Exploration - Production

TEP SA

Block 11B/12B – Discharge n°02

Drilling discharges at Sea

Modeling Study V06

DG/PSR/HSE/EP/ES/ENV/OPS N° 2020-44 September 2020

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ABSTRACT

This study presents the risk to the marine environment coming from the exploration drilling activities in Block 11B/12B, for one discharge location. The discharges were estimated in terms of cuttings and mud volumes based on the current drilling program for Luiperd-1X (not yet drilled) but optimized from Brulpadda previous drilling operations.

The results presented in the report are based on values available at the time of study preparation. Those results are therefore preliminary and subject to scope modification.

Five scenarios were considered in this study (4 quarters corresponding to the base drilling case and one additional optional scenario corresponding to a similar well architecture but with deeper sections to be drilled). For the four base case scenarios the same quantities of cuttings and mud to be discharged were used for the modelling. Only the discharged period was different from scenario 1 to 4 (January, March, June and September). For the optional scenario, same mud composition was considered but larger quantities to be used and discharged; larger quantities of cuttings as well.

For all the scenarios, the overall risk calculation shows a significant risk observed from sea bottom to up to 100 m above seabed and between 12 to 35 km West/South West from the discharge point, due to the release of Barite used in the sections 42" and 26". Significant risk has been also observed between 0 and 100 m depth, between 10-24 km (scenario1-4) and up to 25km (scenario 5) mainly to the West/South West from the discharge point. However, the risk is limited both in terms of time and space with only a few tiny patches with significant risk observed. This risk is mainly due to the Clayseal Plus to be used for the drilling of all sections with a riser (hydrochloric acid). For each area at risk, the risk is short term and intermittent, and not present in the water after the end of the operations.

A significant risk has also been observed in the sediments for **all the scenarios** between 160 m and 400 m away from the discharge point for the scenario 1 to 4, up to 720 m for the scenario 5. The risk observed last up to 1500 days (≈4 years) after the end of drilling operations. This risk is mainly due to the natural sediment grain size change due to the deposit of the riserless section (between 75% and 86 % of the risk depending on the scenario).

The risk calculation approach used is a priori and 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).

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1. Introduction

Total Exploration & Production Republic of South Africa (TEP SA) intends to carry out exploration drilling activity in Block 11B/12B in offshore South African waters (hereafter called the project). The proposed activity for Block 11B/12B comprises drilling of up to 10 exploration wells.

To inform the Environmental and Social Impact Assessment, and to further understand all risks related to offshore discharges, this report has been prepared to present the disturbance resulting from the cuttings and mud discharges from drilling operations onto the water column and the superficial sediments at seabed taking into account one discharge location (worst cases).

2. Materiel & method

2.1 Discharge information

2.1.1 Study area

➢ <u>Location</u>

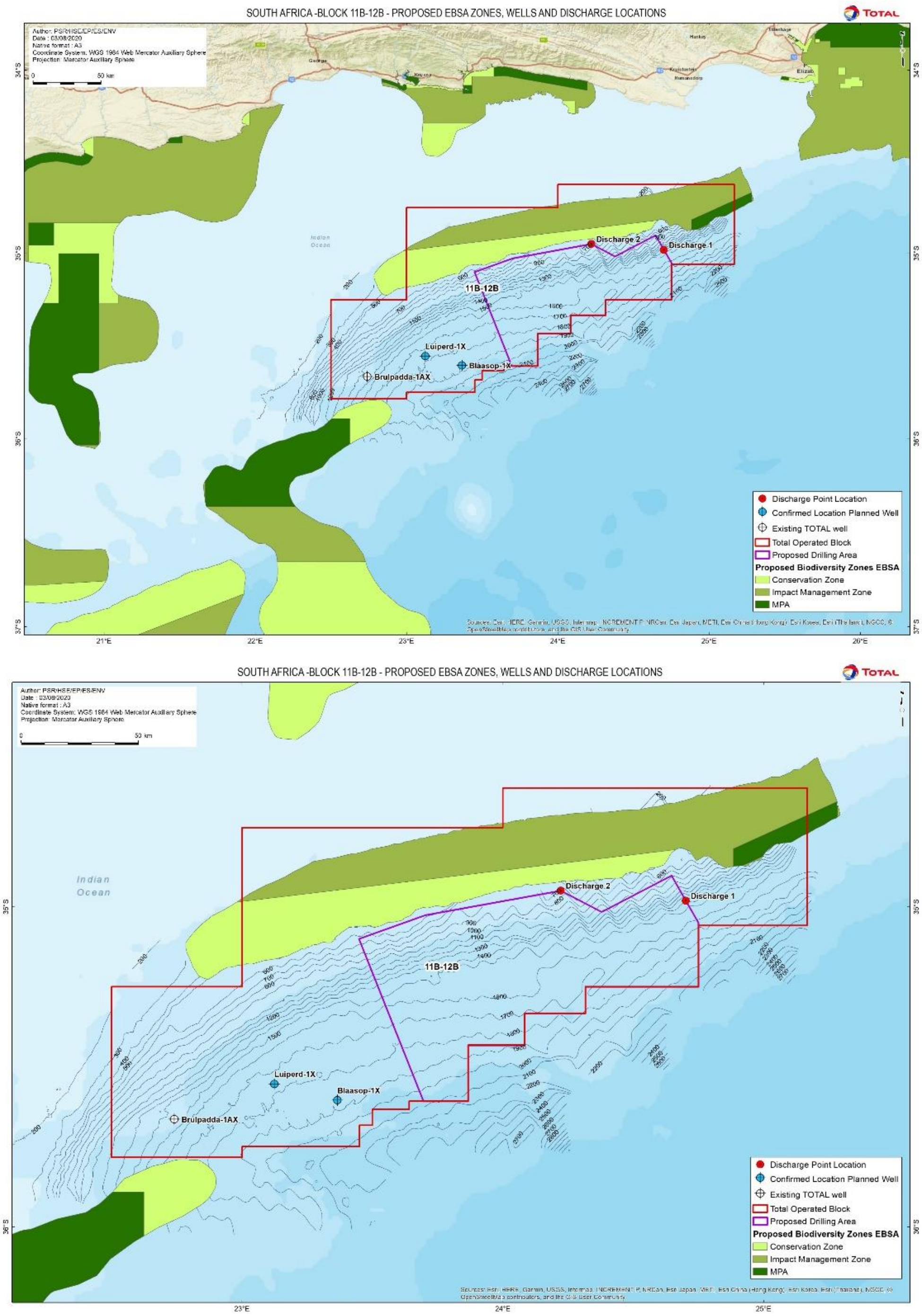


Figure 1: Study location and protected areas

The exact locations of the wells to be drilled within the area of interest in Block 11B/12B are not yet known because this is still under assessment by the exploration teams. Several wells are proposed to be drilled in the Block. Two discharge locations were selected to cover the area of interest in the Block to be drilled after discussion with the affiliate and the company in charge of the ESIA (SLR). Three main criteria were considered for the selection of discharge locations (release location for the modelling study) leading to worst case scenarios:

- Water depth
- Distance from the coast
- Sensitive area.

The two discharge locations (Discharge 1 & 2 Figure 1) considered for the modelling study will be pseudo vertical wells approximately 89 km from the shore at 1 254 m water depth (priority 1) and approximately 98 km from the shore at 690 m water depth (priority 2) (MEMW Software Depth Database). The locations selected were the closest to the coast and the sensitivity areas at two different depths. The wells will be drilled using a mobile offshore drilling unit (MODU).

2.1.2 Well design & 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 (via Service request form: Appendix 1). The designs will be the same for both wells. Well design (e.g. number of sections, depth) is based on the current drilling program for Luiperd-1X (not yet drilled) but optimized from Brulpadda previous drilling operations. Two designs were considered: a base case design and an optional design.

The well base case design is described as below:

- 1st section: 42" section to be drilled riserless with Sea Water & Hi-vis Sweep & Water based mud (WBM=PAD mud)
- 2nd section: 26'' section to be drilled riserless using Sea Water & Hi-vis Sweep & WBM (PAD mud)
- 3rd section: 17 ½'' section to be drilled with a riser using HydroGuard High Performance Water Base Mud
- 4th section: 12 ¼" to be drilled with a riser using HydroGuard High Performance Water Base Mud
- 5th section: 8 ½" to be drilled with a riser using KCl/Glycol/ Polymer Water Base Mud
- Two batch release of KCl/Glycol/ Polymer Water Base Mud will be done during Logging and P&A phases.

For the optional case, same design is considered with longer sections to be drilled with the riser as detailed below.

Table 1: Cuttings and mud volumes per phase

Well design	Wellbore diameter (")	Section length (m)	Drilling /operation duration (Hours)	Discharge duration (Hours)	Time before next operation (days)	Released cuttings (tons)	Quantity of mud discharged (MT)
Base case and optional case	42''	83	4.75	4.75	4	260	768
	26''	504	22.4	22.4	10	606	2521
Base case	17 ½''	504	15.5	84	3	253	836
	12 ¼''	504	50.4	108	2.5	114	475
	8 ½''	505	50.5	108	2.5	55	326
	Logging	/	96	96	0	0	740
	P&A	/	72	72	0	0	740
Optional case	17 ½''	971	30	163	3	488	1613
	12 ¼''	971	97	209	2.5	220	917
	8 ½''	971	97	209	2.5	106	629
	Logging	/	185	185	0	0	1428
	P&A	/	139	139	0	0	1428

The two first sections to be drilled, 42'' and 26'' sections, are planned to be drilled riserless using WBM (Service request form). For these sections to be drilled riserless, all cuttings and mud are discharged to the seabed for each well.

The following sections, 17 ½'', 12 ¼'' and 8 ½'' sections, are planned to be drilled with a riser using WBM (Service request form). In this case all the mud and the cuttings generated will be discharged 1 m below sea surface (17 ½'', 12 ¼'' and 8 ½'').

At the end of these drilling operations, the well(s) will be prepared to be closed permanently. This is described as Plug & Abandonment (P&A) in the report. Different regulatory bodies have their own requirements for plugging operations. Most require that cement plugs be placed and tested across any open hydrocarbon-bearing formations. At this stage, the mud is used as primary barrier (against hydrocarbons kick) until the well has been abandoned. The mud will then be displaced to sea water.

If operations are performed into the well, whatever the operation, the well will be full of mud and discharge will happen regularly as part of the regular mud treatment (to keep it up to specs).

Cutting estimates were calculated using TOTAL internal Guide & Manual (GM EP FP 476: Drill cuttings waste management).

2.1.3 Mud composition

The mud composition presented in this report is based on a provisional formulation provided by the Fluid team as this is the only available information at the date of the study. **The composition may slightly vary depending on the contractor's selection and may later be modified to suit operational needs.** Fluid program is based on the current drilling program for Luiperd-1X (not yet drilled) but optimized from Brulpadda last drilling operations. Several types of drilling fluid (details provided in service request form) will be used for drilling operations with different compositions and densities.

Table 2: types of muds (WBM) used for the different sections

	Type of WBM	Density
42''	Pad mud	1.30 sg
26''	Pad mud	1.30 sg
17.5''	HPWBM	1.07 sg
12.25''	HPWBM	1.07 sg
8.5''	KCL WBM	1.18sg

WBM fluids use sea water and additives such as weighting agent (barite), viscosifiers (e.g. Barazan D), fluid loss control, pH control (e.g. Caustic soda), etc…

Table 3: Composition of WBM used

<table>
<tr><th colspan="4">WBM Hi-vis sweep to be used for 42'' section</th></tr>
<tr><th colspan="2"></th><th>Concentration (kg/t)</th><th>Mass (t)</th></tr>
<tr><td colspan="2">PAC R</td><td>9.7</td><td>2.4</td></tr>
<tr><td colspan="2">Barabuf</td><td>2.8</td><td>0.2</td></tr>
<tr><td colspan="2">Soda ash</td><td>1.2</td><td>0.3</td></tr>
<tr><th colspan="4">WBM pad mud to be used for 42'' section</th></tr>
<tr><td colspan="2">Barazan D</td><td>2.7</td><td>3.12</td></tr>
<tr><td colspan="2">PAC L</td><td>3.3</td><td>0.75</td></tr>
<tr><td colspan="2">KCL</td><td>57.4</td><td>46.18</td></tr>
<tr><td colspan="2">Barabuf</td><td>0.4</td><td>1.3</td></tr>
<tr><td colspan="2">Soda Ash</td><td>0.6</td><td>0.50</td></tr>
<tr><td colspan="2">Barite</td><td>240.9</td><td>125.5</td></tr>
<tr><th colspan="4">WBM Hi-vis sweep to be used for 26'' section</th></tr>
<tr><td colspan="2">PAC R</td><td>9.7</td><td>10</td></tr>
<tr><td colspan="2">Barabuf</td><td>0.7</td><td>0.7</td></tr>
<tr><td colspan="2">Soda ash</td><td>1.1</td><td>1.1</td></tr>
<tr><th colspan="4">WBM pad mud to be used for 26'' section</th></tr>
<tr><td colspan="2">Barazan D</td><td>2.7</td><td>4</td></tr>
<tr><td colspan="2">PAC L</td><td>3.3</td><td>4.9</td></tr>
<tr><td colspan="2">KCL</td><td>57.3</td><td>85.4</td></tr>
<tr><td colspan="2">Barabuf</td><td>0.5</td><td>0.7</td></tr>
<tr><td colspan="2">Soda ash</td><td>0.7</td><td>1.1</td></tr>
<tr><td colspan="2">Barite</td><td>240.8</td><td>358.8</td></tr>
<tr><th colspan="4">Hydroguard high performance WBM to be used for 17.5'' section</th></tr>
<tr><td colspan="2">KCL</td><td>75</td><td>62.5</td></tr>
<tr><td colspan="2">NaCl</td><td>24</td><td>20.3</td></tr>
<tr><td colspan="2">Barabuf</td><td>0.7</td><td>0.6</td></tr>
<tr><td colspan="2">Barazan D</td><td>3</td><td>2.5</td></tr>
<tr><td colspan="2">PAC L</td><td>7.9</td><td>6.6</td></tr>
<tr><td rowspan="2">Clayseal Plus</td><td>Triethylenetetramine, polymer with oxirane (90%)</td><td rowspan="2">18.7</td><td>14.8</td></tr>
<tr><td>Hydrochloric acid (10%)</td><td>0.8</td></tr>
<tr><td colspan="2">Dextrid E</td><td>18.7</td><td>15.6</td></tr>
<tr><td colspan="2">Clay Sync II</td><td>4.7</td><td>3.9</td></tr>
<tr><td colspan="2">GEM GP</td><td>28</td><td>23.4</td></tr>
<tr><td colspan="2">Soda ash</td><td>0.6</td><td>0.5</td></tr>
<tr><td colspan="2">Sodium Bicarbonate</td><td>1</td><td>0.8</td></tr>
<tr><th colspan="4">Hydroguard high performance WBM to be used for 12.25'' section</th></tr>
<tr><td colspan="2">KCL</td><td>75</td><td>35.5</td></tr>
<tr><td colspan="2">NaCl</td><td>24</td><td>11.5</td></tr>
<tr><td colspan="2">Barabuf</td><td>0.6</td><td>0.3</td></tr>
<tr><td colspan="2">Barazan D</td><td>2.9</td><td>1.4</td></tr>
</table>

PAC L		8	3.8
Clayseal Plus	Triethylenetetramine, polymer with oxirane (90%)	23.4	8.5
	Hydrochloric acid (10%)		0.4
Dextrid E		18.7	8.9
Clay Sync II		4.6	2.2
GEM GP		28	13.3
Sodium bicarbonate		As required	0.4
Soda Ash		0.6	0.3
Starcide		1.3	0.6
KCL Glycol / Polymer WBM to be used for 8.5'' section			
KCL		68	22.1
NaCl		22	7.2
Barabuf		3	1
Barazan D		2	0.6
PAC L		7	2.3
Clayseal Plus	Triethylenetetramine, polymer with oxirane (90%)	17	5.2
	Hydrochloric acid (10%)		0.3
FilterChek		12	3.9
GEM GP		25	8.3
BARACARB 150		25	8.3
BARACARB 50		55	18
Barite		As Required	555
Starcide		0.4	49
N-Drill HT Plus		1.7	100
KCL Glycol / Polymer WBM to be used for LOGGING			
KCL		40.6	1000
NaCl		13.2	40000
Barabuf		1.9	100
Barazan D		1	420
PAC L		4.3	80.86
Clayseal Plus	Triethylenetetramine, polymer with oxirane (90%)	9.6	562.3
	Hydrochloric acid (10%)	0.5	0.364
FilterChek		7.1	100
GEM GP		15.2	310
BARACARB 150		15.2	440
BARACARB 50		33	440
Barite		As Required	555
Starcide		0.7	49
N-Drill HT Plus		3	100
KCL Glycol / Polymer WBM to be used for P&A			
KCL		40.6	1000
NaCl		13.2	40000
Barabuf		1.9	100

Barazan D		1	420
PAC L		4.3	80.86
Clayseal Plus	Triethylenetetramine, polymer with oxirane (90%)	9.6	562.3
	Hydrochloric acid (10%)	0.5	0.364
FilterChek		7.1	100
GEM GP		15.2	310
BARACARB 150		15.2	440
BARACARB 50		33	440
Barite		As Required	555
Starcide		0.7	49
N-Drill HT Plus		3	100

The 2 first sections (42” and 26”) are drilled riserless with sea water and the mixture of both sea water and cuttings is discharged at the seabed (≈ 1 254 m water depth for well 1 and 690 m water depth for well 2). All the other sections (17 ½’’, 12 ¼” and 8 ½”) will be drilled risered. For those sections, cuttings and mud are discharged 1 m below sea surface.

