Africa Oil SA Corp SOUTH AFRICA

Well Drilling in
Block 3B-4B

DRILLING DISCHARGE MODELLING

TECHNICAL REPORT

Date: **02nd April 2024**

Identification page

Title	:	Exploration Well Drilling in Block 3B-4B off the West Coast of South Africa – Drilling Discharge Modelling WBM + NADF
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Location - Date	:	Pau – April 2024

- **Study's Reference**: OPP-2023-01-0100
- **Number of volumes**: 1

Keywords: Drilling Discharge, water column, sediment, discharge point.

Geographical references: South Africa / Offshore / Block 3B-4B

Abstract:

Africa Oil SA Corp South Africa intends to carry out exploration drilling activity in Block 3B-4B in offshore waters of the South African West Coast in the South Atlantic Ocean (hereafter called the project).

To prepare the Environmental and Social Impact Assessment (ESIA), and to further understand all risks related to offshore drilling discharges, this report has been prepared to present the environmental risks resulting from the cuttings and mud discharges from drilling operations into the water column and onto the surface seabed sediments considering two discharge locations, called Points A and D, and for two different types of mud: Water Based Mud (WBM) and Non Aqueous Drilling Fluid (NADF). Discharge points selected for the study scenarios (refer to Section 1.3) represents the worst-case locations of the potential five well locations identified in the area of interest for drilling.

To perform this project, the ParTrack module from Marine Environmental Modelling Workbench (MEMW) software (v 14.1) was used. This tool is among the best in its class for drilling discharge modelling, considering its capabilities to determine the chemical and physical impact of the drilling discharge in the marine environment. Four modelling periods were considered, *i.e.* all the Quarters of the year.

Main conclusions are as follows:

***Reminder:* Risk>5% = significant risk = potential impact of the compartment (water column or sediment).**

Remark: The calculated risk has also to be balanced because of the very conservative approach used in the model. Thus, high conservative safety factors were used (i.e. 1000) for chemicals, following the approach recommended by OSPAR/EU regulation. Recovery calculation is also quite conservative, not considering all the processes in place.

Water Based Mud Scenarios – Point D

Water Column

The environmental risk in the water column is medium, with a value of 52% to 55% and is due to the Riserless sections and the displacement discharges, given that the risk is mainly due to the release of Bentonite, and Barite to a lesser extent. The maximum risk distance reached is 260 m all around the discharge point but is quickly dispersed and diluted by the local currents, because there is no more risk after 5 days (i.e. after the 26" section displacement discharge).

Sediment

Contrary to the water column, the environmental risk for the sediment is mainly due to the physical contamination by the riserless and risered sections discharge (and not the chemical contamination). The risk is significant in the sediment from day 1 to 1030 days after (less than 3 years), mainly due to the end of the riserless sections discharged. The highest risk is reached just after the end of riserless discharge, and decreases quickly 2 years and 9 months after operations, with no more risk in the sediment after 3 years. The main contributors to the environmental risk for the sediment are physical, *i.e.* the thickness deposit of the discharge and the grain size change of the natural sediment (due to higher grain size particles released during the discharge).

The risk of these discharge operations seems limited close to the release point, less than 300m around the release point, for both water column and sediment for Water based Mud scenarios. The risk in the water column is quickly dispersed by the currents and is not present anymore after the operations only due to riserless discharge.

The risk in the sediment is more physical than chemical, and is therefore more persistent especially close to the discharge point, because the high grain size particles are difficult to disperse by bottom currents, weaker than surface currents.

Non-Aqueous Based Mud Scenarios – Point D & Point A

Water Column

The environmental risk in the water column is present from the surface to the seabed for both Points D and A, meaning that both types of discharges (risered and riserless) will have an impact. The environmental risk is mainly due to the NADF released during risered sections discharges for all the seasons. The main contributor to the risk in the water column is chemical, and due to the EDC-99DW released during the risered sections drilling. The Bentonite discharged during the riserless sections drilling is the second most impacting component for the Water Column. Due to the strong currents in the area, the environmental risk in the water column is present for several kilometres. However, strong currents present in this area allow a quick dispersion and dilution of the chemicals: the risk reached is very high close to the discharge point, but this is of short duration.

There is no more risk in the water column after the end of the operations for all the Quarters as result of dispersion and dilution processes due to the strong currents in this area.

Sediment

As for the water column, the environmental risk for the sediment is mainly chemical than physical, mainly due to components of the NADF released during the drilling of the risered sections: the fatty acid present in the EZMUL NT-A, Invermul NT-B and EDC-99DW-C, responsible for 74% to 80% to the total risk.

The physical risk, *i.e.* the grain size change of the natural sediment and the thickness deposit of the discharge, contributing together to less than 10 % of the total risk. The oxygen depletion in the sediment is responsible for values around 15% to the total risk, and is a mix of physical and chemical impact.

With the use of Non Aqueous Drilling Fluid, the risk of these discharge operations is potentially high, but limited in time for the water column, and close to the release point. The risk in the water column and in the sediment is more chemical than physical since Non-Aqueous Based Mud contains components with very low PNEC (Predicted No-Effect Concentration), which can have a higher environmental risk, even released in small quantities. Based on the simulation work, the presence of introduced chemicals is most significant in the sediment, mainly due to the chemicals present in the risered sections being discharged. The highest risk is reached just after the end of the drilling operations, peaking around day 25, and decreases quickly 66 days after operations. However low levels of residual compounds may still be present for up to 10 years near the wellbore location, where dispersion and dilution processes are not as efficient compared to within the water column (lower currents on the seabed).

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EIMS: Liam Whitlow

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1 Introduction

1.1 Preamble

Africa Oil SA Corp South Africa intends to carry out exploration drilling activity in Block 3B-4B in offshore waters of the South African West Coast in the South Atlantic Ocean (hereafter called the project).

To prepare the Environmental and Social Impact Assessment (ESIA), and to further understand all risks related to offshore drilling discharges, this report has been prepared to present the environmental risks resulting from the cuttings and mud discharges from drilling operations into the water column and onto the surface seabed sediments considering two discharge locations, called Points A and D, and for two different types of mud: Water Based Mud (WBM) and Non Aqueous Drilling Fluid (NADF). Discharge points selected for the study scenarios (refer to Section 1.3) represents the worst-case locations of the potential five well locations identified in the area of interest for drilling.

To perform this project, the ParTrack module from Marine Environmental Modelling Workbench (MEMW) software (v 14.1) was used. This tool is among the best in its class for drilling discharge modelling, considering its capabilities to determine the chemical and physical impact of the drilling discharge in the marine environment.

Four modelling periods were considered, representing the four quarters of the year. One should note that the scenarios are characterized by the discharge location, a discharge composition (including mud and cuttings) and amounts released during the operations for each section. The scenarios considered for this study are based on best available input data at the time of the study and are discussed in this report.

1.2 Discharge Points Selection and Location

The Applicant is proposing to drill up to five exploration wells within an AOI within Block 3B/4B. The exact locations of the wells to be drilled within the area of interest in Block 3B-4B are not yet known, however indicative target points have been identified, namely Points A to E (refer to Figure 1).

As several well locations were proposed, the two locations were selected for modelling based on:

- Distance from the coast: it will directly influence the travel time and quantities that may be stranded on the shoreline.
- Proximity of marine protected areas (MPAs) and critical biodiversity areas (CBAs) that might be impacted especially by drilling discharges which are more localized than oil spill (refer to separate oil spill modelling study) (see Figure 1).
- Currents directions that could potentially cause the drill cuttings drift towards Marine Protected Areas.

Two locations are retained, considered as the worst-case locations inside the area of interest, and are presented on Figure 1:

- The Point D was selected as the worst-case release point for WBM and NADF cases.
- The Point A was selected as an additional worst-case release point for NADF only. This point was selected north from the D point, to verify if some differences in the currents speeds and directions could bring cuttings and chemicals in other areas.

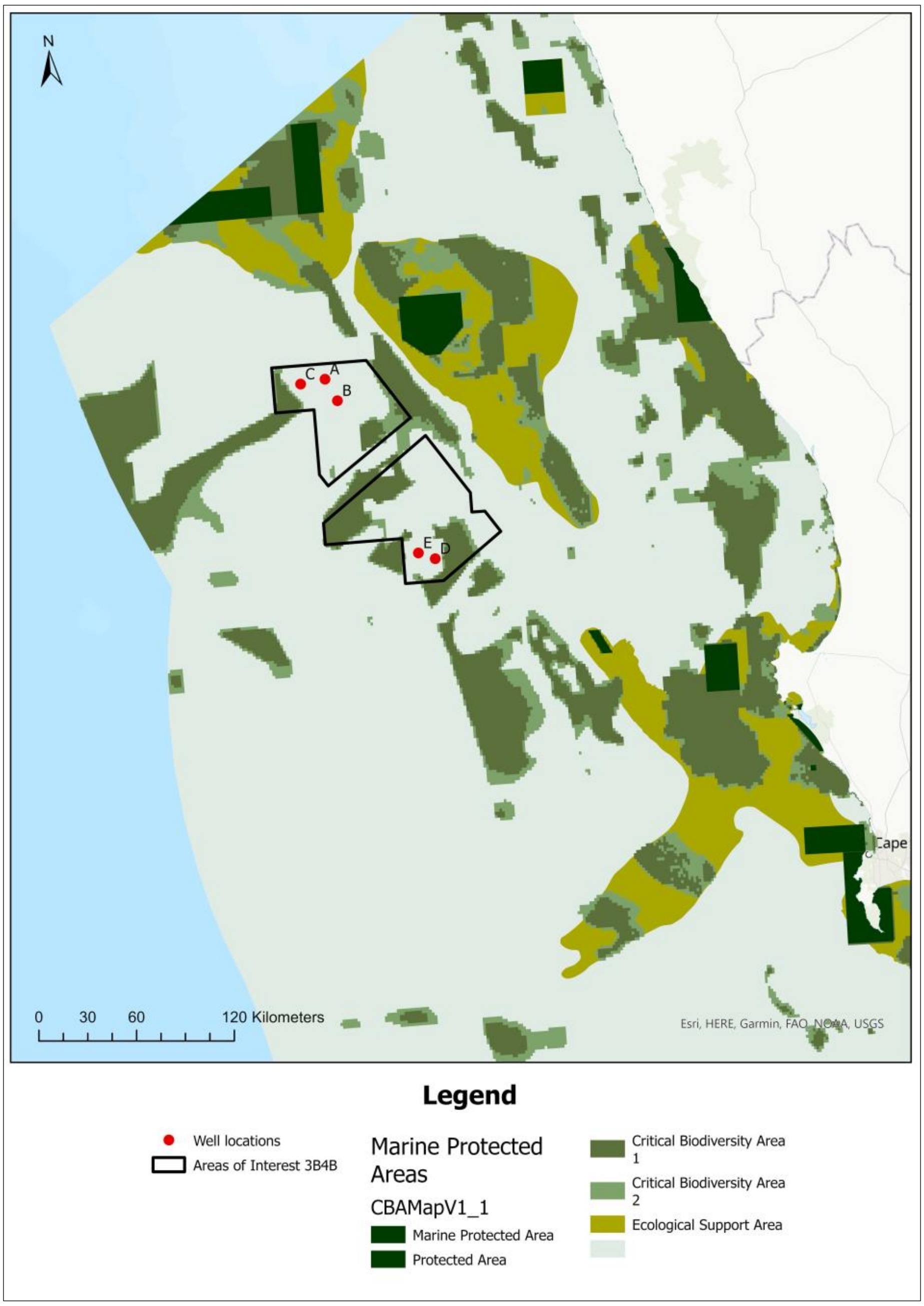


Figure 1: Release points locations, area of interest and sensitivity map

The characteristics of the selected location are presented in Table 1.

Table 1: Release points depth and currents and winds trends

RELEASE POINT	Coordinates (WGS84)	Water Depth (m)	Surface currents main directions (to)	Winds main directions (from)
A	Longitude: 15° 5' 10.52"E Latitude : 31° 05' 13.79" S	1626	WSW to NNE	S to SE
D	Longitude: 15° 42' 19.51"E Latitude : 32° 07' 33.38" S	1499	WSW to NNE	S to SE

2 Material and Method

2.1 Environmental data

2.1.1 Seasons and Environmental Average Data

The four Quarters of the year are studied in this project.

Environmental data used for the modelling simulations are detailed in Table 2:

Table 2: Environmental average data.

Upper water column temperature (°C)	Season 1: 20.2 Season 2: 19.2 Season 3: 16.4 Season 4: 16.9
Lower water column temperature (°C)	2.6
Salinity (‰)	35
Seawater oxygen content (mg/l)	5.2
Suspended sediment (mg/l)	4
Air Temperature (°C)	19
Median Grain Size (mm)	0.01

Temperature and salinity data detailed in the table above are coming from Copernicus global-reanalysis-001-030-monthly dataset over 1993-2020 at the release location. Oxygen content and suspended sediment is a synthesis between data from TEPNA 2913B-Venus EBS (2018) and - TEPSA 567 EMPr update seismic (2013).

2.1.2 Metocean Dataset (3D Currents & 2D Wind Data)

The current data used are based on a 3-year dataset (1st of January 2019 – 31st of December 2021) which comprises 3D currents from the continuous current hindcast at each grid point:

- 3D currents
  - NetCDF format (OSCAR compatible)
  - 3 years of data (1st of January 2019 – 31st of December 2021)
  - Spatial resolution at least 1/32°
  - Vertical resolution: 32 layers with different resolutions (5m layers at surface, 500 m layers at 5500 m)
  - For the wind dataset, a blend of wind observations by satellite and model was used on a single layer.
  - Time step: 3 hours.

The start time simulation of the drilling discharge scenarios is set to the year of 2021 (last year of the available metocean dataset), for each quarter.

2.1.3 Bathymetry

The Synbap depth database (Figure 2 and Figure 3), integrated in the ParTrack Software, was used for the simulations in this study.

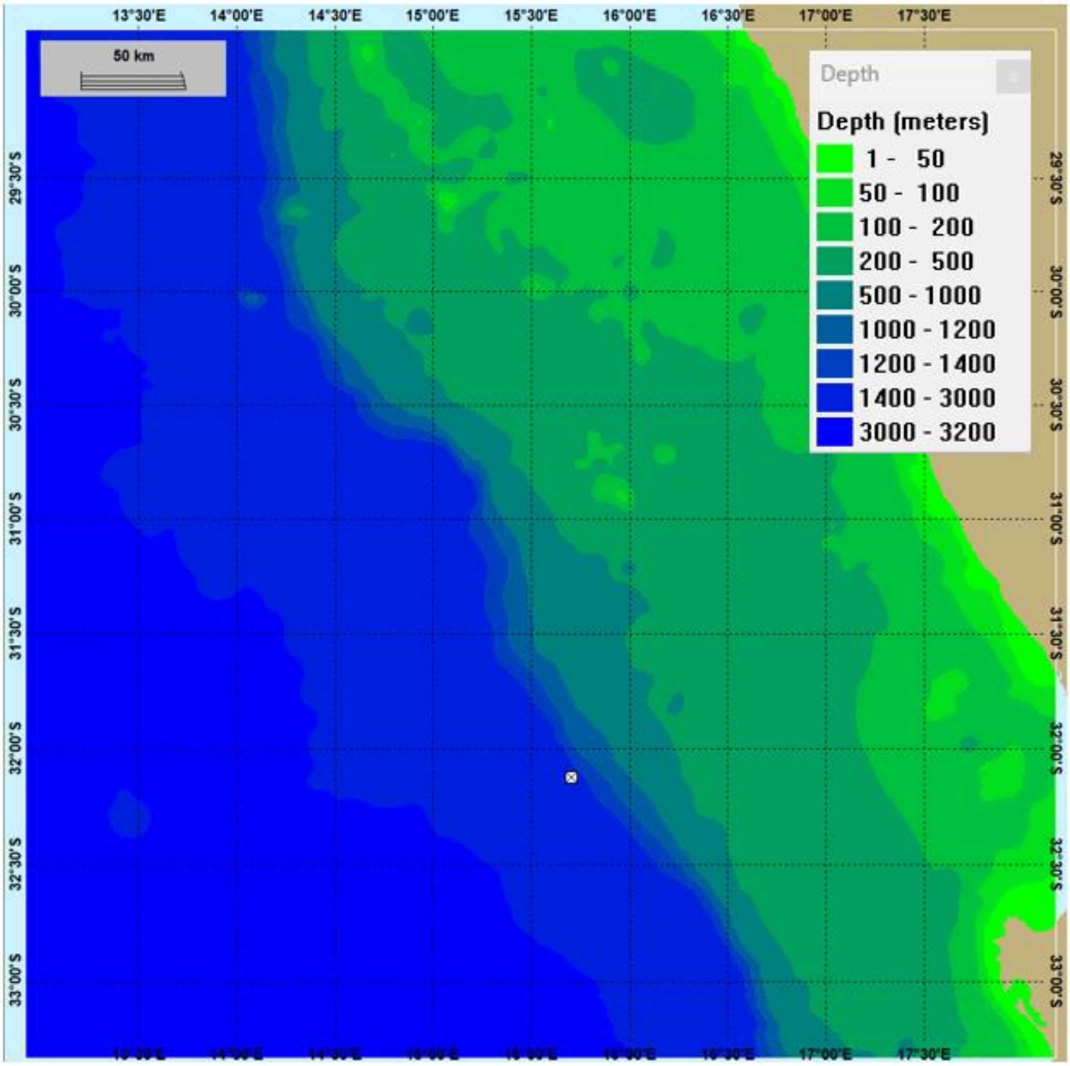


Figure 2: Bathymetry used within the model – Point D (*Source: Synbap / MEMW*)

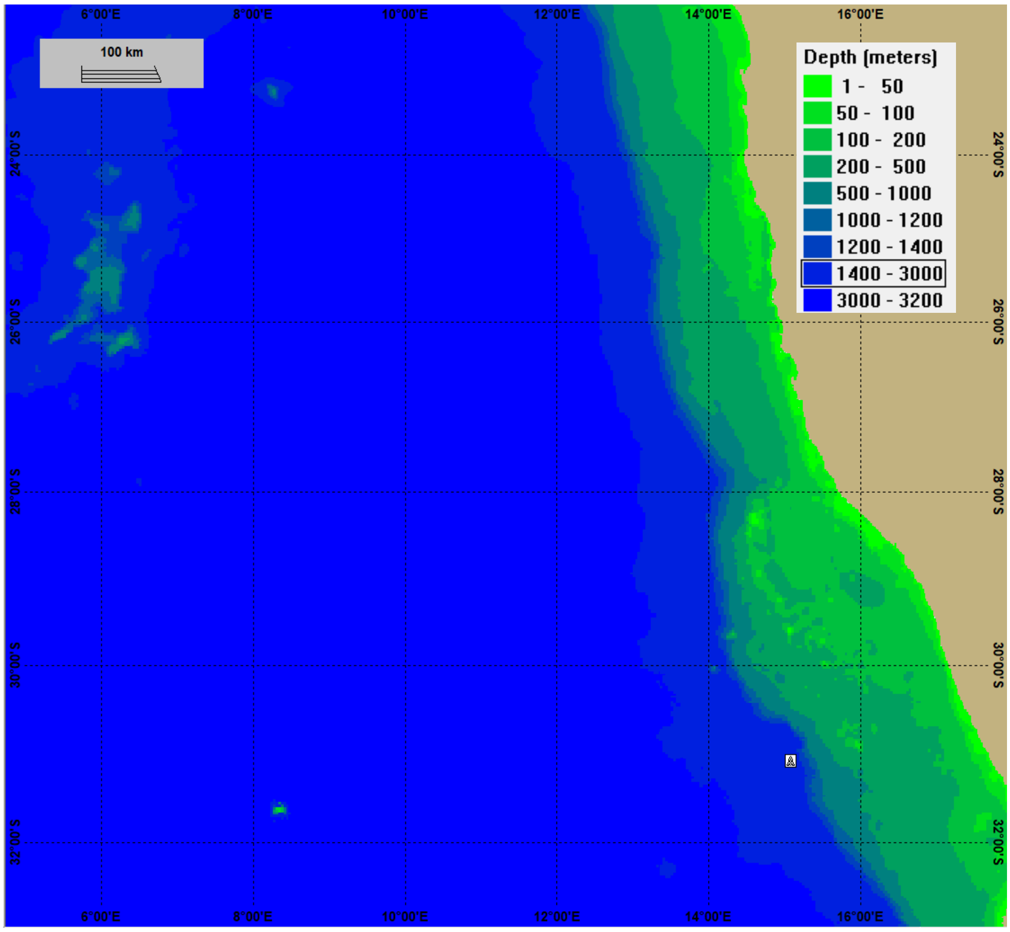


Figure 3 Bathymetry used within the model – Point A (*Source: Synbap / MEMW*)

2.2 Discharge Information

2.2.1 Water Based Mud Scenarios

2.2.1.1 Well design and drilled cuttings volumes estimation

Well design & drilled cuttings volumes estimation were provided by drilling engineers from the head-quarter/affiliate in charge of preparing the well design for this project.

In the case of a well design for a water-based mud drilling scenario, the following discharge was simulated from Point D only.

The well base case design is described as below (Table 3):

- 1st section: 36” section to be drilled riserless with WBM;
- 2nd section: 26’’ section to be drilled riserless using WBM;
- Suspension / Displacement before drilling of the section 17.5”;
- 3rd section: 17 ½’’ section to be drilled with a riser using KCL/Glycol mud;
- 5th section: 12 ¼” section to be drilled with a riser using KCL/Glycol mud;
- 6th section: 8 ½” section to be drilled with a riser using KCL/Glycol mud.

The total duration of simulation for operations duration is 47 days and 19 hours (total duration of operational discharge+ lag time in between the operation).

Table 3 – Drilling Mud Information

Wellbore diameter (")	36"	26"	Suspension / Displacement before drilling of section 17.5"	17.5"	12.25"	8.5"
Sections length (m)*	70	320		700	1050	1160
Drilling rate (m/h)						
Volume of cuttings cum	40	76		74	61	27
Cuttings discharged (yes/No)	Yes	Yes		yes	yes	yes
Type of mud used while drilling	Sea Water	Sea Water		KCL/glycol	KCL/glycol	KCL/glycol
Mass of Fluid Discharged (t)	209	135		133	109	61
Indicative time before next operation (hours) – (including time to prepare next operation. cementing operation. Liner. casing. pressure tests…) = no discharge	20	40		72	105	60
Suspension/ displacement/kill mud before drilling next section (yes/No)	No	No	Yes	Yes	Yes	Yes
Type of mud used for Suspension/clean-up/displacement	Seawater, viscous sweeps & WBM	Seawater, viscous sweeps & WBM	High Viscous Gel sweeps / KCl Polymer PAD mud	KCL/glycol	KCL/glycol	KCL/glycol
quantity of mud discharged for Suspension/clean-up/displacement (T)			30			
Discharge DEPTH (m)	Sea floor	Sea floor	Sea floor	10 m below Sea Surface	10 m below Sea Surface	10 m below Sea Surface
Discharge diameter (meters)	1.0668	0.6604	0.6604	0.2794	0.2794	0.2794

**Simulation with 3750 m of total Section Length was re-run for Q1, there is absolutely no change in the results compared to the results presented in this report (because the amounts of the main contributors to the environmental risk do not change).*

2.2.1.2 Mud Composition

The indicative mud composition presented in this report (considered worst-case) is based on a provisional formulation provided by the Africa Oil Corp Fluid team as this is the only available information at the date of the study (Table 4). **The composition may vary slightly depending on the contractor's selection and may later be modified to suit operational needs.** Several types of drilling fluid (details provided in service request form) will be used for drilling operations with different compositions and densities.

Table 4 – Properties of the drilling mud components

Product	Function	KOC	PNEC	Density	Solubility
Barite	Weighting Agent	100	200	4.2	0
Bentonite	Weighting Agent	100	88	2.5	0
Potassium Chloride	Shale inhibitor	1	100	1.98	355000
Caustic Soda	Alkalinity Control	1	20	2.13	1.00E+06
Soda Ash	Hardness Control	1	200	2.52	21500
Chemvis	Viscosifier	3.25	2000	0.989	989000
Chem PAC LV	Fluid Loss	1	1000	1.5	100000

Product	Function	KOC	PNEC	Density	Solubility
Chem Stratch	Fluid Loss (stratch)	1	1000	0.7	100000
Glyfor MC	Glycol Shale Inhibitor	1	100	1.98	355000
Chemcide	Biocide	1	1.38	1.32	5400

2.2.2 Non Aqueous Drilling Fluid Scenarios

2.2.2.1 Well design and drilled cuttings volumes estimation

Well design and drilled cuttings volumes estimation were provided by drilling engineers from the head-quarter/affiliate in charge of preparing the well design for this project with the use of Non Aqueous Drilling Fluid. In order to capture the deepest drilling depths envisioned at either release points A or D for the cuttings simulation, the total well depth was increased to 3,750 meters below the sea bottom. The following discharge was simulated from Point A and Point D.

The well base case design is described as below (Table 5):

- 1st section: 36" section to be drilled riserless with WBM;
- 2nd section: 26'' section to be drilled riserless using WBM;
- Suspension / Displacement before drilling of the section 17.5" using High Viscous Gel Sweeps/CaCl Polymer PAD mud;
- 3rd section: 17 ½'' section to be drilled with a riser using NADF (also called NADF for Non Aqueous Drilling Fluid);
- 5th section: 12 ¼" section to be drilled with a riser using using NADF;
- 6th section: 8 ½" section to be drilled with a riser using NADF.

The total duration of simulation for operations duration is 23 days and 19 hours (total duration of operational discharge + lag time in between the operation).

Table 5 – Well architecture and estimated cuttings and volumes released

Wellbore diameter (")	36"	26"	Suspension/ Displacement before drilling 17.5" hole	17.5"	12.25"	8.5"
Sections length (m)	100	775		800	1325	750
Drilling rate (m/h)	45	35		30	30	15
Mass of cuttings (metric Tons)	160	879		411	334	92
Cuttings discharged (yes/No)	yes	yes		yes	yes	yes
Type of mud used while drilling	Sea Water	Sea Water, WBM Polymer Mud	*CaCl Polymer PAD Mud*	NADF	NADF	NADF
quantity of mud discharged while drilling, including OOC for NADF (Tons)	338	541	1047	57 (1)	46 (1)	13 (1)
Cuttings & mud Discharge duration (Hours)	5	51	6	53	75	89
Discharge DEPTH (m)	Sea Floor	Sea Floor	Sea Floor	10m below sea surface	10m below sea surface	10m below sea surface
Discharge diameter (in)	36"	26"	26"	10-12"	10-12"	10-12"
Indicative time before next operation (days) – (including time to prepare next operation. cementing operation. Liner. casing. pressure tests…) = no discharge	1	6	*NA*	5	5	4
Suspension/ displacement/kill mud before drilling next section (yes/No)	no	no	*yes*	yes	yes	yes
Type of mud used for Suspension/clean-up/displacement	Seawater, viscous sweeps & WBM	Seawater, viscous sweeps & WBM	High Viscous Gel Sweeps/CaCl Polymer PAD mud	NADF	NADF	NADF
quantity of mud discharged for Suspension/clean-up/displacement (T)	NA	NA	34	NA	NA	NA
Suspension/clean-up/displacement duration (hours) – Default value 12 Hrs	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs
Discharge DEPTH (m)	Sea Floor	Sea Floor	Sea Floor	10m below sea surface	10m below sea surface	10m below sea surface
Discharge diameter (in)	36"	26"	26"	10-12"	10-12"	10-12"
Discharge diameter (m)	0.9144	0.6604	0.6604	0.2794	0.2794	0.2794

The Table 6 presents the release properties used in the simulations.

Table 6 – Release Properties of the NADF scenarios

RELEASE PROPERTIES		
ORIENTATION of discharge	Vertical	
	RELEASE TEMPERATURE (°C)	**Release salinity (g/L)**
42''	While drilling: Close to seabed temperature 4 °C	10-18 g/l
*26''	While drilling: Close to seabed temperature 4 °C	25 – 35 g//l Cl^-
	While Suspension/Clean-up: 25 °C	
17.5''	25°C	0
12.25''	25 °C	0
8.5''	25 °C	0

2.2.2.2 Mud Composition

The indicative mud composition presented in this report (considered worst-case) is based on a provisional formulation provided by the Africa Oil Corp Fluid team as this is the only available information at the date of the study (Table 7), based on the properties of the similar DWOB project. **The composition may vary slightly depending on the contractor's selection and may later be modified to suit operational needs.** Several types of drilling fluid (details provided in service request form) will be used for drilling operations with different compositions and densities.

Table 7 – Properties of the drilling mud components (Estimation based on analog well data and area drilling)

Mud type	Density of mud	name	composition	Function	Concentration (kg/T)	Mass (T)	PNEC (ppb)	KOC	Solubility(ppm)	density	Biodegradation (%)	KOW	Vapour pressure
42" Riserless Sea water SW + Gelsweeps	1.08	Bentonite (particle)		Weighting Agent	69	22.5	170	Calculated using Kow	0	2.5	0	1	0
		Caustic Soda		Alkalinity	0.6	0.18	20	Calculated using Kow	1000000	2.13	0	1	0.02
		Soda Ash		Hardness	0.6	0.18	200	Calculated using Kow	212500	2.52	0	1	0
26" Riserless SW + Gelsweeps (3060 – 3833m)	1.08	Bentonite (particle)		Weighting Agent	69	37.5	170	Calculated using Kow	0	2.5	0	1	0
		Caustic Soda		Alkalinity	0.6	0.3	20	Calculated using Kow	1000000	2.13	0	1	0.02
		Soda Ash		Hardness	0.6	0.3	200	Calculated using Kow	212500	2.52	0	1	0
26" Riserless – displacement 1.30 sg $CaCl_2$ (PAD + Kill Mud)	1.3	Caustic Soda		Alkalinity	0.8	0.8	20	Calculated using Kow	1000000	2.13	0	1	0.02
		Soda Ash		Alkalinity	0.8	0.8	200	Calculated using Kow	212500	2.52	0	1	0
		BARAZAN		Viscosifier	0.8	0.8	420	Calculated using Kow	100000	1.6	93 in 28 days	1	0
		Calcium Chloride		Inhibitor	385	400	23000	Calculated using Kow	745000	2.15	0	0	0
		PAC R		Viscosifier	0.8	0.8	87.26	Calculated using Kow	100000	1.6	60 in 28 days	1	0
			A			13.6	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03

Mud type	Density of mud	name	composition	Function	Concentration (kg/T)	Mass (T)	PNEC (ppb)	KOC	Solubility(ppm)	density	Biodegradation (%)	KOW	Vapour pressure
17,5'' NADF	1.15	EDC-99DW	B	Base oil	435	0.0026	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
			C			0.65	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			D			1.9	23000	Calculated using Kow	745000	2.15	0	0	0
			E (particle)			0.78	440	using Kow	0	2.6	0	0	0
		INVERMUL NT	A	Emulsifier	61	0.75	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			B			0.75	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			C			0.125	8800	Calculated using Kow	900000	0.9	91 in 28 days	6.5	0
			D			0.125	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
		EZMUL NT	A	Emulsifier	35	1	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			B			0.29	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			C			0.0715	8800	Calculated using Kow	900000	0.9	91 in 28 days	6.5	0
			D			0.0715	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
		Duratone-E (particle)		Filtration control	22	0.89	400	Calculated using Kow	0	2.6	0	0	0
		LIQUITONE		Filtrate reducer	39	1.61	100	Calculated using Kow	10000	0.98	60 in 28 days	1	0
		Lime			26	1.07	320	Calculated using Kow	1845	2.22	0	1	0
			A (particle)			0.0535	440	Calculated	0	2.6	0	Na	0

Mud type	Density of mud	name	composition	Function	Concentration (kg/T)	Mass (T)	PNEC (ppb)	KOC	Solubility(ppm)	density	Biodegradation (%)	KOW	Vapour pressure
		GELTONE			26			using Kow					
			B			0.0107	23	Calculated using Kow	50	0.88	0	100000 0	0
		BARAVIS IE 568		Viscosifier	13	0.54	100	Calculated using Kow	989000	0.989	85 in 28 days	3.25	0
		Calcium Chloride		Shale Inhibitor	61	2.5	23000	Calculated using Kow	745000	2.15	0	0	0
		Barite (particle)		Weighting Agent	304	12.49	115	Calculated using Kow	0	4.5	0	na	0
		Baracarb (particle)			0.8	0.03	440	Calculated using Kow	0	2.6	0	Na	0
		SteelSeal (particle)			0.6	0.02	1000	Calculated using Kow	0	1.75	0	1	0
		EDC-99DW	A	Base oil	435	11.55	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			B			0.022	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
			C			0.55	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			D			1.65	23000	Calculated	745000	2.15	0	0	0
			E (particle)			0.66	440	using Kow using Kow	0	2.6	0	0	0
		INVERMUL NT	A	Emulsifier	61	0.63	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			B			0.63	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			C			0.105	8800	Calculated using Kow	900000	0.9	91 in 28 days	6.5	0
			D			0.105	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0

Mud type	Density of mud	name	composition	Function	Concentration (kg/T)	Mass (T)	PNEC (ppb)	KOC	Solubility(ppm)	density	Biodegradation (%)	KOW	Vapour pressure
12,25'' NADF	1.15	EZMUL NT	A	Emulsifier	35	0.84	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			B			0.24	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			C			0.06	8800	Calculated using Kow	900000	0.9	91 in 28 days	6.5	0
			D			0.06	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
		Duratone-E (particle)		Filtration control	22	0.8	400	Calculated using Kow	0	2.6	0	0	0
		LIQUITONE		Filtrate reducer	39	1.4	100	Calculated using Kow	10000	0.98	60 in 28 days	1	0
		Lime			26	0.9	320	Calculated	1845	2.22	0	1	0
		GELTONE	A (particle)		26	0.045	440	Calculated using Kow	0	2.6	0	Na	0
			B			0.009	23	Calculated using Kow	50	0.88	0	100000 0	0
		BARAVIS IE 568		Viscosifier	13	0.5	100	Calculated using Kow	989000	0.989	85 in 28 days	3.25	0
		Calcium Chloride			61	2.1	23000	Calculated using Kow	745000	2.15	0	0	0
		Barite (particle)		weighting agent	304	10.6	115	Calculated using Kow	0	4.5	0	na	0
		EDC-99DW	A	Base oil	435	2.05	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			B			0.0039	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
			C			0.1	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			D			0.29	23000	Calculated	745000	2.15	0	0	0

Mud type	Density of mud	name	composition	Function	Concentration (kg/T)	Mass (T)	PNEC (ppb)	KOC	Solubility(ppm)	density	Biodegradation (%)	KOW	Vapour pressure
8,5'' NADF	1.15		E (particle)			0.12	440	Calculated using Kow	0	2.6	0	0	0
		INVERMUL NT	A	Emulsifier	61	0.09	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			B			0.09	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			C			0.015	8800	Calculated using Kow	900000	0.9	91 in 28 days	6.5	0
			D			0.015	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
		EZMUL NT	A	Emulsifier	35	0.14	100	Calculated using Kow	2.17	2.083	2.7 in 28 days	2000	0
			B			0.04	9.8	Calculated using Kow	12	0.798	58.6 in 28 days	100000 0	0.03
			C			0.01	8800	Calculated using Kow	900000	0.9	91 in 28 days	6.5	0
			D			0.01	1101	Calculated using Kow	955000	0.955	92 in 28 days	10	0
		Duratone-E (particle)		Filtration control	22	0.1	400	Calculated using Kow	0	2.6	0	0	0
		LIQUITONE		Filtrate reducer	39	0.2	100	Calculated using Kow	10000	0.98	60 in 28 days	1	0
		Lime			26	0.1	320	Calculated in	1845	2.22	0	1	0
		GELTONE	A (particle)		26	0.006	440	Calculated using Kow	0	2.6	0	Na	0
			B			0.0012	23	Calculated using Kow	50	0.88	0	100000 0	0
		BARAVIS IE 568		Viscosifier	13	0.1	100	Calculated using Kow	989000	0.989	85 in 28 days	3.25	0
		Calcium Chloride		Shale Inhibitor	61	0.3	23000	Calculated	745000	2.15	0	0	0

Mud type	Density of mud	name	composition	Function	Concentration (kg/T)	Mass (T)	PNEC (ppb)	KOC	Solubility(ppm)	density	Biodegradation (%)	KOW	Vapour pressure
								using Kow					
		Barite (particle)		weighting agent	304	2.4	115	Calculated using Kow	0	4.5	0	na	0

2.3 Model

2.3.1 Marine Environmental Modelling Workbench (MEMW)

The MEMW suite software allows modelling several types of Exploration & Production's discharges to the environment. The current version of the software used was MEMW 14.1, released in 2023.

The Dose-Related Exposure Assessment Model (DREAM) is a three-dimensional multiple component pollutant transport, exposure, dose, and effects assessment model designed to support rational management of environmental risks associated with operational discharges of complex mixtures. Each component in the mixture is described by a set of physical-chemical-toxicological parameters. To support management of environmental risks, the EIF (Environmental Impact Factor) has been developed as a method for evaluating potential environmental risks from produced water and drilling discharges. The method gives a quantitative measure of the potential risks and is thus able to form a basis for reduction of impacts in a systematic and a quantitative manner. The EIF method is based on a PEC/PNEC approach. That is, the concentration PEC (Predicted Environmental Concentration) for some compound discharged into the recipient is compared to some concentration threshold limit PNEC (Predicted No Effect Environmental Concentration) for that compound. **When PEC is higher than the threshold PNEC, there may be a potential risk for damage on the biota in the recipient. When the PEC is lower than the PNEC threshold, the risk for damage is considered to be "acceptable".**

The model was developed for assessing the consequences of regular, planned discharges to the marine environment. DREAM helps visualizing and analyzing discharges occurring over extended time periods and in the water column. Some of the tasks suitable for DREAM include the ParTrack model (Drilling discharges including discharges of drill muds and cuttings). Additional environmental impact calculations for bottom sediments and particle stress in the water column are available.

It is typically used for anticipating the spreading and deposition of discharge from drilling.

In DREAM, the model concept applied is a "particle" (or Lagrangian) approach. The model generates particles at the discharge point, which are then transported with the currents and turbulence in the sea. Different properties of the particles are associated with each particle. Chemical concentrations in the water column are computed from the time- and space-variable distribution of pseudo-Lagrangian particles.

These particles are of two types:

- those representing dissolved substances (soluble added chemicals),
- those representing droplets composed of less soluble added chemical components or solid particulate matter in the discharge (cuttings, weighting agents).

These latter particles are pseudo-Lagrangian in that they do not move strictly with the currents but may rise or settle according to their physical characteristics. Particles will sink down on the sea floor with sinking velocities dependent on their size and density. The particles in the weighting material (i.e. barite) are also assumed to sink to the sea floor in accordance with the sinking velocity of the particles (given by their size and density).

