached to the substrata and infrastructure surrounding the discharge. These do not have the opportunity to move to avoid toxic affects and potentially are the most exposed communities to the plume. Even though these organisms cannot move, the plume would be continually moving around them depending on the direction and speed of ambient currents. Sessile invertebrates that are attached to the FPSO (i.e. biofouling) may therefore be sporadically exposed to high concentrations of PFW, with the potential for accumulation of hydrocarbons in their tissues. The impact of this process would be limited by measures undertaken to control biofouling of the vessel and by natural depuration during periods when these organisms are positioned in clean seawater.

6.5 MOTILE ORGANISMS

Figure 6.1 shows the typical exposure periods for motile organisms such as fish. These have the ability to swim and might move in and out of the plume. Exposure periods are likely to be sporadic and short lived and therefore unlikely to be at levels which would harm the organism. Moreover, the volume of water exposed to concentrations above PNEC values is relatively small both under present and projected discharge rates.

6.6 MARINE MAMMALS

As marine mammals feed on fish and/or plankton, they are most likely to be affected by trophic transfer (i.e. bioaccumulation of chemicals from food) and potential biomagnification. However, vertebrates are able to metabolise and excrete the type of chemicals that contribute most to the risk. They are also generally migratory so their exposure period is expected to be low and individuals would not be likely to be affected by any localised contamination that may occur.

6.7 SEABIRDS

Seabirds are harmed mainly by the physical properties of floating oil and not the toxicity (Furness and Camphuysen 1997). The PFW plume is not expected to create surface slicks at concentrations that could be harmful through direct coating of feathers, or through ingestion during preening. As with the marine mammals, there is the potential for trophic transfer and indirect effects such as changes in the availability of food sources. As the food source is not likely to be impacted, the risk to sea birds is low.

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8. ABBREVIATIONS

AHD	Australian Height Datum
BOD	Basis of Design
Eni	ENI-JPDA-06-105 PTY LTD
EIF	Environmental Impact Factor
EIS	Environmental Impact Statement
FPSO	Floating Production Storage and Offloading facility
HAT	Highest Astronomic Tide
HYCOM	HYbrid Coordinate Ocean Model
JPDA	Joint Petroleum Development Authority
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
PEC	Predicted Environmental Concentration
PFW	Produced Formation Water
PNEC	Predicted No Effect Concentration
PPM	Parts Per Million