2.2 MODEL

2.2.1 Marine Environmental Modeling Workbench (MEMW)

The MEMW suite software allows modeling several types of E&P's discharges to the environment. The current version of the software used is MEMW 10.0.1, latest released from 2019.

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 larger 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 releases to the marine environment. DREAM helps visualizing and analyzing releases occurring over extended time periods and in water column. Some of the tasks suitable for DREAM include the ParTrack model (Drilling discharges) comes with the DREAM module and includes releases of drill muds and cuttings. Additional environmental impact calculations for bottom sediments and particle stress in the water column are available here.

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 release (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 be sinking down on 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 center, 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 neighbor particle,
- time since release,
- 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 release, 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 releases of oil, in which the near-surface vertical evolution may be of interest.

The position of each particle locates the center 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 behavior of pollutants in DREAM are presented in Figure 2 below.

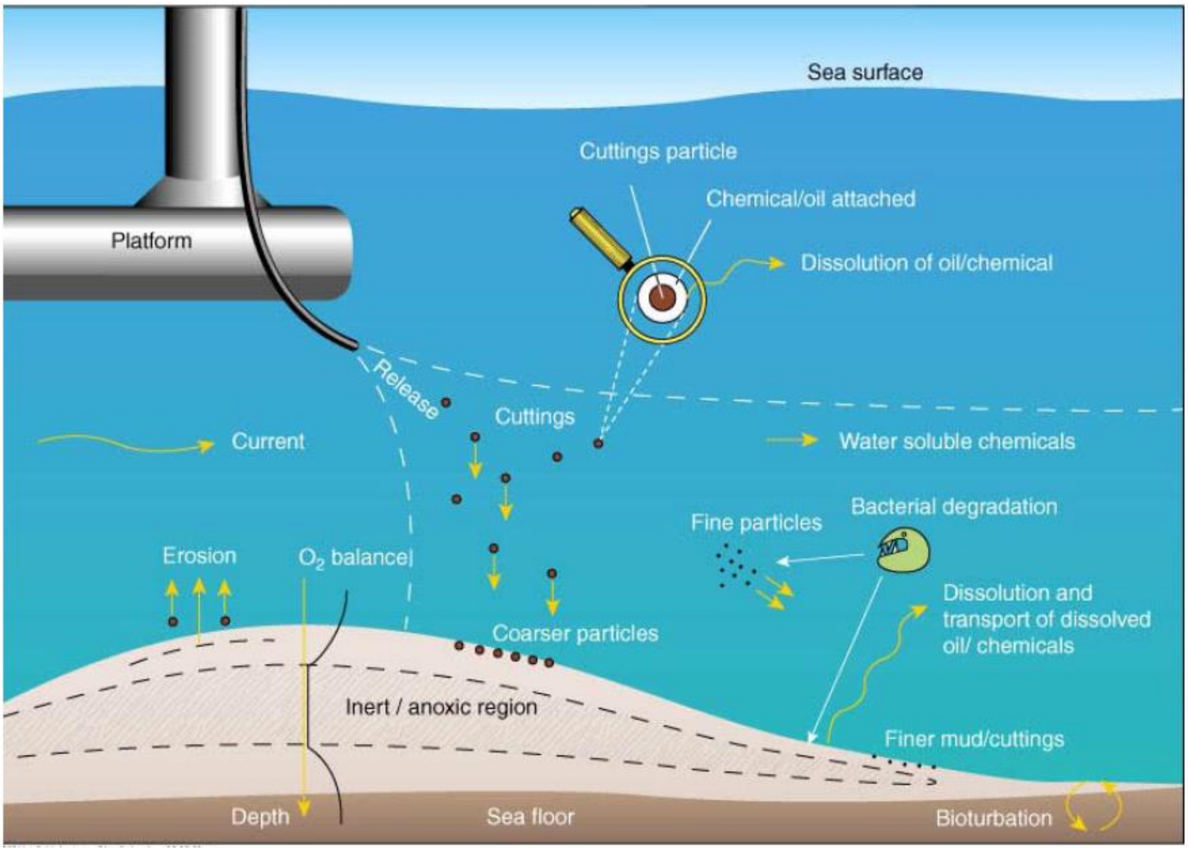


Figure 2: Phenomenon considered in water column and sediment (from SINTEF)

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 0ppm concentration.
For large Pow, Kow or Koc values (≥ 1000), the chemicals are assumed to deposit on the sea floor.

To summarize, the following stressors concentrations (PEC) will be calculated:

- water colum:
  - 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

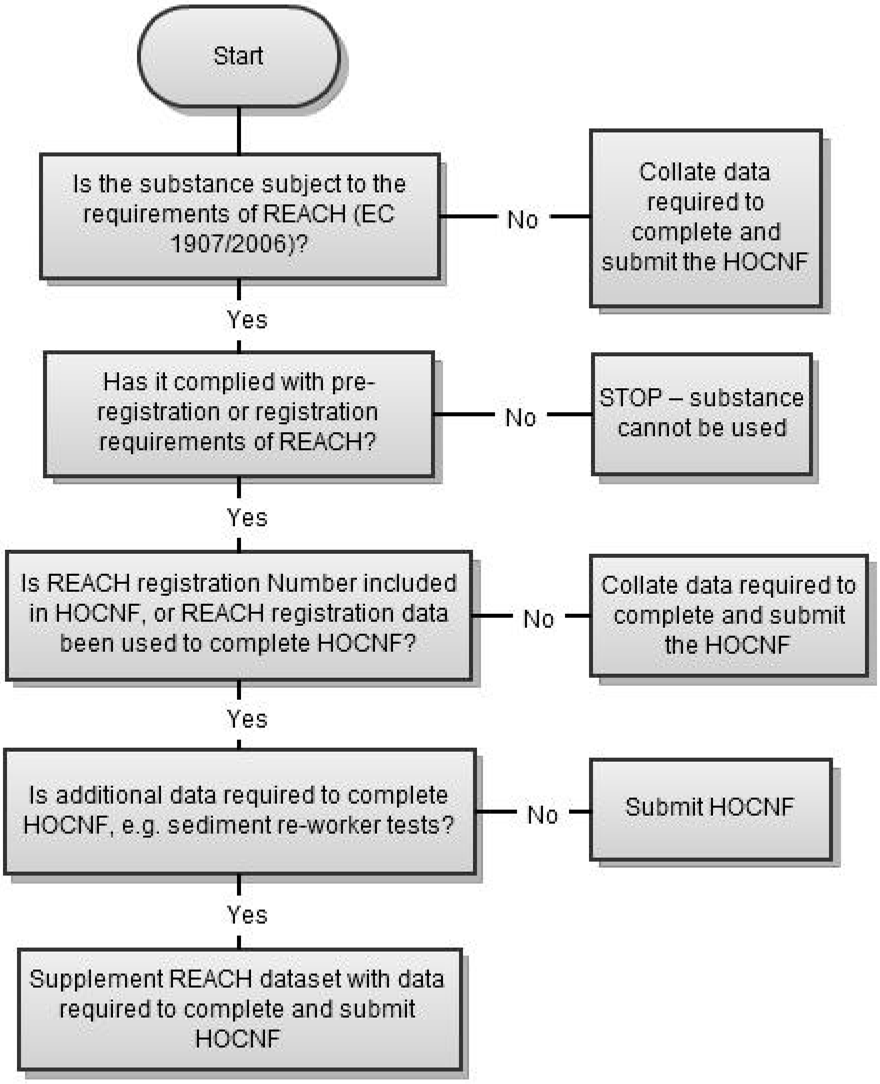
The model is driven by winds and currents either produced by other numerical models or measured as time series in the region of interest. Global datasets of bathymetry and coastlines are supplied with the system and can be augmented by the user via standard GIS and/or ASCII formats.

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).

2.2.2 Chemical hazard classification as per OSPAR recommendation

To reduce the overall impact of offshore chemicals on the marine environment, OSPAR has adopted a harmonised 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 Harmonised 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 for that substance (i.e. Persistence- Bioaccumulation - Toxicity criteria). Suppliers should therefore follow the REACH compliance flowchart below.



PLONOR 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 Harmonised 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 ofall offshore chemicals registered is also available on the CEFAS website (https://www.cefas.co.uk/data-and-publications/ocns/) 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 color banding as shown in the table below (HQ and color band applicable in the UK and the Netherlands).

Table 4: HQ and color 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 Harmonised 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. 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% in28 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 5: 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).

Table 6: Component properties & grainsize distribution for particulates

name		composition	density	solubility	Biodegradation (%)	Vapour pressure	KOC	PNEC (ppb)	KOW	Vapour pressure	PLONOR	OSPAR compliant
Barabuf		Not Available	3.56	10 000	0	0	1	100	0	0	yes	yes
BARACARB 150		Calcium Carbonate / Ground Marble	2.7	0	0	0	1	440	na	0	yes	yes
BARACARB 50		Calcium Carbonate / Ground Marble	2.7	0	0	0	1	440	na	0	yes	yes
Barazan D		Polysaccharide/Xanthan Gum	1.6	100000	93	0	1	420	0	0	No	yes
Barite	A	Crystalline silica, quartz	2.6	0	0	0	1	440	na	0	yes	yes
	B	Barium Sulphate	4.5	3.1	0	0	1	115	5	0		
Clay Sync II		Not Available	1.04	100000	2.8 (21days)	0	1	1160	0	0	no	Substitution warning
Clayseal Plus	A	Triethylenetetramine, polymer with oxirane (95%)	1.0561	10000	0	0	1	562.3	0	0	no	Substitution warning
	B	Hydrochloric acid (5%)	1.27	500000	100	45.6	1	3.25	0	45.6		
Dextrid E		Modified Starch/Complex carbohydrate	1.5	100000	70	0	1	1000	0	0	yes	yes
FilterChek		Not Available	1.5	100000	60	0	1	100	0	0	no	Yes
GEM GP		Polyethylene glycol butyl ether	0.989	989000	69	0	2.75	310	2.76	0	no	yes
KCL		Potassium Chloride	1.98	355 000	0	0	1	1000	0	0	yes	yes
NaCl		Sodium Chloride	2.163	317 000	0	0	1	40000	0	0	yes	yes
N-Drill HT plus		Not Available	1.5	100000	0	0	1	100	0	0	no	yes
PAC L		Polysaccharide	1.6	100000	60	0	1	80.86	0	0	yes	yes
PAC R		Polysaccharide	1.6	10000	60	0	1	80.86	0	0	yes	yes
Soda ash		Sodium Carbonate	2.52	212500	0	0	1	242	0	0	yes	yes
Sodium bicarbonate		Sodium bicarbonate	2.21	93400	0	0	1	576	0	0	yes	yes
Starcide		3, 3'-Methylene bis (5-methyl oxazolidine)	1.069	2800000	90	0	78	49	78	0	no	yes

DRILL CUTTINGS				
Diameter Mm	Weight %	Density SG	Velocity m/s	Velocity m/day
0.007	10	2.4	1.9E-05	1.7
0.015	10	2.4	8.8E-05	7.6
0.025	10	2.4	2.5E-04	21.2
0.035	10	2.4	4.8E-04	41.6
0.05	10	2.4	9.8E-04	84.9
0.075	10	2.4	2.2E-03	191.0
0.2	10	2.4	1.6E-02	1356.5
0.6	10	2.4	5.7E-02	4898.9
3	10	2.4	2.1E-01	17988.5
7	10	2.4	3.2E-01	27483.8

DRILLING MUD (Barite...)			
Diameter mm	Weight, %	Velocity, m/s	Velocity, m/day
0.0007	10	4.4E-07	0.04
0.001	10	9.1E-07	0.08
0.002	10	3.6E-06	0.31
0.003	10	8.2E-06	0.71
0.005	10	2.3E-05	1.96
0.009	10	7.4E-05	6.35
0.014	10	1.8E-04	15.37
0.018	10	2.9E-04	25.41
0.028	10	7.1E-04	61.49
0.05	10	2.3E-03	196.08

PNEC: Predicted No Effect Concentration

KOC: partitioning coefficient between oil and water

PLONOR: substance considered to Pose Little Or No Risk to the environment

After pre-screening analysis against OSPAR requirements all chemicals are recognized as OSPAR compliant

2.2.3 Risk approach

Discharges modeling to better assess the risk was handled for drilling cuttings, mud discharges and adsorbed mud discharges.

The drill cuttings discharges are variable and depend on the section diameter and the section length. These cuttings are discharged at seabed as there is no marine riser for the top-hole sections of the well (this is applicable to the 42'' and 26'' sections for the case of Block 11B/12B in South Africa). The cuttings form a hillock on the sea bottom around the subsea wellhead, whose form is dictated by the currents at seabed. Around the wellhead, where the deposit is higher, the non-mobile benthic species are generally buried.

During drilling operations once the marine riser has been connected to the subsea wellhead, rock spoil of drilling (called drill cuttings), derived from the layers through which the well is drilled, rise to the surface (at the platform level) with the drilling mud in circulation. At the level of the drilling rig, this mixture of cuttings and mud is separated by sieving (shale shakers), then cuttings are discharged to the sea. The shape of the plume and the deposition of cuttings on the seabed during these phases drilled through the marine riser is 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 TOTAL.

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).

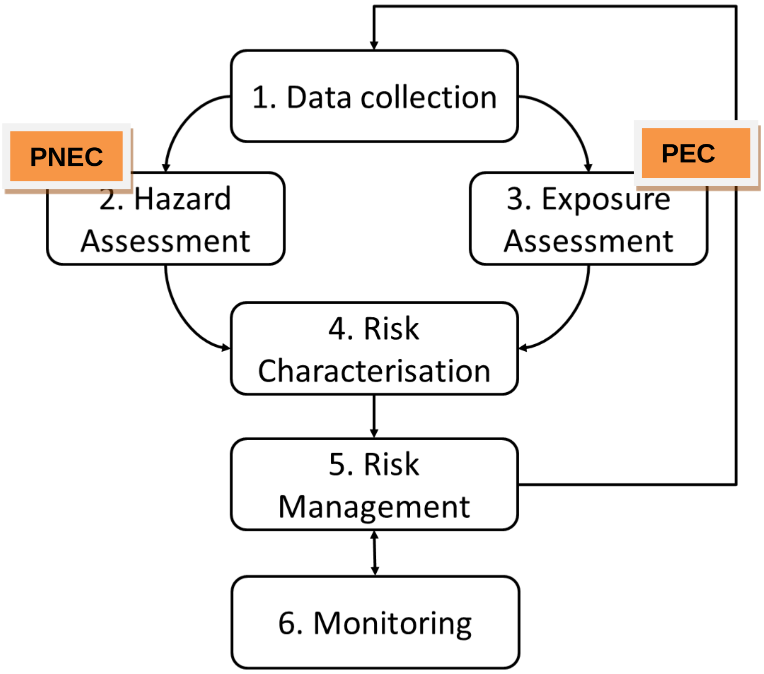


Figure 3: Risk Based Approach philosophy

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 the ones 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 will be provided.

Impact: 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 definition in chapter 3.1) 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.

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 will be.