Each mathematical particle represents conceptually a Gaussian cloud of dissolved chemicals, droplets, or sinking particles. Concentration fields are built up in the model from the superposition of all these clouds of contaminants. Each cloud consists of an ellipsoid with a particle at its centre, and semi-axes a function of the time-history of the particle (Ellipsoids encountering boundaries are truncated, with mass being conserved through reflection from the boundary, sorption to the boundary, or some combination of the two).

Particles representing dissolved substances carry with them the following attributes:

- x, y, and z spatial coordinates,
- mass of each chemical constituent represented by the particle,
- distance to and identity of the nearest neighbour particle,
- time since discharge,

- spatial standard deviations in x, y, and z.

Particles representing non-dissolved substances, such as oil droplets, drill muds or cuttings, carry two additional attributes:

- mean droplet diameter,
- droplet density.

Concentrations (PEC) are computed within one of three user-specified three-dimensional grid systems. The first is a translating, expanding grid that follows the evolution of a discharge, thus providing higher resolution during the early stages, and lower resolution as time progresses. The second is a fixed grid, with resolution defined by the user. The third is a grid with fixed horizontal resolution, but time-variable vertical resolution. This latter grid is useful, for example, in resolving surface discharges of oil, in which the near-surface vertical evolution may be of interest.

The position of each particle locates the centre of a moving, spreading ellipsoidal cloud, with axes a function of the time-history of the particle. The theoretical distribution of mass within the ellipsoid is Gaussian.

Processes governing the behaviour of pollutants in DREAM are presented in Figure 4 below.

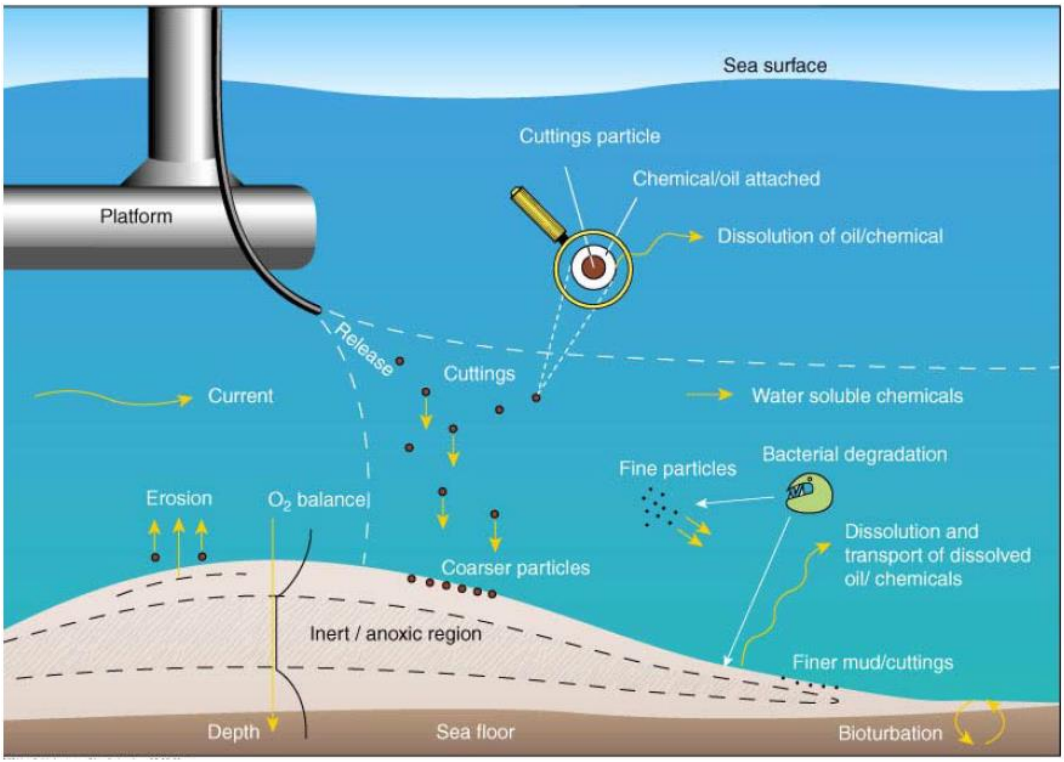


Figure 4 Phenomenon considered in water column and sediment (from SINTEF)

For each chemical in the mixture, the governing physical and chemical processes are considered individually, such as:

- vertical and horizontal dilution and transport,
- dissolution from droplet form,
- volatilization from the dissolved or surface phase,
- particulate adsorption/desorption and settling,
- degradation, and
- sedimentation to the sea floor.

Chemicals with low Pow or Kow (*i.e*. *n*-octanol-water partition coefficient) or Koc (Organic Carbon-Water Partitioning Coefficient) < 1000 are assumed to dissolve (completely) in the water column. No adsorption of the dissolved compounds in the discharge to organic matter, either in the water column or in the sediment, is assumed. Therefore, chemicals with such physical and chemical characteristic will only be detected within the water column. Their concentrations in the sediments will be set a 0 ppm concentration.

For large Pow, Kow or Koc values (≥ 1000), the chemicals are assumed to deposit on the sea floor.

To summarize, the following stressor concentrations (PEC) have been calculated:

- water column:
  - toxic stressors:
    - soluble added chemicals
    - less soluble added chemicals
  - non-toxic stressors:
    - suspended particle matter (particulate chemicals: weighting agents, cuttings)
- sediments:
  - toxic stressors:
    - added chemicals with Kow ≥ 1000
  - non-toxic stressors
    - physical stress leading to changes in grain size distribution
    - physical stress leading to coverage by sedimentation of material - burial
    - chemical biodegradation as a result of organic carbon enrichment leading to oxygen depletion

The model is driven by winds and currents either produced by other numerical models or measured as time series in the region of interest. Global datasets of bathymetry and coastlines are supplied with the system and can be augmented by the user via standard GIS and/or ASCII formats.

More information about the model development can be found on the SINTEF website: https://www.sintef.no/projectweb/erms/reports/ especially in ERMS report 18 (2006) / ERMS report 24 (2007) or in Reed and Hetland (2002). A summary of the Environmental Risk Management System (ERMS) Joint Industry Project is available in Durell et al. (2006). Several studies are available to compare DREAM outcomes with in-situ measurement showing a good agreement between model and field data (Rye, 2005; Rye et al.,2004, 2006, 2012, 2014, Neff et al.,2006; Singsaas et al.,2008; Frost et al.,2014; and Niu et al., 2016).

2.3.2 Chemical hazard classification as per OSPAR recommendation

To reduce the overall impact of offshore chemicals on the marine environment, OSPAR has adopted a harmonized mandatory control system for use and reduction of discharges of offshore chemicals (OSPAR 2000/2 as amended by OSPAR 2005/1). This system promotes the shift towards the use of less hazardous or preferably non-hazardous substances. There is a common OSPAR interpretation of which chemicals are covered and not covered by the control system. The Harmonized Offshore Chemical Notification Format (HOCNF) applies to all chemicals used in connection with offshore exploration and production activities in the OSPAR maritime area.

Chemical suppliers must provide the national authorities with data and information about chemicals to be used and discharged offshore according to the HOCNF. All substances included on a HOCNF also fully comply with the relevant requirements of REACH (Registration, Evaluation, Authorisation and restriction of Chemicals, European Union regulation) for that substance (i.e. Persistence- Bioaccumulation - Toxicity criteria). Suppliers should therefore follow the REACH compliance flowchart (Figure 5).

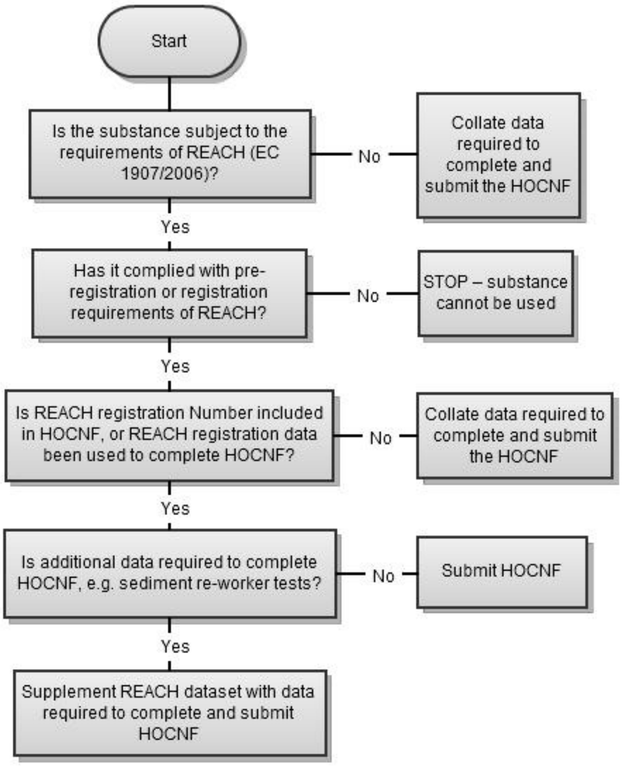


Figure 5 REACH compliance flowchart

PLONOR (Pose Little Or NO Risk to the environment) substance are substances whose use and discharge offshore are subject to expert judgement by the competent national authority of Contracting Parties. These substances do not normally need to be strongly regulated as, from assessment of their intrinsic properties, the OSPAR Commission considers that they pose little or no risk to the environment. In this case, no ecotoxicological information is required.

For non PLONOR substances, a full HOCNF form should be completed to provide the following information in accordance with REACH Guidance on information requirements and chemical safety assessment (for PBT criteria):

- Ecotoxicity data
- Biodegradability
- Partitioning and bioaccumulation potential

Hazard assessment of offshore chemicals is performed based on the OSPAR Harmonized Mandatory Control Scheme (HMCS). Each country member of the OSPAR convention can apply the recommendation with its own system. The example shown hereafter is the implementation of the HCMS in the UK. This approach has been selected because it is fully described and available in gov.uk website and CEFAS website. Moreover, the status of all offshore chemicals registered is also available on the CEFAS website (Offshore Chemical Notification Scheme (OCNS) - Cefas (Centre for Environment, Fisheries and Aquaculture Science)) and revised every two weeks.

Chemicals are ranked according to their calculated Hazard Quotients (HQ) by the CHARM (Chemical Hazard Assessment and Risk Management) mathematical model, which uses toxicity, biodegradation and bioaccumulation data provided by suppliers on the HOCNF form.

The HQ is converted to a colour banding as shown in the Table 8 below (HQ and colour band applicable in the UK and the Netherlands).

Table 8 HQ Colour bands

Minimum HQ value	Maximum HQ value	Colour banding	
>0	<1	Gold	
≥1	<30	Silver	
≥30	<100	White	Lowest hazard
≥100	<300	Blue	↓ Highest hazard
≥300	<1000	Orange	
≥1000		Purple	

Chemicals which are hazardous to the marine environment are subject to substitution warnings under the Harmonized Mandatory Control Scheme (HMCS).

Substances not applicable to CHARM model (*i.e*. inorganic substances, hydraulic fluids or chemicals used only in pipelines) are assigned an OCNS grouping A – E, with A being the greatest potential environmental hazard and E being the least (see Table 9) Revised (cited above). Then, final grouping is adjusted based on P and B criteria (Persistence and biodegradation) as described below:

- Readily biodegradable: results of >60% biodegradation in 28 days (OECD 306,301B -F method), >70% in 28 days (OECD 301A, 301E) to an OSPAR HOCNF accepted ready biodegradation protocols
- Inherently biodegradable: results of >20% and <60% (<70%) to an OSPAR HOCNF accepted ready biodegradation protocol.
- Not biodegradable: results from OSPAR HOCNF accepted ready biodegradation protocol or inherent biodegradation protocol are <20%, or half-life values derived from aquatic simulation tests indicate persistence
- Non-bioaccumulative: Log Pow <3, or BCF ≤100, the molecular weight is ≥700
- Bioaccumulative: Log Pow ≥3, or BCF >100, the molecular weight is <700, or if the conclusion of a weight-of-evidence expert judgement under OSPAR Agreement 2008-5 is negative.

Table 9 Initial OCNS grouping

Initial Grouping	A	B	C	D	E
Result for Aquatic toxicity data (ppm)	<1	>1-10	>10-100	>100-1,000	>1,000
Result for sediment toxicity data (ppm)	<10	>10-100	>100-1,000	>1,000-10,000	>10,000

Increase by 2 groups (e.g. from C to E)	Increase by 1 group (e.g. from C to D)	Do not adjust initial grouping	Decrease by 1 group (e.g. from C to B)	Decrease by 2 groups (e.g. from C to A)
Substance is readily biodegradable and is non-bioaccumulative	Substance is inherently biodegradable and is non-bioaccumulative	Substance is not biodegradable and is non-bioaccumulative or	Substance is inherently biodegradable and bioaccumulates	Substance does not biodegrade and bioaccumulates
		Substance is readily biodegradable and bioaccumulates		

Aquatic toxicity refers to the Algae EC50, Crustacean LC50, and Fish LC50 toxicity tests (units = ppm or mg/kg). Sediment toxicity refers to the Sediment re-worker LC50 test (units = ppm or mg/kg).

2.3.3 Risk approach

The risk is calculated for drilling cuttings and mud components discharged to the environment.

The drill cuttings discharges are variable and depend on the section diameter and the section length. These cuttings are discharged at seabed (riserless drilling stage) as there is no marine riser for the top-hole sections of the well (this is applicable to the 36" and 26" sections for the case of Block 3B-4B). The cuttings form a hillock on the sea bottom around the subsea wellhead, the form of which is dictated by the currents at seabed. Around the wellhead, where the deposit is higher, the non-mobile benthic species are generally buried.

During the second phase of drilling when the marine riser has been connected to the subsea wellhead, drill cuttings are brought to the surface (at the platform level) in circulation with the drilling mud. At the drilling unit, this mixture of cuttings and mud is separated by sieving (shale shakers), then cuttings are discharged to the sea (the oil content will be reduced to 6.9% by weight of cuttings before release). The shape of the plume in the water column and the deposition of cuttings on the seabed during these risered drill phases are influenced by the strength and direction of marine currents over the entire water column.

As ParTrack is an extension of DREAM, the use of ParTrack encompasses the functionalities of both modules.

Environmental risk assessment is based on the comparison of the ecosystem exposure to a compound (chemical, oil) with the ecosystem sensitivity for this compound.

The conventional PEC (Predicted Environmental Concentration) / PNEC (Predicted No Effect Concentration) ratio approach is used for environmental risk assessment (Reed et al., 2001). It is well established and accepted within and outside the European Union for Chemical environmental risk assessment (Technical Guidance Document on Risk

Assessment, 2003). This ratio gives an indication of the likelihood of adverse environmental effects to occur as a result of exposure to the contaminants.

In the DREAM module, the exposure is represented by the PEC and can be quantified with various physical parameters. PEC is obtained by estimations using an environmental fate model, considering processes like adsorption, degradation, diffusion, dispersion and volatilization for water column as well as bioturbation, stratification and degradation for sediment compartment (flocculation processes are not included). The basis for the tool was developed by Provann (Reed et al., 1996), a computer application for simulating the fate of offshore discharge scenarios with a three-dimensional dispersion model. The development was carried out as a joined industry project (JIP), among them TotalEnergies.

The PNEC represents the ecosystem sensitivity to the exposure. For toxic risk, its value is usually derived from standardized eco-toxicity tests on species. For the physical risk factors, PNEC is obtained by field survey coupled with the statistical analysis of the variation in species sensitivity (Species Sensitivity Distributions, SSD).

Figure 6 presents the global risk approach philosophy.

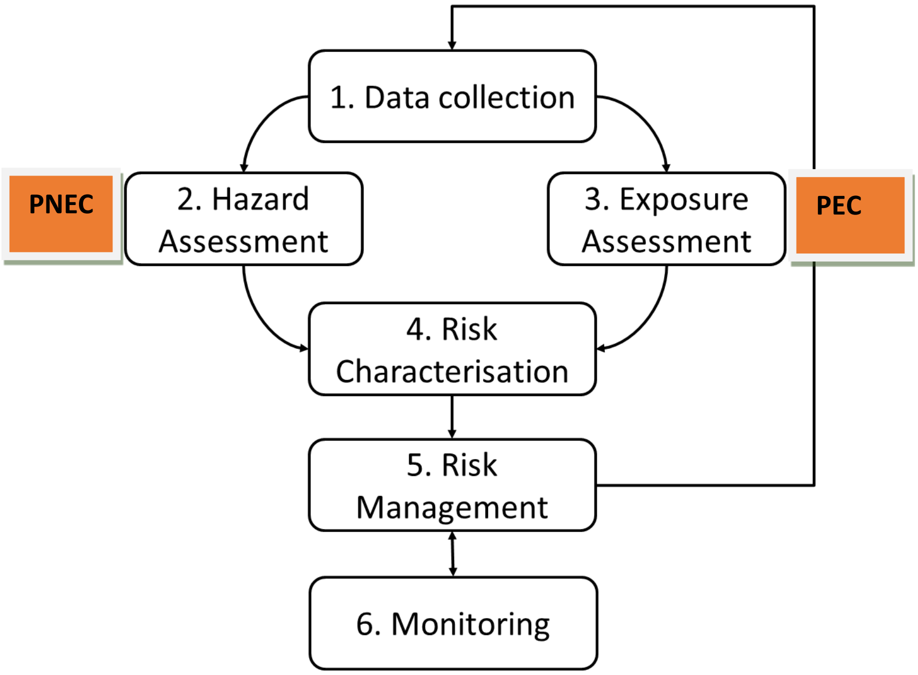


Figure 6 Risk Based Approach philosophy

The nature and intensity of the potential environmental effects/impacts that could occur are not defined by the model. But they can range from sub-lethal effects like growth, feeding and reproduction inhibition at lower concentrations to acute mortality at higher concentrations.

The PNECs used in the risk calculations were derived from toxic thresholds provided by the supplier for the drilling fluid components, following the methodology recommended by OSPAR (i.e. applying conservative safety factors up to 1000 to the toxic thresholds). Due to the safety factors used, this approach is meant to be very conservative.

For physical effect, the PNECs used were those available in the model derived from field studies and benchmark studies available in the literature.

As a clarification, it is noted that Risk and Impact have different significations:

Risk: The PEC / PNEC ratio gives an indication of the **likelihood of adverse effects to occur** as a result of exposure to a specific chemical. The DREAM model is a risk assessment tool; it determines the risk level. In DREAM, probabilistic approach is not possible for drill cuttings and mud discharges, so no probability of the calculated risk is provided.

<u>Impact:</u> The **level of environmental impacts** must be confirmed on-site in the water column, in the seabed and in the marine ecosystem (EBS, EIA, monitoring surveys). The DREAM model is not an impact assessment tool, but the Environmental Impact Factor (EIF) (see description in Modelling Results Discharge Point 1) is a good way to compare the different scenarios between them.

The relation between PEC/PNEC ratio and risk to the marine environment is given by the curve below (Figure 7).

It is commonly accepted worldwide, for chemical environmental risk assessment, that when the PEC for a contaminant reaches its corresponding PNEC threshold (when PEC = PNEC and so PEC/PNEC = 1), a risk will be expected to the exposed ecosystem.

A significant risk corresponds to a calculated concentration in the environment (PEC) exceeding the predicted no effect concentration (PNEC = toxic threshold value/safety factor for chemical stressors) to a level likely to potentially impact 5% of species in a typical ecosystem. In other words, **a significant risk would occur for a PEC/PNEC ratio above 1 corresponding to a potential risk for 5% of the species in the ecosystem. The larger the PEC/PNEC ratio will be the larger the percentage of species potentially impacted.**

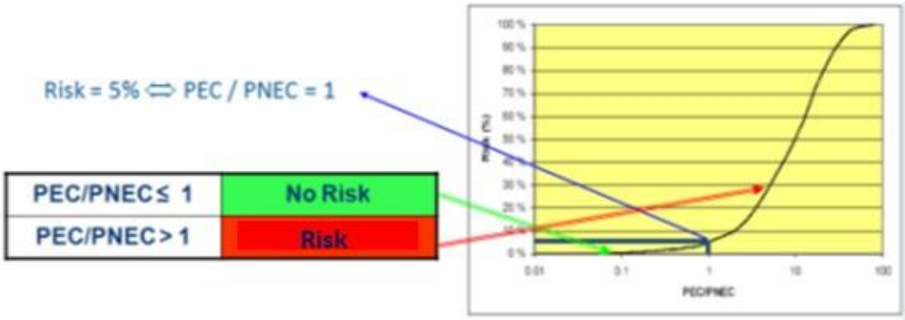


Figure 7 Relation between risk level and concentration estimation

Ecotoxicological data used for all products come most of the time from the MSDS or lab results provided by the product supplier and are completed by bibliographic research when needed.

The physical stress is calculated using the same approach (PEC/PNEC). For the physical risk in the sediments no concentration can be calculated so the PNEC corresponds to a change rather than a concentration threshold (Predicted no effect change).

The PEC/PNEC ratio is only an indicator of risk and for stressors with different modes of action PEC over PNEC ratios cannot directly be compared (Smit *et al*., 2005). The SSDs provide a mean to calculate a more quantitative and comparable risk indicator: the Potentially Affected Fraction of species (PAF). The PAF value can be explained as the probability that randomly selected species is exposed to a concentration exceeding its chronic no effect level at a certain level of exposure. The exposure of organisms to substances is considered acceptable in case where less than 5% of the species is at risk (corresponding to a PEC/PNEC ratio of 1). For all stressors PAF levels will be calculated corresponding to the predicted levels of exposure per grid cell.

In model grid cells in the water column and sediments, PAFs for exposure to all stressors has been calculated. For the calculation of the combined risk related to the exposure from toxic and non-toxic stressors associated with drilling impacts additivity is a pragmatic working assumption.

Therefore, Potentially Affected Fractions (PAFs) calculated for the different stressors are combined in a multi stressor PAF value (msPAF) or joint risk probability. The msPAF per grid cell is calculated assuming independent action.

The risks from the non-toxic stressors are added to the risks from the toxic stressors to arrive at the total EIF for the water column and the sediments. This addition implies that the risks caused by physical stresses from particles are considered “equivalent” to chemical stresses for the water column.

2.3.4 Risk assessment modelling

The DREAM model allows one to perform a risk assessment on marine environment by presenting parameters such as the Significant risk, Maximum risk, etc.

Glossary as follows:

Effluent: Correspond to cuttings + drilling fluid.

Significant risk: the risk could be displayed as the result of the PEC/PNEC calculation in the model or as a percentage (percentage of communities in the ecosystem potentially impacted). Risk presenting a level above 5% corresponds to a calculated concentration in the environment (PEC) exceeding the toxic threshold value (PNEC). It means that there is a potential risk to impact 5% of a typical population.

Maximum risk: represents the compilation of all maximum significant risks (> 5%) at any time compiled over the whole modelling period.

Risk stressors: physical or chemical phenomenon which can be responsible of a risk to the environment.

Results below present the risk to the marine environment induced by each specific substance and/or stressor in the water column and the sediments compartments defined as follows:

- **Water column:**

Toxicity of chemicals in the water column:

PEC is the calculated chemical concentration in the environment after discharge, expressed in ppm (= mg/l), of the discharged substance, calculated in the water column after its dispersion in the marine environment.

PNEC is the maximum concentration, expressed in ppm (= mg/l), causing no harm to the ecosystem. According to European recommendations, PNEC is obtained from ecotoxicological values (LC50, NOEC, etc.) adjusted with safety factors. For several typical discharges implying of the basic compounds (lead, barium, etc.) the PNEC values are integrated into the model MEMW.

Physical effects of suspended matter in the water column:

The ratio PEC/PNEC will be superior to 1 (potential risk) when the suspended matter is superior to the threshold value accepted by the marine organisms. Depending on the suspended matter considered, different thresholds are used.

- **Sediments:**

Toxicity of chemicals in sediment:

PEC is the calculated concentration of the substance in the sediment pore water after the discharge, expressed in ppm averaged over the upper 3 cm of the sediment layer.

PNEC is the maximum concentration accepted in the sediment pore water with no impact for the ecosystem. Above this threshold, potential harm to the ecosystem might be observed. The toxicity of the substances is calculated based on partitioning (that is, only the part of the chemical that dissolves into the pore water is assumed to be bioavailable, and therefore toxic). For HOCNF chemicals, the partition coefficient is assumed to be given by the log Pow coefficient.

Physical Burial of organisms in the sediment:

PEC is the total calculated thickness, in mm, of the added layer caused by the deposition on the seafloor.

PNEC (Predicted no effect change) is the threshold value of thickness variation accepted by benthos: PNEC thickness is 6.5 mm. This value is derived from the statistical description of the variation in sensitivity (Species Sensitivity Distributions-SSD). Above this threshold, potential harm to the ecosystem might be observed.

Change in the sediment structure - grain size:

PEC represents the calculated change, in % due to the discharge, of the median grain size in the sediment, averaged over the upper 3 cm of the sediment layer.

PNEC (Predicted no effect change) is the maximal change between the natural sediment grain size (median grain size provided by TEEPSA for the area: 0.007 mm or 7 µm) and the grain size after the discharge without toxic effect on the benthos. PNEC grain size= 115 µm (*i.e*. 1543% variation for Block 3B-4B) (Smit et al., 2008). As the natural sediment grain size is 0.007 mm and a variation under 1543% is non-significant, the grain size change maps will be presented with a key presenting the variation higher than 1543% (ignoring the variations lower than this value). Above this threshold, potential harm to the benthos might be observed.

Oxygen depletion in the sediment:

PEC is the calculated reduction of the oxygen content (%) in the sediment layer due to the discharge, integrated over the layer where bioturbation is taking place (about 10 cm). The free oxygen depletion is calculated from re-calculating the new free oxygen profile after discharge. The biodegradation from the added organic matter (chemicals) in the new sediment layer may then cause a reduction of the free oxygen content in the pore water of the sediment layer. The actual reduction of the free oxygen content in the pore water of the sediment layer is calculated by taking the difference between the new oxygen content in the pore water of the sediment after discharge and the oxygen content before discharge.

PNEC (Predicted no effect change) is the threshold level for hypoxia: PNEC oxygen = 20% of initial O_2 concentration. Above this threshold, potential harm to the ecosystem might be observed.

- **Ecosystem recovery:**

The model also allows for including the time variations of the stressors defined. This is important, because the time variations form the basis for calculating the recovery time of the sediment layer. The diagenetic equations in the model include the time development of these stressors. The following factors are included in the sediment risk calculations in order to calculate the "restitution time" of the sediment layer, that is, the time needed to bring the EIF of the sediment layer back to "normal":

- Bioturbation
- Biodegradation
- Recolonization
- Natural deposition after discharge

Because no local information was available default values were used for recovery kinetics.

More information is available in ERMS report n°1 (2003).

2.3.5 Model parameters

All the parameters used for the WBM scenarios are presented in Table 10 below.

Table 10 Model parameters of the Water Based Mud drilling discharge scenarios

Parameters		Sediment	Water column
Bathymetry		Synbap	Synbap
Grid size		5 km x 5 km	50 km x 50 km
Horizontal resolution (cell)		20 m	50 m
Vertical resolution (cell)		45 m	250 m
Number of model particles to be used for representing droplets or solid particles		5 000	10 000
Number of model particles to be used for representing the dissolved contaminants		5 000	10 000
Depth where the concentration will be calculated	Min depth (m)	1400	0
	Max depth (m)	1600	2500
Model duration		50 days total + 10 years	50 days total
Time step		3 hours	3 hours
Output interval		6 hours	6 hours

All the parameters used for the NADF scenarios are presented in Table 11 below.

Table 11 Model parameters of the Non Aqueous Drilling Fluid drilling discharge scenarios

Parameters		Sediment	Water column
Bathymetry		Synbap	Synbap
Grid size		8 km x 8 km	30 km x 30 km
Horizontal resolution (cell)		25 m	30 m
Vertical resolution (cell)		200 m	66 m
Number of model particles to be used for representing droplets or solid particles		5 000	10 000
Number of model particles to be used for representing the dissolved contaminants		5 000	10 000
Depth where the concentration will be calculated	Min depth (m)	0	0
	Max depth (m)	2200	2200
Model duration		25 days total + 10 years	25 days total
Time step		2 hours	15 min
Output interval		3 hours	1 hour

All the model parameters for the Sediment compartment are described in the Table 12.

Table 12 Advanced sediment compartment model parameters

Parameters	Values
Depth of the Sediment layer for impact calculation in the simulation	10 cm (default value)
Total duration of the sediment impact calculation	10 years
Characteristic time for the biota in the sediments to recover after impact	5 years (default value)
Vertical interval used for toxicity and grain size change in risk calculation	3 cm (default value)
Critical angle of repose which control redeposition of sediments	30 degrees (default value)
Minimum total deposition in a grid for calculation of impact	Estimated dynamically by the model
Sediment grid thickness (vertical separation of grid points in a sediment cell)	1 mm (default value)
Mean mixed depth of sediment = lower limit of the active bioturbation layer	9.7 cm (default value)
Porosity of natural sediment = volume of pore water/total volume	0.6 (default value)
Oxygen concentration pore water at depth	0.01 mg/l (default value)
Natural burial rate	Estimated dynamically by the model
Carbon content at sea floor = % w/w of dry sediment	Estimated dynamically by the model
Average bioturbation coefficient	Estimated dynamically by the model
Bioirrigation* coefficient	1 (default value)

**Bioirrigation coefficient (dimensionless) is based on composition of biota on the site according to the NIVA trait analysis model. The dimensionless factor will be demultiplied with the molecular diffusion coefficient for dissolved oxygen in order to arrive to actual biodiffusion in cm²/hour.*

2.3.6 Limits of the model

Like every model, MEMW has limitations as detailed below:

- The outcomes of the model depend on **model parameterization**:
  - This model is a simplification of real operations and, as such, it could not consider every variable in the modelling to allow reasonable/achievable time for processing and reasonable/ achievable size of files generated: for those reasons, results might vary depending on how the model has been parameterized. This model is a four-dimension model calculating plume dispersion in X, Y, Z axis over the time. For this reason, calculations are done based on a selected number of vertical layers (in general between one and one hundred, depending on the total water depth) which could be increased or reduced leading to a decrease in model resolution. Calculations are also done on horizontal cells with very fine to very low resolution (from 1 m to several km) depending on the

objectives and which can influence the results (see Table 15). This should also be considered for conclusions.

The results of the model depend on **inputs data**, because this data used corresponds to worst-case in term of mud quantity and chemical composition, leading to potential overestimation. The input data that could impact the results:

- Well design (section length, drilling rates, etc.)
- Discharge coordinates
- Metocean data format and resolution (winds, currents): hind cast data.
- Bathymetry
- Discharges (composition, quantity, etc.). For this point, the diameter of the discharge corresponds to the hole diameter, which might be an over-simplification because the discharge occurs while drilling with the drill bite inside the hole. The discharge will happen via the upper section of the annulus on a much-limited surface.
- Fluid program data (mud and chemicals to be used)

- All the results presented in this report are based on **historical metocean databases** and are used to better understand the fate of the drill cutting discharges and how it may impact the ecosystem. Stochastic approach is not possible in this model for drill cuttings modelling. For this reason, worst case scenarios are presented in this report (in term of distance from the discharge point). Because these results are based on historical database (past metocean dataset with a fair representation of the long-term variability over the Block studied here) and because a deterministic approach has been used, no probability of occurrence is presented in this report. **The scenarios presented in this report tend to be worst case scenario prepared for the purpose of the ESIA**, but it cannot be considered as a prediction of what may happen in the future at one specific time.

- For **risk calculation**, the approach used by the model is the one in use in the European union (i.e. PEC/PNEC). PNEC is derived from toxicity thresholds using very conservative safety factor (in general 1000 due to lack of data available for chronic risk). **This approach is very conservative and must be balanced considering knowledge of environmental specialist for the study area** (presence or absence of sensitive species/habitats should be considered).

- The scenarios are deterministic and do **not allow to provide probabilities** of the calculated risk.

3 Modelling Results

The Environmental Impact Factor (EIF) described in the results below is a relevant quantitative figure. The EIF (water column) represents the volume of sea water where the environmental risks exceed 5% (i.e. where a significant risk to the ecosystem exists). For the water column, an EIF value of 1 (one) represents a volume of sea water of 100,000 m^3 (100 m x 100 m x 10 m) where the risks exceed 5%. For the sediments, an EIF of 1 (one) represents an area of sediments of 10,000 m^2 (100m x 100m) where the environmental risks exceed 5% (i.e. where a significant risk to the ecosystem exists).

3.1 WATER BASED MUD SCENARIOS

3.1.1 Water Column – All Quarters

3.1.1.1 Environmental risk for the water column

The outcomes of the model for the maximum cumulative risk in the water column associated with the discharge of drilling operations for all the sections of the discharge point is presented in Figure 8. This figure displays the cumulative risk at any time of the calculation (with significant risk in red).

Figure 8 shows that the environmental risk of the riserless discharge for all the quarters is limited in the water column from 1240 m to 1500 m depth. The risk induced by the risered discharge is null (no red plume at the surface).

This area at risk is centralized around the discharge point, following the bottom currents that are very low, with maximum distance varying from 210 to 260 m from the release point (depending on the Quarter).

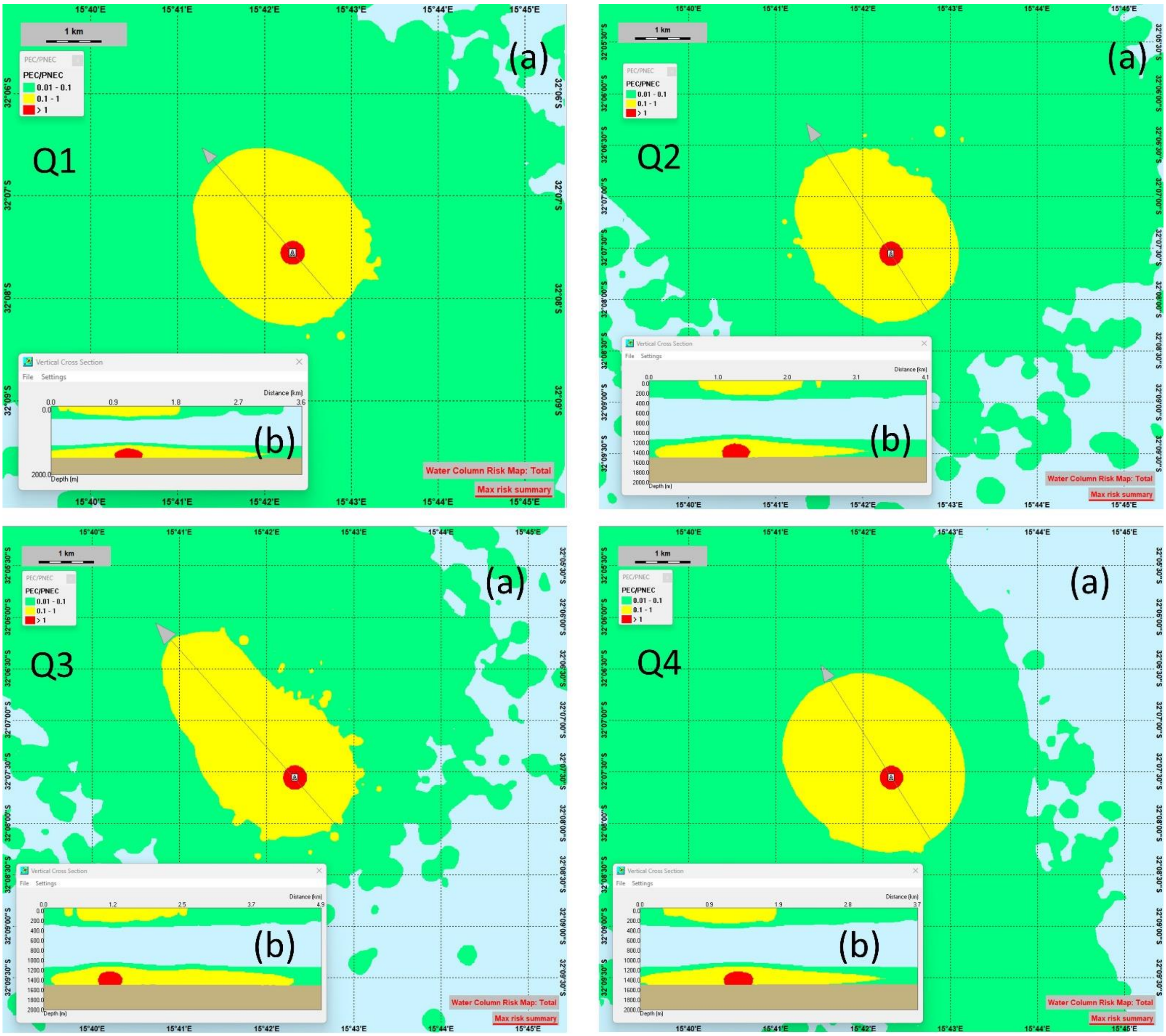


Figure 8 Maximum cumulative risk of drilling operations for the four Quarters throughout the water column at any time for the discharge (a) Risk map – (b) Vertical cross section of the water column

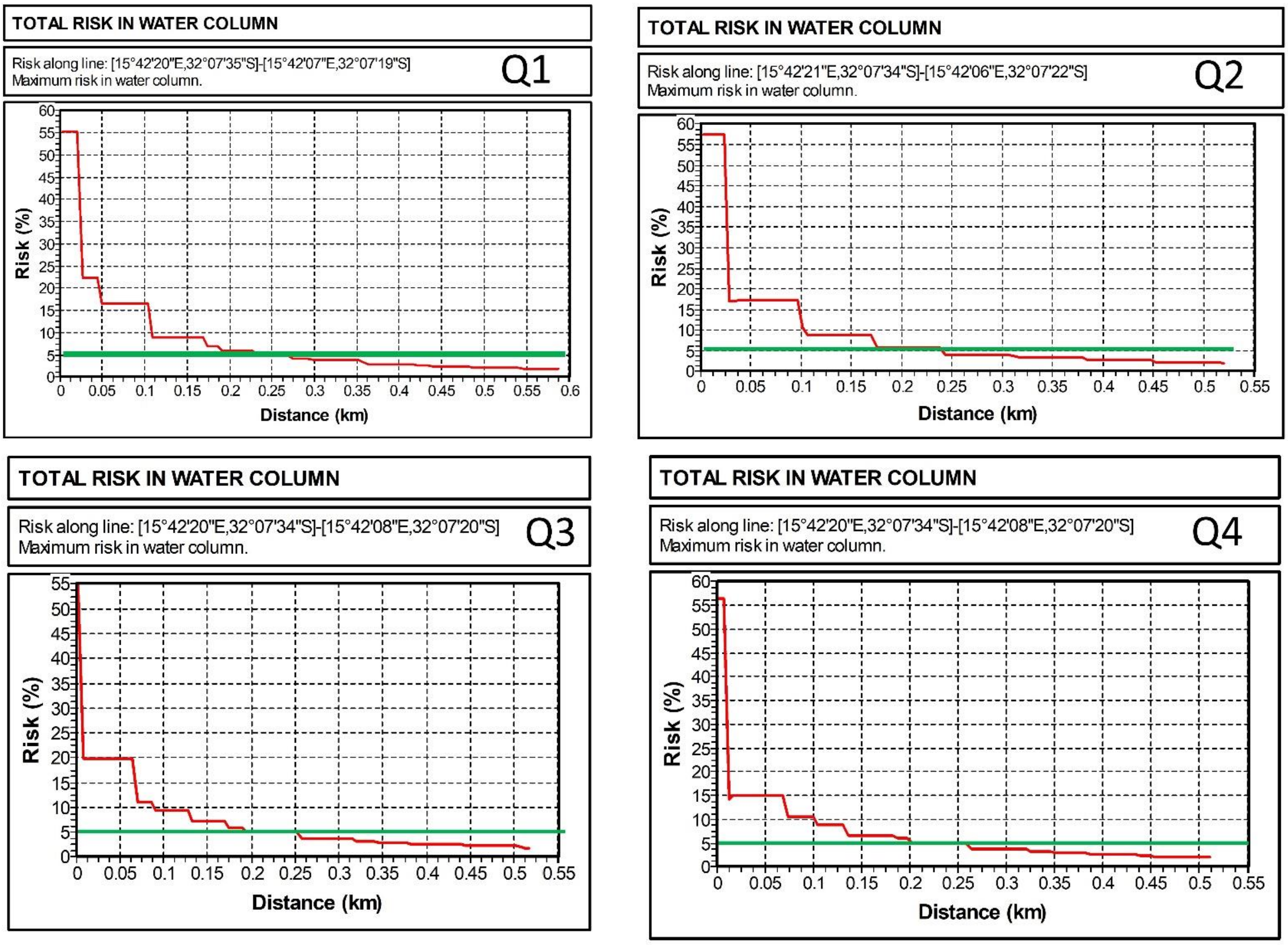


Figure 9 Risk value along a line for entire discharge for the four Quarters

The Figure 9 above illustrates the cumulative risk value along a line (from the discharge point to towards NorthWest) for the entire discharge: the maximum values are between 55 and 57 % of risk depending on the Quarter, which is not so high (100% is often reached in the drilling discharge studies).

The Table 14 present the maximum risk values in the water column and distances from the discharge point for all the Quarters.

Table 13 Maximum risk values in the water column for all the Quarters

PERIOD	MAX. ENVIRONMENTAL RISK	DISTANCE OF SIGNIFICANT RISK FROM DICHARGE POINT
Q1	55 %	250 m
Q2	57 %	240 m
Q3	55 %	250 m
Q4	56 %	260 m

The risk is short term in the water column, because of the natural dispersion and dilution induced by the currents.

3.1.1.2 Environmental Risk Contributors

Figure 10 shows the contributors to the risk over the time for the different sections for Quarter 1 (taken as an example, because all the quarters present similar results).

Only rislerless sections and the displacement of the 26” section present some risk. The risk of the riserless sections (1 and 2) is due to the Bentonite and Barite present in these sections; the risk induced by the displacement of the 26” section is mainly due to Bentonite and Barite, and a very small part is due to chemcide and caustic soda.

The maximum instantaneous EIF value is reached during the drilling of the 36” section, due to the presence of Bentonite, representing a volume of water of 450×10^5 m^3 with a significant risk (*i.e.* a potential impact). There is no more risk in the water column after the end of the discharge of the 26” displacement, meaning that the Risered Section will induce no risk for the water column.

Figure 10: Main contributors to the risk over the time in the water column for the Quarter 1: Figure on the top presenting relative percentage of contributors for each section; Figure on the bottom presenting instantaneous maximum volume of water at risk

Figure 11 and Figure 12 present the main contributors to the overall risk in the water column for all the Quarters.

The Bentonite is the main contributor to the risk with 70% to 77% of the overall risk. The Barite is the second main contributor representing 19% to 27% of the overall risk. Some chemical risk is due to Caustic Soda and Chemcide released during the 26” section’s displacement, but with low contribution values (1%). The other products have unsignificant risk, representing a total of 3% of the overall risk.

The maximum risk in term of volume of water at risk (EIF) is reached during the season 4, but with values close to the other seasons.

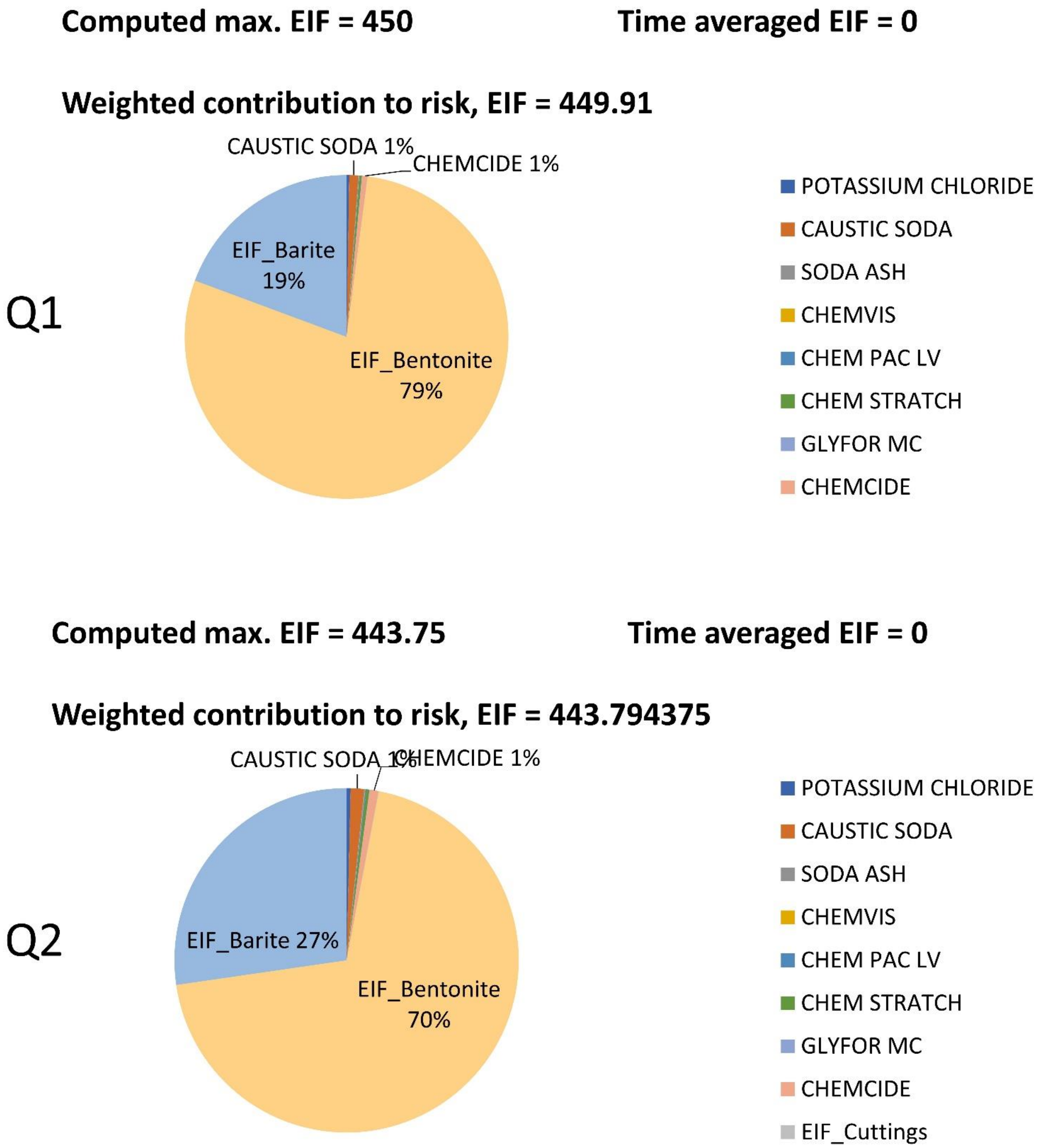


Figure 11 Main contributors to the risk in the water column for Quarters 1 and 2

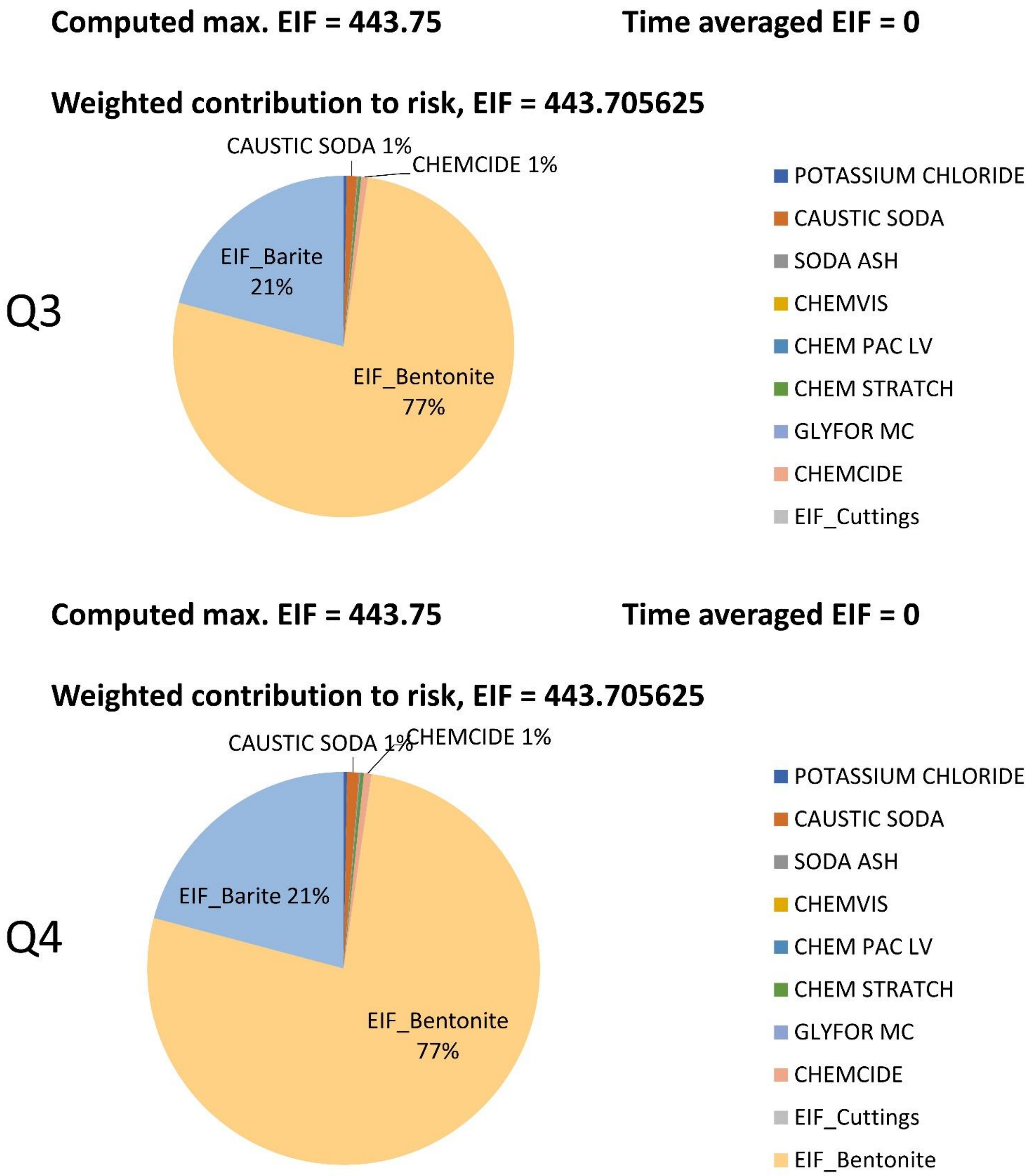


Figure 12 Main contributors to the risk in the water column for Quarters 3 and 4

3.1.1.3 Results Summary for the Water Column

The environmental risk in the water column is medium, with a value of 52% to 55% and is due to the Riserless sections and the displacement discharges, given that the risk is mainly due to the release of Bentonite, and Barite to a lesser extent.

The maximum risk distance reached is 260 m all around the discharge point but is quickly dispersed and diluted by the local currents, because there is no more risk after 5 days (i.e. after the 26” section displacement discharge).

There is no more risk in the water column after the end of the riserless sections discharge for all the Quarters thanks to dispersion and dilution processes.

3.1.2 Sediment – All Quarters

3.1.2.1 Environmental risk and main contributors

The outcomes of the model for the maximum significant risk (risk > 5%, meaning with a potential impact) for the four Quarters associated with the discharges all sections during drilling operations for the sediments are presented in Figure 13 and Figure 14.

A reduced area with significant risk above 5% is observed in the sediment close to the discharge. At the end of the operations, a significant risk is observed up to 100 m to 115 m maximum around the discharge point depending on the Quarter. A maximum risk of 14% to 17% has been calculated located on the release point (depending on the Quarter). The maximum value is for Quarter 4. There is no more risk observed 10 years after the operations (average time for sediment restoration after drilling operations). This will be developed in the following sections.

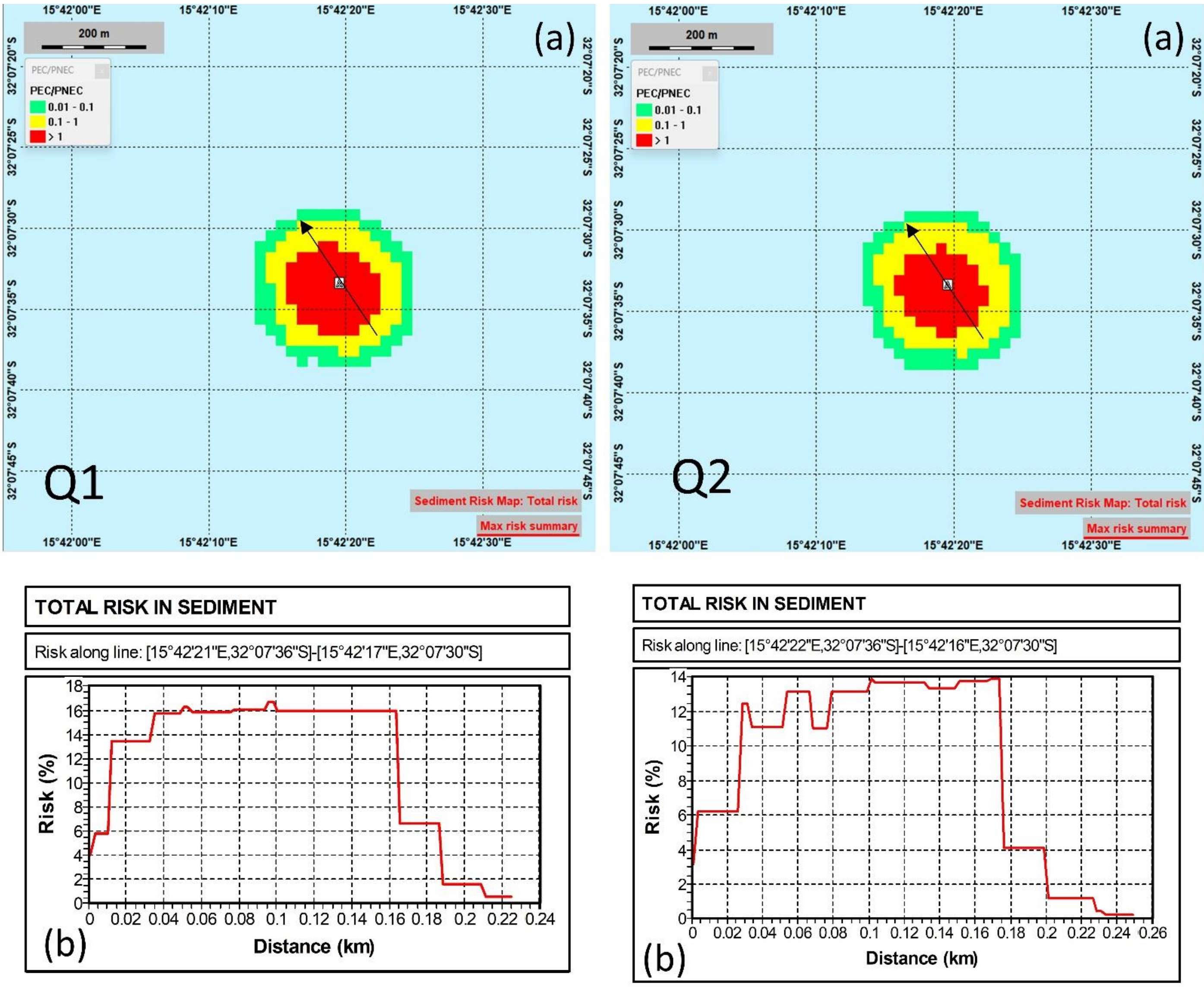


Figure 13 Maximum potential risk in the sediment for Quarters 1 and 2

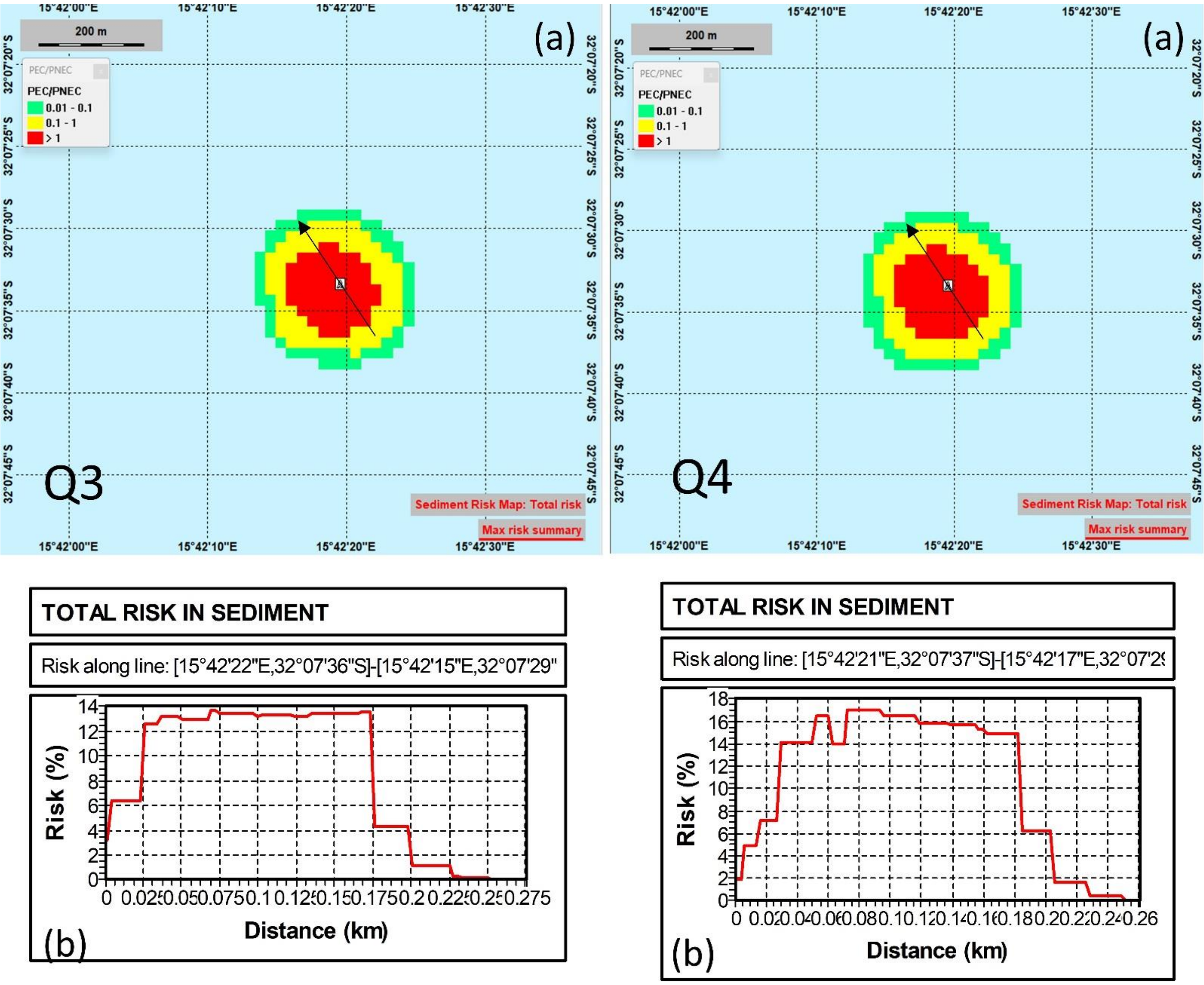


Figure 14 Maximum potential risk in the sediment for Quarters 3 and 4

Figure 15 presents the Environmental risk for the sediment and the contributors to the risk for a 10 years' period for the Quarter 4 (taken as an example because having the highest EIF for sediment). The risk is significant in the sediment from day 1 to 1030 days after (less than 3 years), mainly due to the end of the riserless sections discharged. The highest risk is reached just after the end of riserless discharge, and decreases quickly 2 years and 9 month after operations, with no more risk in the sediment after 3 years (Figure 15, bottom graph).

Despite insignificant over the time, the environmental risk for the sediment due to the entire discharge is physical, induced by the thickness deposit and the grain size change of the discharges.

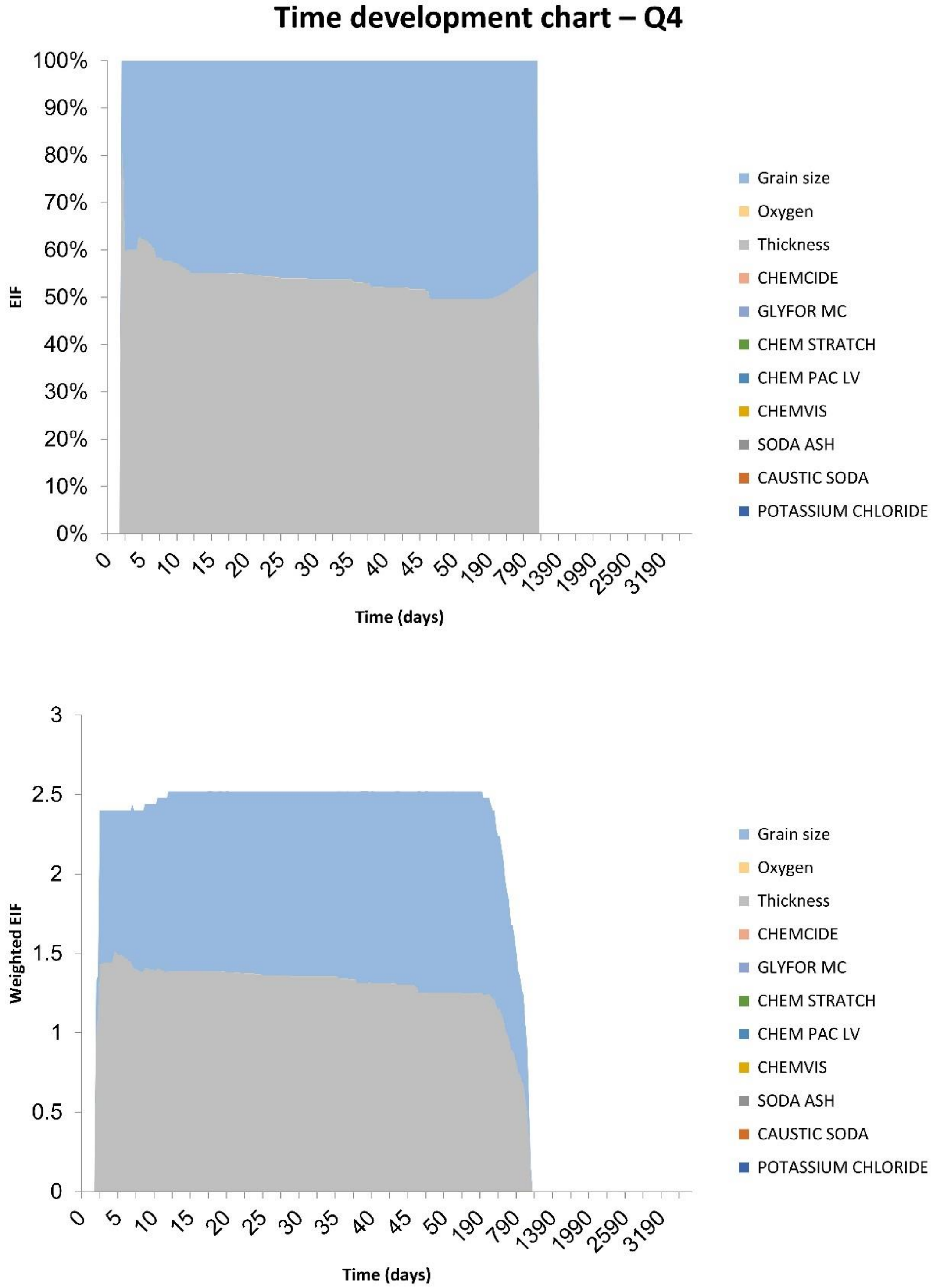


Figure 15 Main contributors to the risk over the time in the sediment for the Quarter 4: Figure on the top presenting relative percentage of contributors; Figure on the bottom presenting instantaneous maximum surface of sediment at risk

Figure 16 and Figure 17 show the main contributors to the environmental risk for all the Quarters, considering all sections to be discharged, over the 10 years extension period studied. The main contributors to the environmental risk for the sediment are physical, *i.e.* the grain size change of the natural sediment (due to higher grain size particles released during the discharge), with 35% to 48% of contribution to the risk depending on the Quarter; and the thickness deposit of the discharge, contributing to 52% to 65% of the total risk depending on the Quarter.

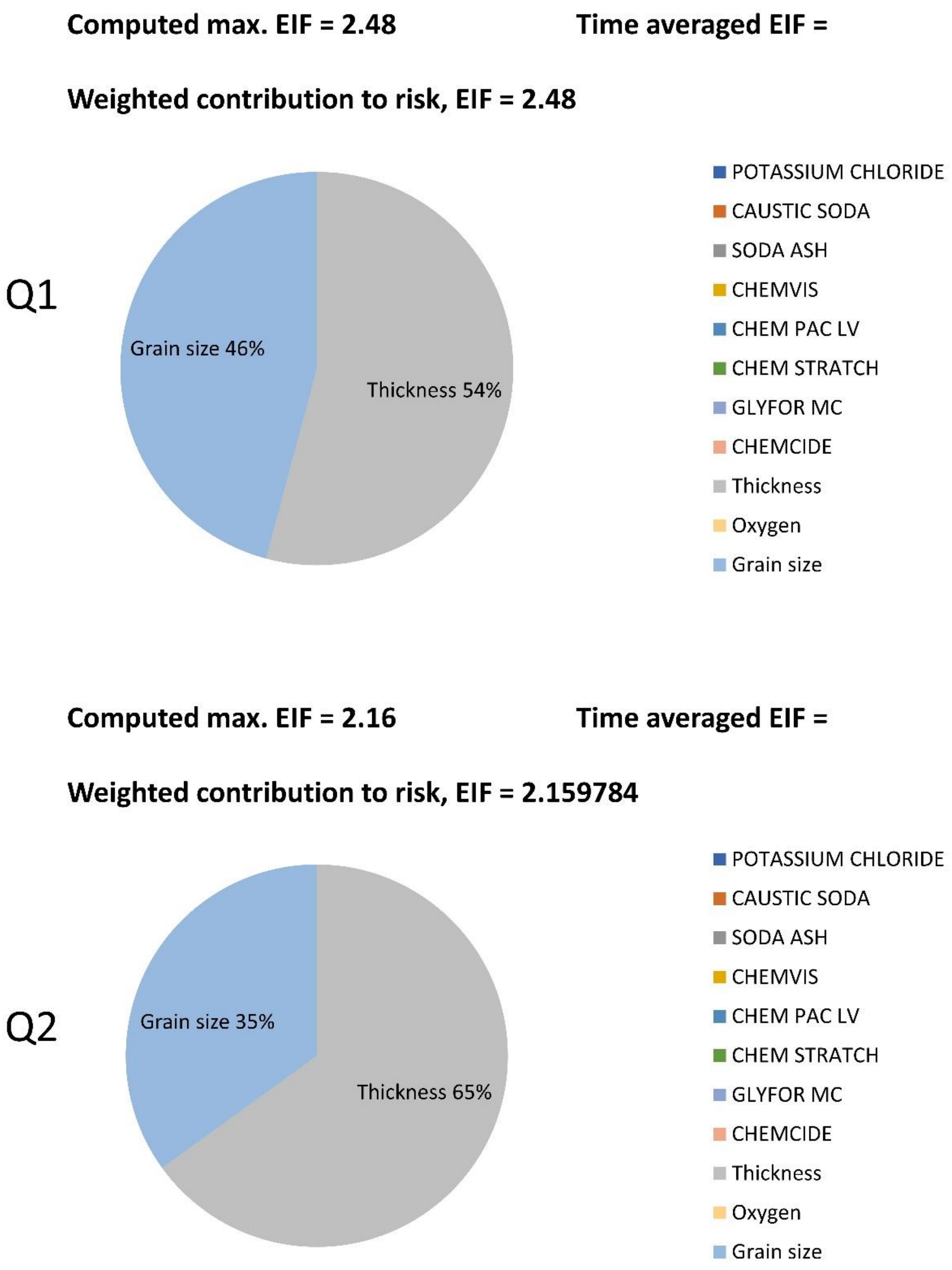


Figure 16 Main contributors to the risk in the sediment for Quarters 1 and 2

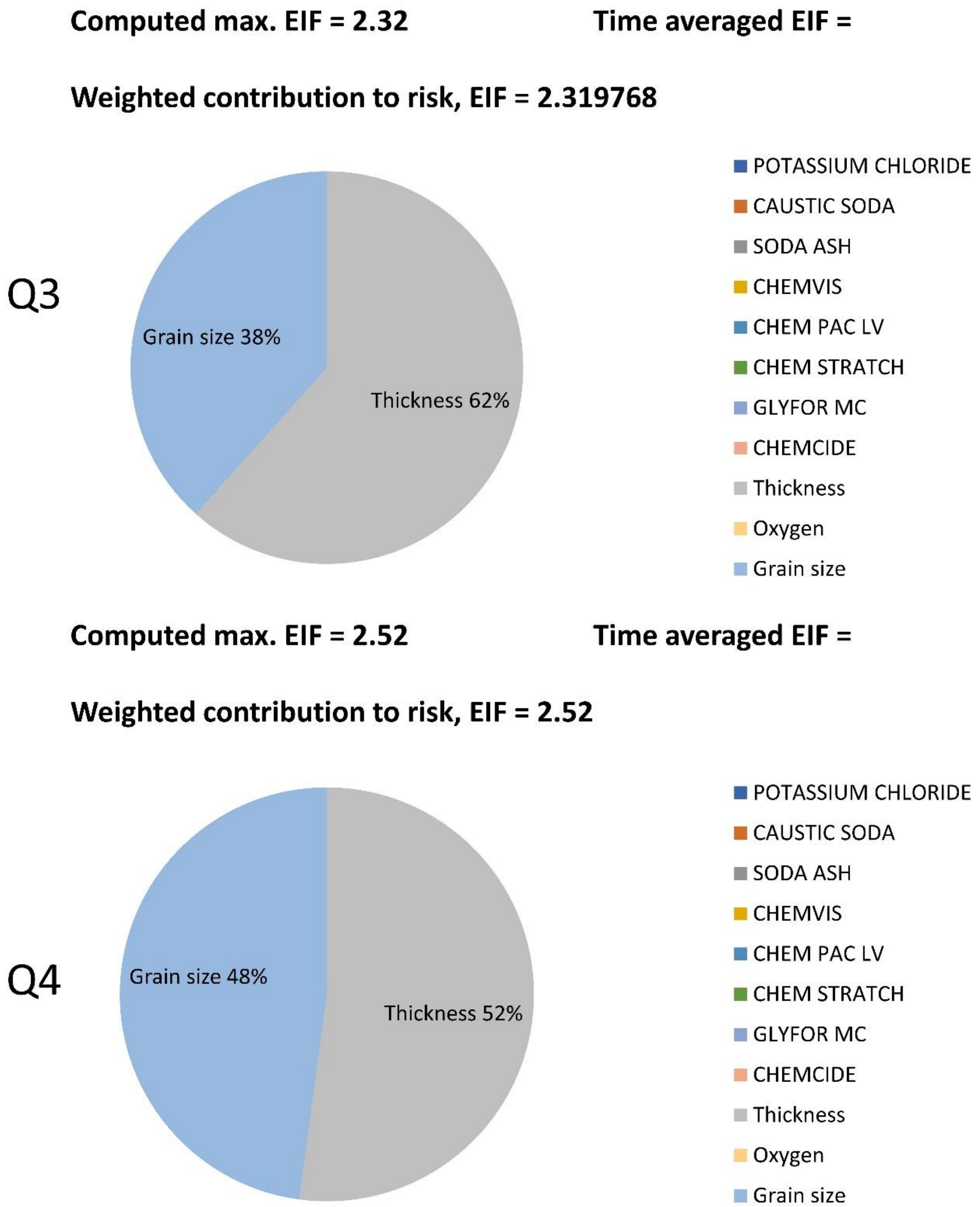


Figure 17 Main contributors to the risk in the sediment for Quarters 3 and 4

3.1.2.2 Thickness deposit

Figure 18 and Figure 19 show the cuttings thickness deposits 10 years after the end of drilling operations for all the Quarters.

The sediment deposit area is not centralized around the discharge point and is orientated towards NW to SE up to 175 m for the highest value, with a maximum cumulative thickness of 5.4 mm located on the discharge point.

The thickness deposit 10 years after the operations is lower than 6.5 mm (threshold value of thickness variation accepted by benthos, see 2.3.4 Risk assessment modelling) so the impact will be reduced. The deposit value is less than 0.5 mm after 175 m maximum all around the discharge point, meaning that the physical risk limited really close this point.

The highest cuttings deposit is mainly due to the discharge of the riserless sections discharged directly on the seabed, remaining close to the discharge area, due to low-speed bottom currents. For the other sections (17 ½'', 12 ¼” and 8 ½”) discharged at sea surface, the cuttings are spread in the water column towards N by stronger surface currents, leading to lower thickness at the seabed.

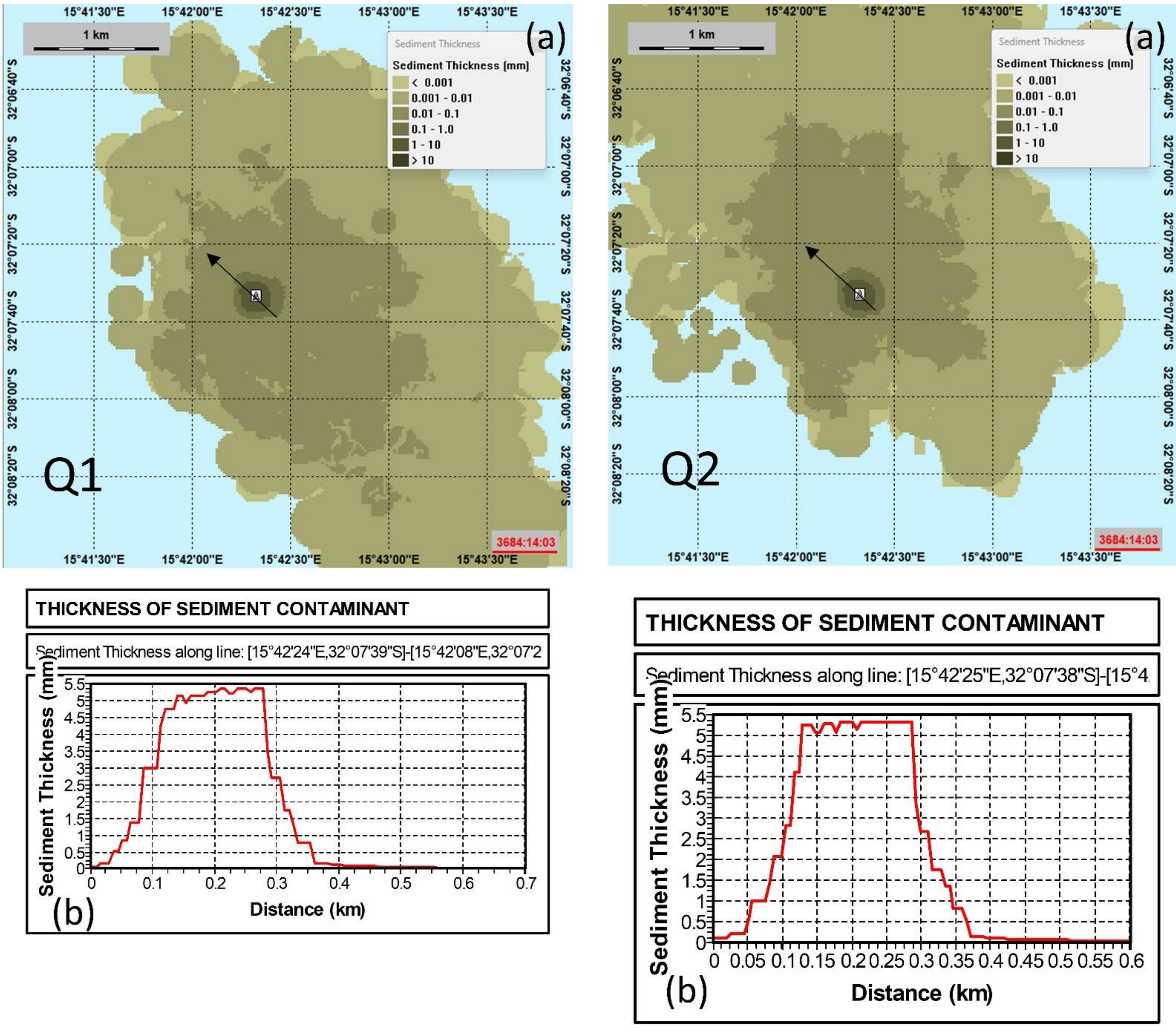


Figure 18 Maximum thickness deposit on the sediment for the Quarters 1 and 2, 10 years after operations

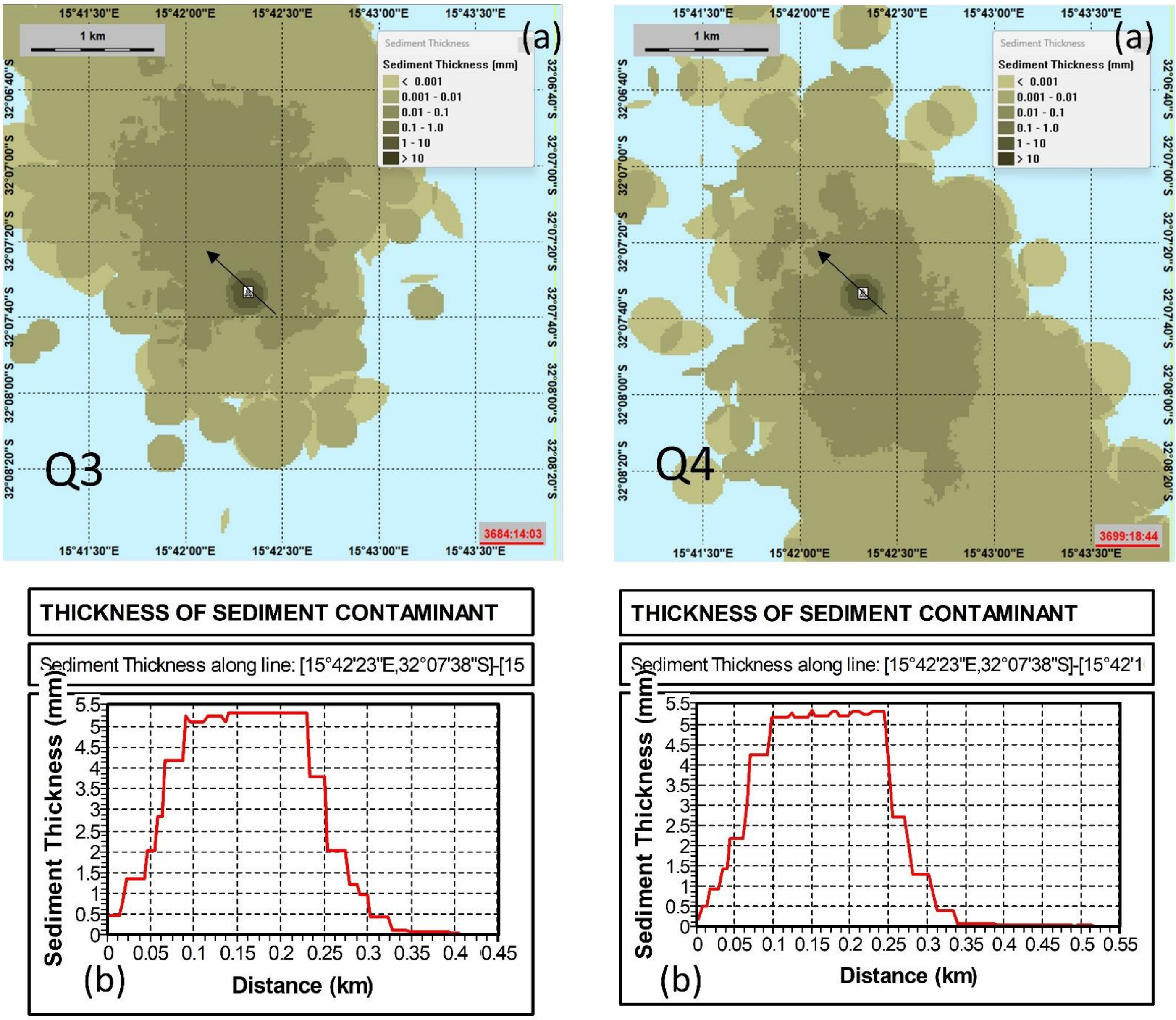


Figure 19 Maximum thickness deposit on the sediment for the Quarters 3 and 4, 10 years after operations

The Table 14 present the thickness deposit values and distances from the discharge point for all the Quarters.