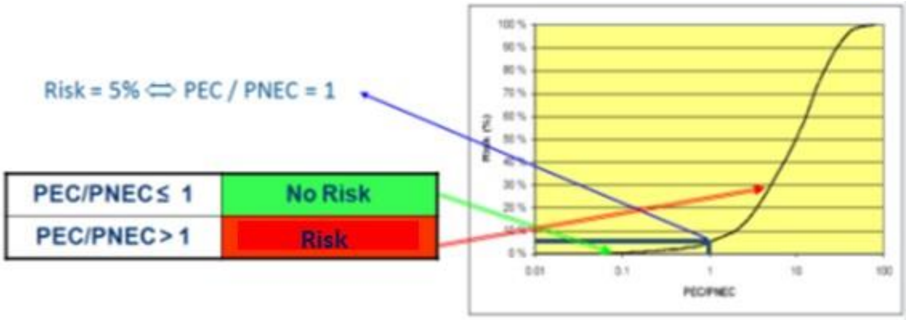


Figure 4: Relation between risk level and concentration estimation

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 will be 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.

2.2.4 Risk assessment modeling

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

<u>Glossary as follows:</u>

Effluent: Correspond to cuttings + drilling fluid

Maximum risk: represents the compilation of all maximum risks at any time compiled over the whole modeling period

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.

Risk stressors: are 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 concentration, expressed in ppm, of the released substance, calculated in the water column after its dispersion in the marine environment.
- PNEC is the maximum concentration, expressed in ppm or mg/l, causing no harm to the ecosystem. According to European recommendations, PNEC is obtained from ecotoxicological values (LC_{50}, 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 (100 ppm for cutting and much lower for weighting agents: see Table 6).

- **Sediments:**

Toxicity of chemicals in sediment:

- PEC is the calculated concentration of the substance in the sediment pore water, 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. 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 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).

Change in the sediment structure - grain size:

- PEC represents the change, in %, 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 TEPSA for the area: 350 µm) and the grain size after the release. PNEC grain size=+/- 52.7 µm (i.e. 15% variation for Block 11B/12B). This value is derived from the statistical description of the variation in sensitivity (Species Sensitivity Distributions-SSD). As the natural sediment grain size is 350 µm and a variation under 15% is non-significant, the grain size change maps will be presented with a key presenting the variation from 5% to >100% (ignoring the variations lower than this range of values).

Oxygen depletion in the sediment:

- PEC is the 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.

- **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 restitution 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

More information is available in ERMS report n°1

2.2.5 Metocean data & bathymetry

- Metocean model selection (model calibration and validation)

The metocean data used for this study were purchased from SAT-OCEAN. SAT-OCEAN have developed innovative and exclusive technologies based on *in-situ*, satellite sea surface temperature, wind and altimetric data by which absolute ocean currents and winds are computed, anywhere in the world. In effect, coupled inverse/direct modeling approaches combined with the data allow us to measure these quantities from space with very high spatial (1/32°) and temporal resolutions (3-hour output time step) over the model emprise.

Several studies have shown that upper layer oceanic features can be monitored from satellite measurements over long periods of time. SAT-OCEAN merge up to 9 sensor data sets and produce analyzed SST fields accurate to 0.3°C on average compared to surface drifting buoys' temperature measurements. Monitoring the ocean's surface at such resolutions yields the ability to compute absolute 3-dimensional currents worldwide.

Details about model calibration and validation are provided in Appendix 2.

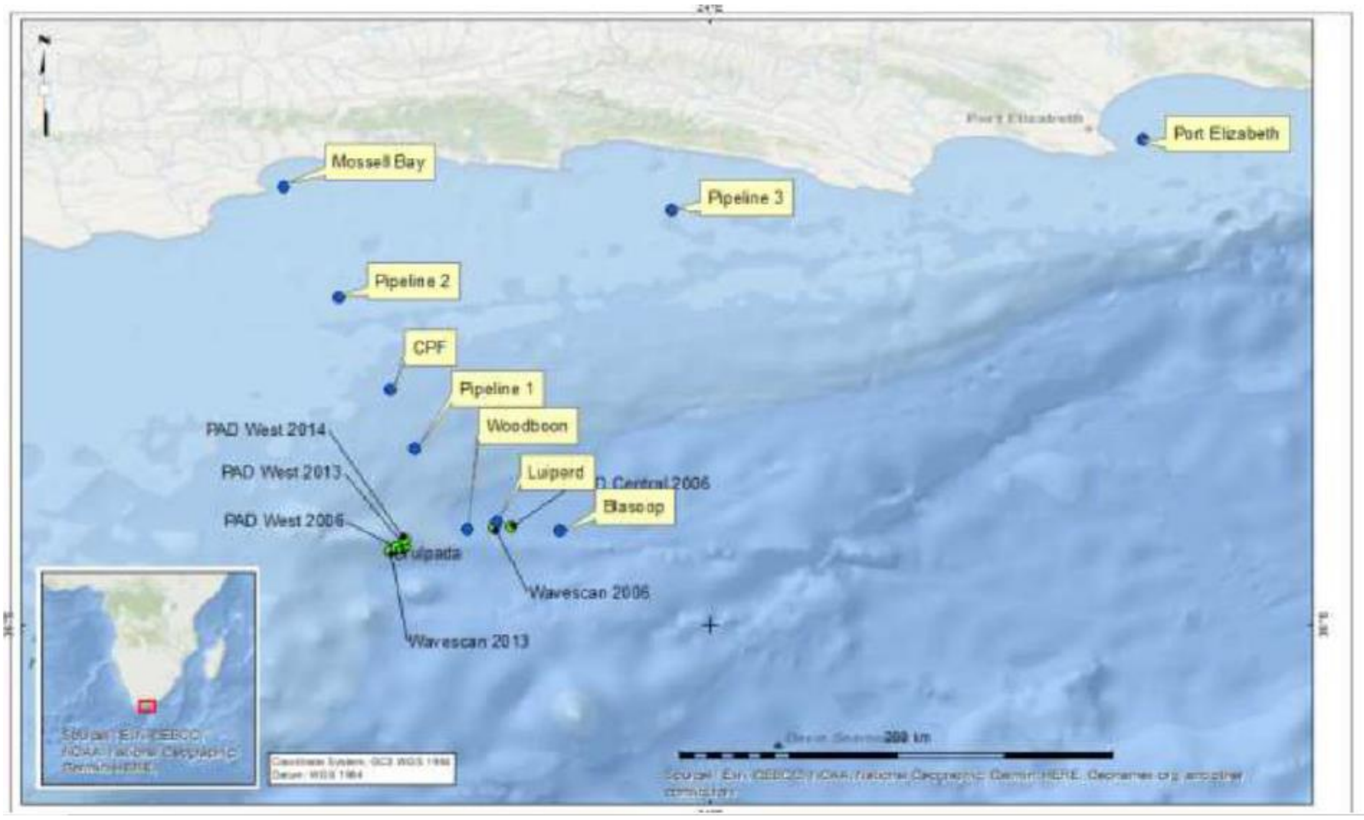
- Metocean model dataset selection

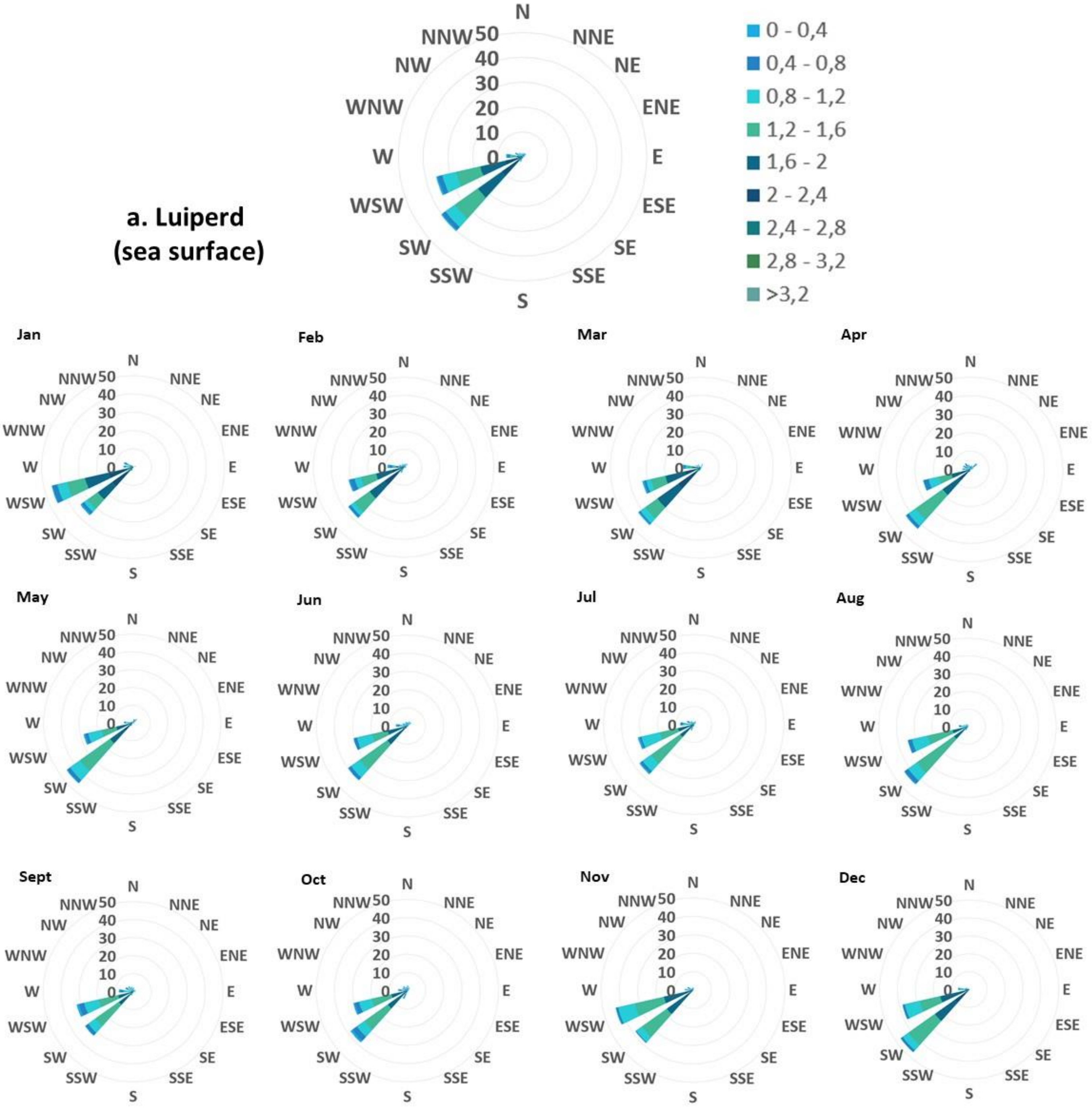
A great portion of the 11B/12B block lies on the pathway of the Agulhas Current, a fast and narrow western boundary current flowing along the eastern and southern coasts of South Africa. The core of the current is generally positioned across the block and is occasionally perturbed by shear edge eddies generated upstream south of Port Elizabeth (34° S) and or Natal pulse anomalies generated offshore Durban.

Current direction can change in response to change in winds and or progression of large eddies. The Agulhas Current does not present any seasonality as the anomalies impacting the current flow, in addition to weather, are sporadic and difficult to predict.

Current statistics from a 20 years dataset is presented in the figure below (all period and monthly statistics).

Surface current CMEMS3D has been computed for the period 1999 – 2018 (20 years) based on CMEMS3D. The Operational Mercator global ocean analysis and forecast system at 1/12 degree (resolved on 50 vertical levels form the surface to 5500m) updated daily.




a. Luiperd
(sea surface)
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
50
40
30
20
10
0
0 - 0,4
0,4 - 0,8
0,8 - 1,2
1,2 - 1,6
1,6 - 2
2 - 2,4
2,4 - 2,8
2,8 - 3,2
>3,2
Jan
Feb
Mar
Apr
May
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Sept
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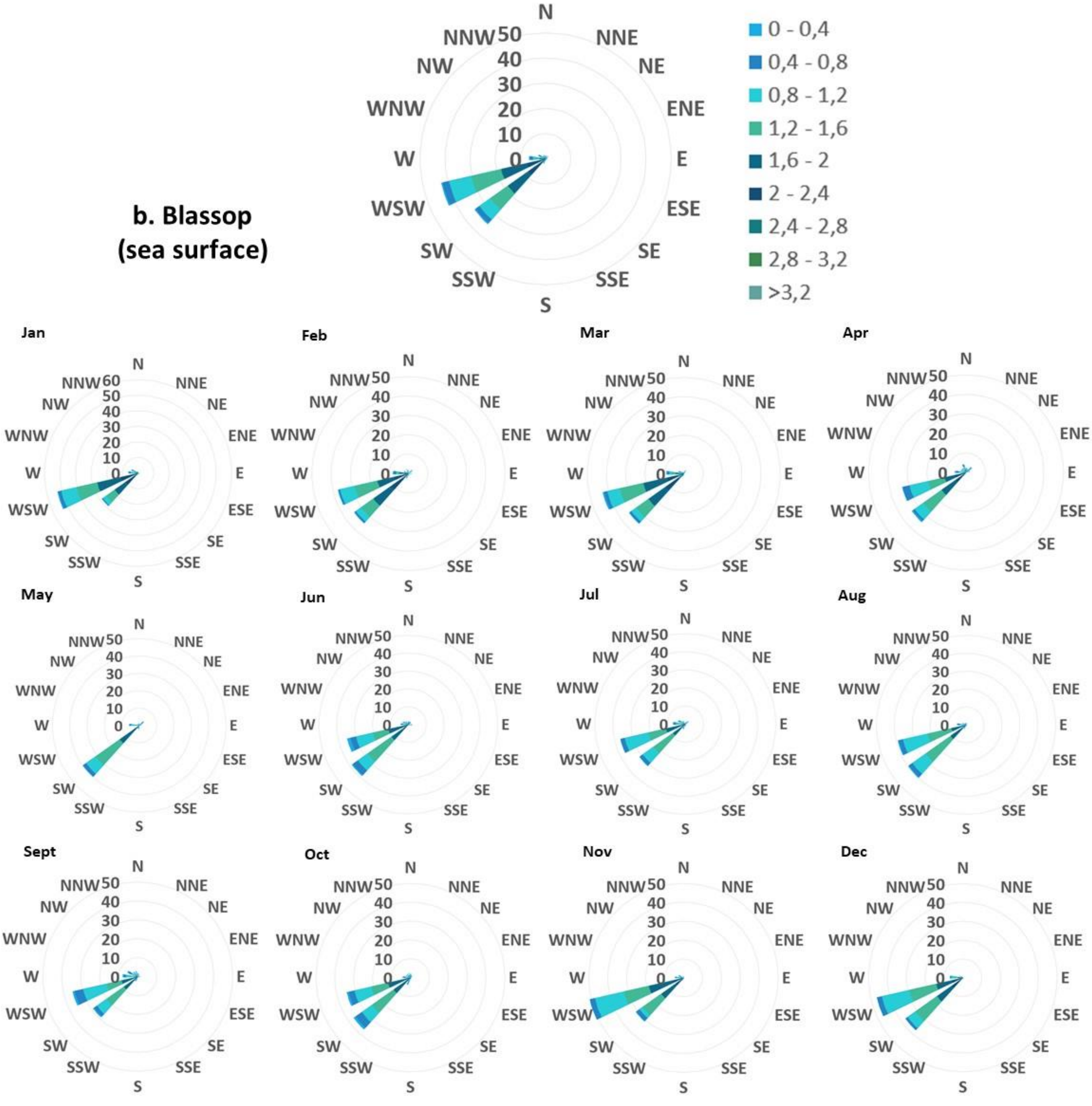
Nov
Dec