Table 14 Maximum thickness deposit around the discharge point for all the Quarters

PERIOD	MAX. THICKNESS	DISTANCE OF SIGNIFICANT THICKNESS FROM DICHARGE POINT
Q1	5.3 mm	160 m
Q2	5.4 mm	175 m
Q3	5.3 mm	165 m
Q4	5.4 mm	160 m

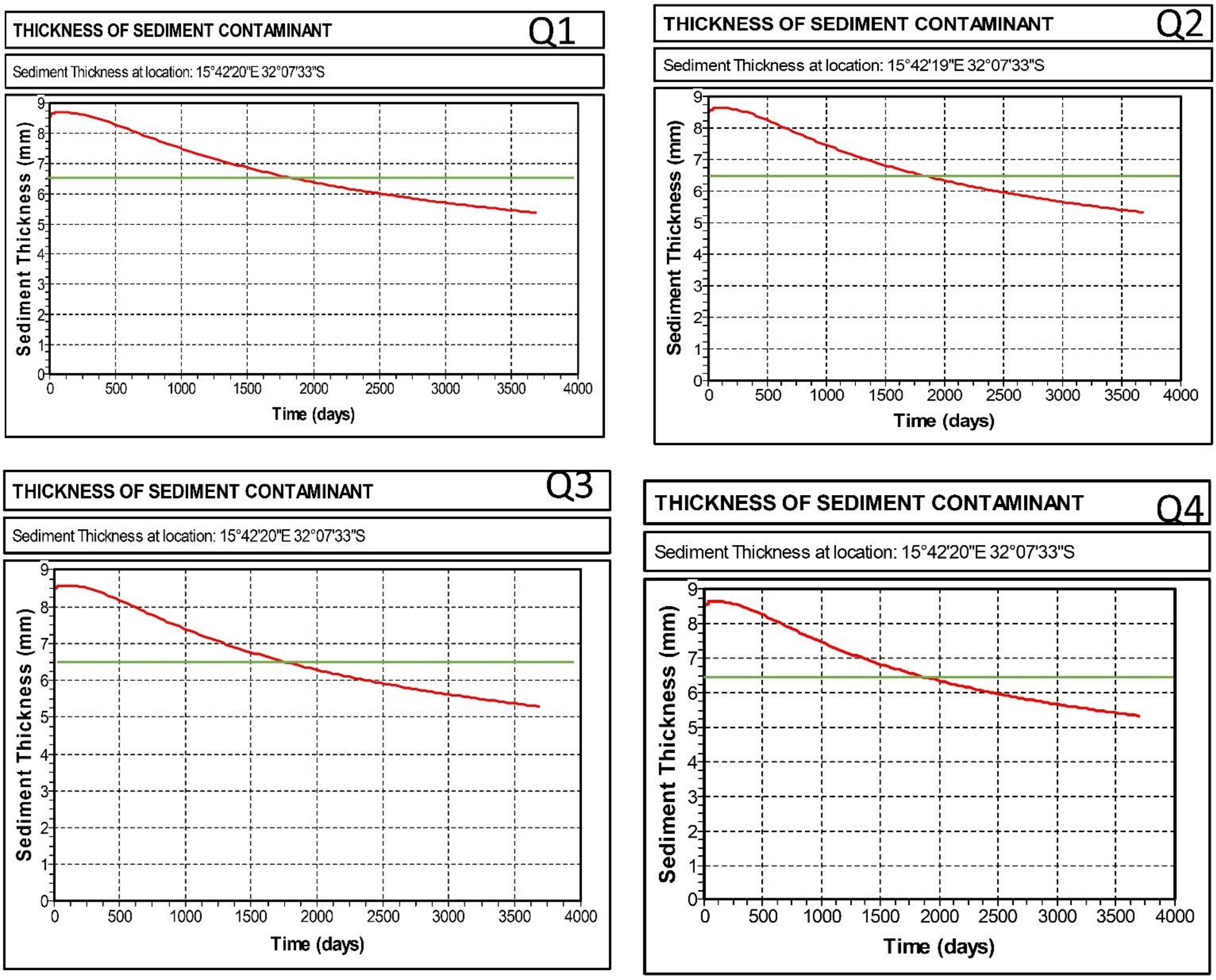


Figure 20 Thickness deposit vs. Time located on the discharge point for all Quarters

The Figure 20 above shows the evolution of the thickness deposit located on the discharge point for all Quarters.

The maximum thickness deposit located on the discharge point, shows a slight decrease one year after the operations, becoming insignificant (< 6.5mm) 5 years after the operations for all the Quarters.

3.1.2.3 Grain size variation

Figure 21 shows the percentage of grain size change 10 years after the drilling operations.

The maximum percentage of grain size change is between 1050% and 1200% located precisely on the release point. The grain size change maximum values are mostly due to the discharge of the riserless sections.

As the surface currents are stronger than the bottom currents and spread the discharge far from discharge point, so the discharge of the risered sections induce a significant grain size change on a larger area than the discharge of the riserless sections, but with lower values.

The grain size change occurs on a larger area during the risered sections discharge, therefore the percentage of grain size change is higher than during the riserless sections discharge.

The Grain Size change is insignificant after 150 m around the discharge point.

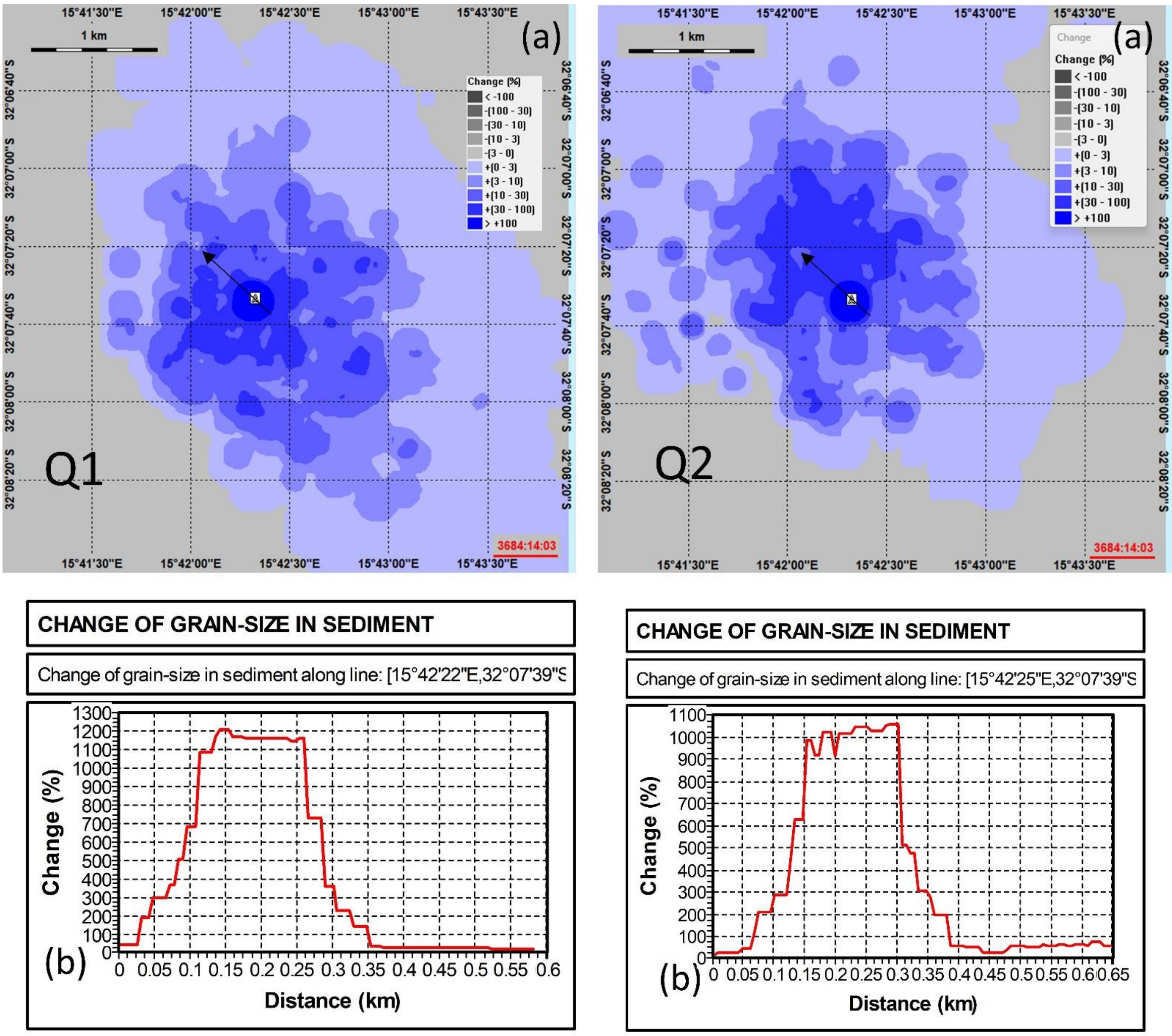


Figure 21 Grain size change on the sediment for Quarters 1 and 2, 10 years after operations

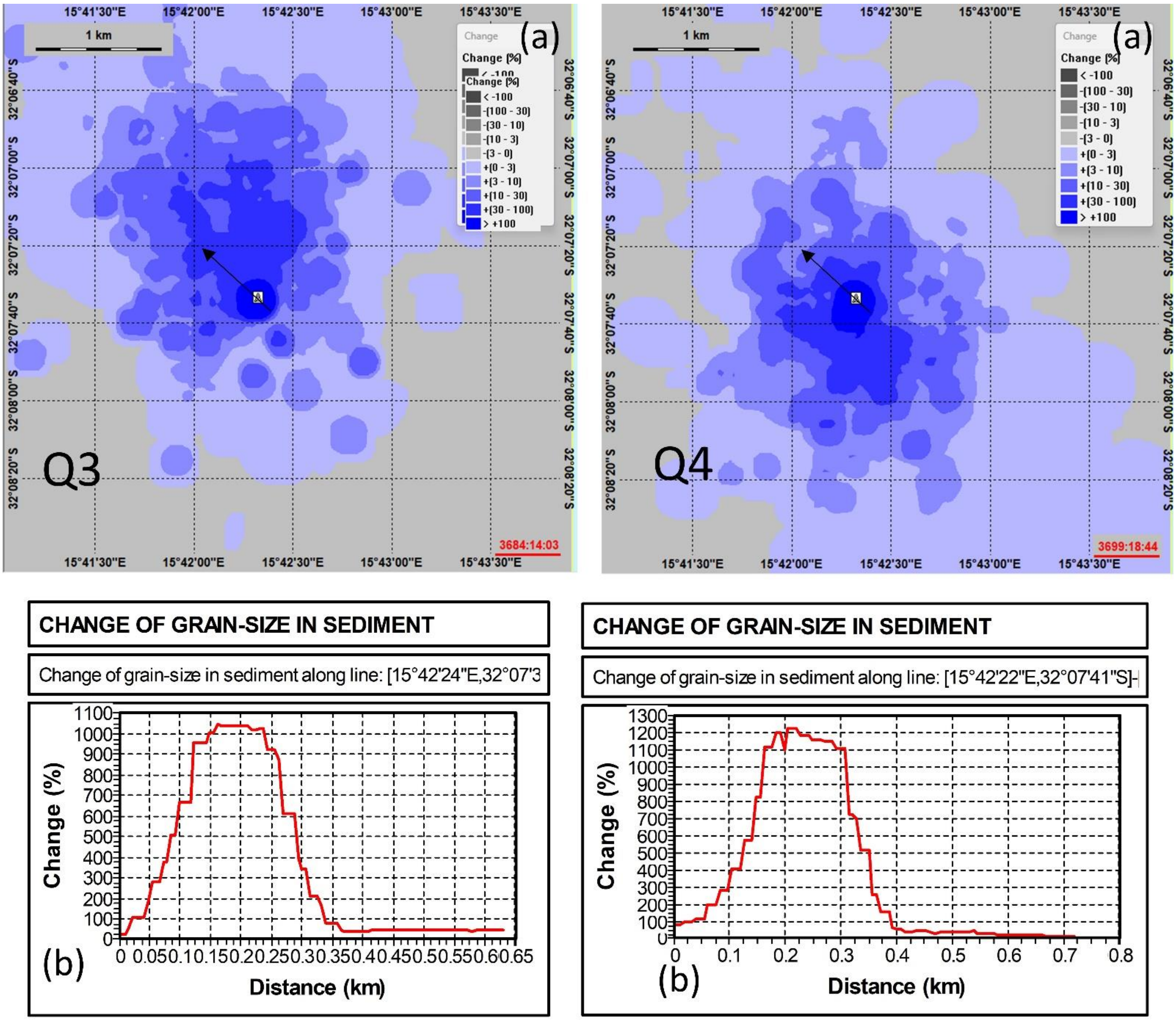


Figure 22 Grain size change on the sediment for Quarters 3 and 4, 10 years after operations

The Table 15 present the grain size change values and distances from the discharge point for all the Quarters.

Table 15 Maximum grain size change values around the discharge point for all the Quarters

PERIOD	MAX. GRAIN SIZE CHANGE	DISTANCE OF SIGNIFICANT GRAIN SIZE CHANGE FROM DICHARGE POINT
Q1	1200 %	150 m
Q2	1050 %	150 m
Q3	1050 %	150 m
Q4	1200 %	150 m

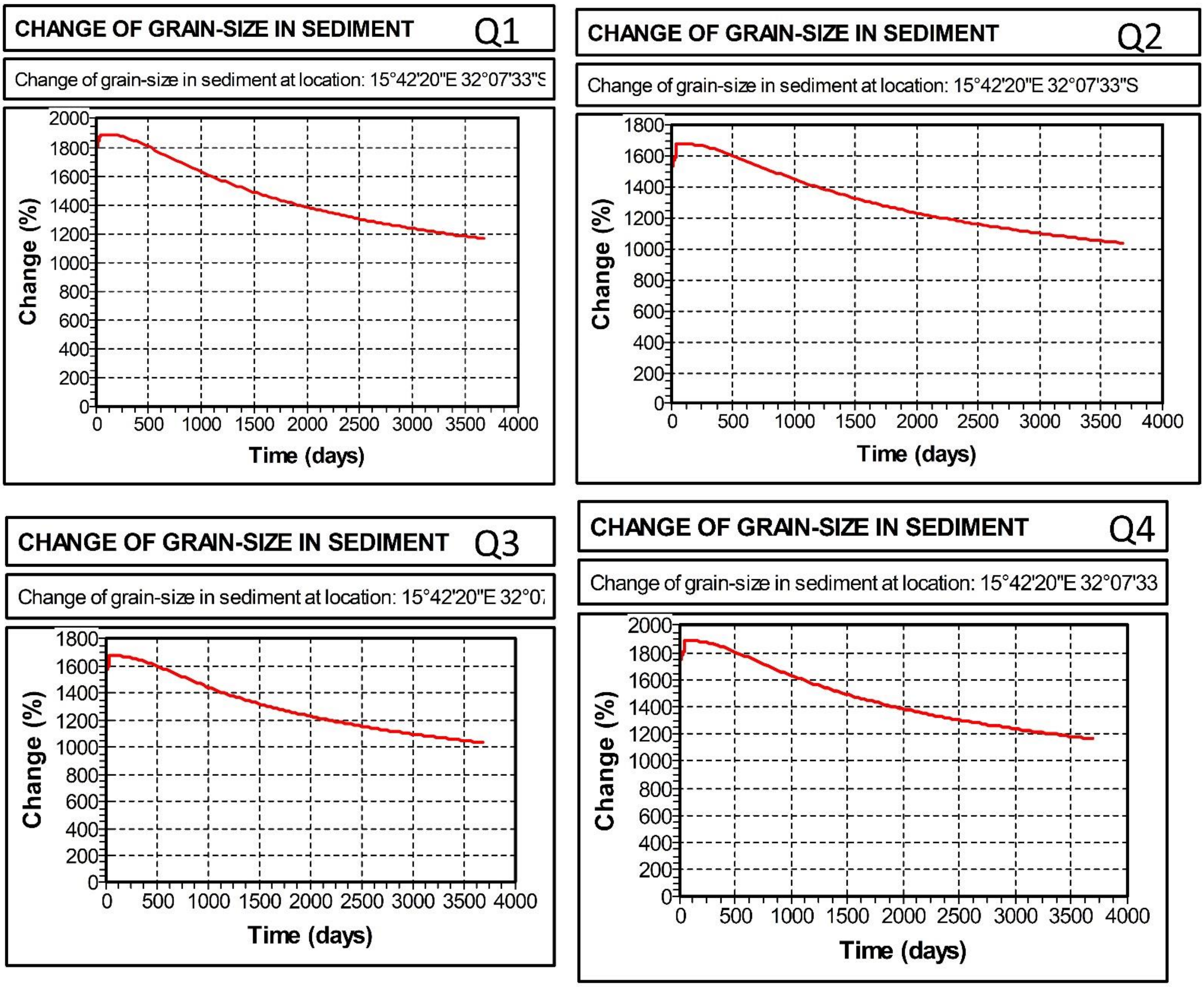


Figure 23 Grain Size variation vs. Time located on the discharge point for all Quarters

The Figure 23 above shows the evolution of the grain size change located on the discharge point for all Quarters.

The maximum grain size change located on the discharge point, between 1700 % and 1900 % show a constant decrease immediately after the operations, remaining around 1000 % to 1200 % 10 years after depending on the Quarter.

3.1.3 Results Summary for the Sediment

Contrary to the water column, the environmental risk for the sediment is mainly due to the physical contamination by the riserless and risered sections discharge (and not the chemical contamination). The risk is significant in the sediment from day 1 to 1030 days after (less than 3 years), mainly due to the end of the riserless sections discharged. The highest risk is reached just after the end of riserless discharge, and decreases quickly 2 years and 9 months after operations, with no more risk in the sediment after 3 years.

The main contributors to the environmental risk for the sediment are physical, *i.e.* the thickness deposit of the discharge and the grain size change of the natural sediment (due to higher grain size particles released during the discharge).

The sediment deposit area is not centralized around the discharge point and is orientated towards an axis from NW to SE but with significant values close to the discharge point (175 m maximum). The maximum thickness deposit located on the discharge point, shows a slight decrease one year after the operations, becoming insignificant (< 6.5mm) 5 years after the operations for all the Quarters.

The maximum percentage of grain size change is 1700 % to 1900% (depending on the Quarter) after the operations, decreasing until 1000 % to 1200 % 10 years after, located precisely on the discharge point. The grain size change is due to the discharge of the riserless and risered sections. The Grain Size change is insignificant after 150 m around the discharge point 10 years after the operations.

3.2 NON AQUEOUS BASED MUD SCENARIO – POINT D

3.2.1 Water Column – All Quarters

3.2.1.1 Environmental risk for the water column for Point D

The outcomes of the model for the maximum cumulative risk in the water column associated with the discharge of drilling operations for all the sections of the discharge point D are presented in Figure 24 and Figure 25. These figures display only the cumulative significant risk (>5%) at any time of the calculation.

These figures show that the environmental risk of the riserless and the risered discharges for all the quarters is present on the entire water column, from the seafloor due to the riserless discharge to the surface due to the discharge from the riser.

This plume represents risk for the water column following the main currents of the water column, with maximum distance varying from 5 to 12 km from the release point on different directions (depending on the quarter).

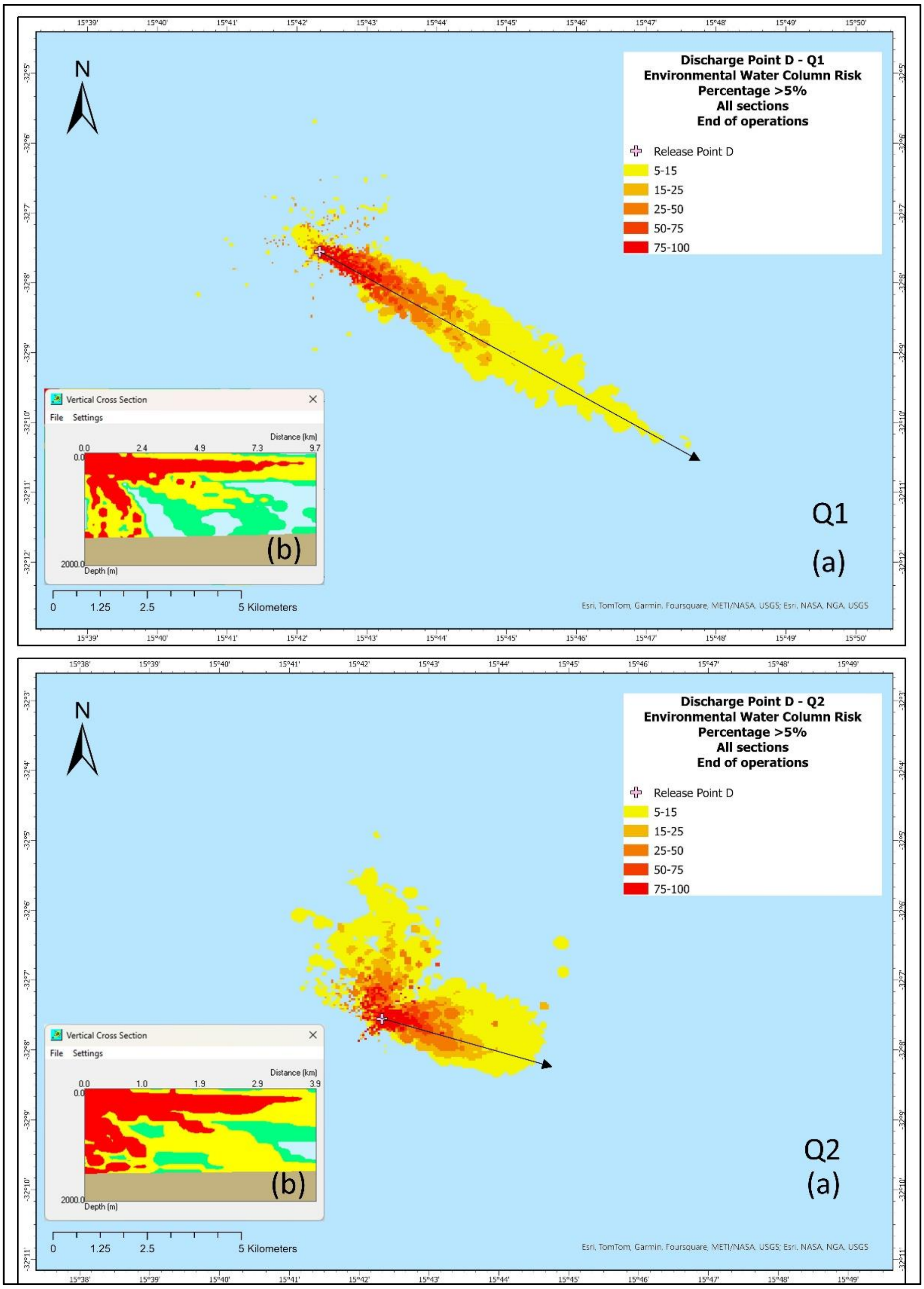
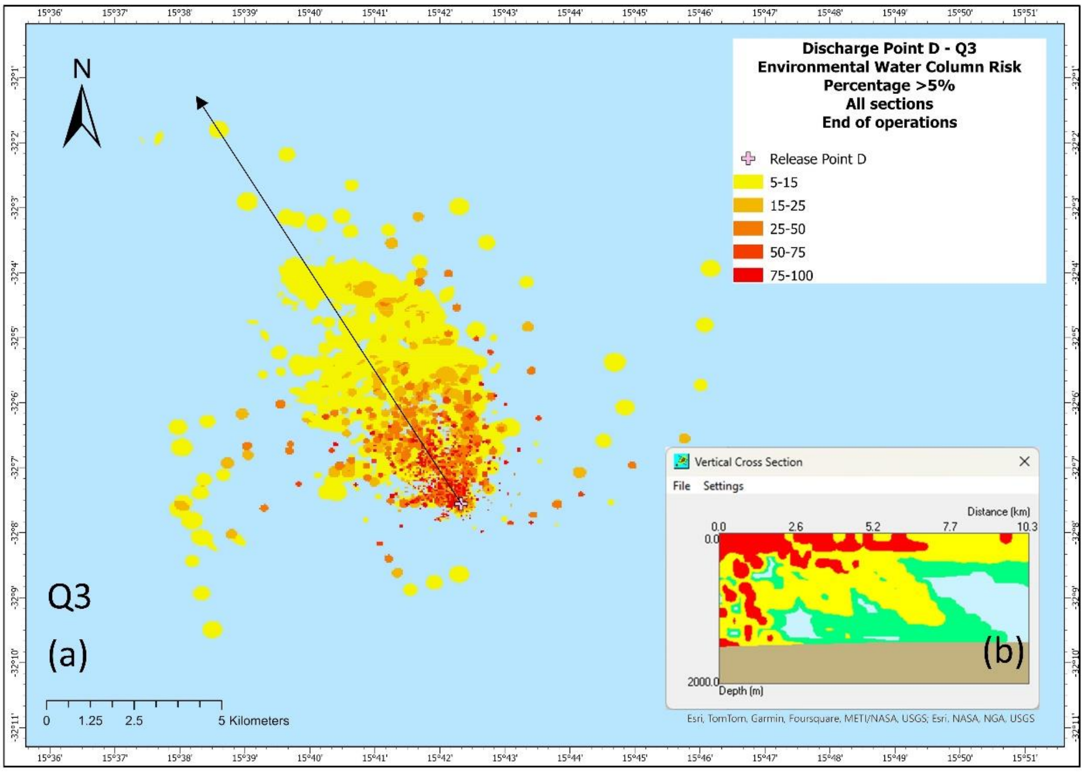


Figure 24 Maximum cumulative risk of drilling operations for Point D for Quarters 1 & 2 throughout the water column at any time for the discharge (a) Risk map – (b) Vertical cross section of the water column



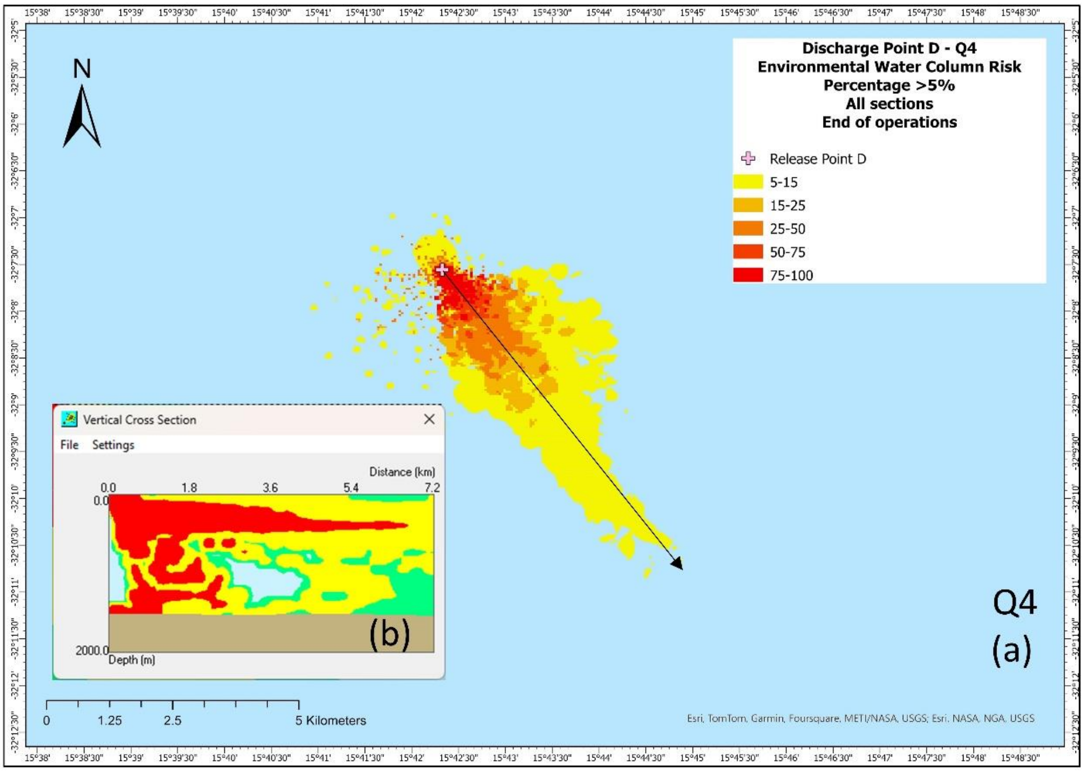


Figure 25 Maximum cumulative risk of drilling operations for Point D for Quarters 3 & 4 throughout the water column at any time for the discharge (a) Risk map – (b) Vertical cross section of the water column

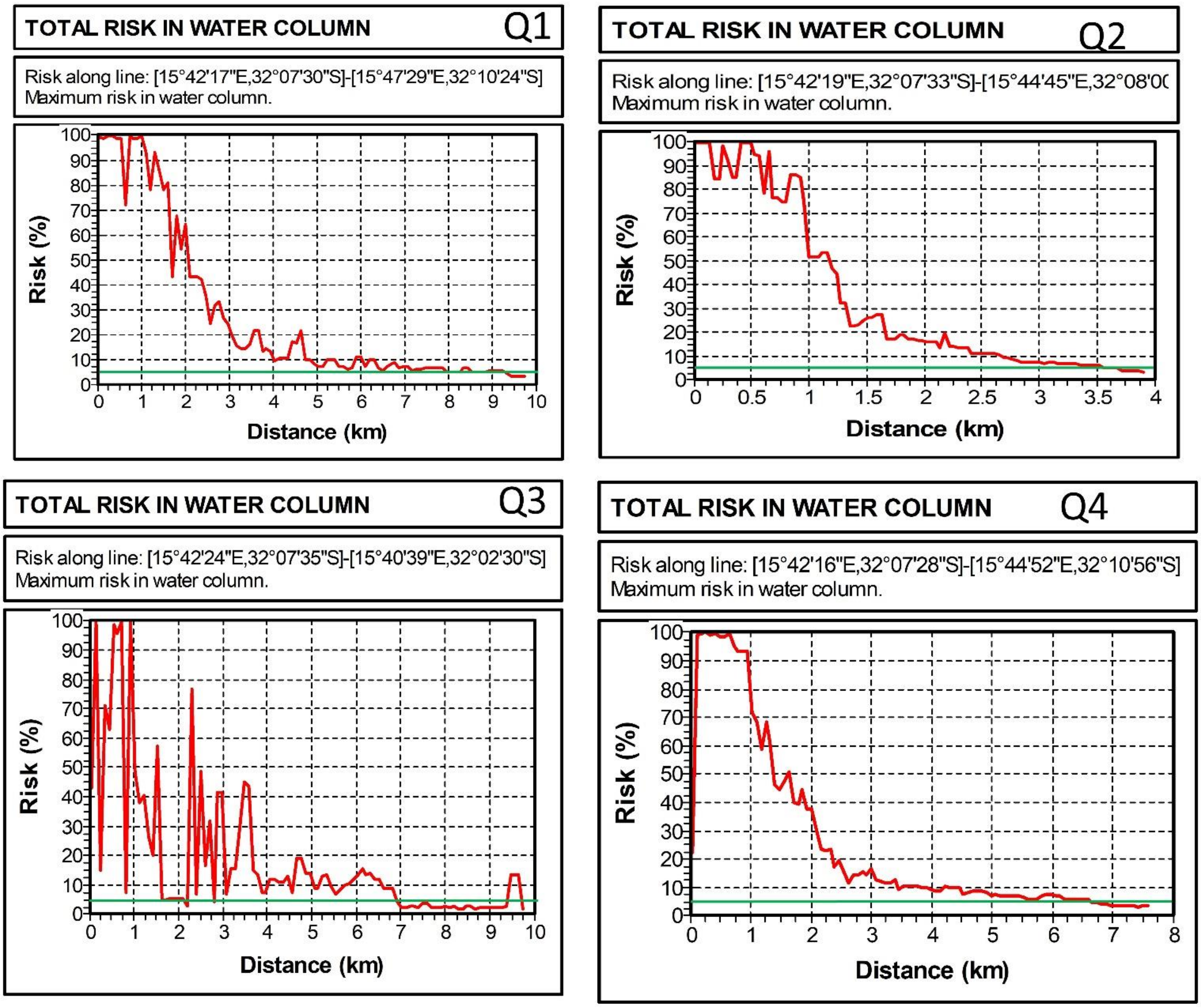


Figure 26 Risk value along a transect for entire discharge for Point D for all four Quarters

Figure 26 illustrates the cumulative risk value along a transect (calculated along the black arrows on the figures above) during discharge: the maximum values are 100% for all the Quarters, until 1 km from the release point, the direction depending on the Quarter.

Table 16 present the maximum risk values in the water column and distances and directions from the discharge point for all the Quarters.

Table 16 Maximum risk values in the water column for Point D for all Quarters

PERIOD	MAX. ENVIRONMENTAL RISK	DISTANCE and DIRECTION OF SIGNIFICANT RISK FROM DICHARGE POINT
Q1	100 %	9.7 km SE
Q2	100 %	5.0 km ESE
Q3	100 %	12.4 km NW
Q4	100 %	7.1 km SE

3.2.1.2 Environmental Risk Contributors & Risk Duration for Point D

Figure 27 shows the contributors to risk over time for the different sections for Quarter 1 (taken as an example, because all the quarters present similar results).

Each section discharge presents some risk for the water column, but with short time duration.

The main contributor of environmental risk in the Water Column during the Riserless sections discharge is due to the presence of Bentonite (contributing to 90% of the risk for this riserless discharges).

The maximum instantaneous EIF value is reached during the drilling of the 17 ½“ and 12 ½“ sections, due to the presence of the hydrotreated light petroleum distillate present in the base oil (EDC-99DW). This component is responsible to 70% to 90% of the environmental risk for the Water Column for the risered discharges.

There is no more risk in the water column after the end of the discharge of the 8 ½” discharge, due to the strong dispersion and dilution of the chemicals as result of strong currents in this area.

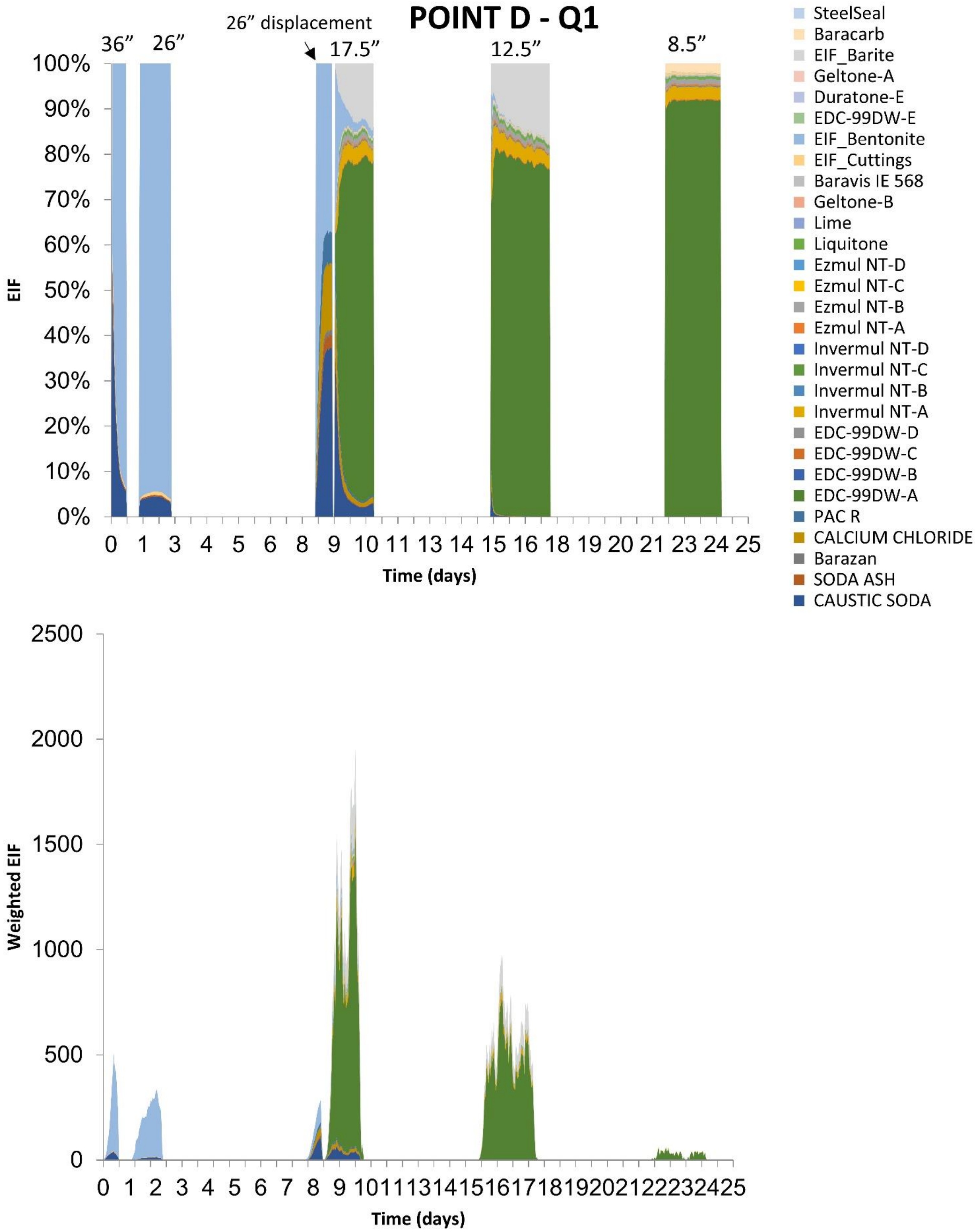


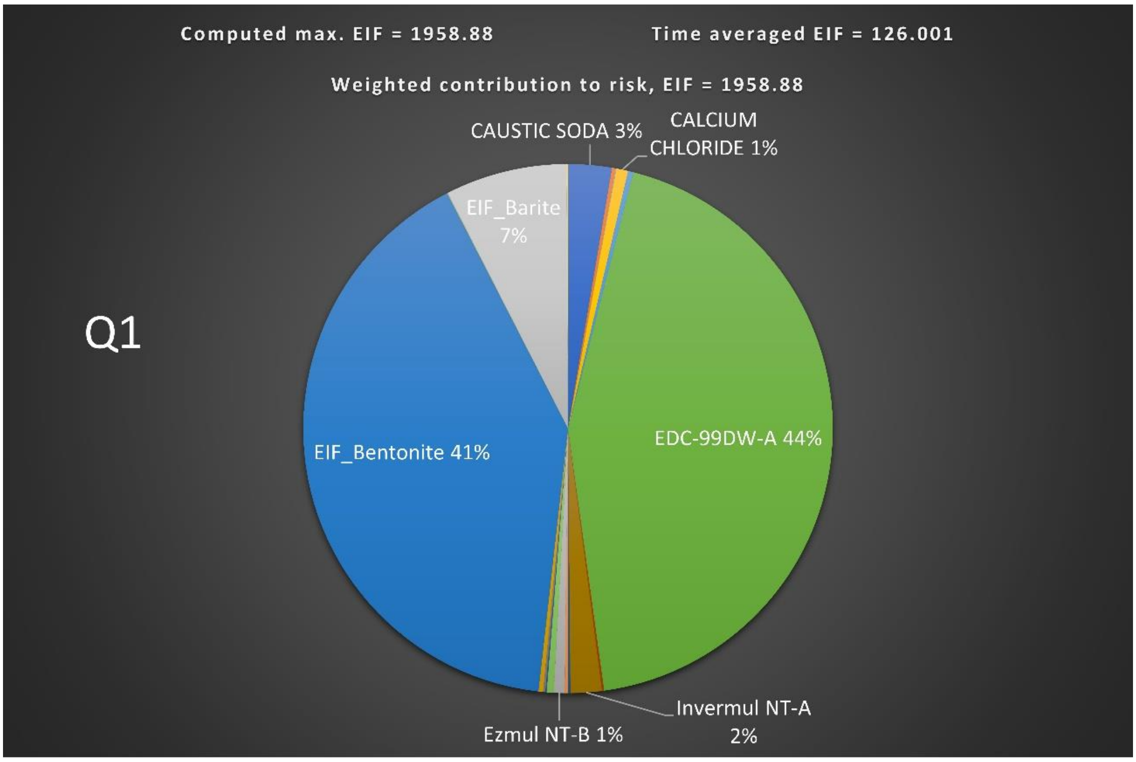
Figure 27: Main contributors to the risk over the time in the water column for the Point D - Quarter 1: Figure on the top presenting relative percentage of contributors for each section; Figure on the bottom presenting instantaneous maximum volume of water at risk

Figure 28 and Figure 29 present the main contributors to the overall risk in the water column for all the Quarters.

For all the seasons, the main contributors are the same. The hydrotreated light petroleum distillate present in the base oil (EDC-99DW), contributes in total to 44% to 63% of the risk depending on the Quarter. This component is present on the mud discharged during the Risered sections drilling operations. As this component has a low PNEC, its toxicity is high, so a small amount released in the environment is quickly impacting the species.

The Bentonite discharged during the riserless sections drilling is the second most impacting component for the Water Column, representing 16% to 41% of contribution depending on the Quarter.

The maximum risk in terms of volume of water at risk (EIF) is reached during the season 3, but with values close to the other seasons. One EIF represent a volume of water of 10^5 cubic meters presenting risk at one time during the entire discharge. For example, the discharge during the Quarter 1 presents a total environmental risk for 1958 * 10^5 m^3 of seawater. But the risk is short term, and is linked to the time step, meaning that most of the risk will be present only for a few hours, and will be quickly dispersed and diluted.



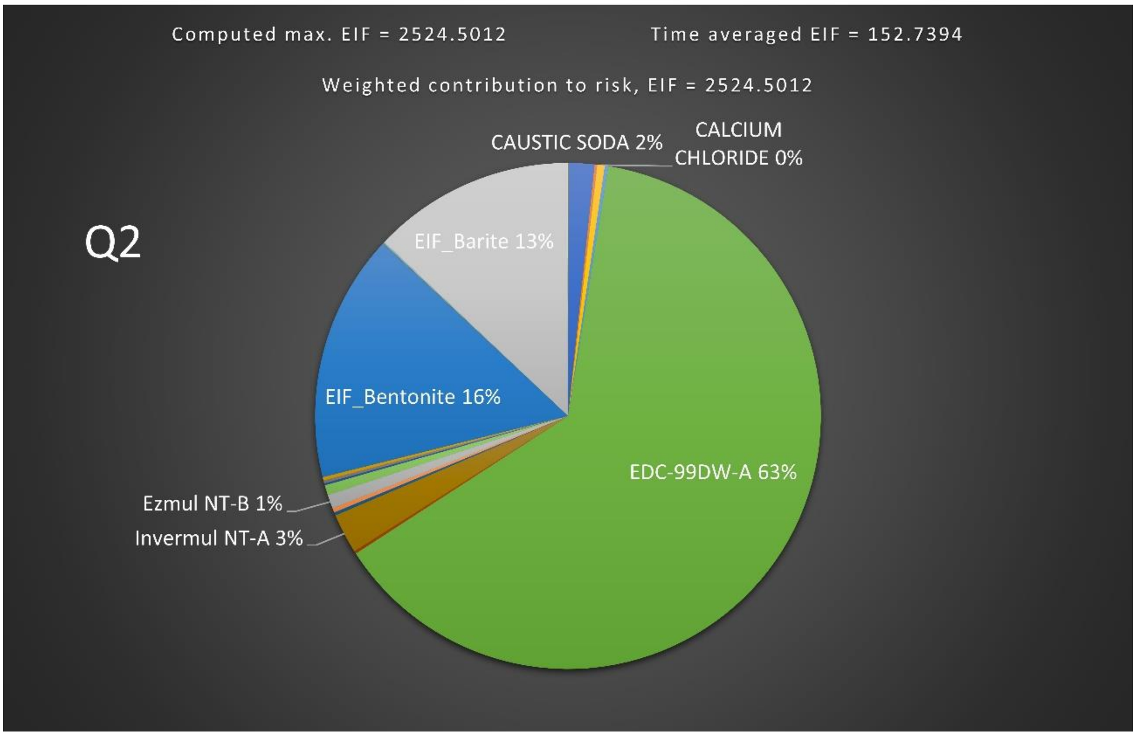
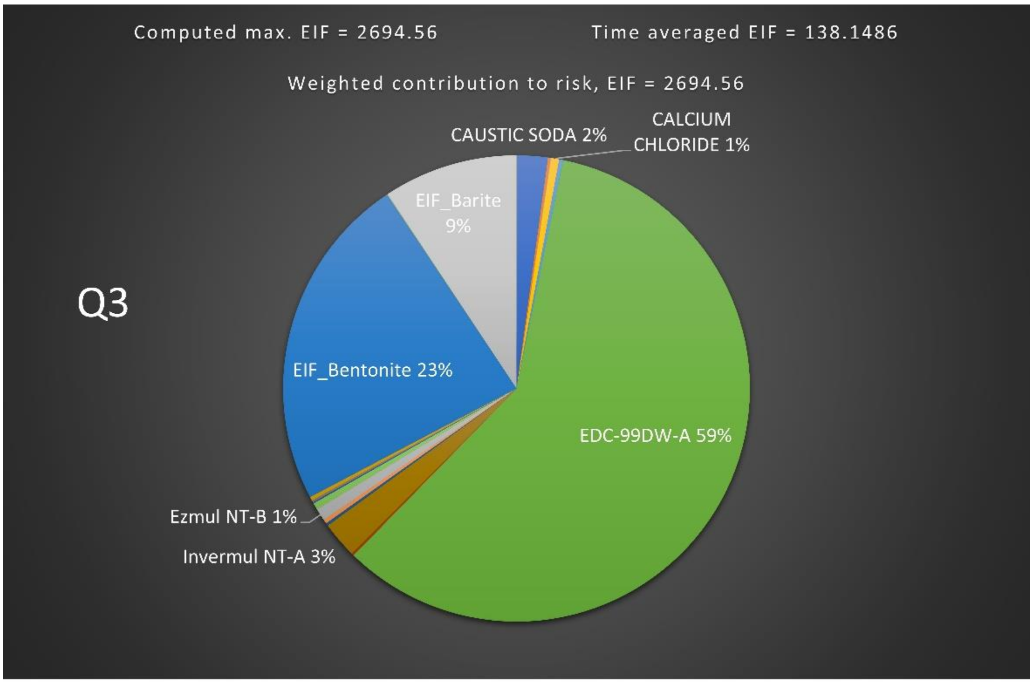


Figure 28 Main contributors to the risk in the water column for Point D - Quarters 1 and 2



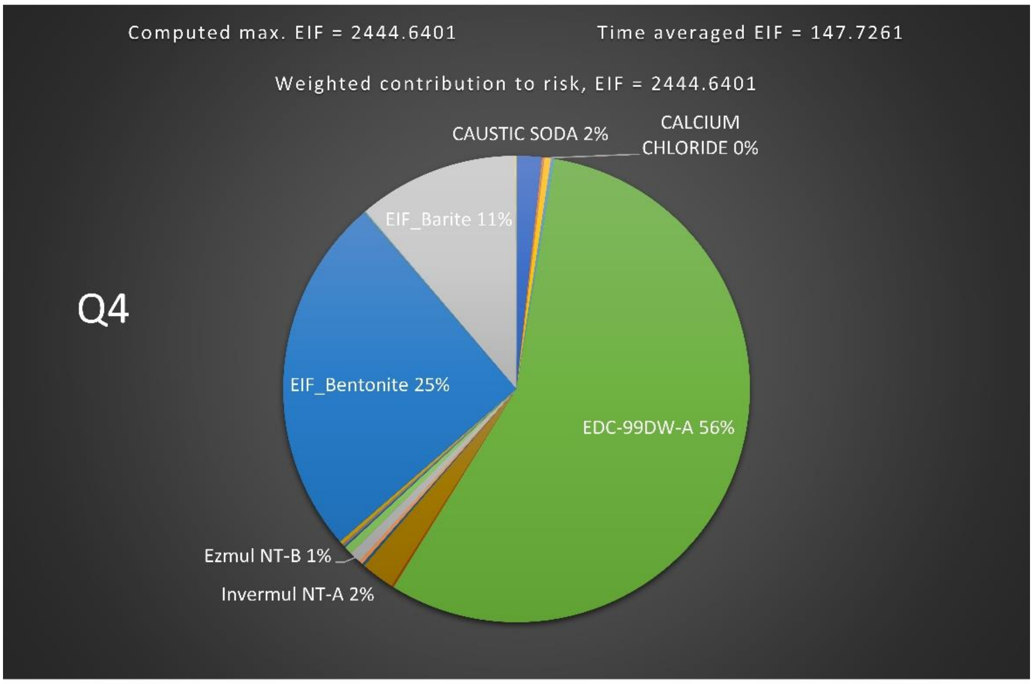


Figure 29 Main contributors to the risk in the water column for Point D - Quarters 3 and 4

3.2.1.3 Results Summary for the Water Column for Point D

The figures and table above show that the environmental risk in the water column is present from the surface to the seabed, meaning that both types of discharges (risered and riserless) will have an impact. The environmental risk is mainly due to the NADF released during risered sections discharges for all the seasons.

The physical risk is due to the release of Bentonite from the riserless sections mainly, using the WBM, and the chemical risk is due to the release of EDC-99DW present in the NADF used during the risered sections drilling.

The maximum risk distance is reached during the discharge of the risered sections and varies depending on the season, from 5 km N from the discharge point for the Quarter 2 (minimum) to 12.4 km NW for the Quarter 3 (maximum). For all seasons, the discharge spreads towards the closest sensitive area.

The main contributor to the risk in the water column is chemical, and due to the EDC-99DW released during the risered sections drilling. The maximum EDC-99DW-A concentration (hydrotreated light petroleum distillate) in the water column is reached during the release of section 17 ½", and Quarter 3 is the period presenting the highest value. All these highest concentration values are reached between 9 and 10 days after the start of the operations, during the 17 ½" section drilling. The Bentonite discharged during the riserless sections drilling is the second most impacting component for the Water Column.

Due to the strong currents in the area, the environmental risk in the water column is present over several kilometers. However, strong currents presente in this area allow a quick dispersion and dilution of the chemicals: the risk reached is very high close to the discharge point, but this is of short duration.

There is no more risk in the water column after the end of the operations for all the Quarters as result of dispersion and dilution processes due to the strong currents in this area.

3.2.2 Sediment – All Quarters

3.2.2.1 Environmental risk and main contributors for Point D

The outcomes of the model for the maximum significant risk (risk > 5%, that which will have a potential impact) for the four Quarters associated with the discharges all sections during drilling operations for the sediments are presented in Figure 30 and Figure 31.

A reduced area with significant risk above 5% is observed in the sediment close to the discharge. At the end of the operations, a significant risk is observed from 1.4 km to 3.6 km maximum around the discharge point depending on the Quarter. A maximum risk of 100% has been calculated located on the release point for each Quarter. There is still some risk observed 10 years after the operations (average time for sediment restoration after drilling operations). This will be developed in the following sections.

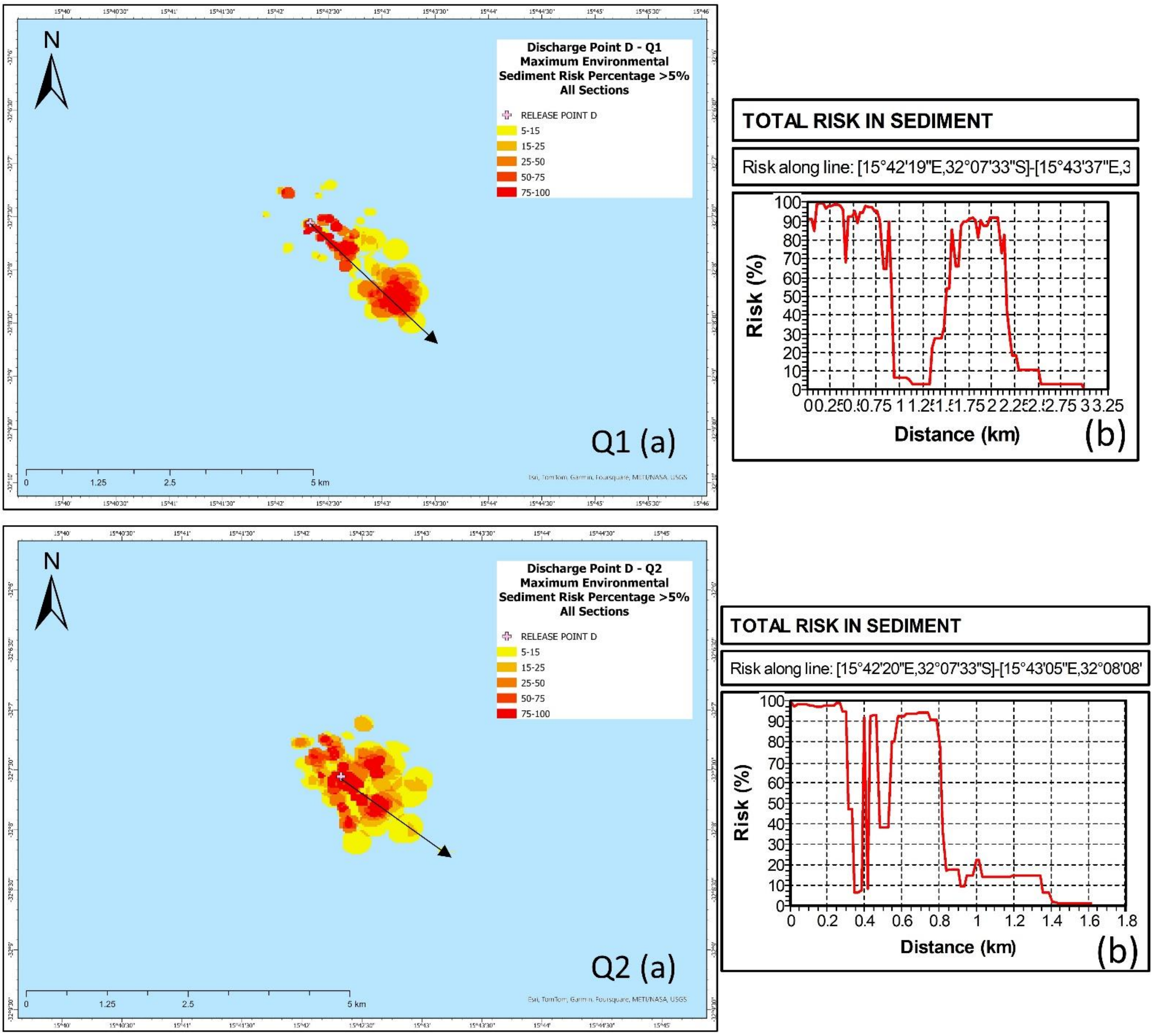


Figure 30 Maximum potential risk in the sediment for Point D - Quarters 1 and 2

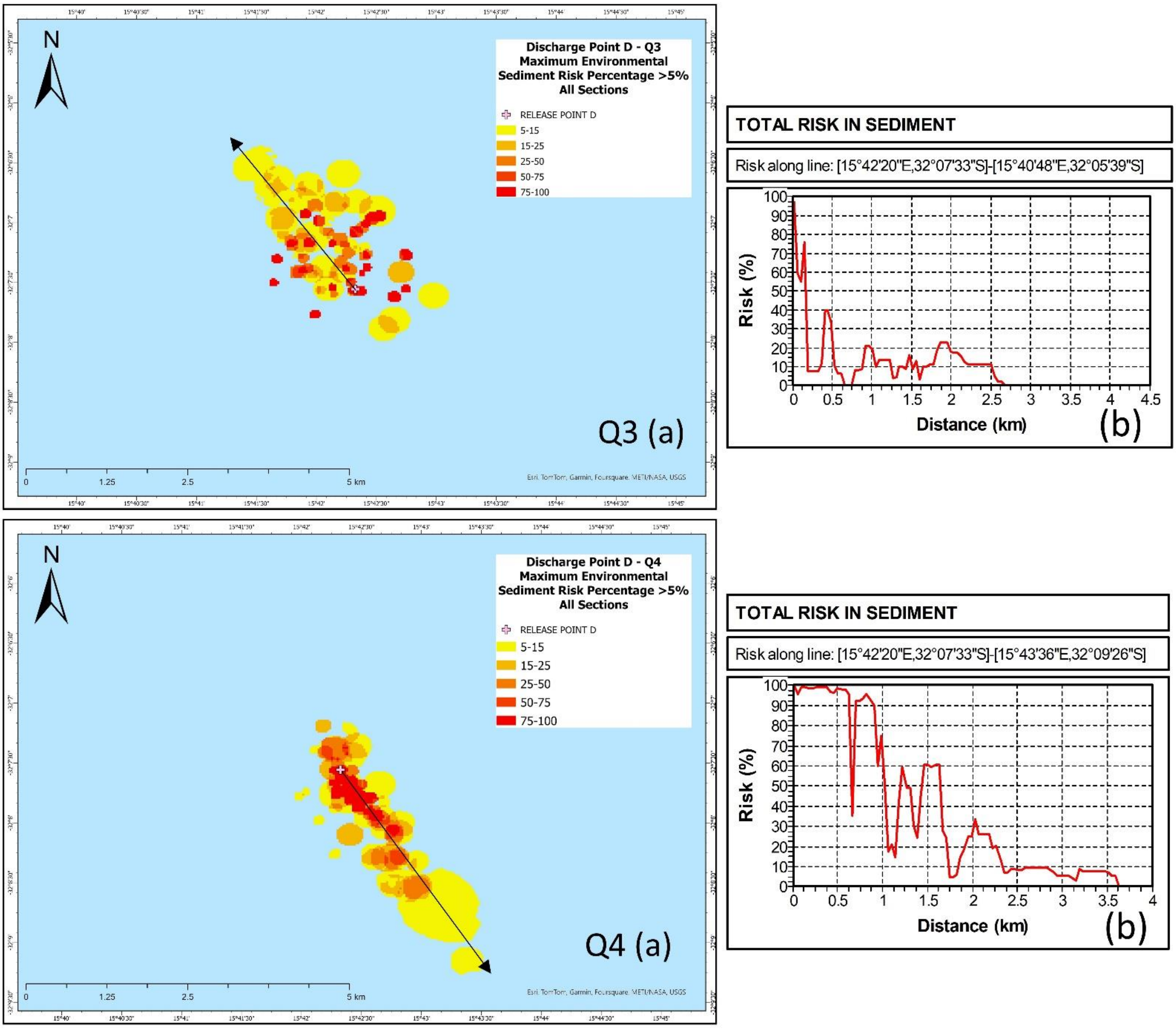


Figure 31 Maximum potential risk in the sediment for Point D - Quarters 3 and 4

The Table 17 present the maximum risk values in the water column and distances and directions from the discharge point for all the Quarters.

Table 17 Maximum risk values in the sediment for Point D for all the Quarters

PERIOD	MAX. ENVIRONMENTAL RISK	DISTANCE and DIRECTION OF SIGNIFICANT RISK FROM DICHARGE POINT
Q1	100 %	2 500 m SE
Q2	100 %	1 430 m SE
Q3	100 %	2 580 m NW
Q4	100 %	3 600 m SE

Figure 32 presents the Environmental risk for the sediment and the contributors to the risk for a 10 year period for the Quarter 1 (taken as an example; all the other quarters present the same results). The risk is significant in the sediment from day 1 to 10 years after, mainly due to the chemicals present in the risered sections discharged. The highest risk is reached just after the end of the operations, around day 25, and decreases quickly 66 days after operations until one year after, and then decreases gradually until 10 years after (Figure 32, bottom graph).

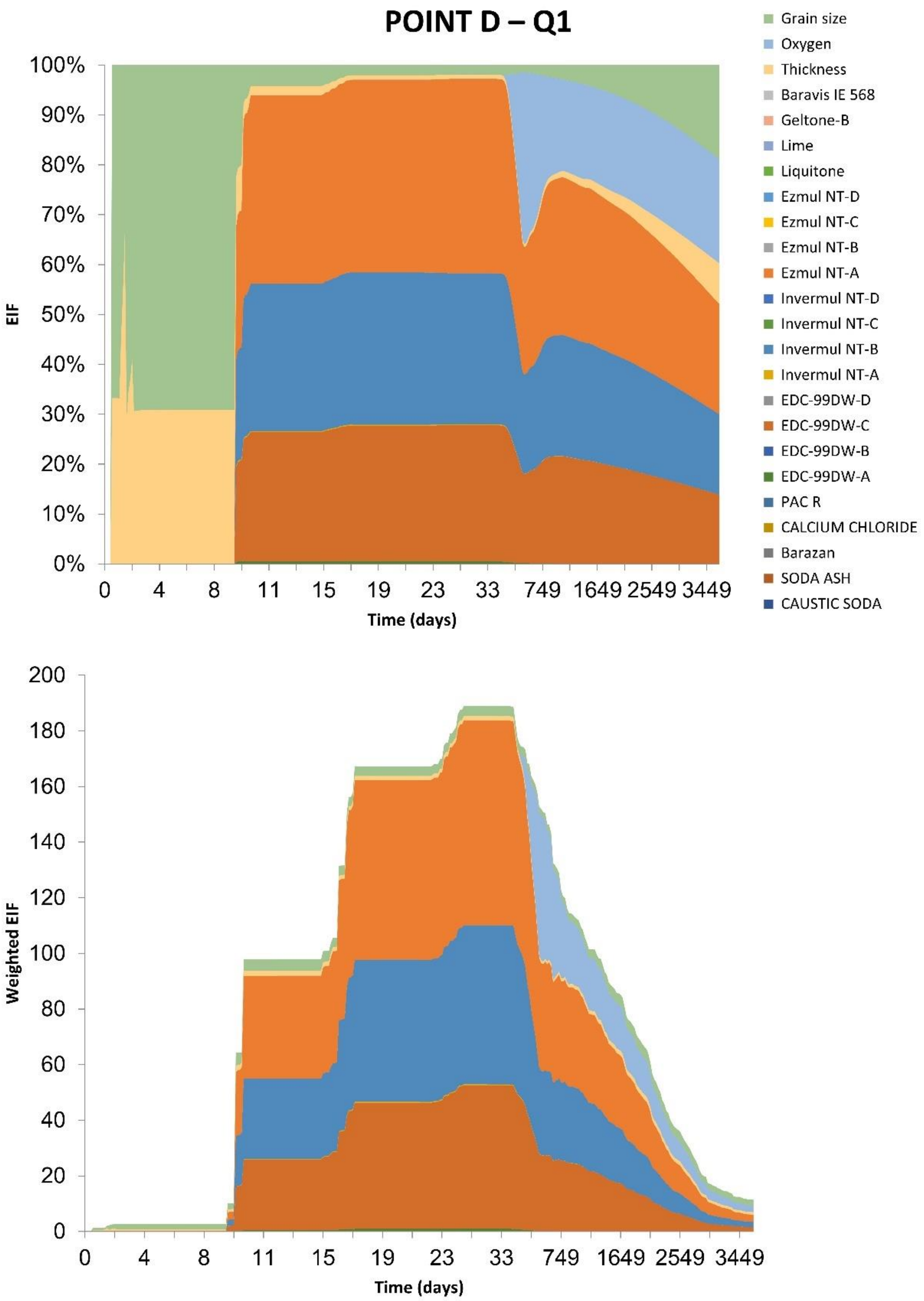
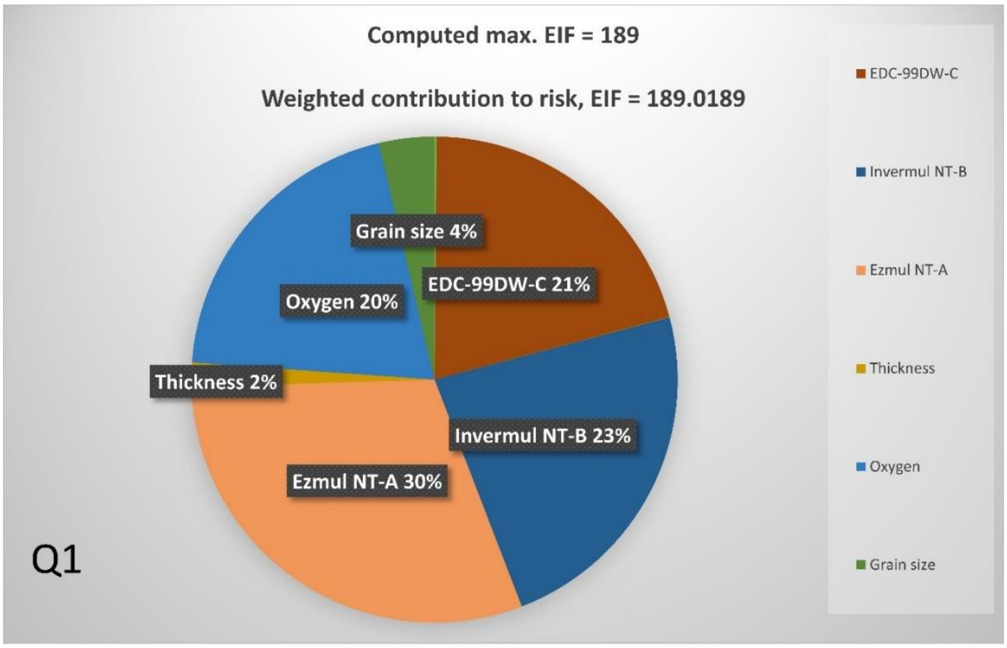


Figure 32 Main contributors to the risk over the time in the sediment for Point D for the Quarter 1: Figure on the top presenting relative percentage of contributors; Figure on the bottom presenting instantaneous maximum surface of sediment at risk

Figure 33 and Figure 34 show the main contributors to the environmental risk for all the Quarters, considering all sections to be discharged, over the 10 year extension period studied. The main contributors to the environmental risk for the sediment are chemical, due to some components of the NADF released during the drilling of the risered sections: the fatty acid present in the EZMUL NT-A, Invermul NT-B and EDC-99DW-C is responsible for 74% to 80% of the total environmental risk.

The physical risk, *i.e.* the grain size change of the natural sediment (due to higher grain size particles released during the discharge), has a contribution to the total risk of 4%; and the thickness deposit of the discharge, contributing to 1 to 2% of the total risk depending on the Quarter.

The oxygen depletion in the sediment is responsible for 14 to 21% to the total risk, and is a mix of physical and chemical impact: the burial effect of the thickness deposit and oxygen consumption during the biodegradation of certain chemicals can lead to this loss of oxygen in the environment.



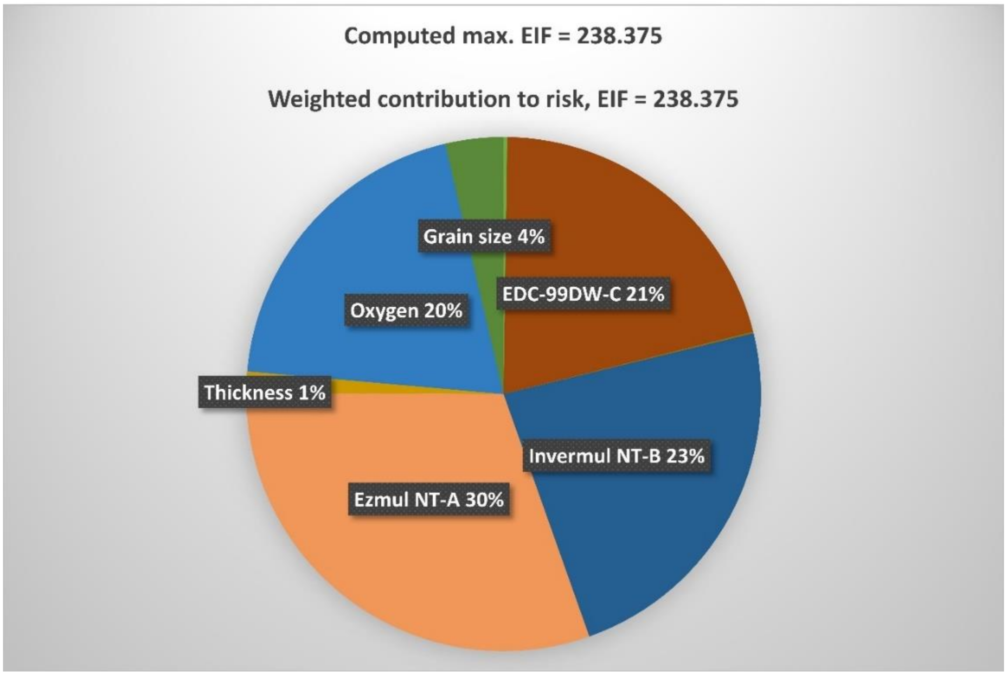
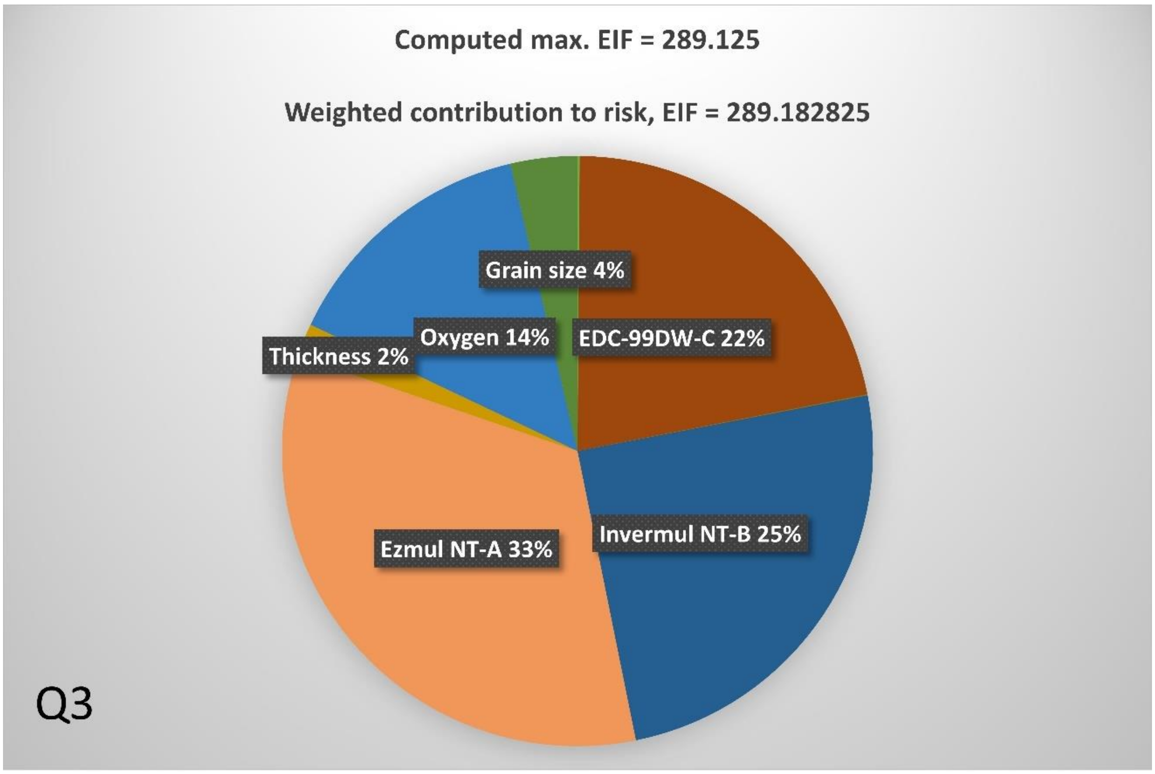


Figure 33 Main contributors to the risk in the sediment for Point D - Quarters 1 and 2



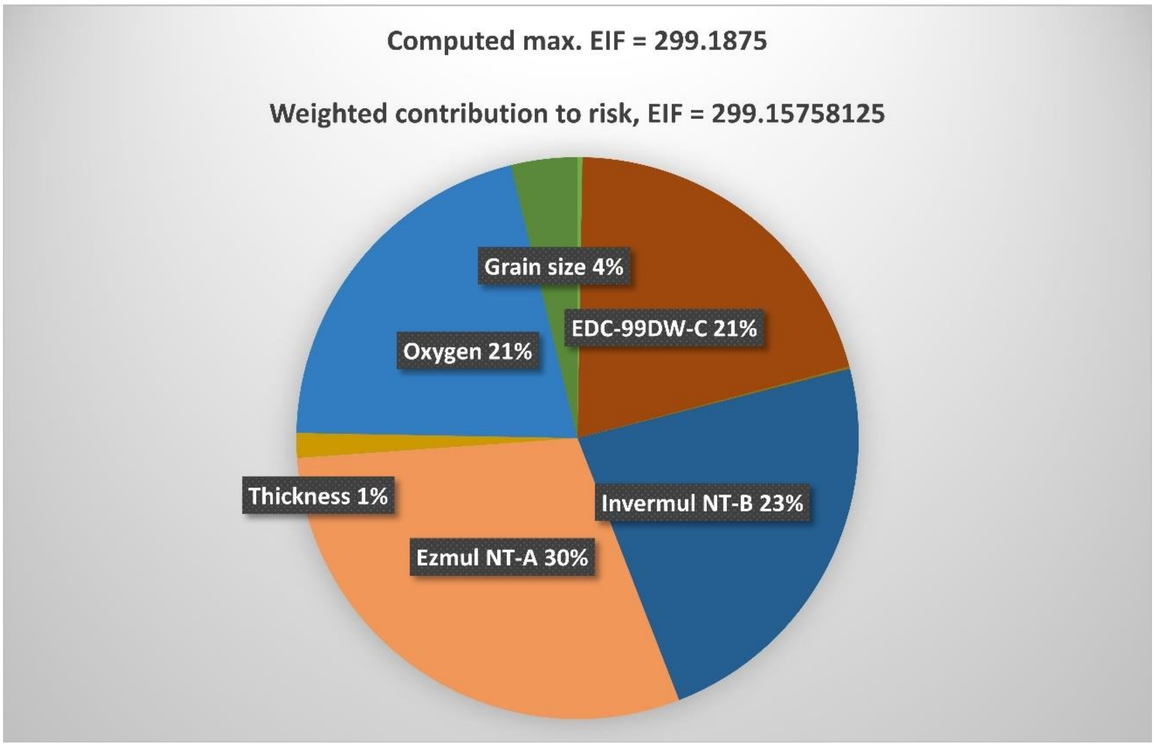


Figure 34 Main contributors to the risk in the sediment for Point D - Quarters 3 and 4

3.2.2.2 Thickness deposit for Point D

Figure 35 and Figure 36 show the cuttings thickness deposits 10 years after the end of drilling operations for all the Quarters.

The particles deposit area is not centralized around the discharge point and is orientated towards NW to SE up to 141 m of distance for the highest value, with a maximum cumulative thickness values between 55.8 and 63.5 mm located on the discharge point.

The thickness deposit 10 years after the operations is still around 30 mm, which is higher than the 6.5 mm (threshold value of thickness variation accepted by benthos, see 2.3.4 Risk assessment modelling) so the impact will be present close to the discharge point (until 140 m maximum) for a long period.