b. Blassop
(sea surface)
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
50
40
30
20
10
0
0 - 0,4
0,4 - 0,8
0,8 - 1,2
1,2 - 1,6
1,6 - 2
2 - 2,4
2,4 - 2,8
2,8 - 3,2
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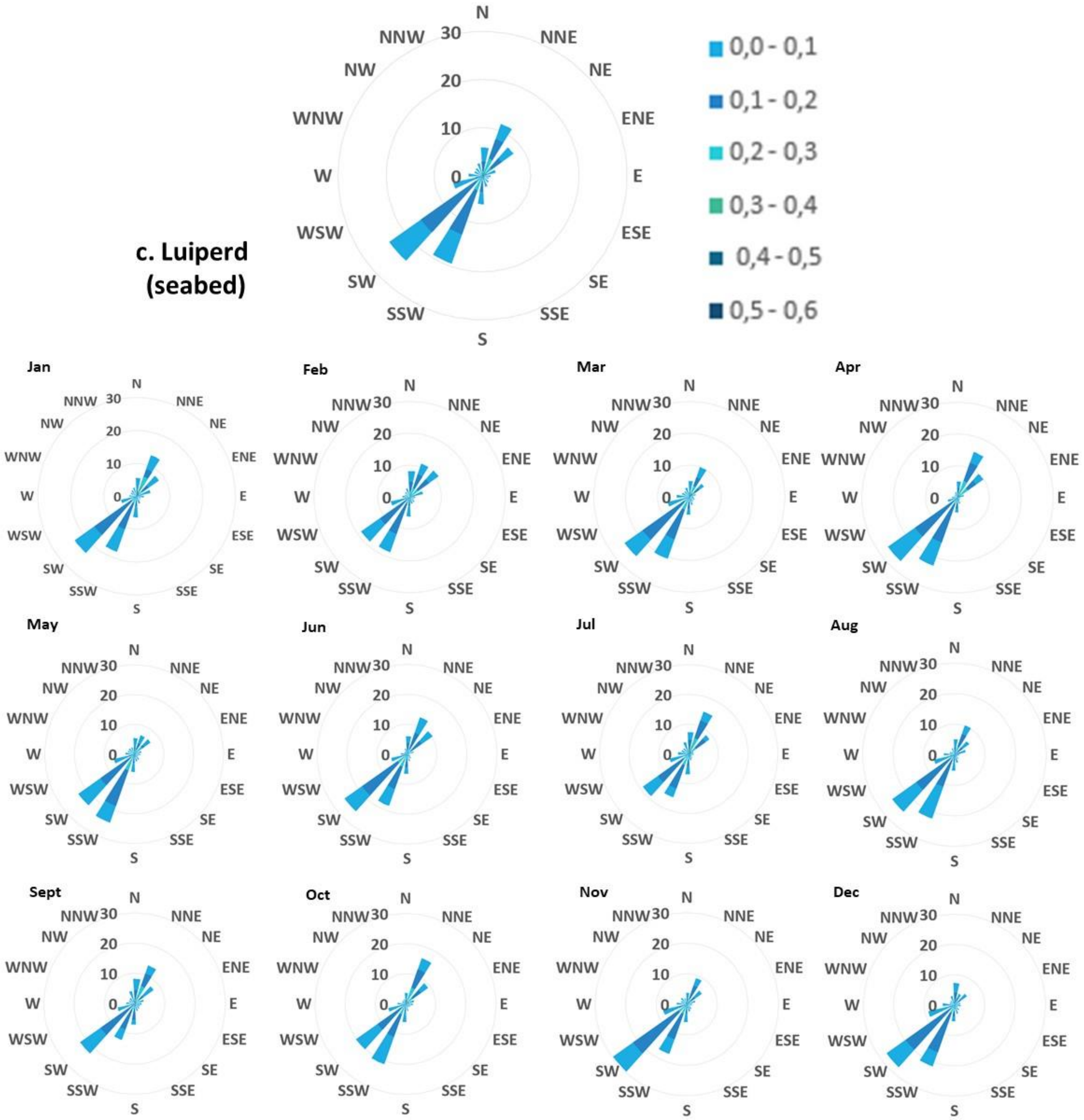
c. Luiperd
(seabed)
0,0 - 0,1
0,1 - 0,2
0,2 - 0,3
0,3 - 0,4
0,4 - 0,5
0,5 - 0,6
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
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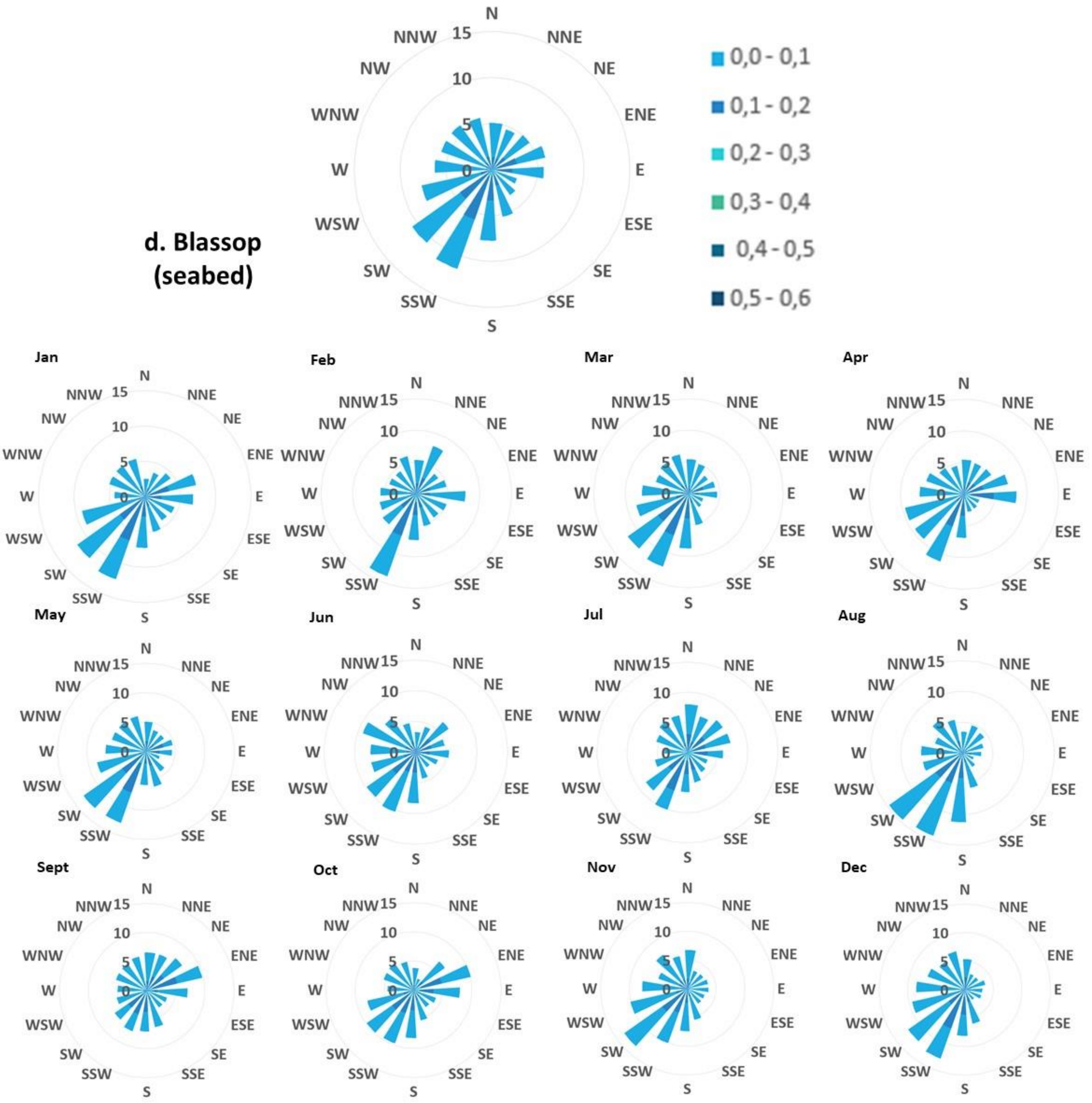


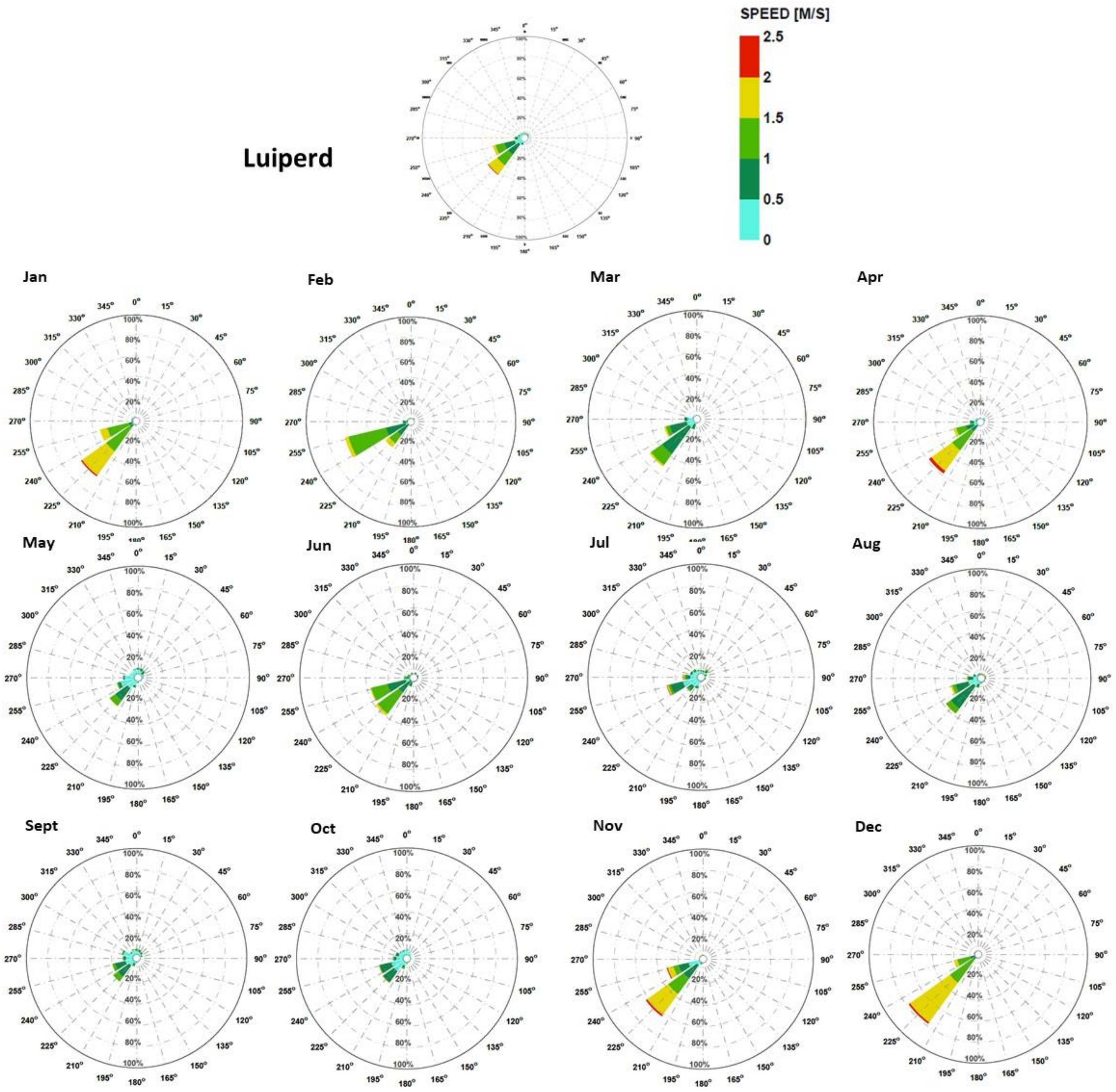
Figure 5: Annual and monthly current statistics in the Block (a. at sea surface at Luiperd; b. at sea surface at Blasoop; c. at seabed at Luiperd; d. at seabed at Blasoop) for the period 1999-2018 (ACTIMAR)

The data used are based on 12 months dataset (1st of January 2012 – 31st of December 2012) which comprises 3D currents from the continuous current hindcast at each grid point:

- 3D currents
    - NetCDF format (OSCAR compatible)

- 12 months of data (1st of January 2012 – 31st of December 2012)
- Spatial resolution at least 1/32
- Vertical resolution: 32 layers
- Time step: 3 hours

Currents used for the modelling study are shown in Figures 6 and 7.



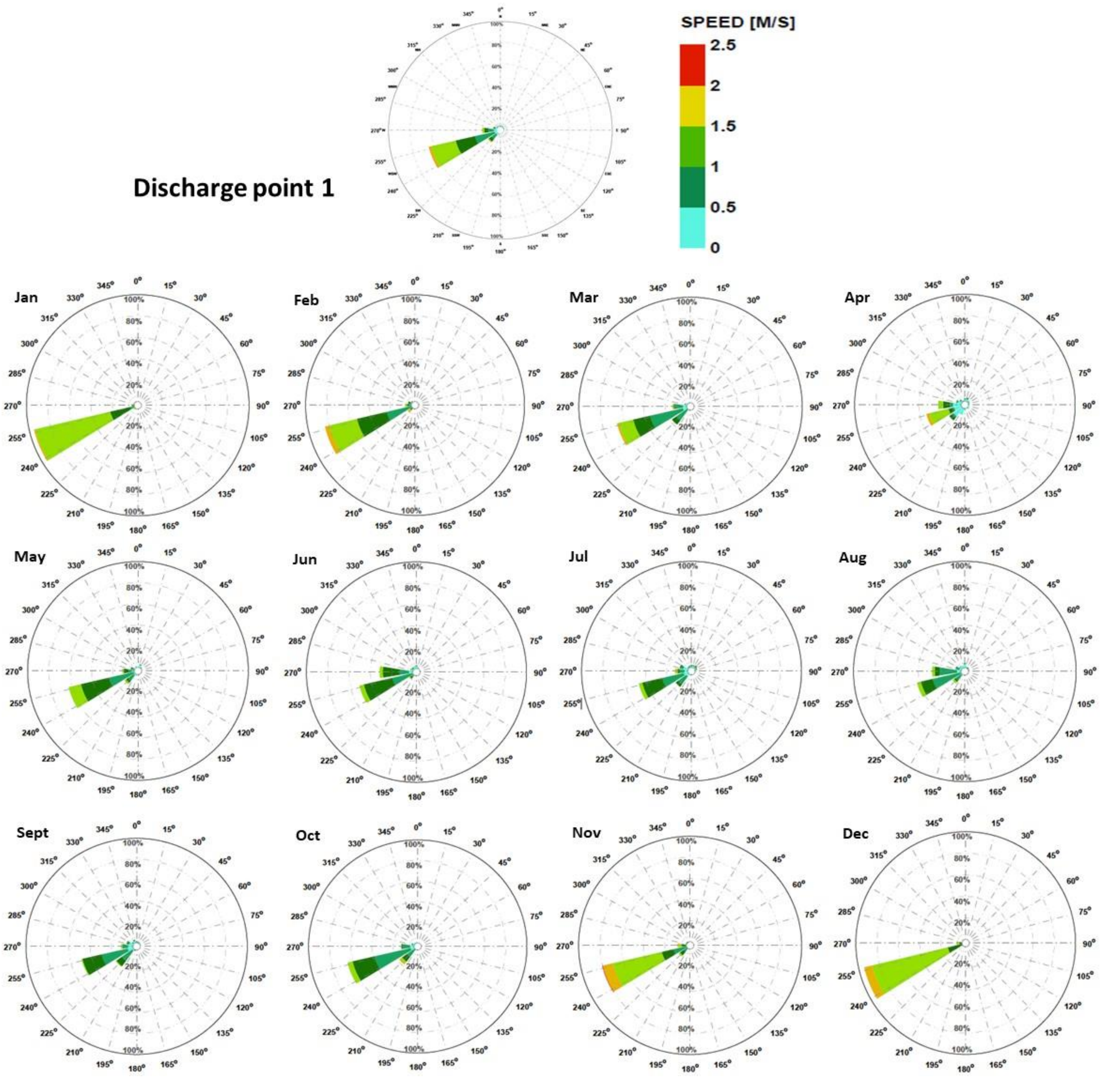
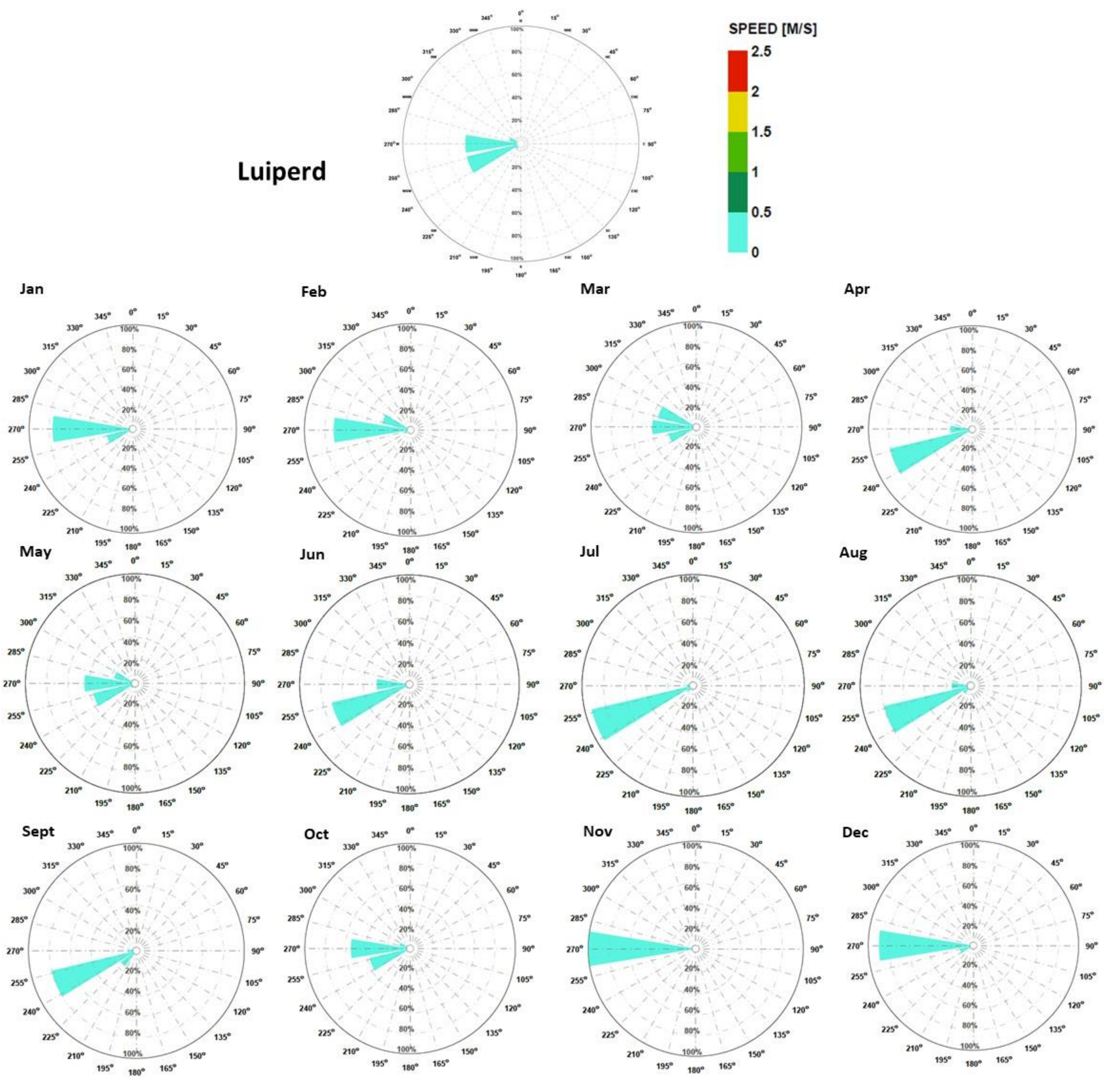