The highest cuttings deposit is mainly due to the discharge of the riserless sections discharged directly on the seabed, remaining close to the discharge area, due to low-speed bottom currents. For the other sections (17 ½'', 12 ¼" and 8 ½") discharged at sea surface, the cuttings are spread in the water column towards N or S by stronger surface currents, leading to lower thickness at the seabed.

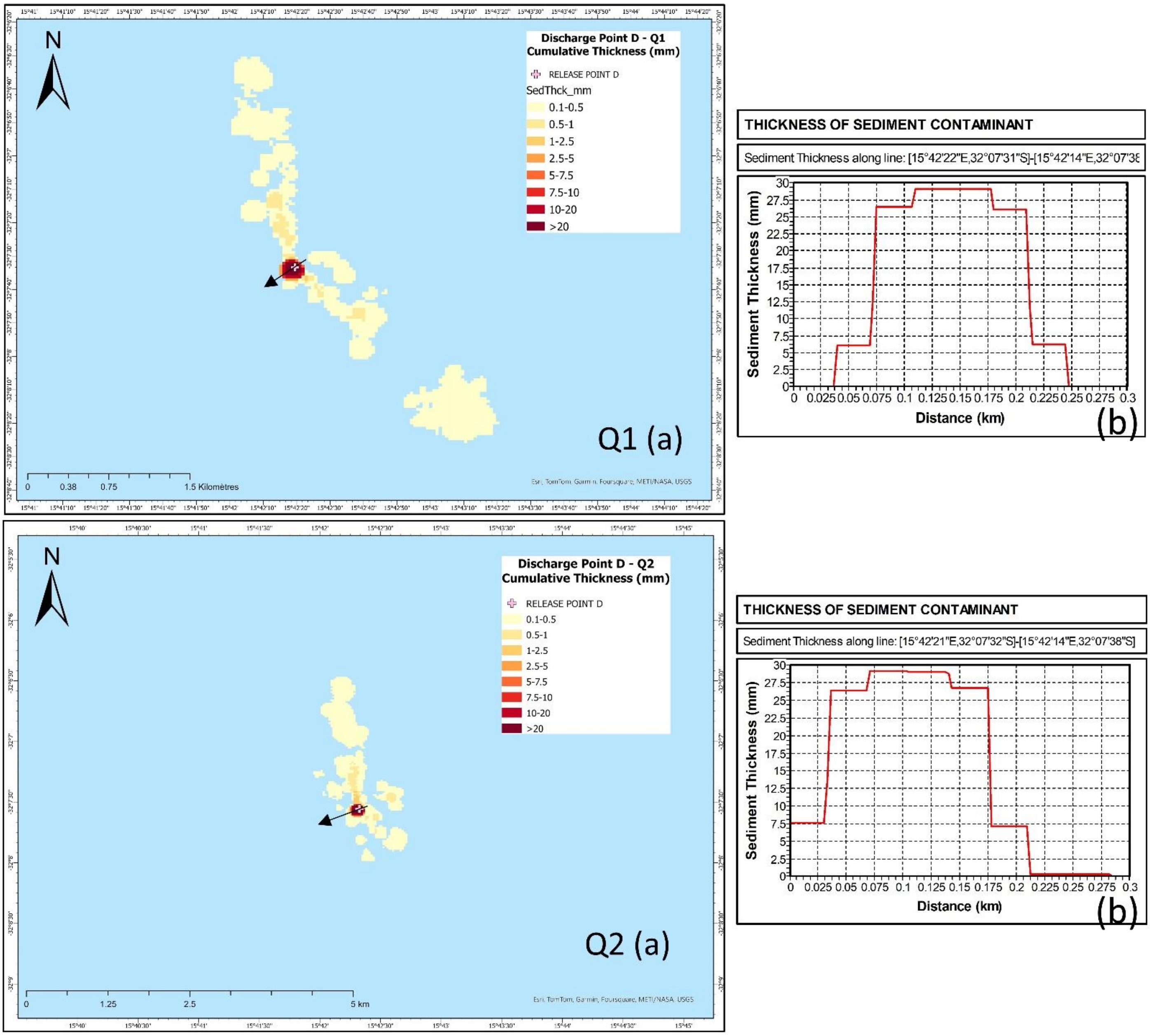


Figure 35 Maximum thickness deposit on the sediment for the Point D - Quarters 1 and 2, 10 years after operations

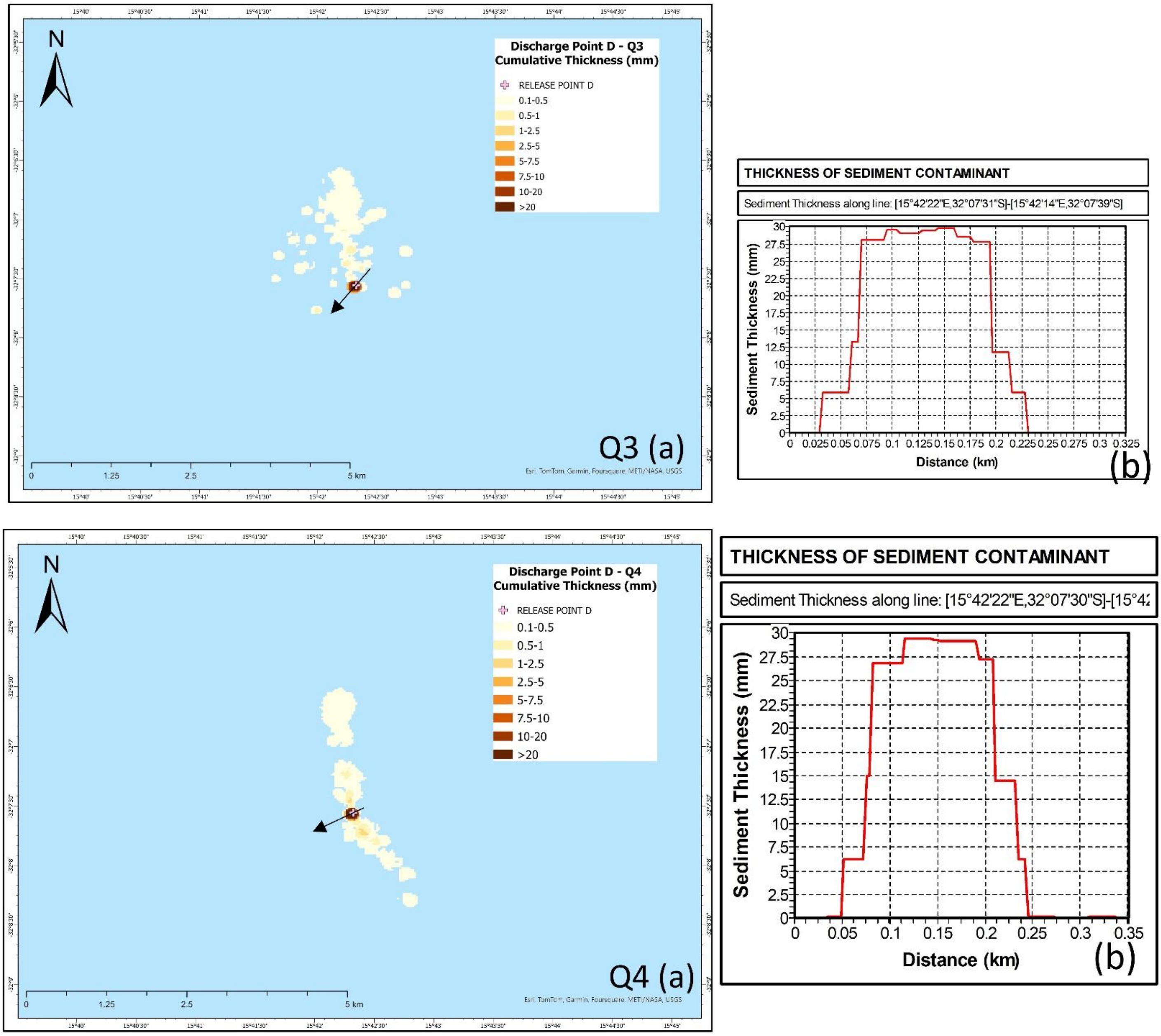


Figure 36 Maximum thickness deposit on the sediment for the Point D - Quarters 3 and 4, 10 years after operations

Table 18 present the thickness deposit values and distances from the discharge point for all the Quarters.

Table 18 Maximum thickness deposit around the discharge point D for all the Quarters

PERIOD	MAX. THICKNESS	DISTANCE OF SIGNIFICANT THICKNESS FROM DICHARGE POINT
Q1	58.9 mm	125 m
Q2	55.8 mm	125 m
Q3	63.5 mm	141 m
Q4	57.9 mm	141 m

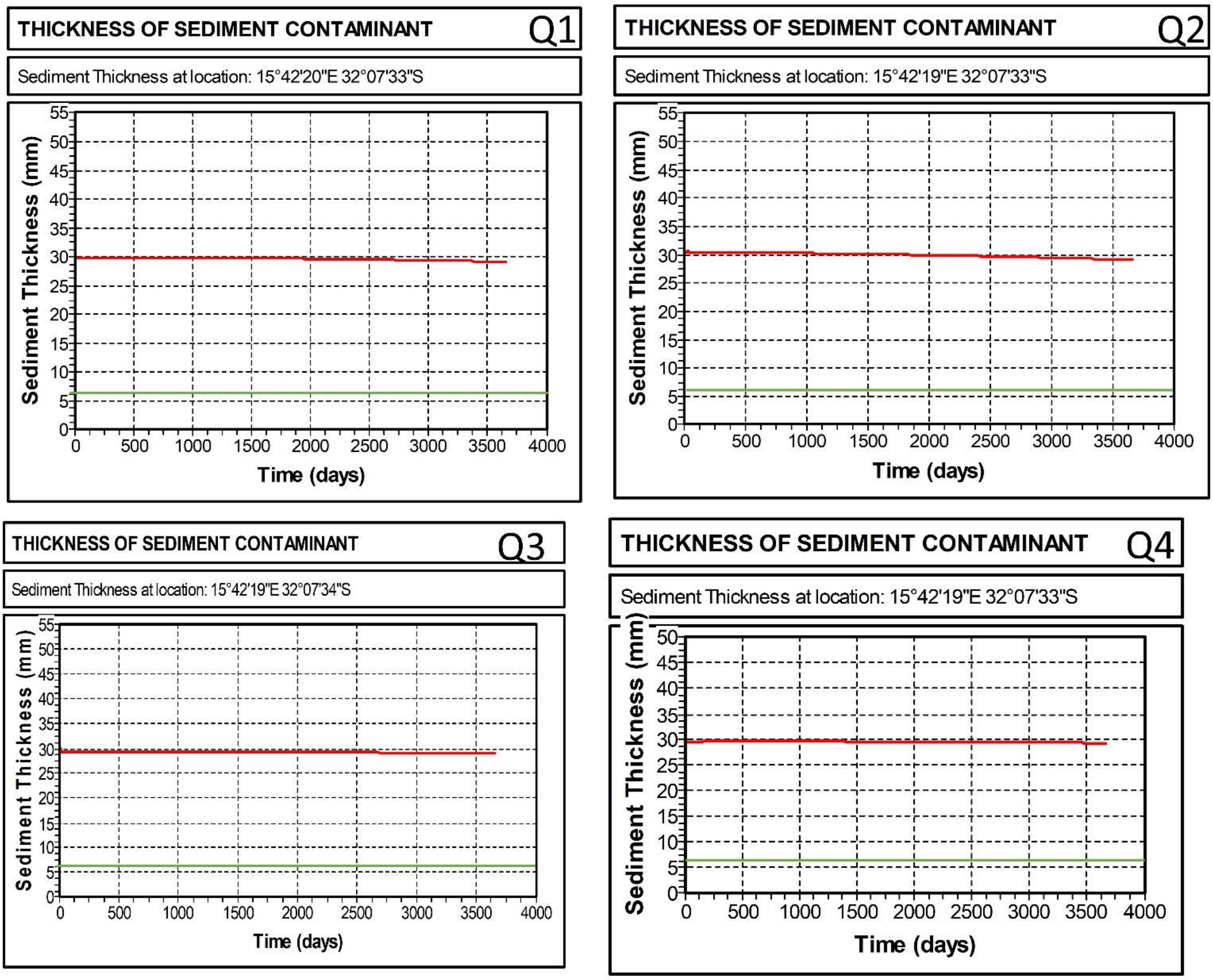


Figure 37 Thickness deposit vs. Time located on the discharge point D for all Quarters

The Figure 37 above shows the evolution of the thickness deposit located on the discharge point for all Quarters.

The thickness deposit located on the discharge point shows no decrease 10 years after the operations.

3.2.2.3 Grain size variation for Point D

Figure 38 and Figure 39 show the percentage of grain size change 10 years after the drilling operations.

The maximum percentage of grain size change is between 4300% to 6000% located precisely on the release point. The grain size change maximum values are mostly due to the discharge of the riserless sections.

As the surface currents are stronger than the bottom currents and spread the discharge far from discharge point. As a result the discharge of the risered sections induce a significant grain size change on a larger area than the discharge of the riserless sections, but with lower values.

The grain size change occurs on a larger area during the risered sections discharge, therefore the percentage of grain size change is higher than during the riserless sections discharge.

The Grain Size change is insignificant after 160 m around the discharge point maximum, but still present 10 years after the operations.

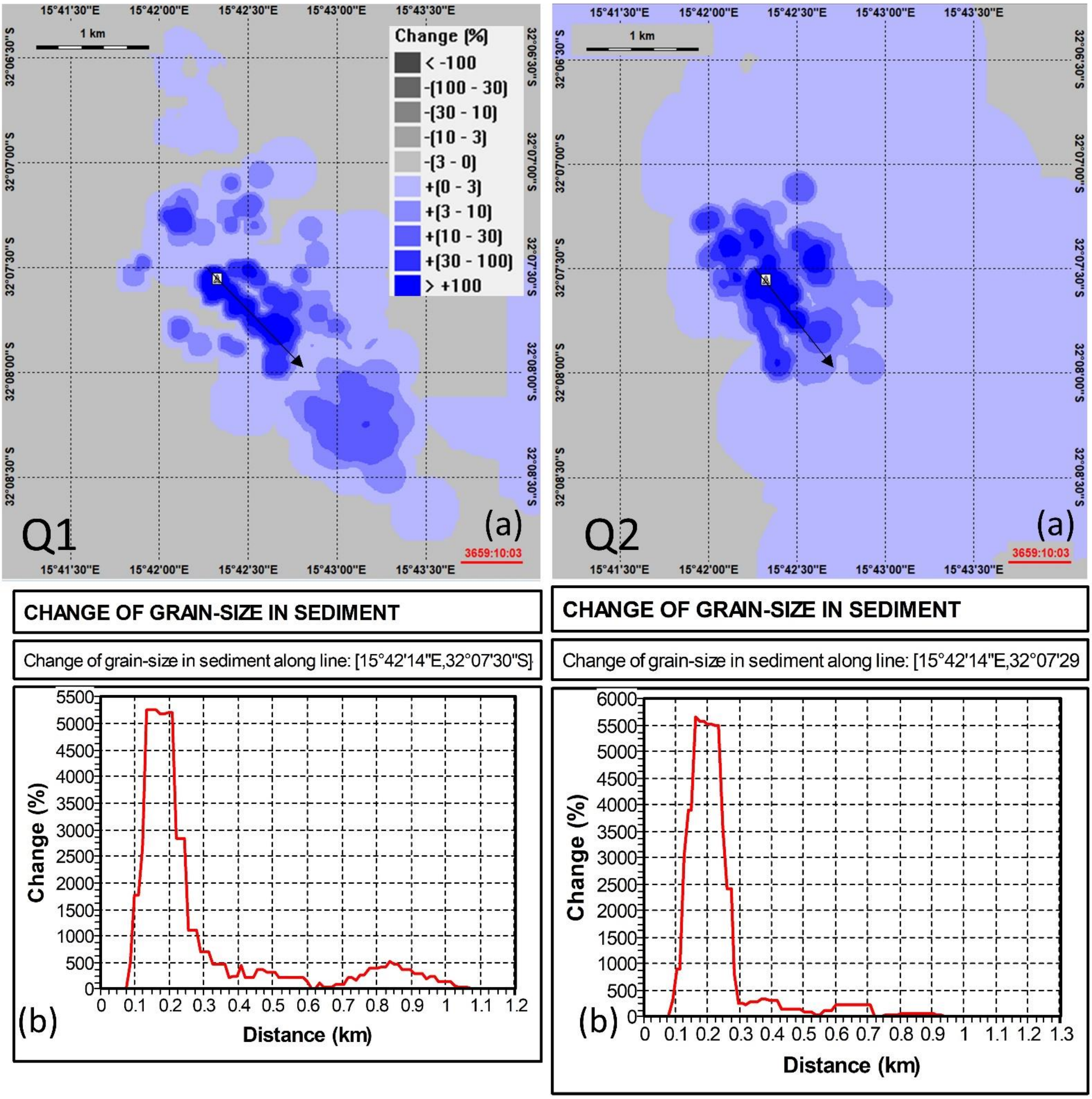


Figure 38 Grain size change on the sediment for Point D - Quarters 1 and 2, 10 years after operations

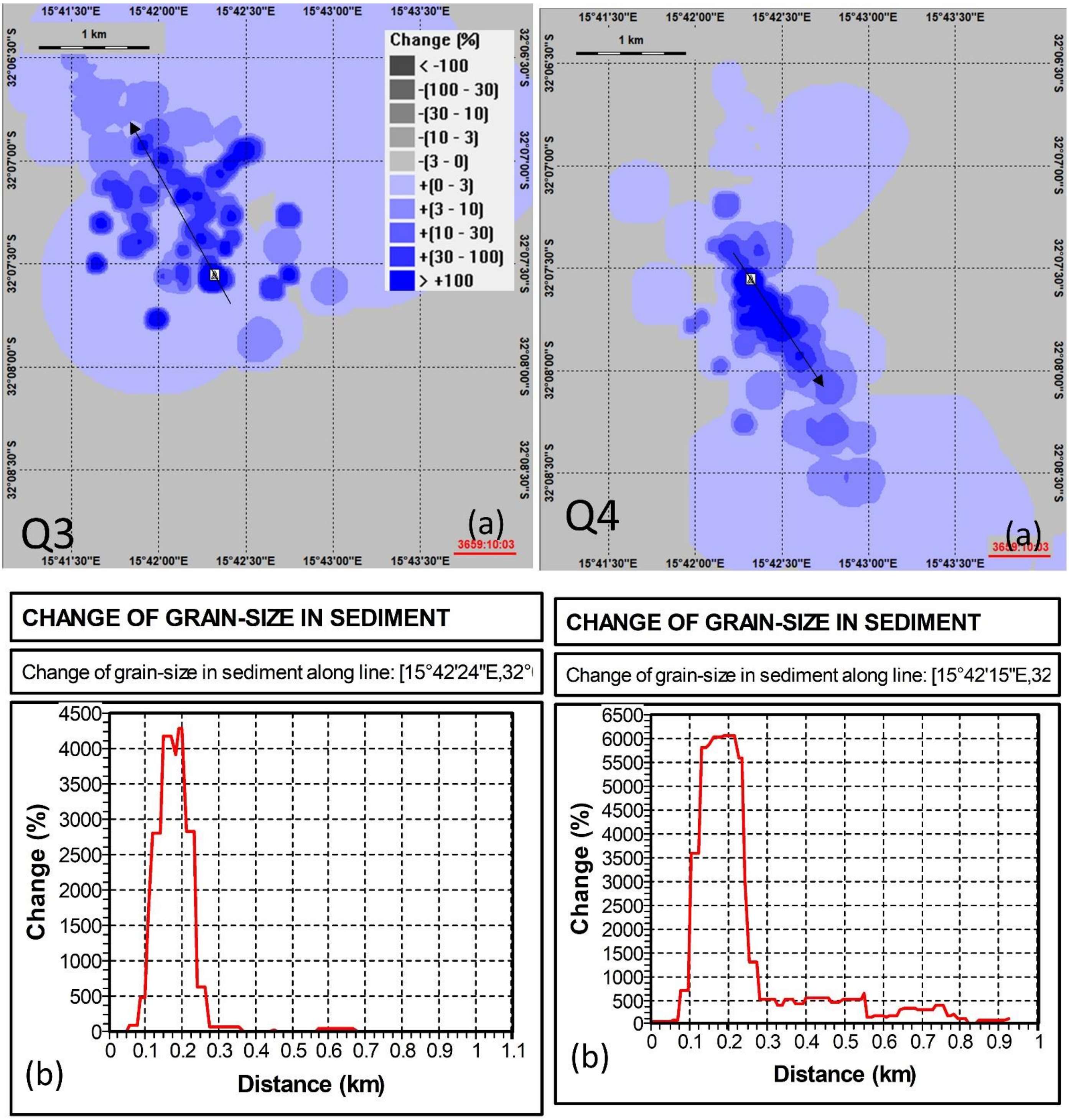


Figure 39 Grain size change on the sediment for Point D - Quarters 3 and 4, 10 years after operations

Table 19 present the grain size change values and distances from the discharge point for all the Quarters.

Table 19 Maximum grain size change values around the discharge point D for all the Quarters

PERIOD	MAX. GRAIN SIZE CHANGE	DISTANCE OF SIGNIFICANT GRAIN SIZE CHANGE FROM DICHARGE POINT
Q1	5250 %	150 m
Q2	5700 %	110 m
Q3	4300 %	160 m
Q4	6000 %	150 m

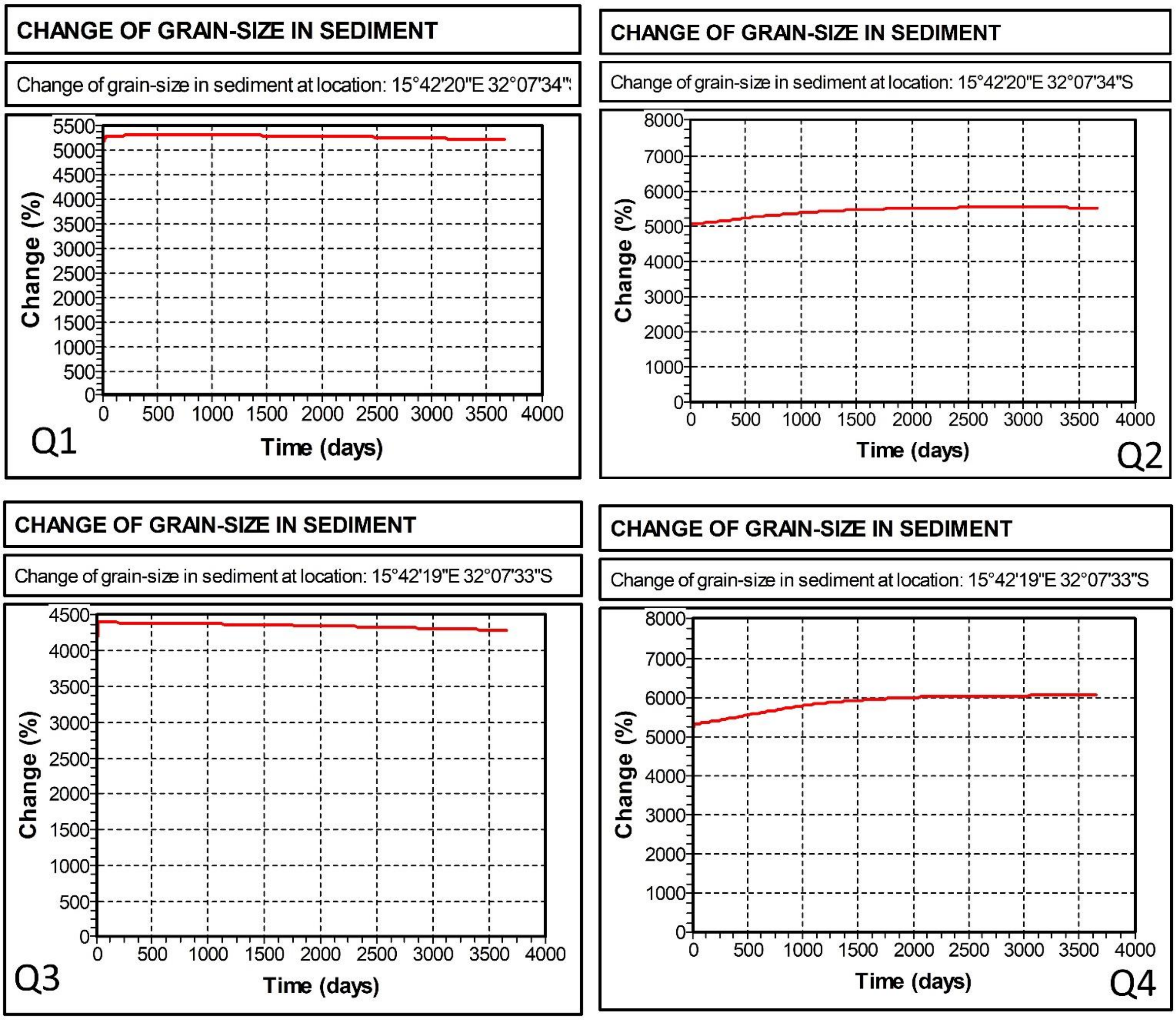


Figure 40 Grain Size variation vs. Time located on the discharge point D for all Quarters

Figure 40 above shows the evolution of the grain size change located on the discharge point for all Quarters.

The maximum grain size change located on the discharge point, show a very light decrease after the operations for Quarters 1 and 3, and a light increase for Quarters 2 and 4 (probably due to the bottom currents leading to some accumulations of cuttings). The values remain high 10 years after the operations for all the quarters.

3.2.3 Results Summary for the Sediment for Point D

As for the water column, the environmental risk for the sediment is mainly chemical than physical, mainly due to components of the NADF released during the drilling of the risered sections: the fatty acid present in the EZMUL NT-A, Invermul NT-B and EDC-99DW-C are responsible together for 74% to 80% of the total environmental risk.

The physical risk, *i.e.* the grain size change of the natural sediment (due to higher grain size particles released during the discharge), has a contribution to the total risk of 4%; and the thickness deposit of the discharge, contributing to 1 to 2% of the total risk depending on the Quarter. The oxygen depletion in the sediment is responsible for 14 to 21% to the total risk, and is a mix of physical and chemical impact.

The particles deposit area is not centralized around the discharge point and is orientated towards NW to SE up to 141 m of distance for the highest value, with a maximum cumulative thickness values between 55.8 and 63.5 mm located on the discharge point. The highest cuttings deposit is mainly due to the discharge of the riserless sections discharged directly on the seabed, remaining close to the discharge area, due to low-speed bottom currents The thickness deposit 10 years after the operations is still around 30 mm, which is higher than the 6.5 mm (threshold value of thickness variation accepted by benthos, see 2.3.4 Risk assessment modelling) so the impact will be present close to the discharge point (until 140 m maximum) for a long period.

The maximum percentage of grain size change is between 4300% to 6000% located precisely on the release point. The grain size change maximum values are mostly due to the discharge of the riserless sections. The Grain Size change is insignificant after a distance of 160 m around the discharge point maximum, but still present 10 years after the operations.

3.3 NON AQUEOUS DRILLING FLUID SCENARIO – POINT A

3.3.1 Water Column – All Quarters

3.3.1.1 Environmental risk for the water column for Point A

The outcomes of the model for the maximum cumulative risk in the water column associated with the discharge of drilling operations for all the sections of the discharge point A are presented in Figure 41 and Figure 42. These figures display only the cumulative significant risk (>5%) at any time of the calculation.

These figures show that the environmental risk of the riserless and the risered discharges for all the quarters is present on the entire water column, from the seafloor due to the riserless discharge to the surface due to the discharge from the riser.

This plume represents risk for the water column following the main currents of the water column, with maximum distance varying from 9 to 13 km from the release point on different directions (depending on the quarter).

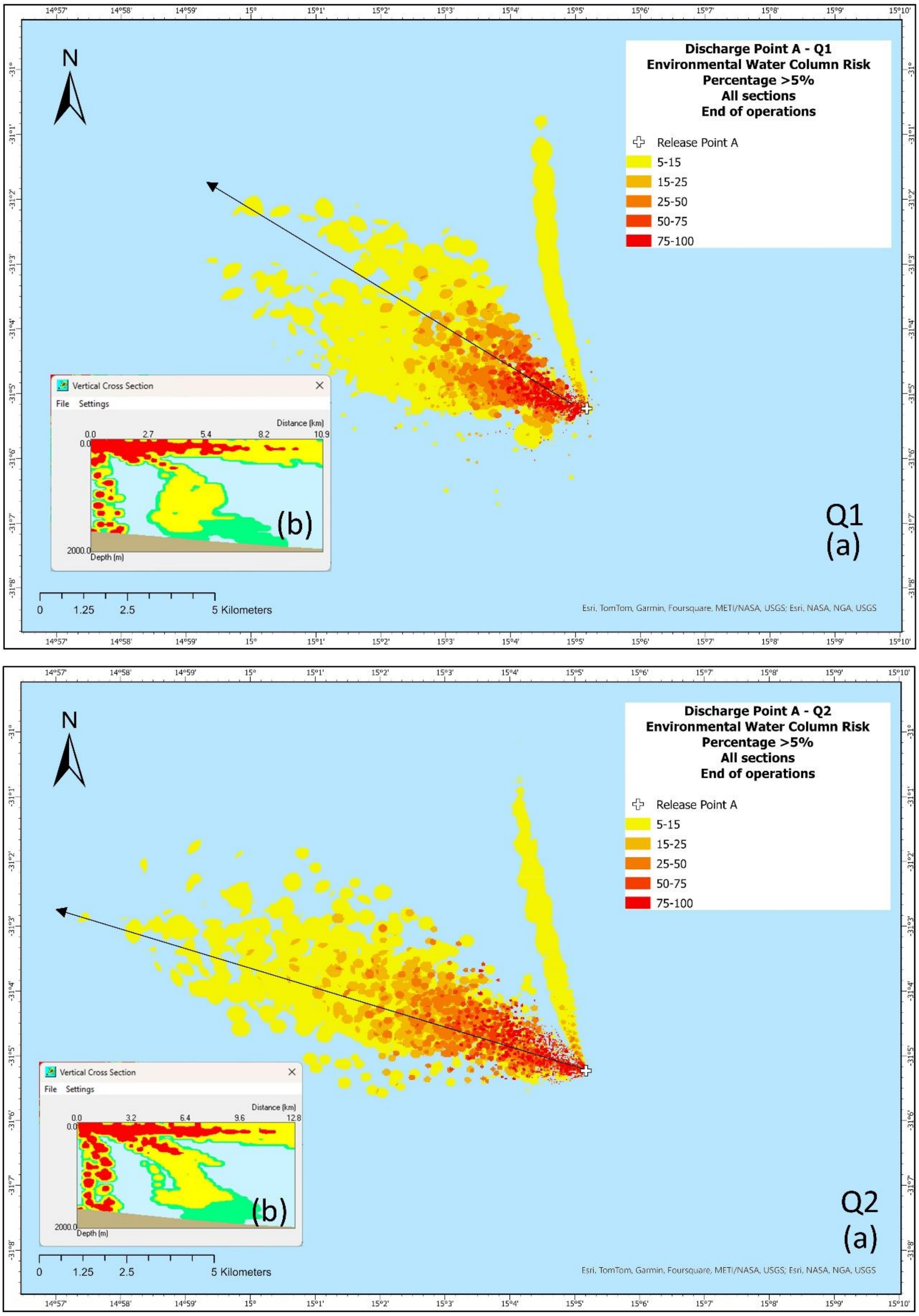


Figure 41 Maximum cumulative risk of drilling operations for Point A for Quarters 1 & 2 throughout the water column at any time for the discharge (a) Risk map – (b) Vertical cross section of the water column

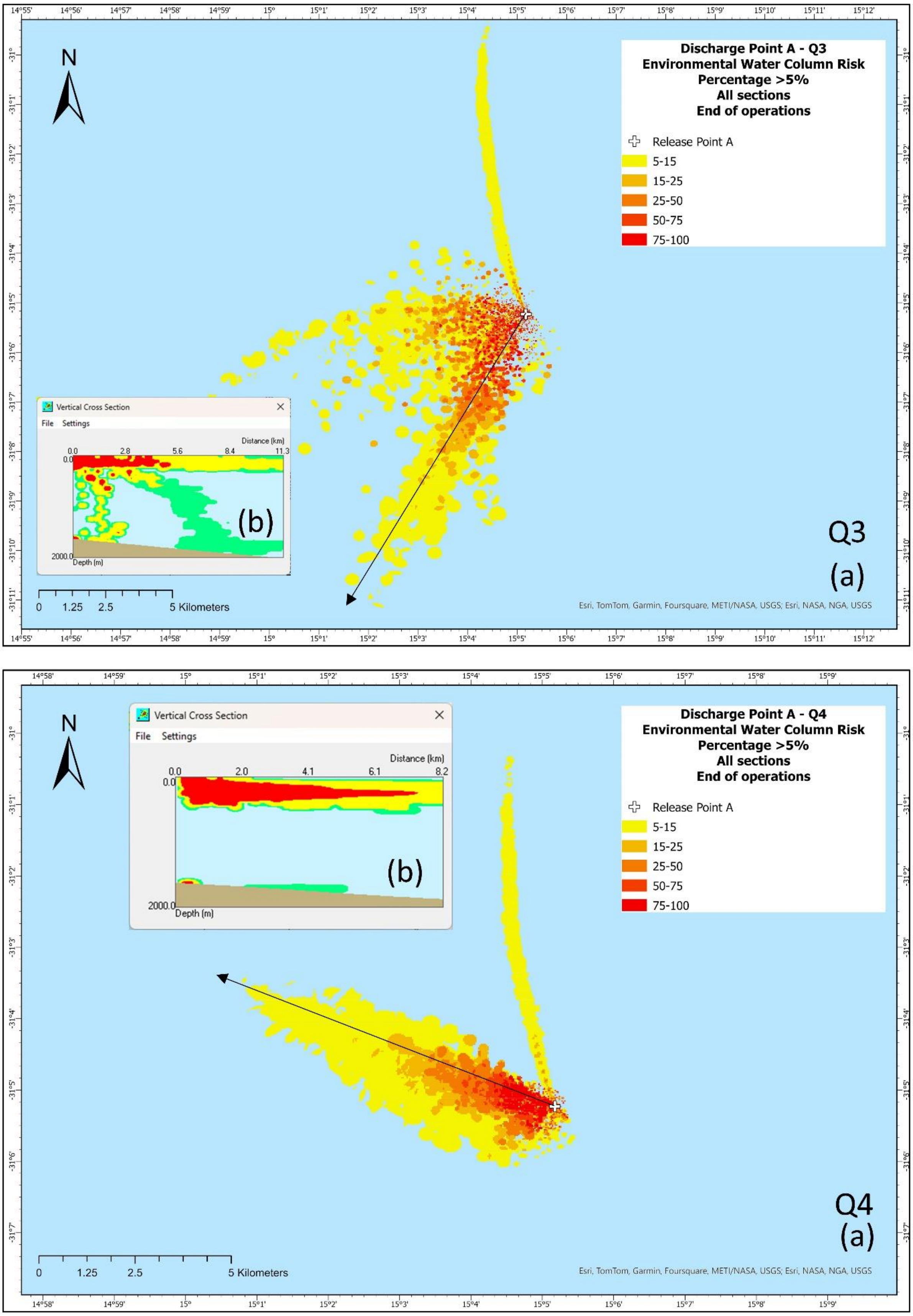


Figure 42 Maximum cumulative risk of drilling operations for Point A for Quarters 3 & 4 throughout the water column at any time for the discharge (a) Risk map – (b) Vertical cross section of the water column

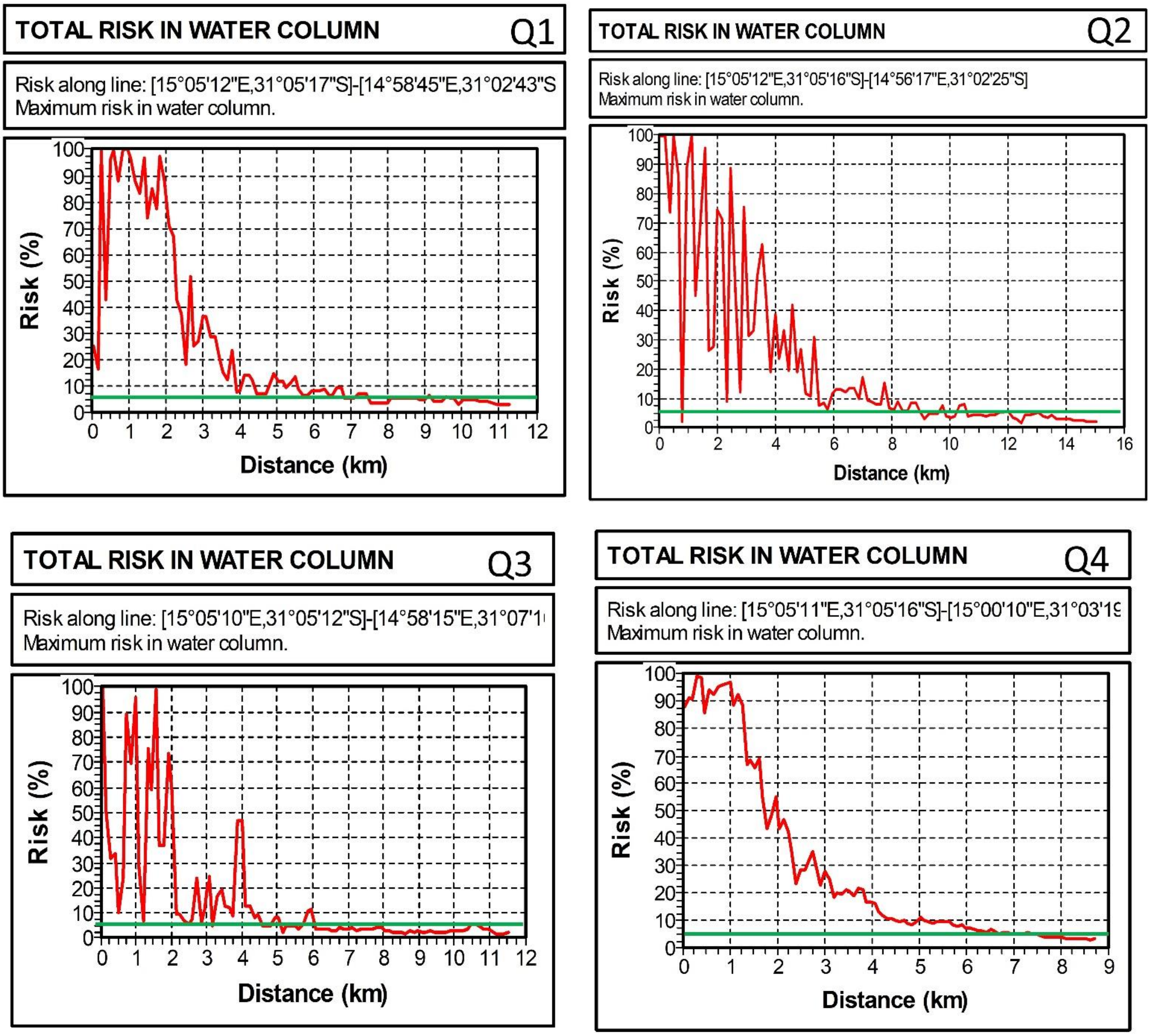


Figure 43 Risk value along a transect for entire discharge for Point A for all four Quarters

Figure 43 illustrates the cumulative risk value along a transect (calculated along the black arrows on the figures above) during discharge: the maximum values are 100% for all the Quarters, until 2 km from the release point, the direction depending on the Quarter.