Figure 6: Annual and monthly current statistics in the Block (a. at sea surface at Luiperd; b. at sea surface at discharge point 1) for the period 2012 (SATOCEAN)

The current roses above compare the annual surface current statistics at Luiperd and discharge point 1 for the 2012 year and the entire period of the hindcast model (1999 to 2018). Both roses show a very good correlation of current speed and direction. Predominant directions are toward SW to WSW at Luiperd for the 2012 year as well as the 20 years period hindcast model with occurrence >70% in both cases and towards WSW to SW further to the east. Shear edge eddies observed during 2012 also impacted the current flow with a recirculation of the surface current toward the northward sectors. However very low occurrence <2% of this recirculation toward shoreline have been detected during 2012 coherent with a longer hindcast period and is generally associated with sporadic progressions of eddy anomalies and or current meanders.


Luiperd
SPEED [M/S]
2.5
2
1.5
1
0.5
0
Jan
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Jul
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Dec

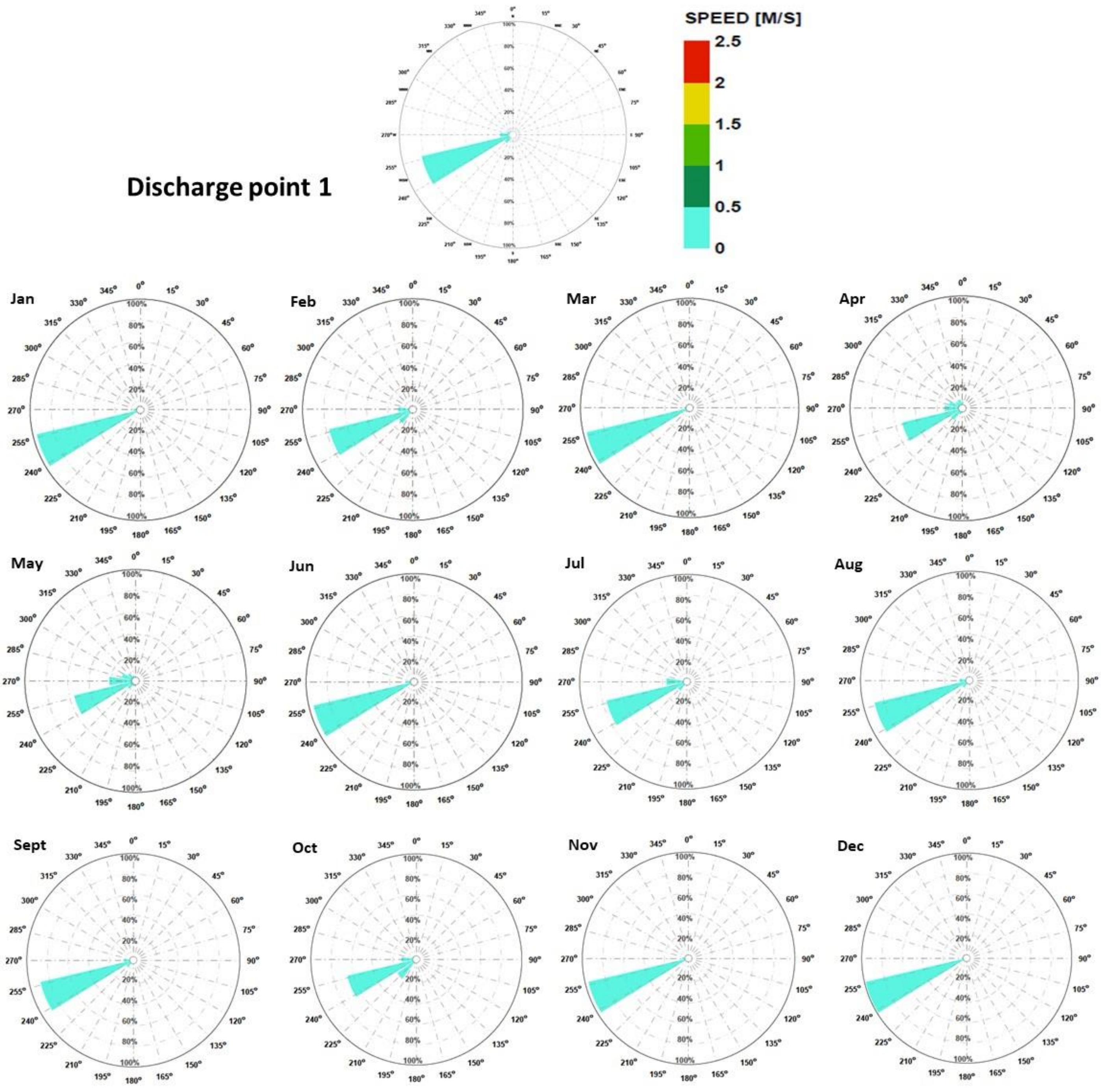


Figure 7: Annual and monthly current statistics in the Block (a. at seabed at Luiperd; b. at seabed at discharge point 1) for the period 2012 (SATOCEAN)

The current roses above compare the annual seabed current statistics at Luiperd and discharge point 1 for the 2012 year and the entire period of the hindcast model (1999 to 2018). Current at seabed for the year 2012 at Luiperd shows a predominate direction toward West/SW (85% occurrence) while directions for the hindcast model are oriented along the zonal axis across the southwestern (55% occurrence) and northeastern (25% occurrence) sectors. Current speed remains for each case very low below 0.5 $m.s^{-1}$. Current at seabed for the year 2012 further to the

East in the Block (Blasoop and discharge point 1) shows a predominate direction toward SW (90% occurrence) while directions for the hindcast model are spraid towards all the directions with one predominate direction to the SW (20% occurrence).

The Figure 8 presents the current vectors at seabed and sea surface used in the model for January 1st 2012.

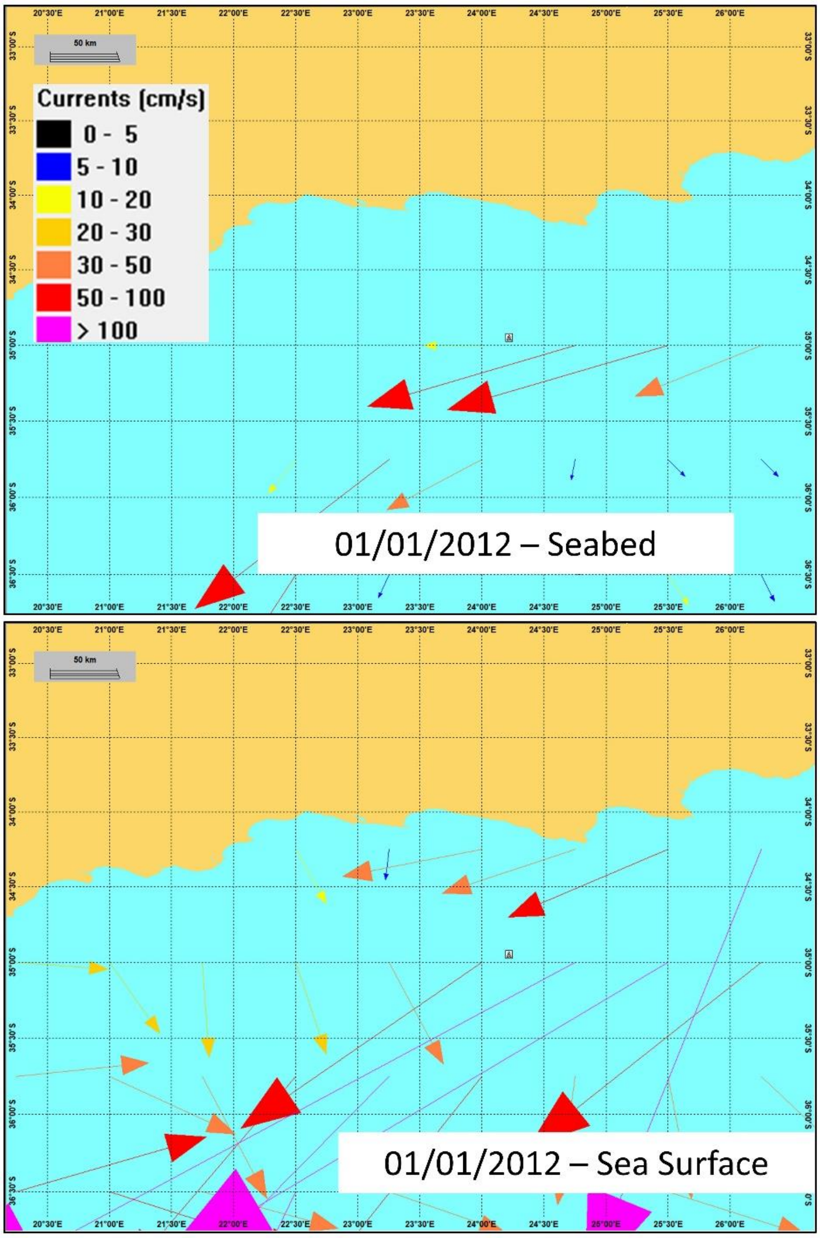


Figure 8: Example of currents vector used for the study for the Seabed and the Sea Surface

Wind has been extracted from ERA-interim hindcast model which is a global atmospheric reanalysis available from 1950 to present (70 years) and continuously updated in real time. The spatial resolution of the data set is approximately 31 km on 137 vertical levels from the surface up to 0.01 hPa. The ERA-5 data assimilation and forecast produces hourly analysis fields.

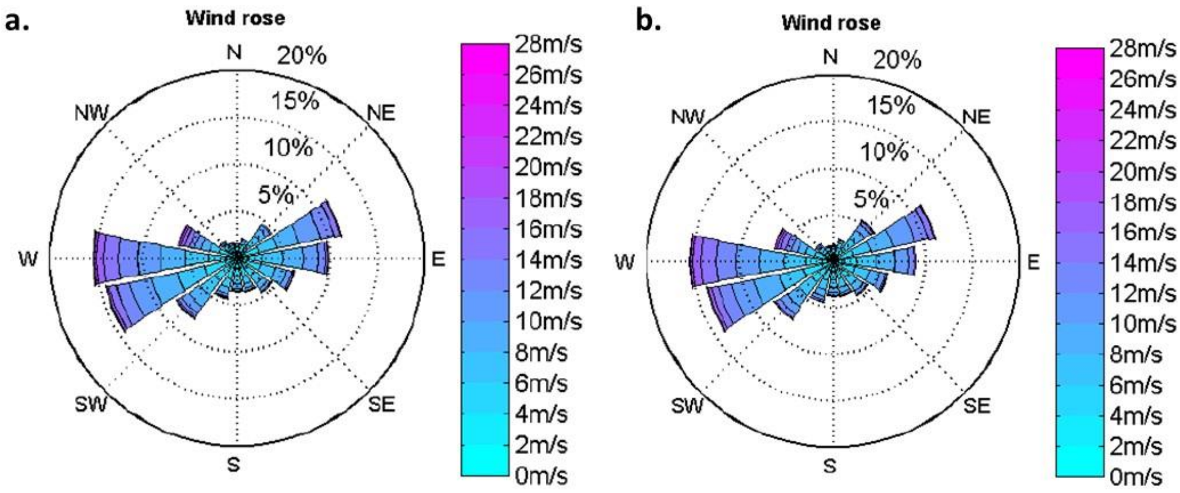


Figure 9: Wind statistics in the Block for the period 1950 – 2019 (a. at Luiperd; b. at Blasoop) (ACTIMAR)

The data used are based on 12 months dataset (1st of January 2012 – 31st of December 2012) which comprises 2D winds (associated to the 3D currents) from the continuous current hindcast at each grid point:

- Associated 2D Winds
    - NetCDF format (OSCAR compatible)
    - 12 months of data (1st of January 2012 – 31st of December 2012)
    - Time step: 3 hours.

Winds used for the modelling study are shown in Figure 10.

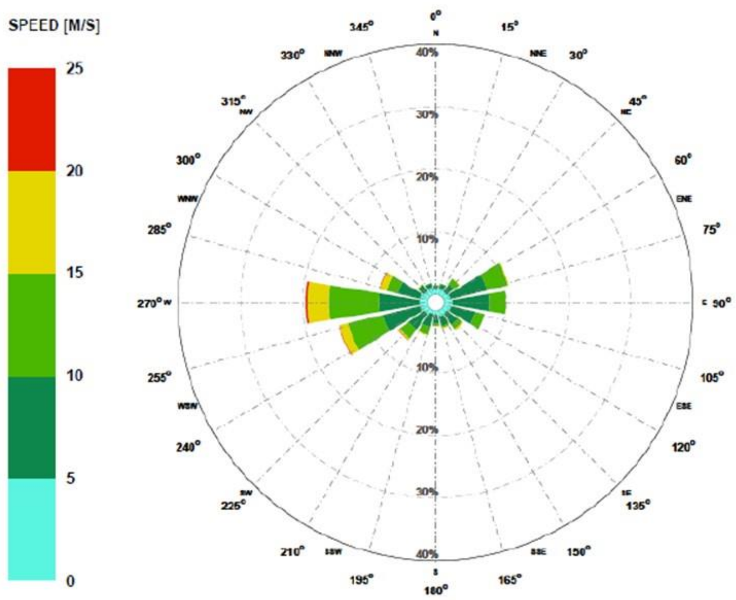


Figure 10: Wind annual statistics in the Block in 2012 at Luiperd (SATOCEAN)

The wind roses above compare the annual wind statistics at Luiperd for the year 2012 and the entire period of the hindcast model (1950 to 2019) [3]. Roses show a very good correlation in terms of frequency of occurrence for wind speed and direction. Both show predominant wind directions between SW and WNW sectors (45% occurrence), and in a lesser extent between NE and ESE sectors (30% occurrence). Lower frequency of occurrence below 10% is observed in both cases for winds flowing from the Southern sector towards the shorelines.