Table 20 present the maximum risk values in the water column and distances and directions from the discharge point for all the Quarters.

Table 20 Maximum risk values in the water column for Point A for all Quarters

PERIOD	MAX. ENVIRONMENTAL RISK	DISTANCE and DIRECTION OF SIGNIFICANT RISK FROM DICHARGE POINT
Q1	100 %	10.3 km NW
Q2	100 %	13.2 km WNW
Q3	100 %	11.9 km SW
Q4	100 %	9.2 km NW

3.3.1.2 Environmental Risk Contributors & Risk Duration for Point A

Figure 44 shows the contributors to risk over time for the different sections for Quarter 1 (taken as an example, because all the quarters present similar results).

Each section discharge presents some risk for the water column, but with short time duration.

The main contributor of environmental risk in the Water Column during the riserless sections discharge is due to the presence of Bentonite (contributing to 90% of the risk for this riserless discharges).

The maximum instantaneous EIF value is reached during the drilling of the 17 ½“ and 12 ½“ sections, due to the presence of the hydrotreated light petroleum distillate present in the base oil (EDC-99DW). This component is responsible to 68% to 73% of the environmental risk for the Water Column for the risered discharges.

There is no more risk in the water column after the end of the discharge of the 8 ½” discharge, due to the strong dispersion and dilution of the chemicals as result of strong currents in this area.

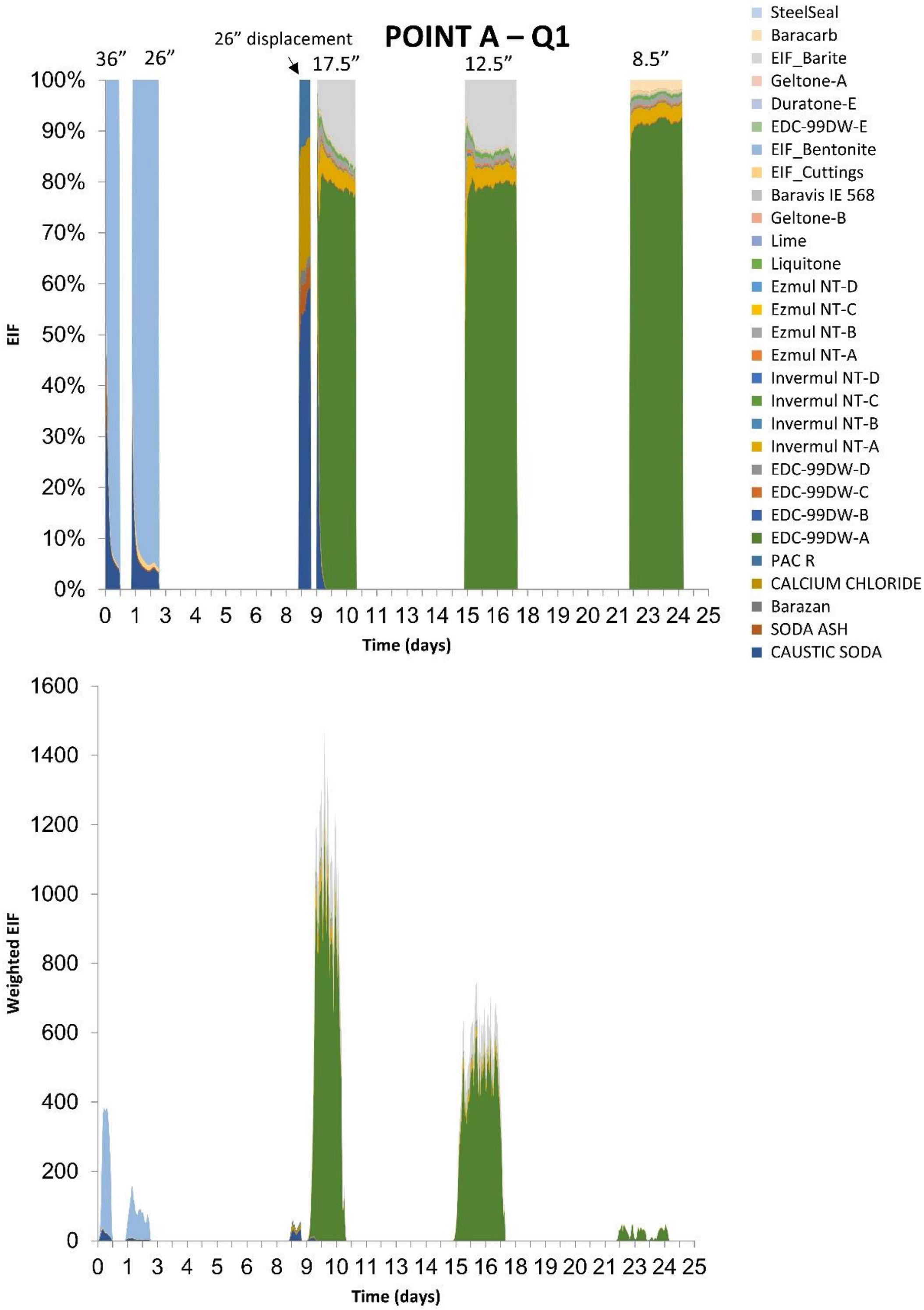


Figure 44: Main contributors to the risk over the time in the water column for the Point A - Quarter 1: Figure on the top presenting relative percentage of contributors for each section; Figure on the bottom presenting instantaneous maximum volume of water at risk

Figure 45 and Figure 46 present the main contributors to the overall risk in the water column for all the Quarters.

For all the seasons, the main contributors are the same. The hydrotreated light petroleum distillate present in the base oil (EDC-99DW), contributes in total to 68% to 73% of the risk depending on the Quarter. This component is present on the mud discharged during the Risered sections drilling operations. As this component has a low PNEC, its toxicity is high, so a small amount released in the environment is quickly impacting the species.

The Bentonite discharged during the riserless sections drilling is the second most impacting component for the Water Column, representing 6% to 13% of contribution depending on the Quarter.

The maximum risk in terms of volume of water at risk (EIF) is reached during the season 4, but with values close to the other seasons. One EIF represent a volume of water of 10^5 cubic meters presenting risk at one time during the entire discharge. For example, the discharge during the Quarter 1 presents a total environmental risk for 1479 * 10^5 m^3 of seawater. But the risk is short term, and is linked to the time step, meaning that most of the risk will be present only for a few hours, and will be quickly dispersed and diluted.

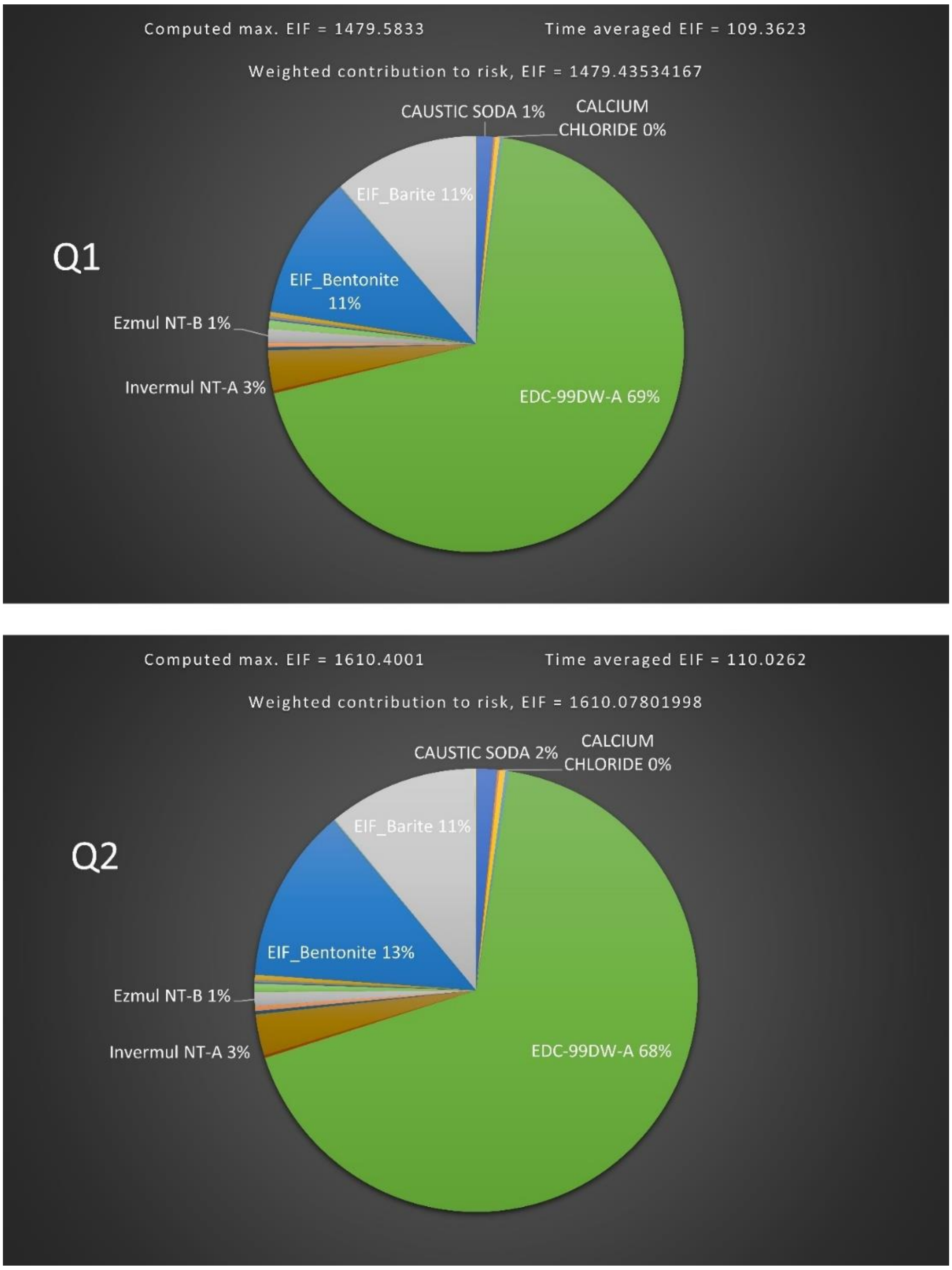
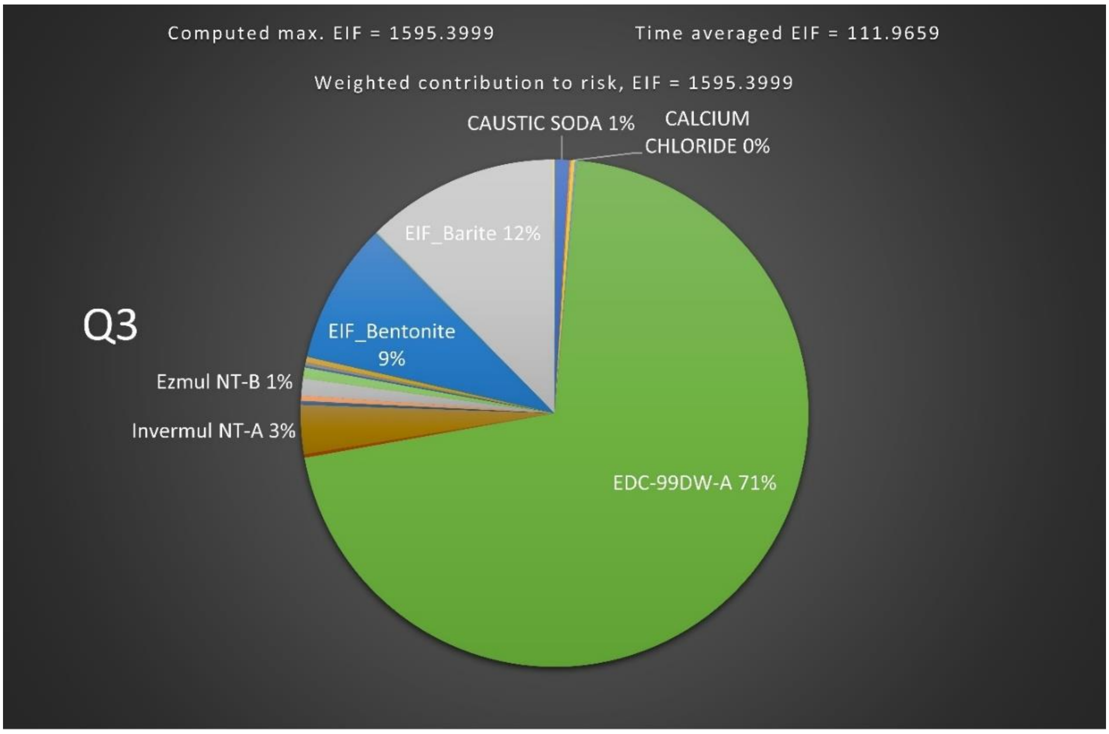


Figure 45 Main contributors to the risk in the water column for Point A - Quarters 1 and 2



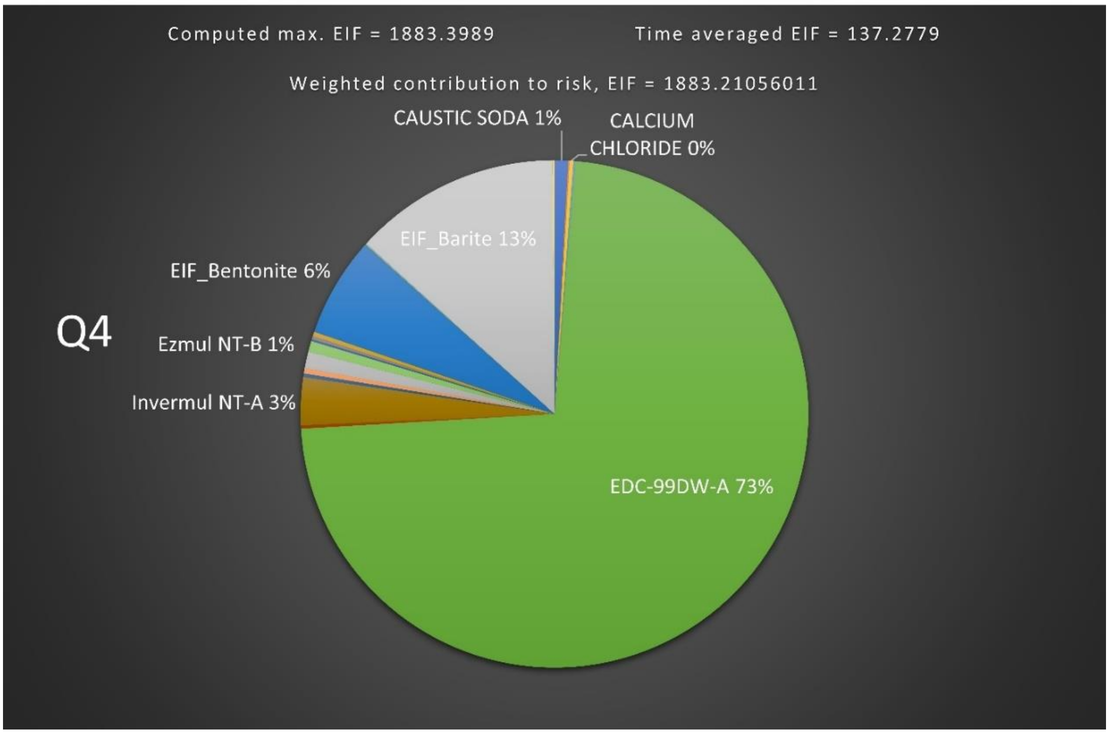


Figure 46 Main contributors to the risk in the water column for Point A - Quarters 3 and 4

3.3.1.3 Results Summary for the Water Column for Point A

The figures and table above show that the environmental risk in the water column is present from the surface to the seabed, meaning that both types of discharges (risered and riserless) will have an impact, like for the Point D. The environmental risk is mainly due to the NADF released during risered sections discharges for all the seasons.

The physical risk is due to the release of Bentonite from the riserless sections mainly, using the WBM, and the chemical risk is due to the release of EDC-99DW present in the NADF used during the risered sections drilling.

The maximum risk distance is reached during the discharge of the risered sections and varies depending on the season, from 9.2 km N from the discharge point for the Quarter 4 (minimum) to 13.2 km NW for the Quarter 2 (maximum). Contrary to the results of the Point D, the Point A is further away from sensitive areas, so the plumes of contaminants would be dispersed before reaching some of these areas.

The main contributor to the risk in the water column is chemical, and due to the EDC-99DW released during the risered sections drilling. The maximum EDC-99DW-A concentration (hydrotreated light petroleum distillate) in the water column is reached during the release of section 17 ½", and Quarter 4 is the period presenting the highest value. All these highest concentration values are reached between 9 and 10 days after the start of the operations, during the 17 ½" section drilling. The Bentonite discharged during the riserless sections drilling is the second most impacting component for the Water Column.

Due to the strong currents in the area, the environmental risk in the water column is present for several kilometers. However, the strong currents in the area allow a quick dispersion and dilution of the chemicals: the risk reached is very high close to the discharge point, but is of short duration.

There is no more risk in the water column after the end of the operations for all the Quarters as result of dispersion and dilution processes due to the strong currents in this area.

3.3.2 Sediment – All Quarters

3.3.2.1 Environmental risk and main contributors for Point A

The outcomes of the model for the maximum significant risk (risk > 5%, that which will have a potential impact) for the four Quarters associated with the discharges all sections during drilling operations for the sediments are presented in Figure 47 and Figure 48.

A reduced area with significant risk above 5% is observed in the sediment close to the discharge. At the end of the operations, a significant risk is observed from 2.3 km to 4.5 km maximum around the discharge point depending on the Quarter. A maximum risk of 99% has been calculated located on the release point for each Quarter. There is still some risk observed 10 years after the operations (average time for sediment restoration after drilling operations). This will be developed in the following sections.

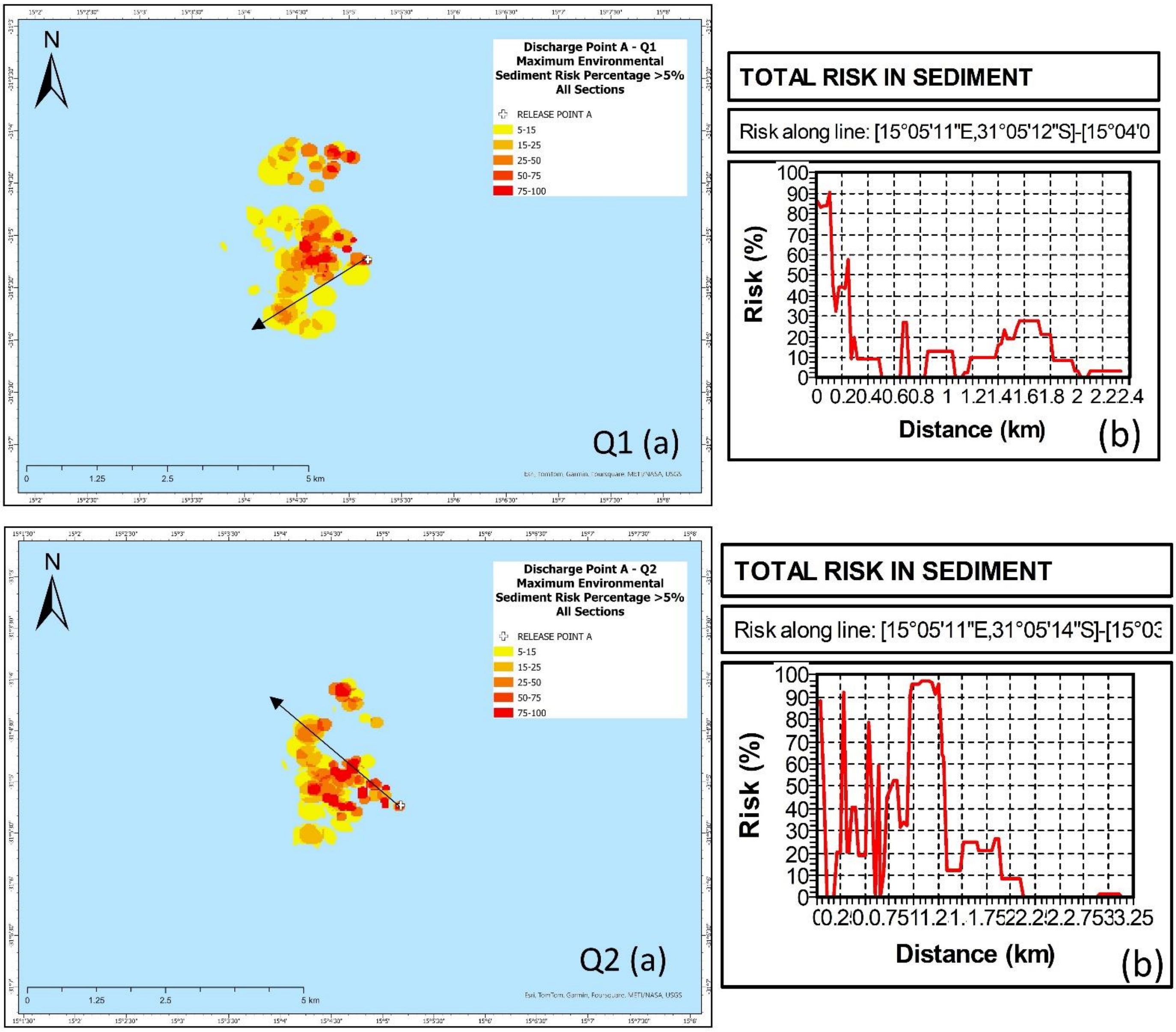


Figure 47 Maximum potential risk in the sediment for Point A - Quarters 1 and 2

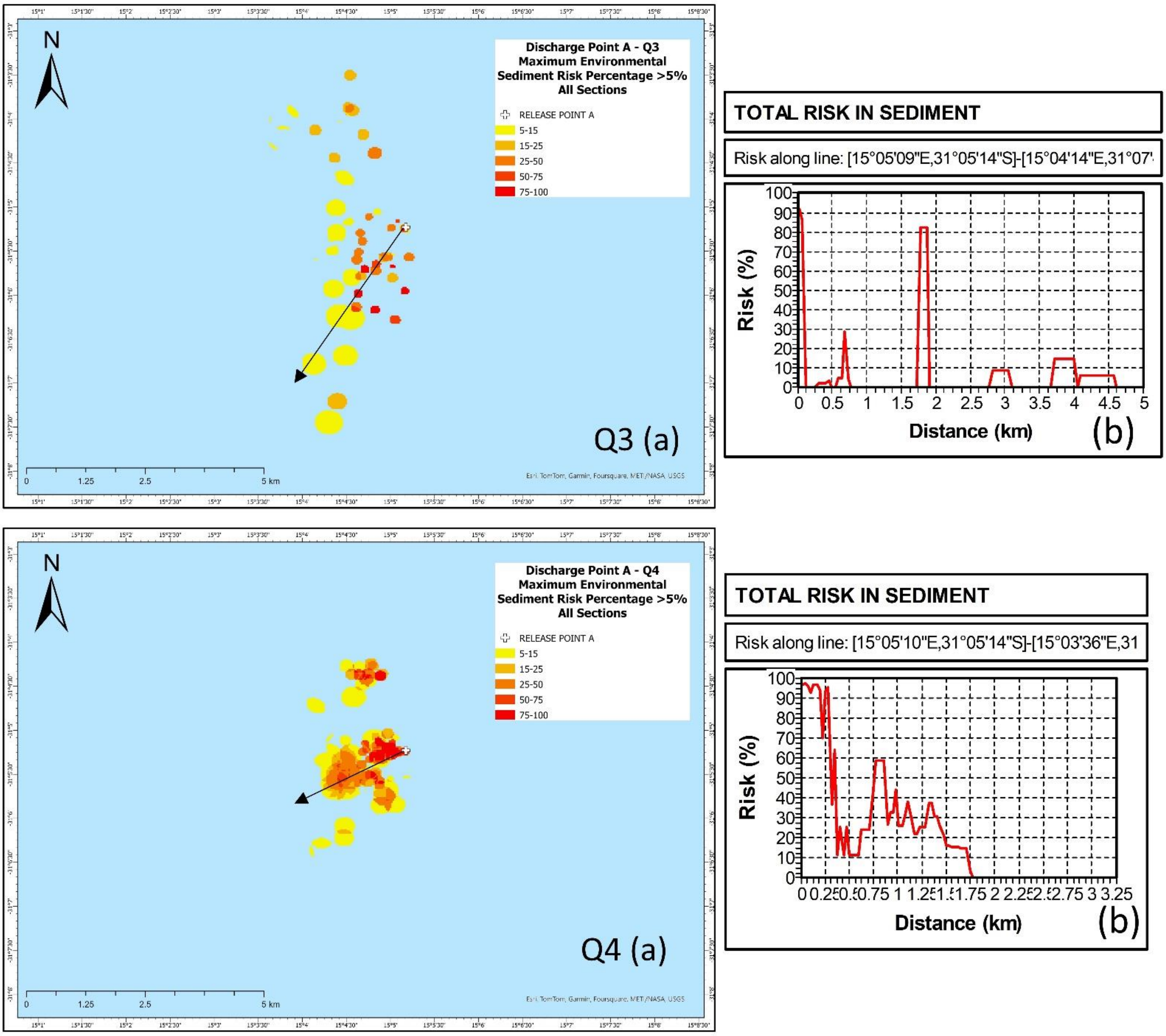


Figure 48 Maximum potential risk in the sediment for Point A - Quarters 3 and 4

The Table 21 present the maximum risk values in the water column and distances and directions from the discharge point for all the Quarters.

Table 21 Maximum risk values in the sediment for Point A for all the Quarters

PERIOD	MAX. ENVIRONMENTAL RISK	DISTANCE and DIRECTION OF SIGNIFICANT RISK FROM DICHARGE POINT
Q1	100 %	2 330 m NNW
Q2	100 %	2 498 m NW
Q3	100 %	4 573 m SSW
Q4	100 %	2 752 m SSW

Figure 49 presents the Environmental risk for the sediment and the contributors to the risk for a 10-year period for the Quarter 1 (taken as an example; all the other quarters present the same results). The risk is significant in the sediment from day 1 to 10 years after, mainly due to the chemicals present in the risered sections discharged. The highest risk is reached just after the end of the operations, around day 25, and quickly decreases 79 days after operations until one year after, and then decreases gradually until 10 years after (Figure 49, bottom graph).

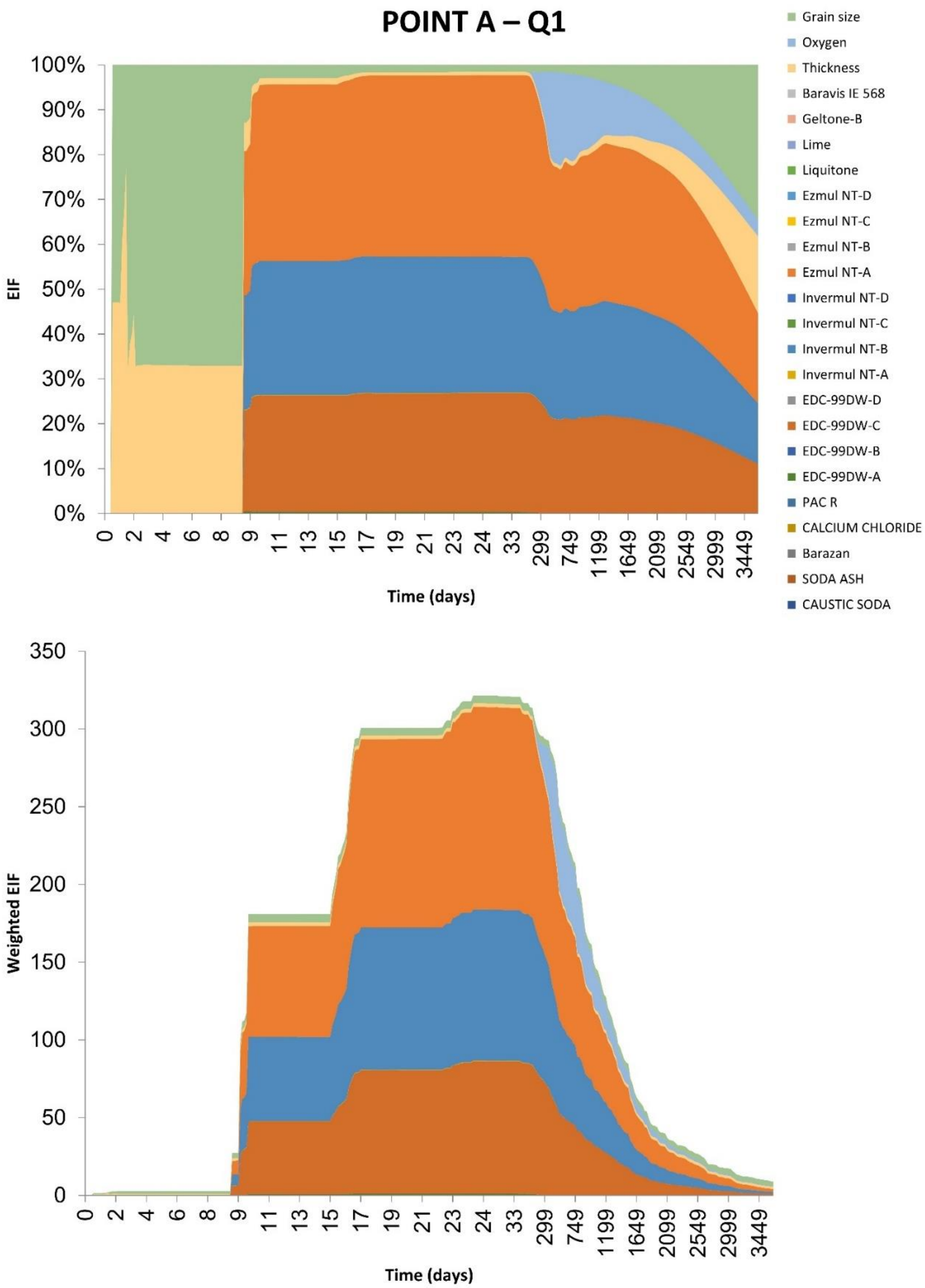


Figure 49 Main contributors to the risk over the time in the sediment for Point A for the Quarter 1: Figure on the top presenting relative percentage of contributors; Figure on the bottom presenting instantaneous maximum surface of sediment at risk

Figure 50 and Figure 51 show the main contributors to the environmental risk for all the Quarters, considering all sections to be discharged, over the 10-year extension period studied. The main contributors to the environmental risk for the sediment are chemical, due to some components of the NADF released during the drilling of the risered sections: the fatty acid present in the EZMUL NT-A, Invermul NT-B and EDC-99DW-C is responsible for 77% to 83% of the total environmental risk.

The physical risk, *i.e.* the grain size change of the natural sediment (due to higher grain size particles released during the discharge), has a contribution to the total risk between 4% to 8%; and the thickness deposit of the discharge, contributing to 2 to 4% of the total risk depending on the Quarter.

The oxygen depletion in the sediment is responsible for 6 to 18% to the total risk, and is a mix of physical and chemical impact: the burial effect of the thickness deposit and oxygen consumption during the biodegradation of certain chemicals can lead to this loss of oxygen in the environment.

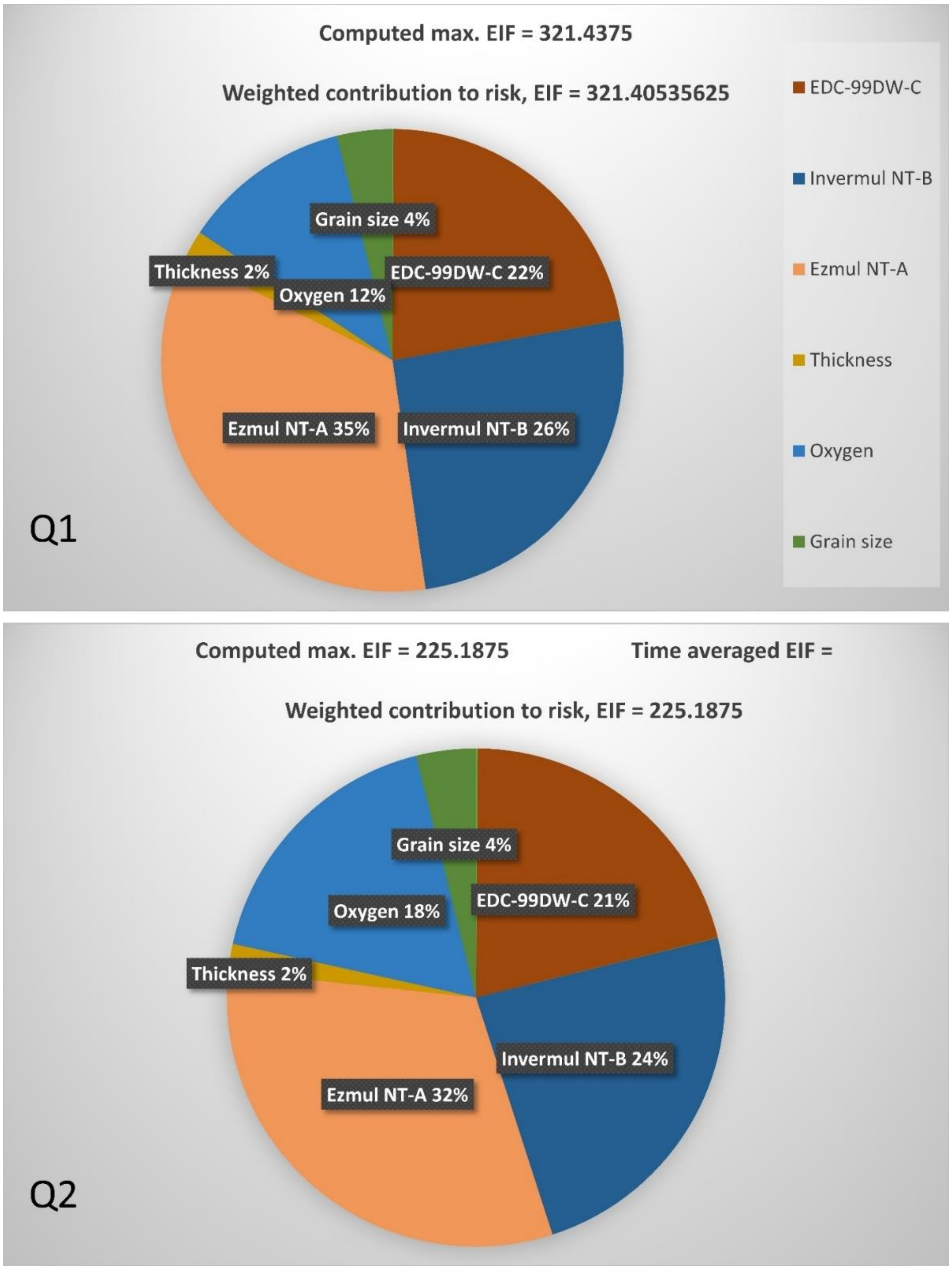


Figure 50 Main contributors to the risk in the sediment for Point A - Quarters 1 and 2

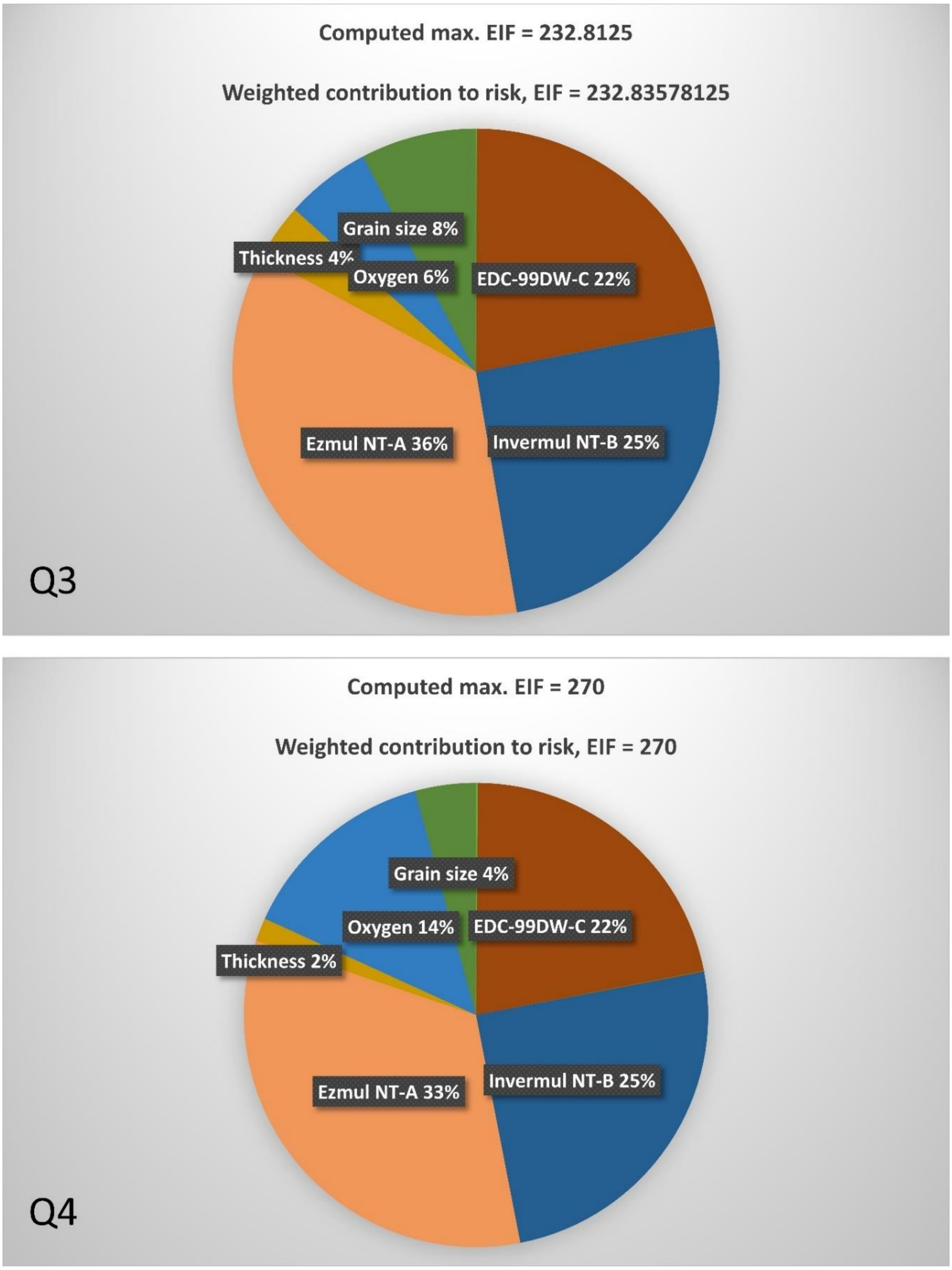


Figure 51 Main contributors to the risk in the sediment for Point A - Quarters 3 and 4

3.3.2.2 Thickness deposit for Point A

Figure 52 and Figure 53 show the cuttings thickness deposits 10 years after the end of drilling operations for all the Quarters.