As a conclusion, both datasets show a good correlation for winds and surface currents at Luiperd and further to the East in the block while it is less the case for the seabed current. For drill cuttings modeling the year 2012 is a fair representation of the long-term variability over the 11B/12B block. The currents are predominantly driven by the Agulhas Current flowing mainly towards SW although occasionally disturbed by eddy activities inducing recirculation towards the shorelines. Predominant wind directions are oriented along the zonal axis (across the western and eastern sectors). However low occurrences of wind directions directed towards shorelines can be observe in both datasets. For the modelling of the riserless section driven by seabed current, caution should be taken using short periods modeling. Model calibration at the deeper layers remain always more challenging due to the lack of measurements and are generally less reliable than at the surface. However, cuttings deposits are expected close to the discharge point.

- Bathymetry

The bathymetry of the MEMW software was used to do the modelling. The bathymetry of the grid used for the modelling study is shown in figure 11.

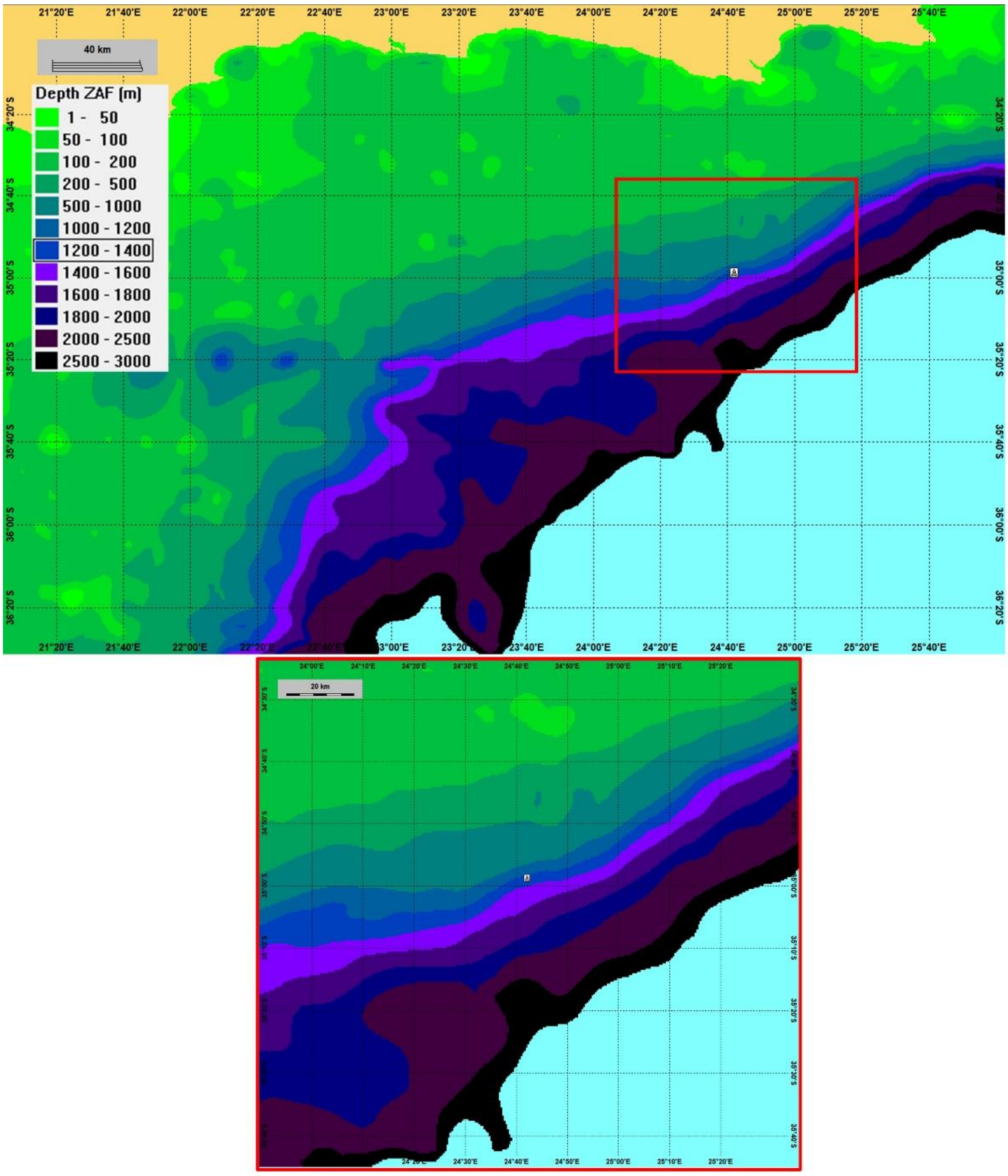


Figure 11: Bathymetry used within the model

2.2.6 Local conditions (provided by TEPSA)

In the model the following environmental data were used both for the discharge itself and for the receiving environment:

	January	March	June	September
UPPER & Lower WATER COLUMN TEMPERATURE (°C)	0m: 22.6; 100m: 15.8; 200m: 12.7; 500m: 9.7; 800m: 7.4; 1000m: 5.7; 1500m: 3.4; 1600m: 3.1	0m: 22.7; 100m: 15.5; 200m: 12.7; 500m: 8.6; 800m: 6.0; 1000m: 4.6; 1500m: 3.3; 1600m: 3.1	0m: 19.5; 100m: 16.7; 200m: 14.7; 500m: 9.7; 800m: 6.4; 1000m: 5.1; 1500m: 3.3; 1600m: 3.1	0m: 18.6; 100m: 14.3; 200m: 11.7; 500m: 7.7; 800m: 5.2; 1000m: 5.1; 1500m: 4.1; 1600m: 3.1
SALINITY (‰)	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8
AIR TEMPERATURE (°C)	21.5	21.2	17.6	16.9
OXYGEN CONTENT (mg/l)	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88
Discharge TEMPERATURE (°C)	42”: 15 26’’: 15 17.5’’: 11 12.25’’: 15 8.5’’: 15			
Median GRAIN SIZE (mm)	0.350			
SUSPENDED SEDIMENT (mg/l)	0			

The data were collected from previous ESIA dataset and bibliographic review.

Discharge temperature and salinity were calculated by the drilling team based on fluid program and reservoir information.

2.2.7 Scenario parameters

The releases characteristics and each phase information, depth, volumes and type of mud are presented in Table 7 and in Figure 12 for the base case scenario. Four scenarios were modelled for each discharge to account for metocean data variability (see 2.2.5).

Table 7: Release characteristics

Characteristics of release scenarios				
Geographical coordinates of the discharges (WGS 84)	Exploration discharge 1	Longitude	24° 42' 3,649"	E
		Latitude	34° 58' 49,765"	S
	Exploration discharge 2	Longitude	24° 13' 18,074"	E
		Latitude	34° 56' 56,043"	S
Diameter of release pipe			- 42'' - 26'' - 17.5'' - 12.25'' - 8.5''	
Start date			- Scenario 1: January 1st - Scenario 2: March 1st - Scenario 3: June 1st - Scenario 4: September 1st	
Drilling Duration (hours)			- 42'': 4.75 - 26'': 22.4 - 17.5'': 15.5 - 12.25'': 50.4 - 8.5'': 50.5 - Logging: 96 - P&A: 72	
Scenario duration (water column)			- Scenario 1: 45 days - Scenario 2: 45 days - Scenario 3: 45 days - Scenario 4: 45 days - Scenario 5: 62 days	
Scenario duration (sediments)			- Scenario 1: 45 days + 10years - Scenario 2: 45 days + 10years - Scenario 3: 45 days + 10years - Scenario 4: 45 days + 10years - Scenario 5: 62 days + 10 years	

For the additional case with longer sections to be drilled with a riser (17.5'', 12.25'', 8.5'' and logging and P&A), same parameters were used except discharge duration which are longer. Additional case was only run for the identified worst-case results obtained for the base case.

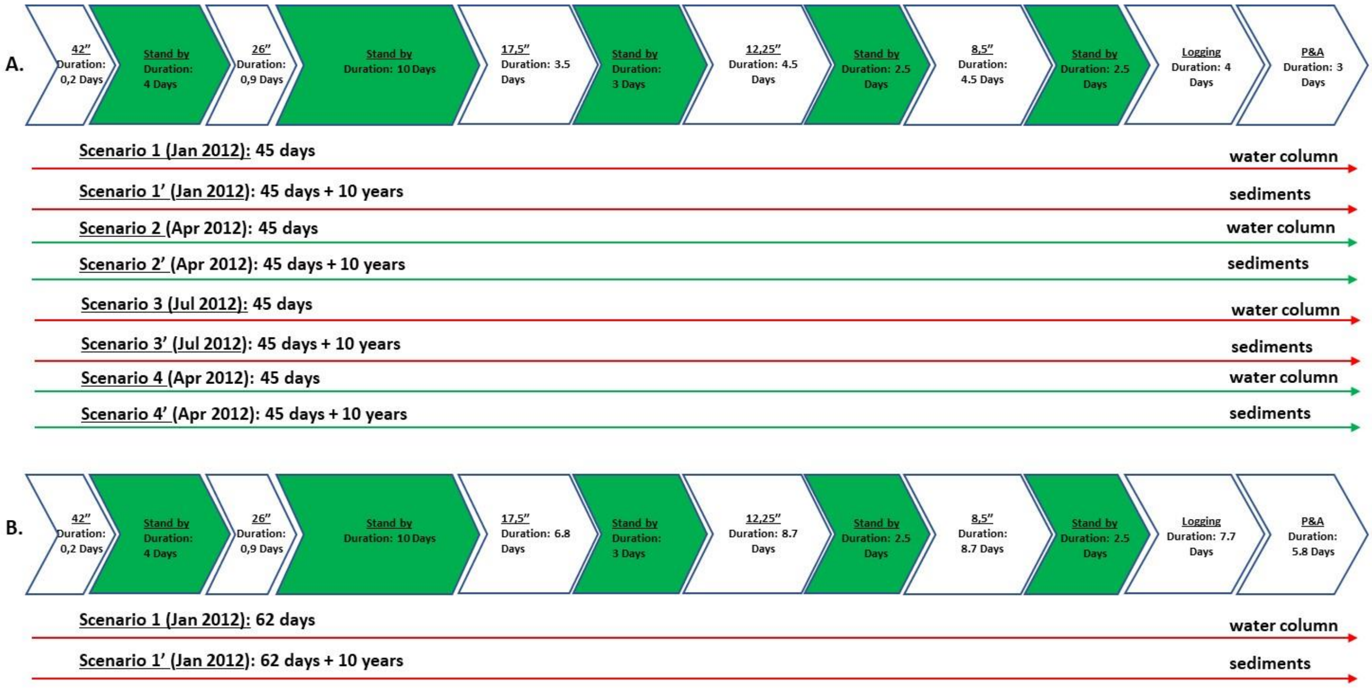


Figure 12: Drilling operations sequence for the base case (A) and for optional case (B)

2.2.8 Model parameters

All the parameters used for the modelling study are presented in Table 8.

Table 8: Model parameters used for the study

Parameters	Sediments					Water column				
Bathymetry	MEMW world bathymetry					MEMW world bathymetry				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Grid size	20 km E x 15 km N	20 km E x 15 km N	20 km E x 15 km N	20 km E x 15 km N	20 km E x 15 km N	55 km E x 35 km N	50 km E x 35 km N	40 km E x 40 km N	40 km E x 40 km N	40 km E x 40 km N
horizontal resolution (cell)	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m	100 m x 100 m
Vertical resolution (cell)	61 m	61 m	61 m	61 m	61 m	61 m	61 m	61 m	61 m	61 m
Number of model particles to be used for representing droplets or solid particles	15 000					15 000				
Number of model particles to be used for representing the dissolved contaminants	30 000					30 000				
Depth where the concentration will be calculated – Min depth (m)	0	0	0	0	0	0	0	0	0	0
Depth where the concentration will be calculated – Maxi depth (m)	1225	1225	1225	1225	1225	1225	1225	1225	1225	1225
Model duration	45days + 10 years	45days + 10 years	45days + 10 years	45 days + 10 years	62 days + 10 years	45 days	45 days	45 days	45 days	62 days
Time step	60 min					5 min				
Output interval	1 hours					1 hour				

All the sediment model parameters are described in the Table 9.

Table 9: Advanced sediment 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 restitute 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
Biorrigation coefficient	1 (default value)

2.2.9 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 take into account 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, in this case 20 layers of 80 m each one for 1600 m of water depth) which could be increased or reduced leading to a decrease in model resolution. Calculations are also done on vertical 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 8). This should also be considered for conclusions.
- The outcomes of the model depend on inputs data such as
  - Well design (section length, drilling rates …)
  - discharge coordinates
  - Metocean data format and resolution (winds, currents): hind cast data.
  - Bathymetry
  - Discharges (composition, quantity…). For this point, the diameter of the release corresponds to the hole diameter, which might be an over-simplification because the discharge occurs while

drilling with the drill bite inside the hole. In reality, 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 11B/12B block studied here) and because a deterministic approach has been used, no probability of occurrence will be 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.

In the model, the results can be displayed and presented in different ways depending on whether or not the smoothing (contouring) post treatment option is activated. Smoothing option might:

- be usefull to better visualizing contour concentrations, especially for a low resolution run, when maps are very pixellised;
- interpolate/average the concentration among a zone leading to a decrease in the absolute maximum value of all variables calculated. For instance, sediments deposit in the near vicinity of the discharge will be lower after the smoothing option has been activated.
- Smoothing may also impact the measured distance from the discharge point (±).

3. Results

3.1 Water column (3D modelling)

Once drilling fluids are released during and/or after drilling operations, a range of chemicals integrate the marine environment.

This first part presents all results regarding the dilution and the dispersion of the drilling fluids additives chemicals in the water column.

The results are derived from a PEC/PNEC analysis. The Predicted Environmental Concentration (PEC) is calculated by the model based on the drilling fluids composition, products characteristics and environmental conditions. This PEC is then compared to the Predicted No Effect Concentrations (PNEC) to characterize whether the anticipated concentration is expected to have a significant risk of impact on the habitat. A significant risk is obtained for PEC/PNEC ratio >1 and for a risk impacting ≥ 5% of the population of organisms.

The Environmental Impact Factor (EIF) 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 10,000m^2 (100m x 100m) where the environmental risks exceed 5% (i.e. where a significant risk to the ecosystem exists).

Based on experience in many DREAM simulations around the world (SINTEF), the absolute value of the EIF only represents an indicative figure whereas its relative value is pertinent as a management tool for the comparison of different release scenarios.

3.1.1 Base case (scenario 1 – 4)

3.1.1.1 Discharge n°2 - Scenario 1 (Start Time January 1st)

3.1.1.1.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk in the water column associated with the discharge of drilling operations, considering scenario 1, is presented in Figure 13, Figure 14, and Figure 15.

These figures show that the environmental risk is due to the discharge of 42'' and 26'' (riserless) sections for the seabed and to the discharge of the sections drilled with a risered (17 ½'', 12 ¼'' and 8 ½'') released sea surface for the upper water column.

These figures show that one part of the total risk is mainly limited to the seabed between 600 m and 700 m for the section drilled riser less (42" and 26"). The maximum risk calculated is up to 92% without smoothing option, very close to the discharge point (Figure 14 and Figure 15). A significant risk has been calculated in an area of up to 30 km to the West / South-West from the discharge point 5 days after the start of the discharge, corresponding to the maximum risk of the riserless sections (Figure 14 and Figure 15).

The risk associated with the discharges of the sections drilled with a riser is located on the first 80 m of the water column from the surface. For these sections drilled with a riser, a significant risk has been calculated to a distance up to 24 km away from the discharge point (between 0 and 80 m depth) to the South West. However, during the discharge at the sea surface, the risk is limited both in terms of time and space with only a few tiny patches with significant risk observed around the discharge and most of the time not significant. The maximum risk reached during the discharge of the riserless sections is 15% during the logging phase close to the discharge point (Figure 15).

The maximum risk reached during the entire operations is 92% very close to the discharge point without the smoothing option (Figure 14).

This area at risk is not centralized around the discharge point and is orientated along an axis starting from the discharge point towards West / South West during the discharge of the riser less sections, following the currents and spread from North East to South West for the discharges at the sea surface. This clearly shows the impact of water column currents on drill cuttings and mud dispersion in the water column.

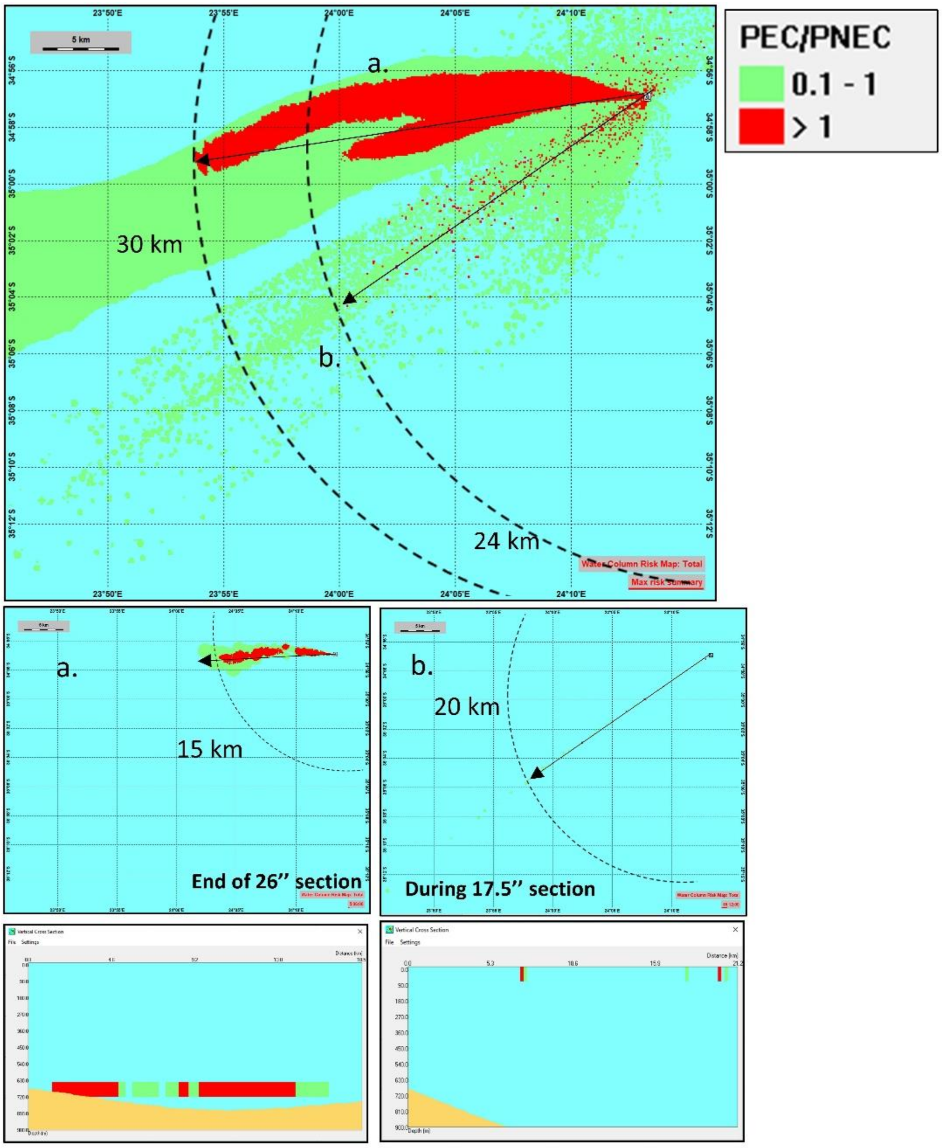


Figure 13: Maximum cumulative risk of drilling operations throughout the water column at any time for the scenario 1 (Start Time January 1st) - (a) example of the plume corresponding to the instantaneous risk at the end of the 26'' section (riserless) and vertical cross section; (b) example of the plume SW direction corresponding to the instantaneous risk during 17.5" section (risered) (discharge at the surface) and vertical cross section.

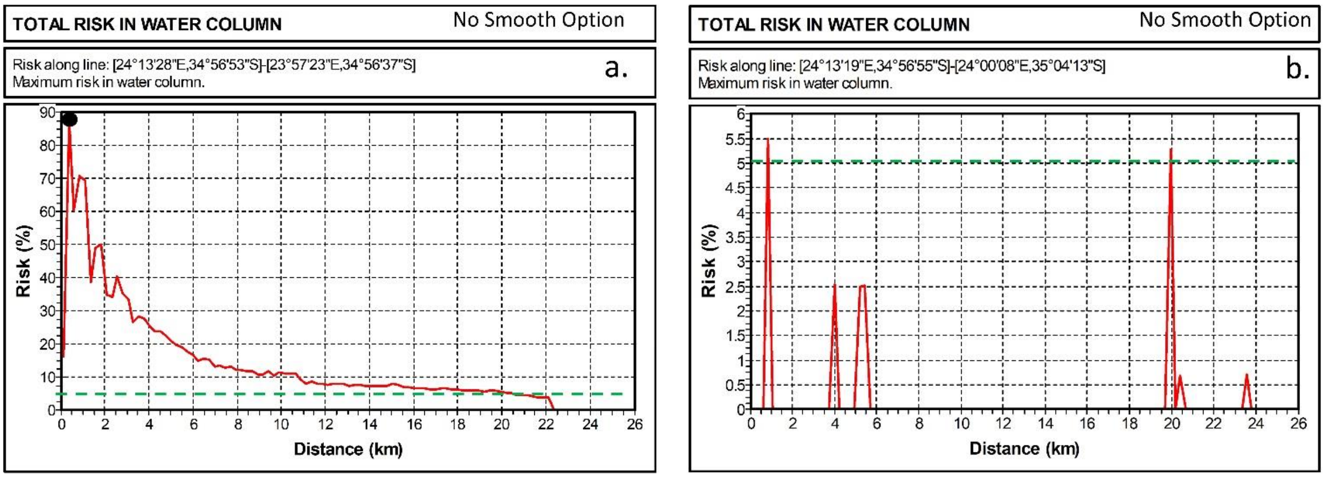


Figure 14: Example of instantaneous risk of drilling operations along a line for the scenario 1 (Start Time January 1st) a. during the discharge of the riserless section (26'') and b. during 17.5" section discharge (black dots symbolize the discharge point; the green dashed lines symbolize the 5% threshold)

Figure 15 clearly shows that the risk is not constant throughout the drilling operations close to the discharge point. Thus 6 periods are clearly observed during the operations (without the smoothing option):

- A first period corresponding to the discharge of the mud and the cuttings of the 42'' section at the very beginning of the operations leading to significant risk to the environment, with a value of 25%.
- A second period with a significant risk (up to 92%) during the discharge of the mud and the cuttings corresponding to the 26'' section, the maximum risk calculated among 6 series of discharge.
- A third period with a not significant risk (less than 5 %) calculated during the discharge of the mud and the cuttings corresponding to the 17.5'' section discharge (however tiny patches with significant risk were observed around the discharge)
- A fourth period corresponding to the discharge of the 12.25'' section with a maximum risk of less than 5 %
- A fifth period corresponding to the discharge of the 8.5'' section with a maximum risk of less than 5 % (however tiny patches with significant risk were observed around the discharge)
- A sixth period corresponding to the discharge during logging and P&A with a maximum risk of 15 %.

Figure 15 also shows for all the sections that the impact of the discharge lasts for all duration of drilling but stops for all sections right after the end of each specific operations. The maximum risk, in term of intensity, is observed at the seabed for the discharge of the 42" and 26" sections, drilled riserless. There is a risk in the water column until day 43, after the end of the P&A discharge.

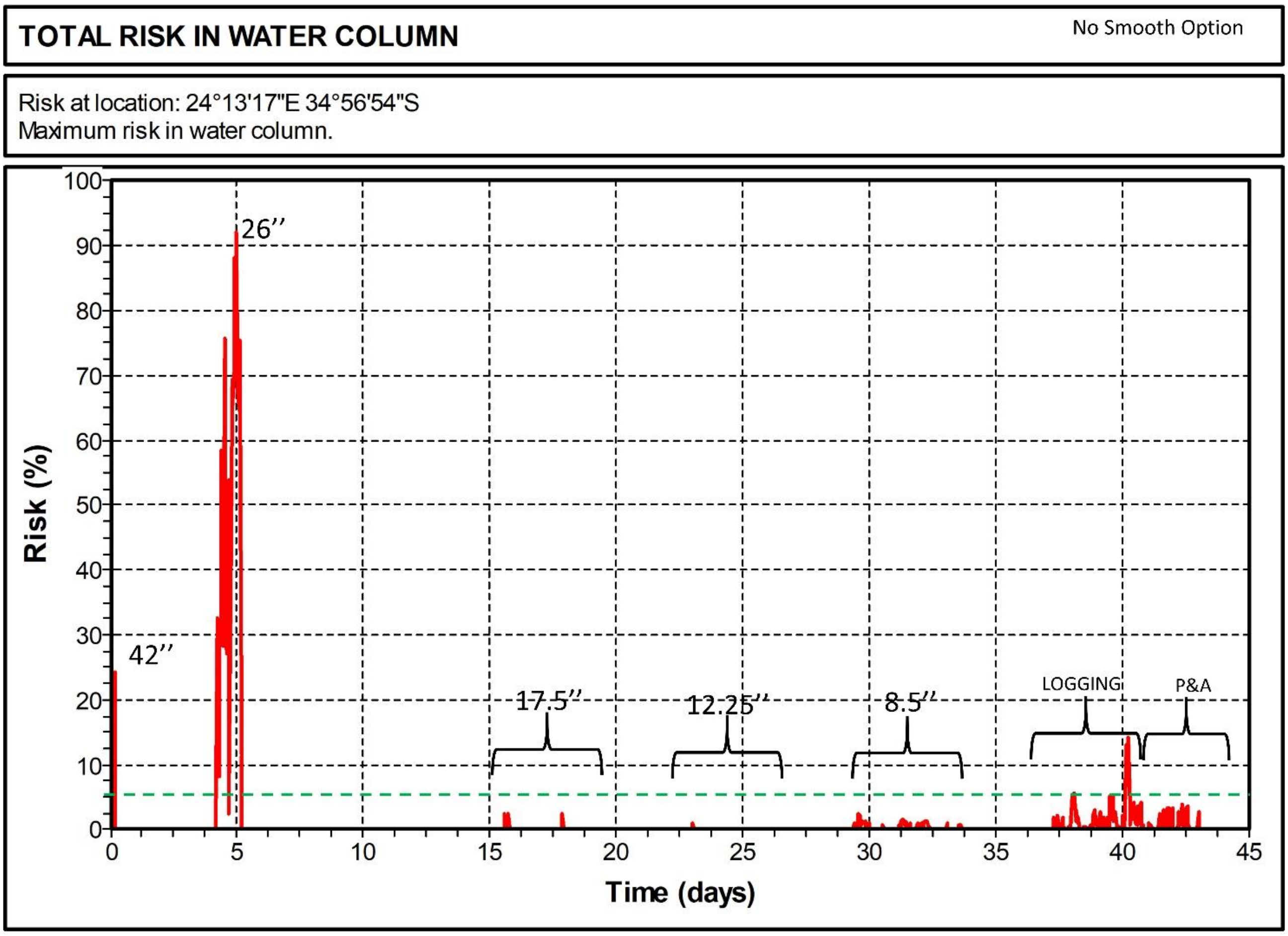


Figure 15: Maximum risk of drilling operations close to the discharge point over the time for the scenario 1 (the green dashed line symbolizes the 5% threshold) (Start Time January 1st)

Figure 16 shows the main contributors over the time for the different sections. In this case, the particulates compounds released (barite) contribute the most to the total environmental risk.

The Barite (component A and B) used in the WBM Pad Mud of the 42" and 26" sections is the main contributor to the total environmental risk to the water column, representing 90% of the total risk.

The hydrochloric acid present in the Clayseal Plus (corresponding to the CLAYSEAL PLUS_B in the Figure) is the main contributor to the total risk in the water column during the discharge of the sections drilled with a riser, contributing to 1% of the total risk.

These results will be further discussed in the following sections.

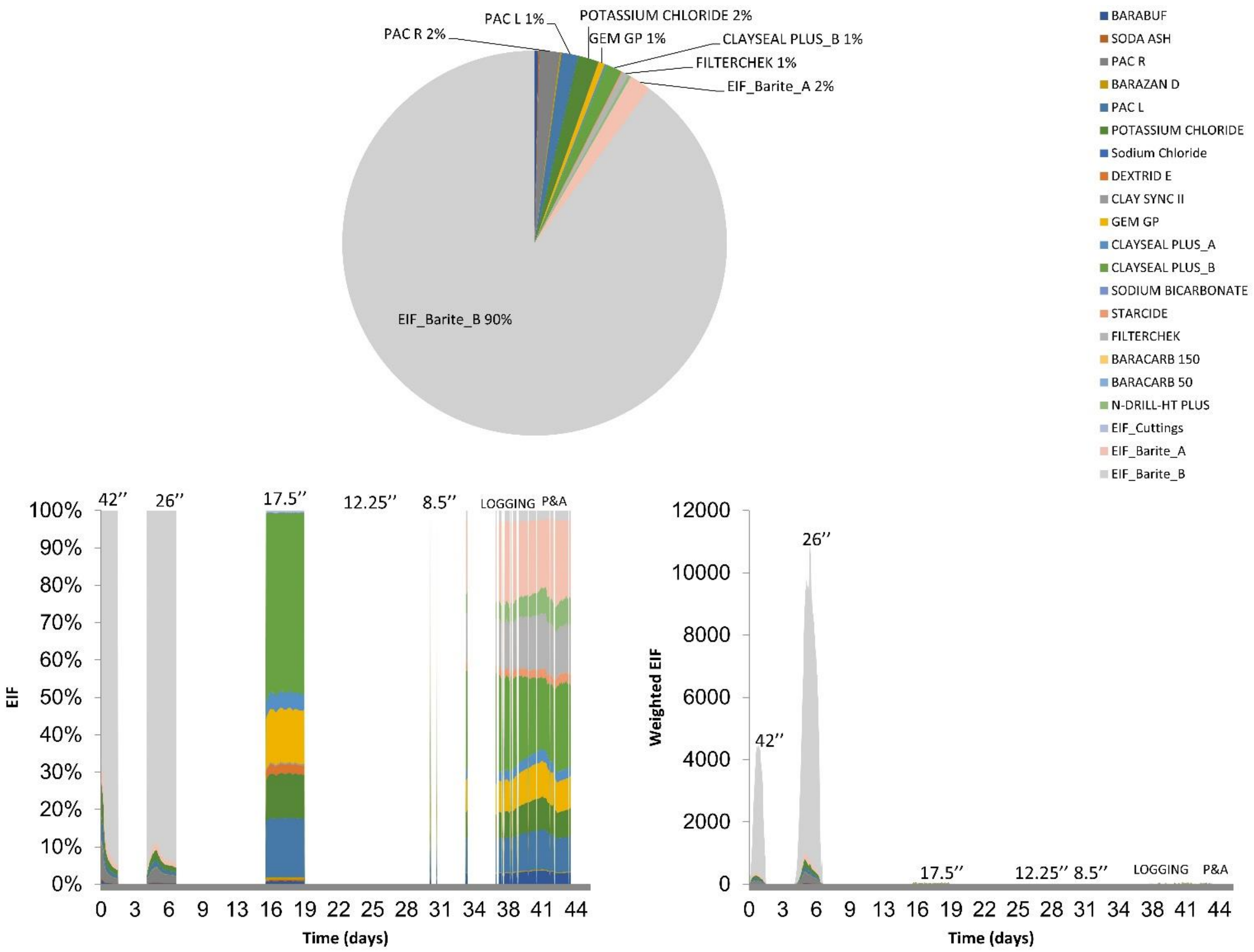


Figure 16: Main contributors to the risk of drilling operations in the water column for the scenario 1 and main contributors to the risk over the time (Start January 1st)

3.1.1.1.2 Discharge concentrations

Figure 17 and Figure 18 show the concentrations of the total discharge and of the main contributors to the environmental risk in the plume around the discharge point (including cuttings and chemicals).

During the discharge of all the sections, the maximum concentrations of total discharge were as described below (without the smoothing option):

- 42” section: up to 14 ppm (cuttings + chemicals)
- 26’’ section: up to 31 ppm (cuttings + chemicals)
- 17.5” section: up to 0.57 ppm (cuttings + chemicals)
- 12.25” section: up to 0.33 ppm (cuttings + chemicals)
- 8.5’’ section: up to 0.26 ppm (cuttings + chemicals)
- Logging and P&A: up to 0.72 ppm (chemicals only)

Figure 17 also shows that the highest contaminant concentrations are observed at the seabed (maximum 100 m above seabed) for the discharge of the 42" and 26" sections, mainly due to the presence of Barite. The Barite is the main contributor of the risk due to the high amounts released at sea during the discharge of the riserless sections.