The particles deposit area is not centralized around the discharge point and is orientated towards NW to SE up to 259 m of distance for the highest value, with a maximum cumulative thickness values between 65.2 and 69.2 mm located on the discharge point.

The thickness deposit 10 years after the operations is still around 30 mm, like for the Point D, which is higher than the 6.5 mm (threshold value of thickness variation accepted by benthos, see 2.3.4 Risk assessment modelling) so the impact will be present close to the discharge point (until 260 m maximum) for a long period.

The highest cuttings deposit is mainly due to the discharge of the riserless sections discharged directly on the seabed, remaining close to the discharge area, due to low-speed bottom currents. For the other sections (17 ½’’, 12 ¼” and 8 ½”) discharged at sea surface, the cuttings are spread in the water column towards N or S by stronger surface currents, leading to lower thickness at the seabed.

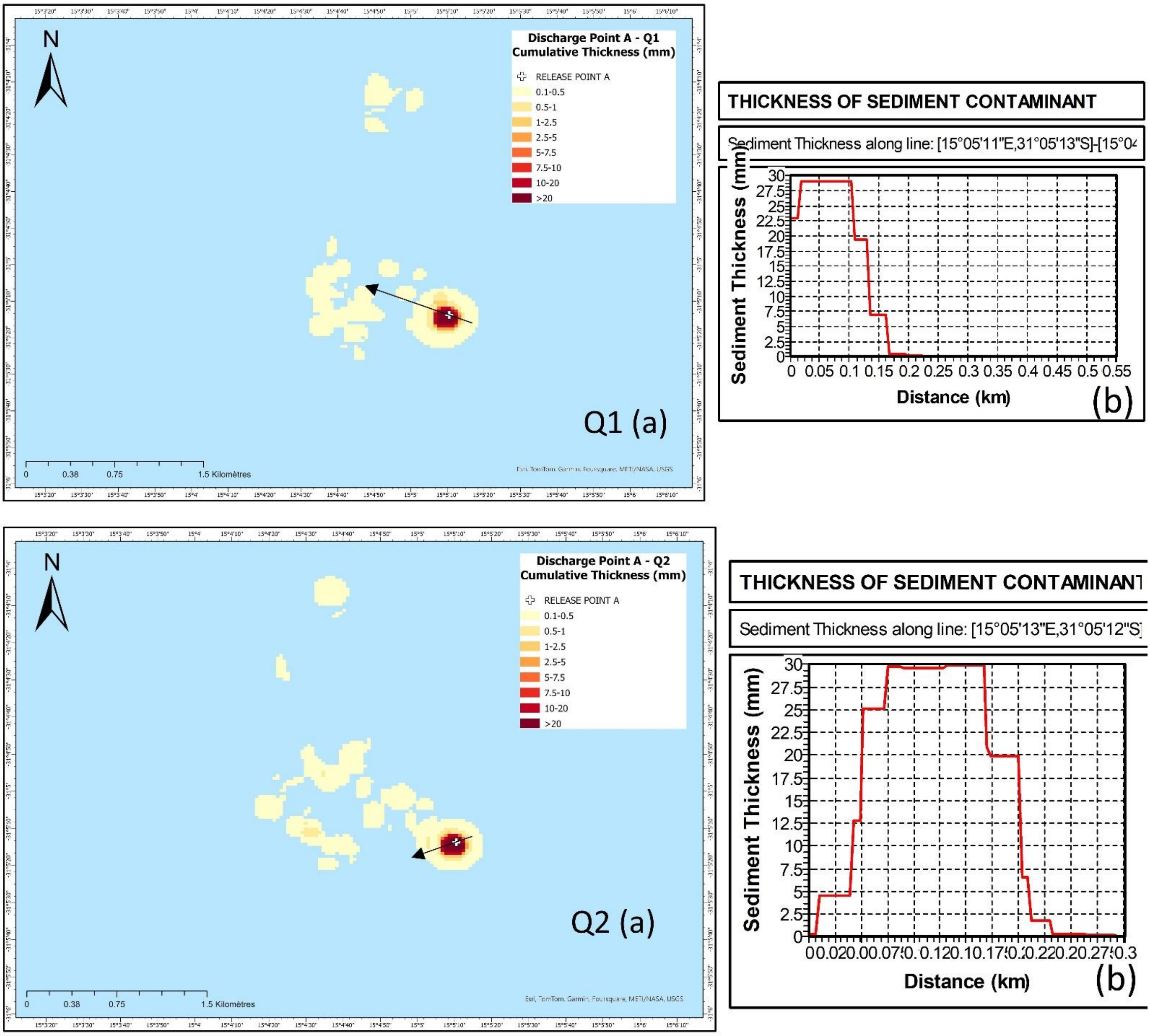


Figure 52 Maximum thickness deposit on the sediment for the Point A - Quarters 1 and 2, 10 years after operations

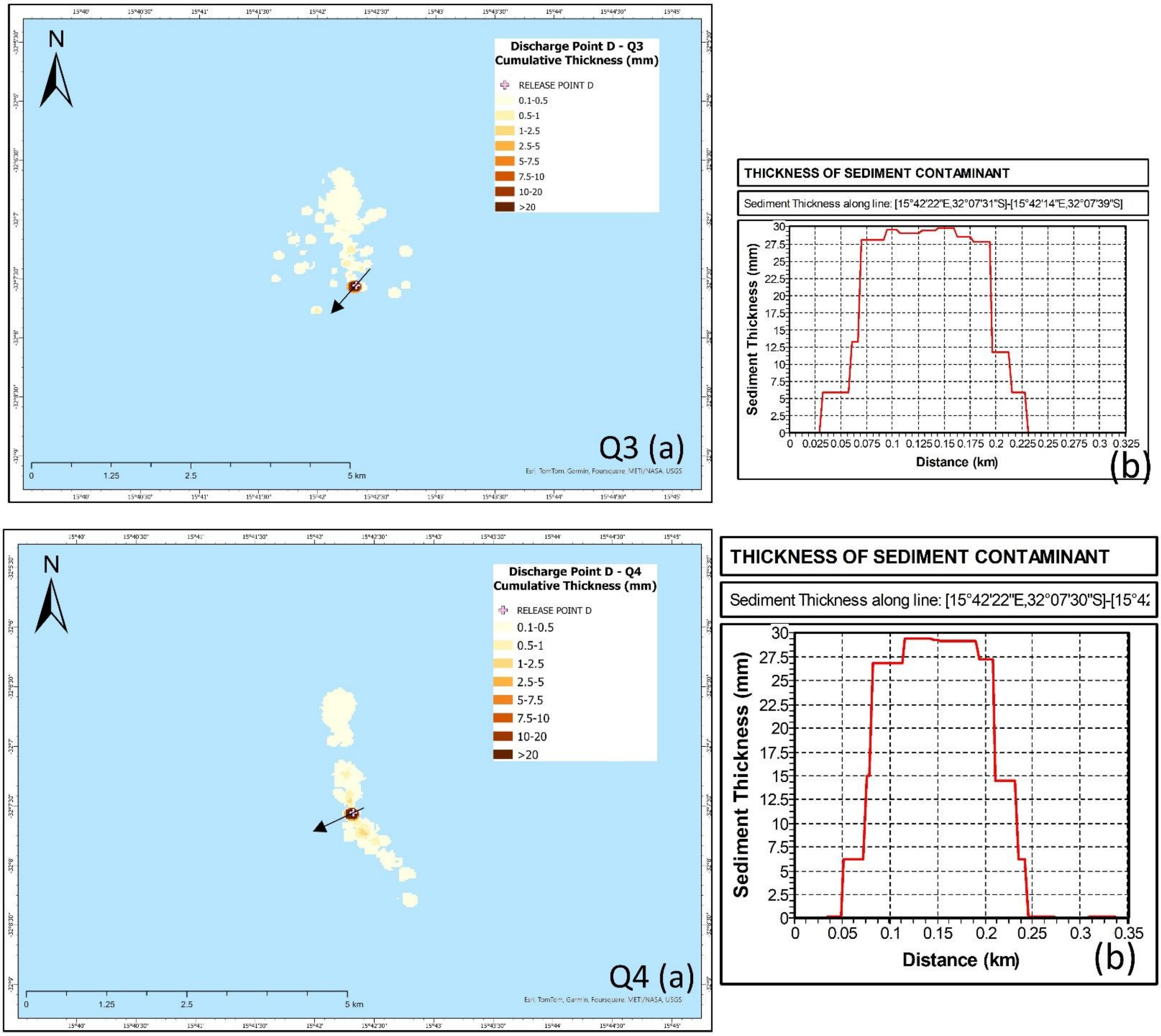


Figure 53 Maximum thickness deposit on the sediment for the Point A - Quarters 3 and 4, 10 years after operations

Table 22 Maximum thickness deposit around the discharge point A for all the Quarters present the thickness deposit values and distances from the discharge point for all the Quarters.

Table 22 Maximum thickness deposit around the discharge point A for all the Quarters

PERIOD	MAX. THICKNESS	DISTANCE OF SIGNIFICANT THICKNESS FROM DICHARGE POINT
Q1	65.2 mm	193 m
Q2	66.5 mm	176 m
Q3	69.2 mm	173 m
Q4	68.3 mm	259 m

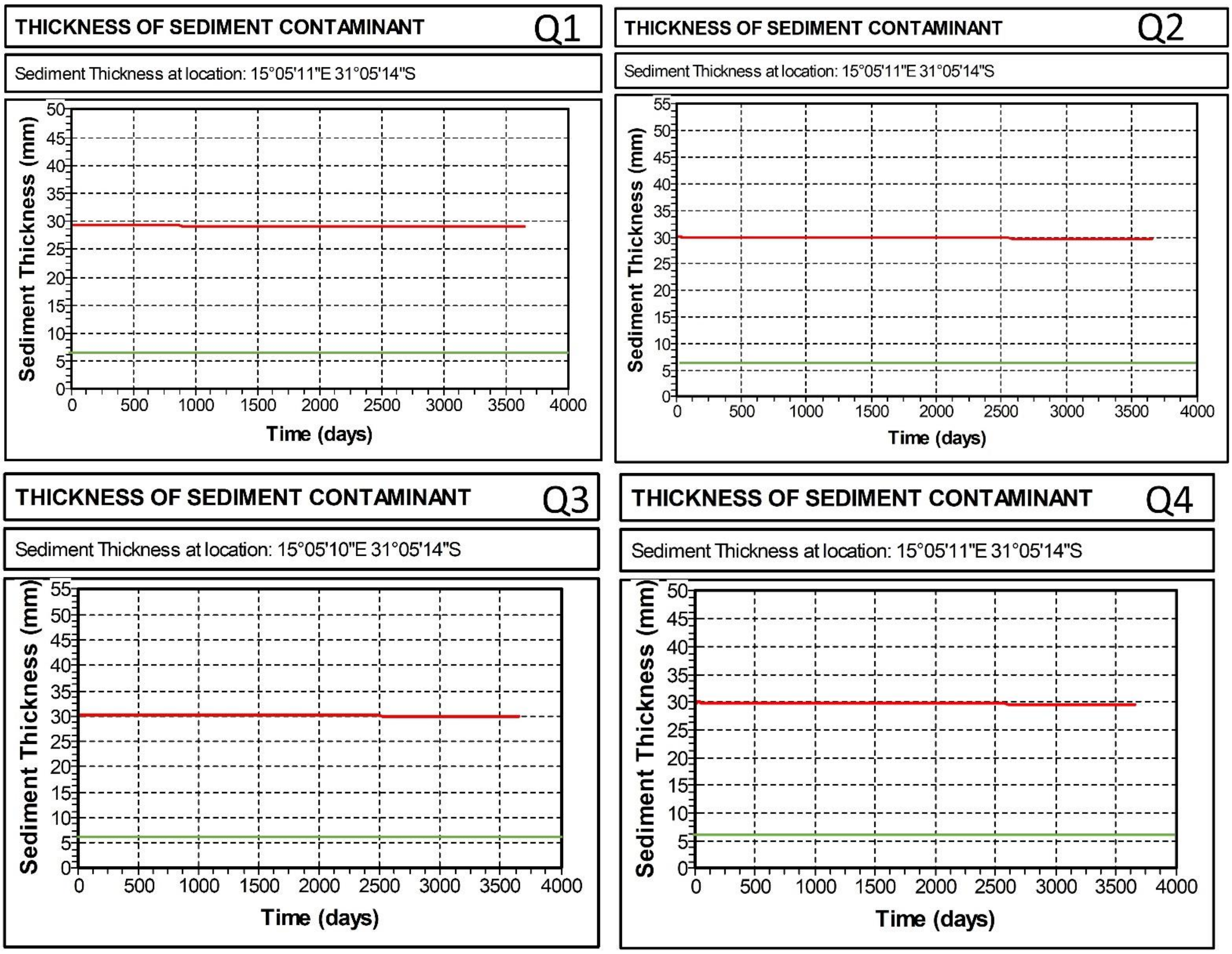


Figure 54 Thickness deposit vs. Time located on the discharge point D for all Quarters

The Figure 54 above shows the evolution of the thickness deposit located on the discharge point for all Quarters.

The thickness deposit located on the discharge point shows no decrease 10 years after the operations.

3.3.2.3 Grain size variation for Point A

Figure 55 and Figure 56 show the percentage of grain size change 10 years after the drilling operations.

The maximum percentage of grain size change is between 4300% to 5000% located precisely on the release point. The grain size change maximum values are mostly due to the discharge of the riserless sections.

As the surface currents are stronger than the bottom currents and spread the discharge far from discharge point. As a result the discharge of the risered sections induce a significant grain size change on a larger area than the discharge of the riserless sections, but with lower values.

The grain size change occurs on a larger area during the risered sections discharge, therefore the percentage of grain size change is higher than during the riserless sections discharge.

The Grain Size change is insignificant after 140 m around the discharge point maximum, but still present 10 years after the operations.

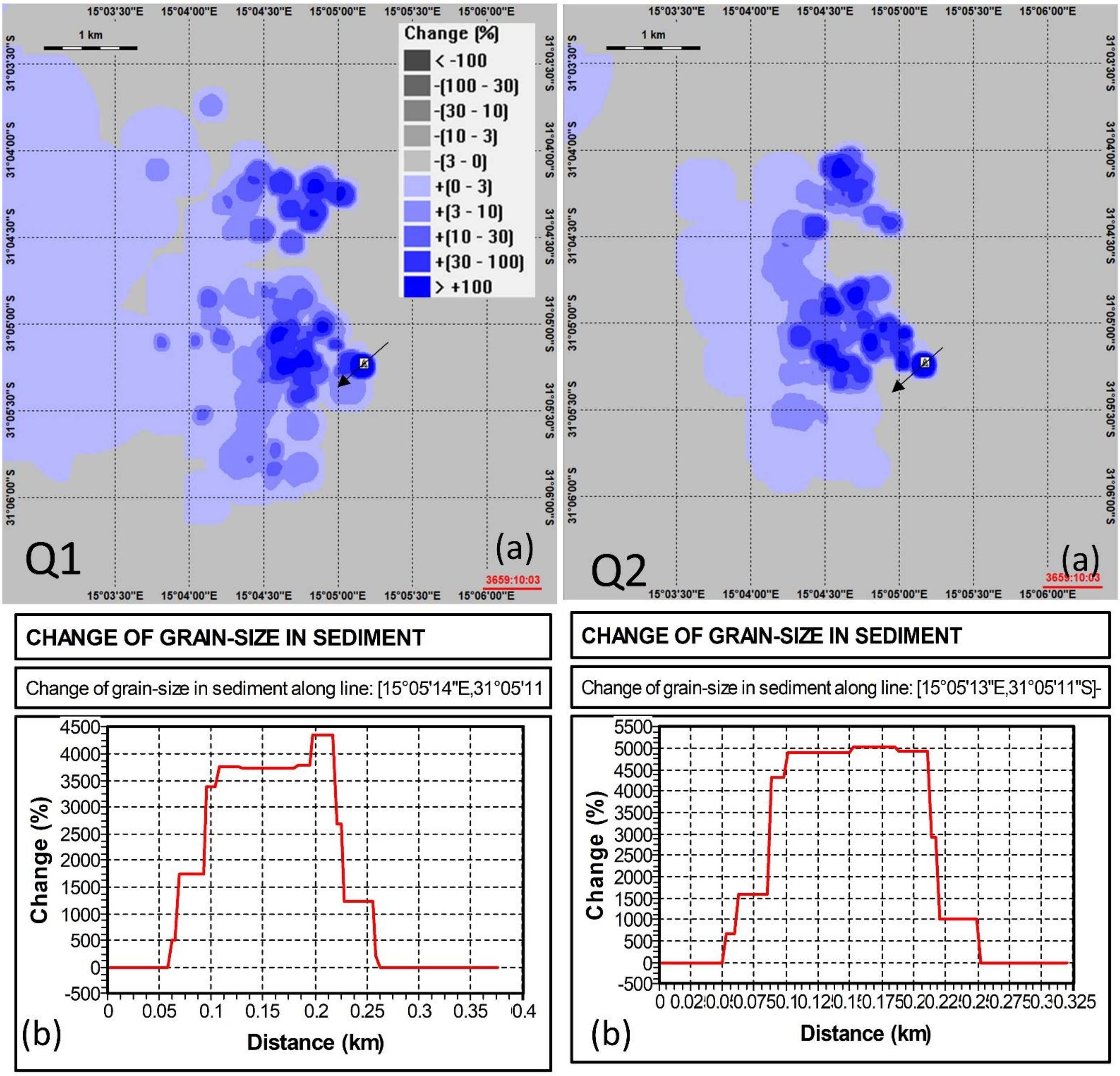


Figure 55 Grain size change on the sediment for Point A - Quarters 1 and 2, 10 years after operations

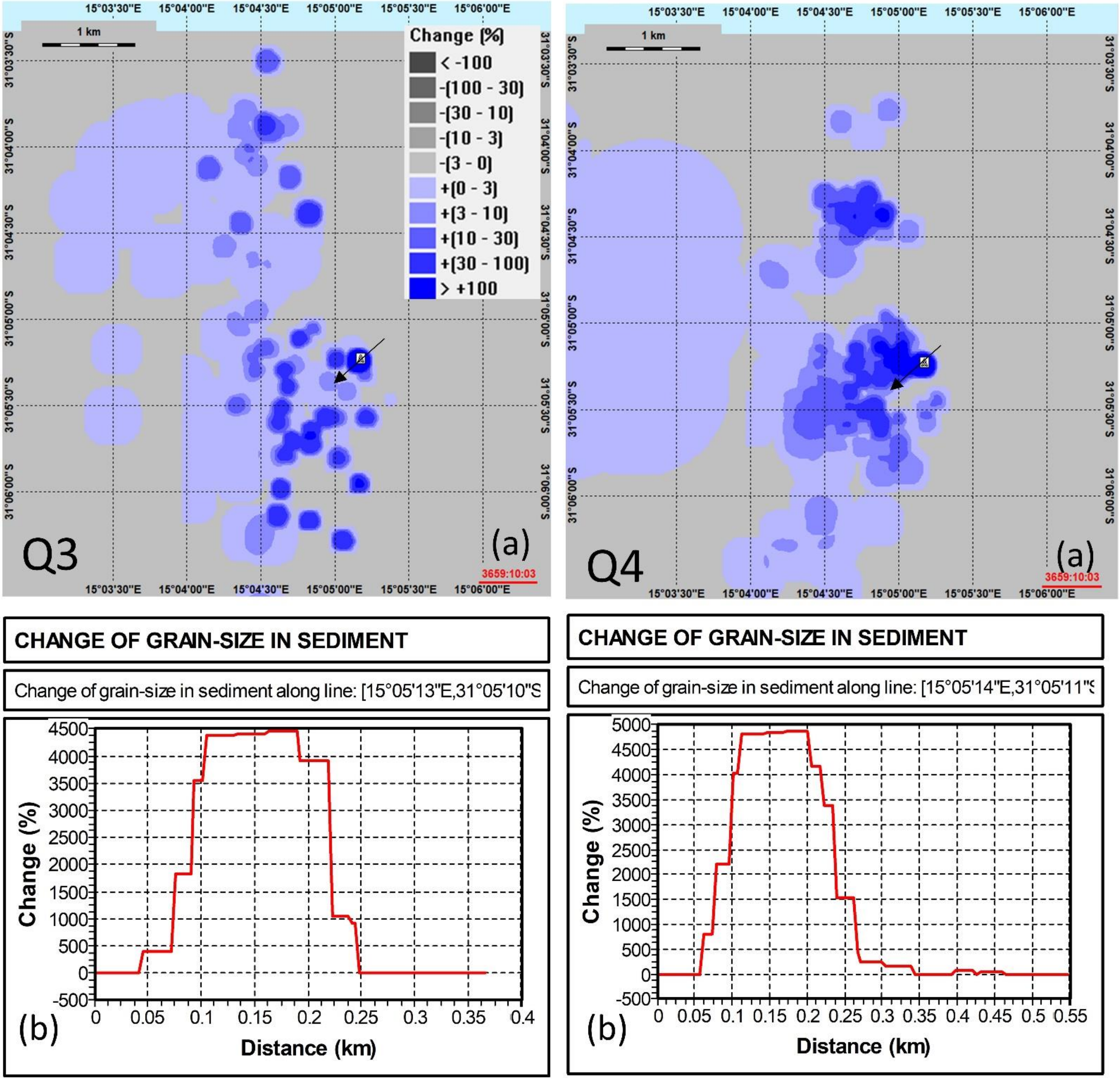


Figure 56 Grain size change on the sediment for Point A - Quarters 3 and 4, 10 years after operations

Table 23 present the grain size change values and distances from the discharge point for all the Quarters.

Table 23 Maximum grain size change values around the discharge point A for all the Quarters

PERIOD	MAX. GRAIN SIZE CHANGE	DISTANCE OF SIGNIFICANT GRAIN SIZE CHANGE FROM DICHARGE POINT
Q1	4300 %	140 m
Q2	5000 %	115 m
Q3	4500 %	125 m
Q4	4900 %	120 m

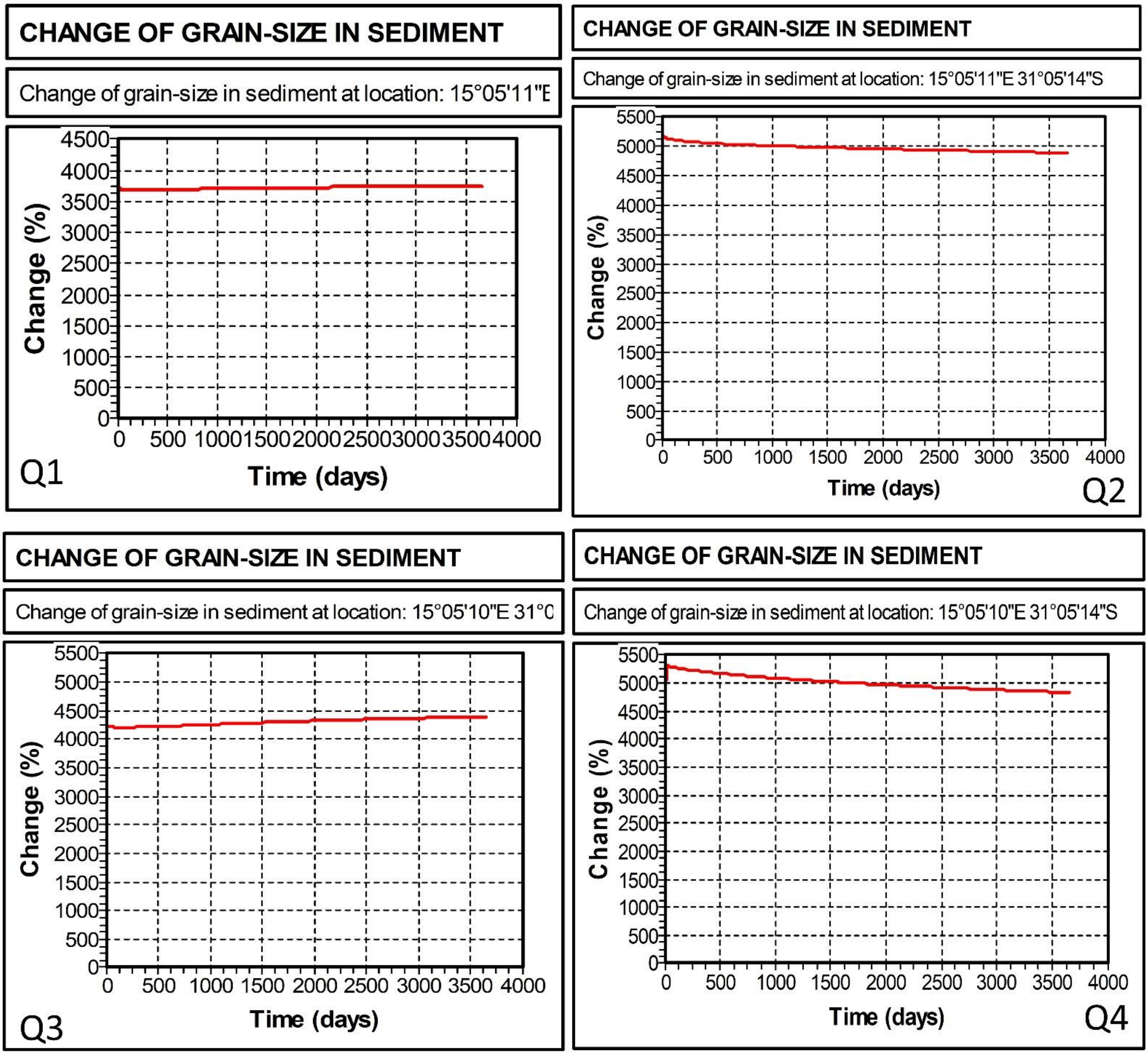


Figure 57 Grain Size variation vs. Time located on the discharge point A for all Quarters

Figure 57 above shows the evolution of the grain size change located on the discharge point for all Quarters.

The maximum grain size change located on the discharge point, show a very light decrease after the operations for Quarters 2 and 4, and a light increase for Quarters 1 and 3 (probably due to the bottom currents leading to some accumulations of cuttings). The values remain high 10 years after the operations for all the quarters.

3.3.3 Results Summary for the Sediment for Point A

As for the water column, the environmental risk for the sediment is mainly chemical than physical, mainly due to components of the NADF released during the drilling of the risered sections: the fatty acid present in the EZMUL NT-A, Invermul NT-B and EDC-99DW-C are responsible together for 77% to 83% of the total environmental risk.

The physical risk, *i.e.* the grain size change of the natural sediment (due to higher grain size particles released during the discharge), has a contribution to the total risk between 4% and 8%; and the thickness deposit of the discharge, contributing to 2 to 4% of the total risk depending on the Quarter. The oxygen depletion in the sediment is responsible for 6 to 18% to the total risk, and is a mix of physical and chemical impact.

The particles deposit area is not centralized around the discharge point and is orientated towards NW to SE up to 259 m of distance for the highest value, with a maximum cumulative thickness values between 65.2 and 69.2 mm located on the discharge point. The highest cuttings deposit is mainly due to the discharge of the riserless sections discharged directly on the seabed, remaining close to the discharge area, due to low-speed bottom currents. The thickness deposit 10 years after the operations is still around 30 mm, which is higher than the 6.5 mm (threshold value of thickness variation accepted by benthos, see 2.3.4 Risk assessment modelling) so the impact will be present close to the discharge point (until 260 m maximum) for a long period.

The maximum percentage of grain size change is between 4300% to 5000% located precisely on the release point. The grain size change maximum values are mostly due to the discharge of the riserless sections. The Grain Size change is insignificant after a distance of 140 m around the discharge point maximum, but still present 10 years after the operations.

4 Conclusion

***Reminder:* Risk>5% = significant risk = potential impact of the compartment (water column or sediment).**

4.1 WATER BASED MUD SCENARIOS

Water Column

The environmental risk in the water column is medium, with a value of 52% to 55% and is due to the Riserless sections and the displacement discharges, given that the risk is mainly due to the release of Bentonite, and Barite to a lesser extent.

The maximum risk distance reached is 260 m all around the discharge point but is quickly dispersed and diluted by the local currents, because there is no more risk after 5 days (i.e. after the 26" section displacement discharge).

There is no more risk in the water column after the end of the riserless sections discharge for all the Quarters thanks to dispersion and dilution processes.

Sediment

Contrary to the water column, the environmental risk for the sediment is mainly due to the physical contamination by the riserless and risered sections discharge (and not the chemical contamination). The risk is significant in the sediment from day 1 to 1030 days after (less than 3 years), mainly due to the end of the riserless sections discharged. The highest risk is reached just after the end of riserless discharge, and decreases quickly 2 years and 9 months after operations, with no more risk in the sediment after 3 years.

The main contributors to the environmental risk for the sediment are physical, *i.e.* the thickness deposit of the discharge and the grain size change of the natural sediment (due to higher grain size particles released during the discharge).

The sediment deposit area is not centralized around the discharge point and is orientated towards an axis from NW to SE but with significant values close to the discharge point (175 m maximum). The maximum thickness deposit located on the discharge point, shows a slight decrease one year after the operations, becoming insignificant (< 6.5mm) 5 years after the operations for all the Quarters.

The maximum percentage of grain size change is 1700 % to 1900% (depending on the Quarter) after the operations, decreasing until 1000 % to 1200 % 10 years after, located precisely on the discharge point. The grain size change is due to the discharge of the riserless and risered sections. The Grain Size change is unsignificant after 150 m around the discharge point 10 years after the operations.

Remark: The calculated risk has also to be balanced because of the very conservative approach used in the model.

Thus, high conservative safety factors were used (i.e. 1000) for chemicals, following the approach recommended by OSPAR/EU regulation. Recovery calculation is also quite conservative, not considering all the process in place.

The risk of these discharge operations seems limited close to the release point, less than 300m around the release point, for both water column and sediment. The risk in the water column is quickly dispersed by the currents and is not present anymore after the operations only due to riserless discharge.

The risk in the sediment is more physical than chemical, and is therefore more persistent especially close to the discharge point, because the high grain size particles are difficult to disperse by bottom currents, weaker than surface currents.

4.2 NON AQUEOUS DRILLING FLUID SCENARIOS

Remark: These results are valid for Points A & D

Water Column

The environmental risk in the water column is present from the surface to the seabed for both Points D and A, meaning that both types of discharges (risered and riserless) will have an impact. The environmental risk is mainly due to the NADF released during risered sections discharges for all the seasons.

The physical risk is due to the release of Bentonite from the riserless sections mainly, using the WBM, and the chemical risk is due to the release of EDC-99DW present in the NADF used during the risered sections drilling. The main contributor to the risk in the water column is chemical, and due to the EDC-99DW released during the risered sections drilling. The maximum EDC-99DW-A concentration (hydrotreated light petroleum distillate) in the water column is reached during the release of section 17 ½”. The Bentonite discharged during the riserless sections drilling is the second most impacting component for the Water Column.

Due to the strong currents in the area, the environmental risk in the water column is present until several kilometres. However, the strong currents present in the area allow a quick dispersion and dilution of the chemicals: the risk reached is very high close to the discharge point, but this is of short duration.

There is no more risk in the water column after the end of the operations for all the Quarters as result of dispersion and dilution processes due to the strong currents in this area.

Sediment

As for the water column, the environmental risk for the sediment is mainly chemical than physical, mainly due to components of the NADF released during the drilling of the risered sections: the fatty acid present in the EZMUL NT-A, Invermul NT-B and EDC-99DW-C, responsible for 74% to 80% to the total risk.

The physical risk, *i.e.* the grain size change of the natural sediment and the thickness deposit of the discharge, contributing together to less than 10 % of the total risk. The oxygen depletion in the sediment is responsible for values around 15% to the total risk, and is a mix of physical and chemical impact.

The particles deposit area is not centralized around the discharge point and is orientated towards NW to SE up to 260 m of distance for the highest value, with a maximum cumulative thickness values around 60 mm located on the discharge point. The highest cuttings deposit is mainly due to the discharge of the riserless sections discharged directly on the seabed, remaining close to the discharge area, due to low-speed bottom currents. The thickness deposit 10 years after the operations is still around 30 mm, which is higher than the 6.5 mm (threshold value of thickness variation accepted by benthos, see 2.3.4 Risk assessment modelling) so the impact will be present close to the discharge point for a long period.

The maximum percentage of grain size change is between 4300% to 6000% located precisely on the release point. The grain size change maximum values are mostly due to the discharge of the riserless sections. The Grain Size change is insignificant after a maximum distance of 160 m around the discharge point maximum, but still present 10 years after the operations.

With the use of Non Aqueous Based Mud, the risk of these discharge operations is potentially high, but limited in time for the water column, and close to the release point. The risk in the water column and in the sediment is more chemical than physical since Non-Aqueous Based Mud contains components with very low PNEC (Predicted No-Effect Concentration), which can have a higher environmental risk, even released in small quantities. Based on the simulation work, the presence of introduced chemicals is most significant in the sediment, mainly due to the chemicals present in the risered sections being discharged. The highest risk is reached just after the end of the drilling operations, peaking around day 25, and decreases quickly 66 days after operations, however low levels of residual compounds may still be present for up to 10 years near the wellbore location, where dispersion and dilution processes are not as efficient compared to within the water column (lower currents on the seabed).

The Table 24 below summarizes the maximum environmental risk distance from the future well for all the seasons:

Table 24 Maximum Environmental Risk distance form the future well for all the seasons

Scenario	Significant Risk Distance (i.e. > 5% = potential risk for 5% of the species in the ecosystem)	
	ER in the Water Column	ER in the Sediment (including Thickness and Grain Size Change)
WBM (Point D)	260m	115m
NADF (Point D)	12 400 m	3600 m
NADF (Point A)	13 200 m	4573 m

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6 Appendices

6.1 Appendix 1 – CV of the H-ES Expert

HES EXPERTISE SERVICES

Benjamin LIVAS

Environmental Modelling Expert

Marine Environmental Project Engineer with 10 years of experience in modelling

SINTEF certified user (MEMW Softwares developers)

PROFILE

- 12 years of experience in Marine and Coastal Environment
- Specialized in Marine Environmental Modelling and GIS

EXPERIENCE

H-Expertise Services S.A.S

- **Since February 2019 - Marine Environmental Modelling Expert – PAU (France)**
  - Operational marine environmental modelling studies for Oil & Gas Companies (accidental oil leaks, chemical product releases, drilling cuttings, environmental impact of the marine environment, etc.)
  - Environmental R&D studies for pollution response research centers and Oil & Gas Companies (comparison of oil slick drift models at sea, supplying databases, etc.)
  - Modelling trainer in oil subsidiaries
  - Site supervision facilitator (STORENGY)

MODIS

- **2010 - 2019 – Project Environmental Engineer – PAU (France)**
  - Certified user (SINTEF) in offshore environmental modelling on the MEWM OSCAR & DREAM modules: oil spill, produced waters, chemicals, drill cuttings and particulate discharges (more than 30 studies carried out)
  - Assistant for modelling deployment training in the deployment of MEWM software for TotalEnergies's HSE teams (Angola, UK, UAE, Nigeria)
  - Team leader on several environmental impact study studies for offshore Oil & Gas installations (Congo, Gabon, Angola): management, HSE, logistics, etc.

CNRS

- **2009 - 2010 - Assistant Engineer – DINARD (France)**
  Coastal geomorphology, GIS, digital terrain models, spatial statistics, field training

HES EXPERTISE SERVICES

EDUCATION

- **2007 - 2008 Master II Biodiversity and Sustainable Development**

  Université des Sciences de PERPIGNAN via Domitia, FRANCE

- **2006 - 2007 Master I Dynamics of aquatic ecosystems**

  Université de Pau et des Pays de l'Adour, UFR Côte Basque, ANGLET, FRANCE

SKILLS

- MEMW Software – OSCAR, DREAM & ParTrack modules (SINTEF certified user)
- GIS (ArcGIS)
- Microsoft Office Environment

LANGUES

- French (Mother tongue)
- English (Fluent)
- Spanish

MISCELLANEOUS

- BOSIET (Basic Offshore Safety Induction and Emergency Training), HUET (Helicopter Underwater Escape Training)
- Response in case of Accidental Hydrocarbon Pollution at Sea and on the Coast (Cedre, BREST)

EIMS | ENVIRONMENTAL IMPACT MANAGEMENT SERVICES

SPECIALIST DECLARATION

EIMS Ref	1570	Project Name	PROPOSED AFRICA OIL SOUTH AFRICA CORP BLOCK 3B/4B EXPLORATION RIGHT

Project Details

Project Name	Proposed Africa Oil South Africa Corp Block 3b/4b Exploration Right
Applicant	Africa Oil SA Corp, Ricocure (Pty) Ltd and Azinam Limited (a wholly owned subsidiary of Eco Atlantic) (the Joint Venture (JV) Partners)
Competent Authority	Department of Mineral Resources

Specialist Details

Specialist Company: H-Expertise Services

Specialist Name: Benjamin Livas

Contact details: Tel +33788418911 Cell

E-mail: benjamin.livas@h-expertise-services.com

Postal Address / Physical Address: 145 Route Gassie 64 370 POMPS

General Declaration

By signing this form, I hereby declare that:

- I act as an independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting undertaking the specialist work as required, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations, and all other applicable legislation.
- I have not, and will not engage in, conflicting interest in the undertaking of the activity.
- I understand to disclose to the applicant and competent authority all material information in my possession that reasonably has or may have the potential of influencing- any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- I have taken into account, to the extent possible, the matters referred to in Regulation 18 when preparing the report, plan or document.
- I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.
- All the particulars furnished by me this form are true and correct.

EIMS | ENVIRONMENTAL IMPACT MANAGEMENT SERVICES

SPECIALIST DECLARATION

EIMS Ref	1570	Project Name	PROPOSED AFRICA OIL SOUTH AFRICA CORP BLOCK 3B/4B EXPLORATION RIGHT

- I will perform all other obligations as expected from an environmental assessment practitioner in terms of the Regulations.
- I am aware of what constitutes an offence in terms of Regulation 48 and that a person convicted of an offence in terms of Regulation 48(1) is liable to the penalties as contemplated in Section 49B of the Act.

Disclosure of Vested Interest

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remunerative for work performed in terms of the Regulations.

Undertaking Under Oath/Affirmation

By signing this form, I swear under oath/affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signatures

Specialist

Name Benjamin Livas Signature [signature] Date 26/03/2024

Commissioner of Oaths

Name Signature Date

Commissioner of Oaths Official Stamp

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