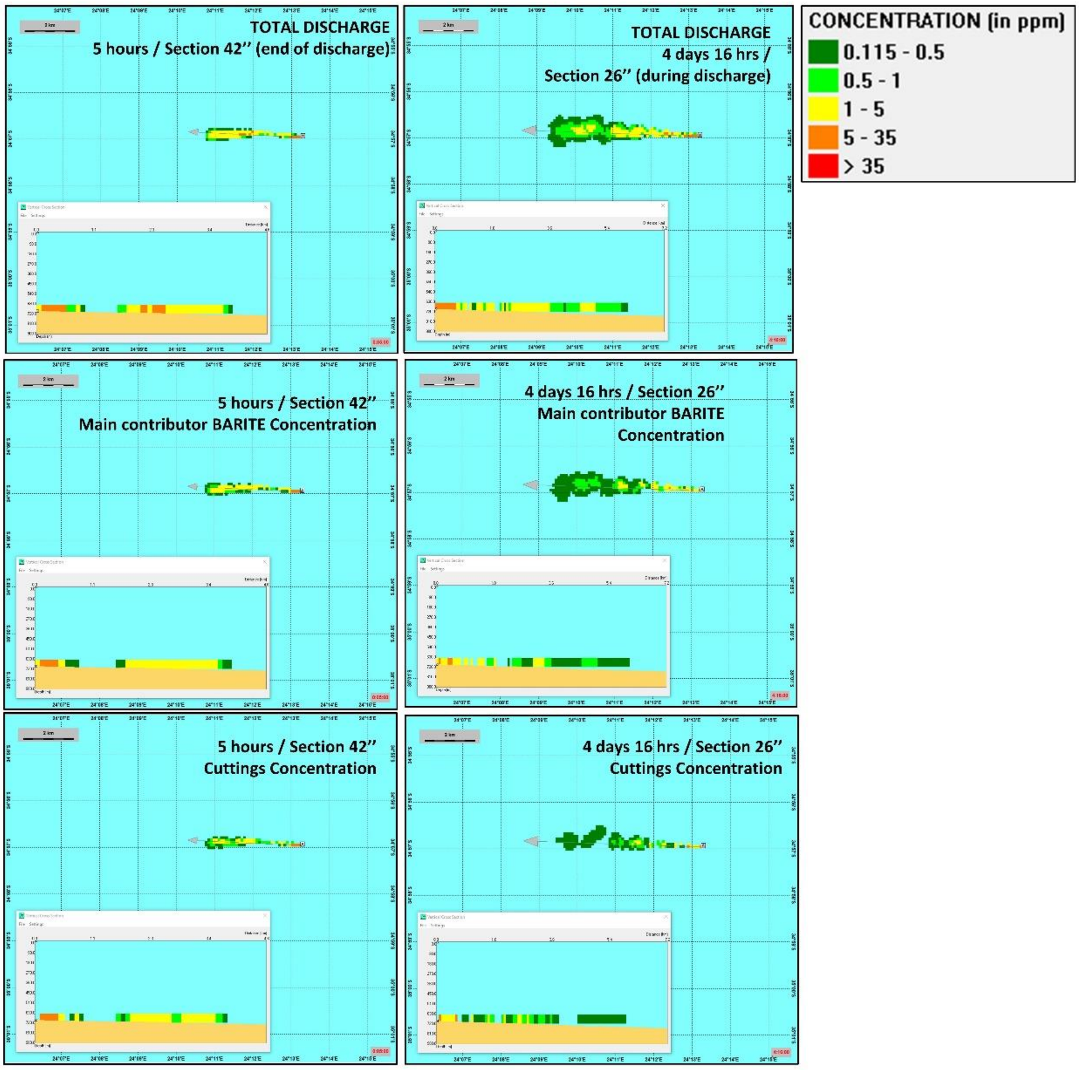


Figure 17: Instantaneous concentrations of total discharge, main contributor and cuttings at one time at the end of drilling operations of the 42" and 26" sections (scenario 1)

Figure 18 shows the concentration of the Clayseal Plus_B in the water column during the discharge of the 17.5" and 12.25" sections.

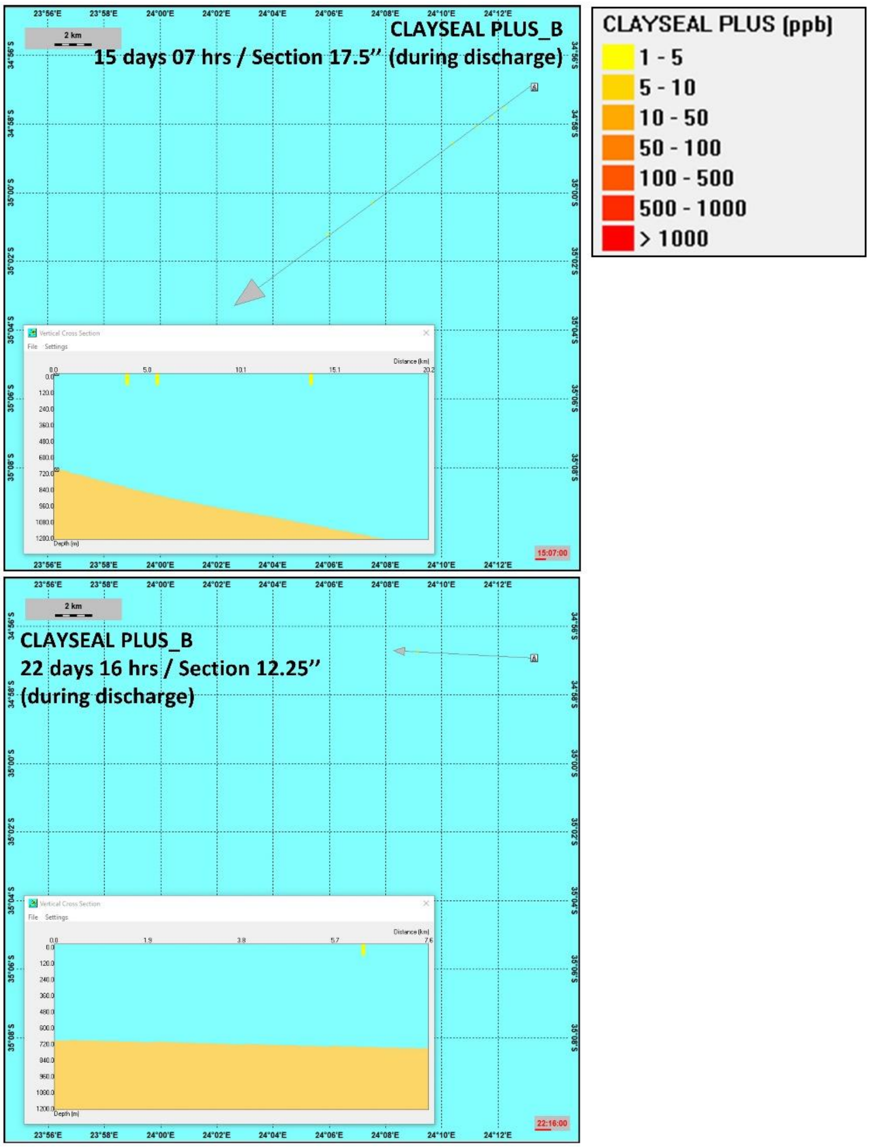


Figure 18: Instantaneous concentrations of Clayseal Plus_B (hydrochloric Acid 10%) above the PNEC (3.25 ppb) during the discharges of the 17.5" and 12.25" sections (scenario 1)

3.1.1.2 Discharge n°2 - Scenario 2 (Start Time March 1st)

3.1.1.2.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk in the water column associated with the discharge of drilling operations, considering scenario 2, is presented in Figure 19, Figure 20 and Figure 21.

These figures show that the environmental risk is mainly due to the discharge of 42'' and 26'' sections for the seabed and to the discharge of the sections drilled with a riser (17 ½'', 12 ¼'' and 8 ½'') released 1 m below sea surface for the upper water column.

These figures show that one part of the total risk is mainly limited to the seabed between 600 m and 700 m for the section drilled riser less (42" and 26"). The maximum risk calculated is up to 80% without smoothing option, very close to the discharge point (Figure 20 and Figure 21).

A significant risk has been calculated in an area of up to 15 km to the West from the discharge point 5 days after the start of the discharge, corresponding to the maximum risk of the riserless sections (Figure 19).

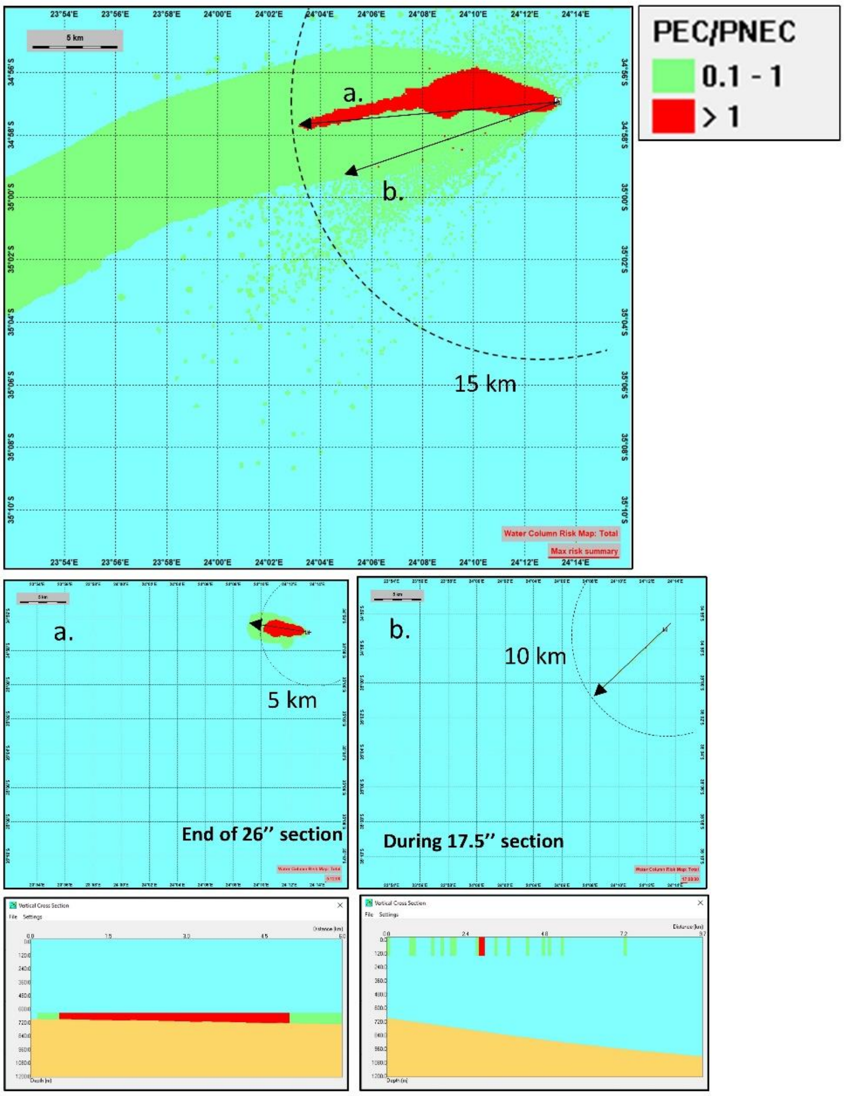


Figure 19: Maximum cumulative risk of drilling operations throughout the water column at any time for the scenario 2 (Start Time March 1st) - (a) example of the plume corresponding to the instantaneous risk at the end of the 26'' section (riserless) and vertical cross section; (b) example of the plume SW direction corresponding to the instantaneous risk during 17.5" section (discharge at the surface) and vertical cross section.

The risk associated with the discharges of the sections drilled with a riser is located on the first 100 m of the water column from the surface. For those sections drilled with a riser, a significant risk has been calculated to a distance up to 10 km away from the discharge point (between 0 and 100 m depth) to the South West (Figure 19b). However, during the discharge at the sea surface, the risk is limited both in terms of time and space with only a few tiny patches with significant risk observed around the discharge. The maximum risk reached during the discharge at the sea surface is always between 5 and 10% and most of the time not significant (Figure 20 and Figure 21).

However, during the discharge at the sea surface, the risk is limited both in term of time and space with tiny patches. The maximum risk reached during the discharge at the sea surface is always between 5 and 10% and most of the time not significant.

The maximum risk reached during the entire operations is 80% very close to the discharge point without the smoothing option (Figure 21).

This area at risk is not centralized around the discharge point and is orientated along an axis starting from the discharge point towards West during the discharge of the riser less sections, following the currents and spread to South West for the discharges at the sea surface. This clearly shows the impact of water column currents on drill cuttings and mud dispersion in the water column.

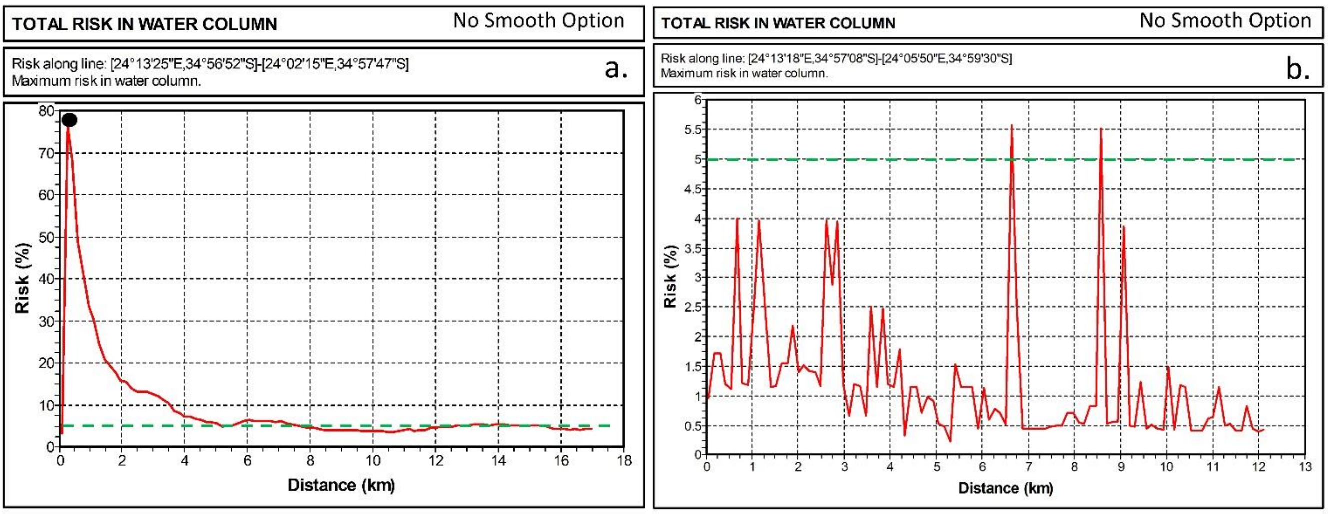


Figure 20: Example of instantaneous risk of drilling operations along a line for the scenario 2 (Start Time March 1st) a. during the discharge of the riserless section (26'') and b. during 17.5" discharge (black dots symbolize the discharge point, the green dashed lines symbolize the 5% threshold)

Figure 21 clearly shows that the risk is not constant throughout the drilling operation. Thus, 6 periods are clearly observed during the operations (with the smoothing option):

- A first period corresponding to the discharge of the mud and the cuttings of the 42'' section at the very beginning of the operations leading to significant risk to the environment with a value of 33%.
- A second period with a maximum risk (up to 80%) during the discharge of the mud and the cuttings corresponding to the 26'' section.
- A third period with a not significant risk (less than 5 %) calculated during the discharge of the mud and the cuttings corresponding to the 17.5'' section discharge (however tiny patches with significant risk were observed around the discharge)
- A fourth period corresponding to the discharge of the 12.25'' section with a maximum risk of less than 5 %
- A fifth period corresponding to the discharge of the 8.5'' section with a maximum risk of less than 5 %
- A sixth period corresponding to the discharge during logging and P&A with a maximum risk of less than 5 % (however tiny patches with significant risk were observed around the discharge).

Figure 21 also shows for all the sections that the impact of the discharge lasts for the duration of drilling but stops for all sections right after the end of each specific operations. The maximum risk in term of intensity is observed in the water column for the discharge of the 42" and 26" sections, drilled riserless. There is a risk in the water column until day 43, after the end of the discharge of the P&A discharge but few kilometers form the discharge point (not visible on the graphic representing the risk very close to the discharge point).

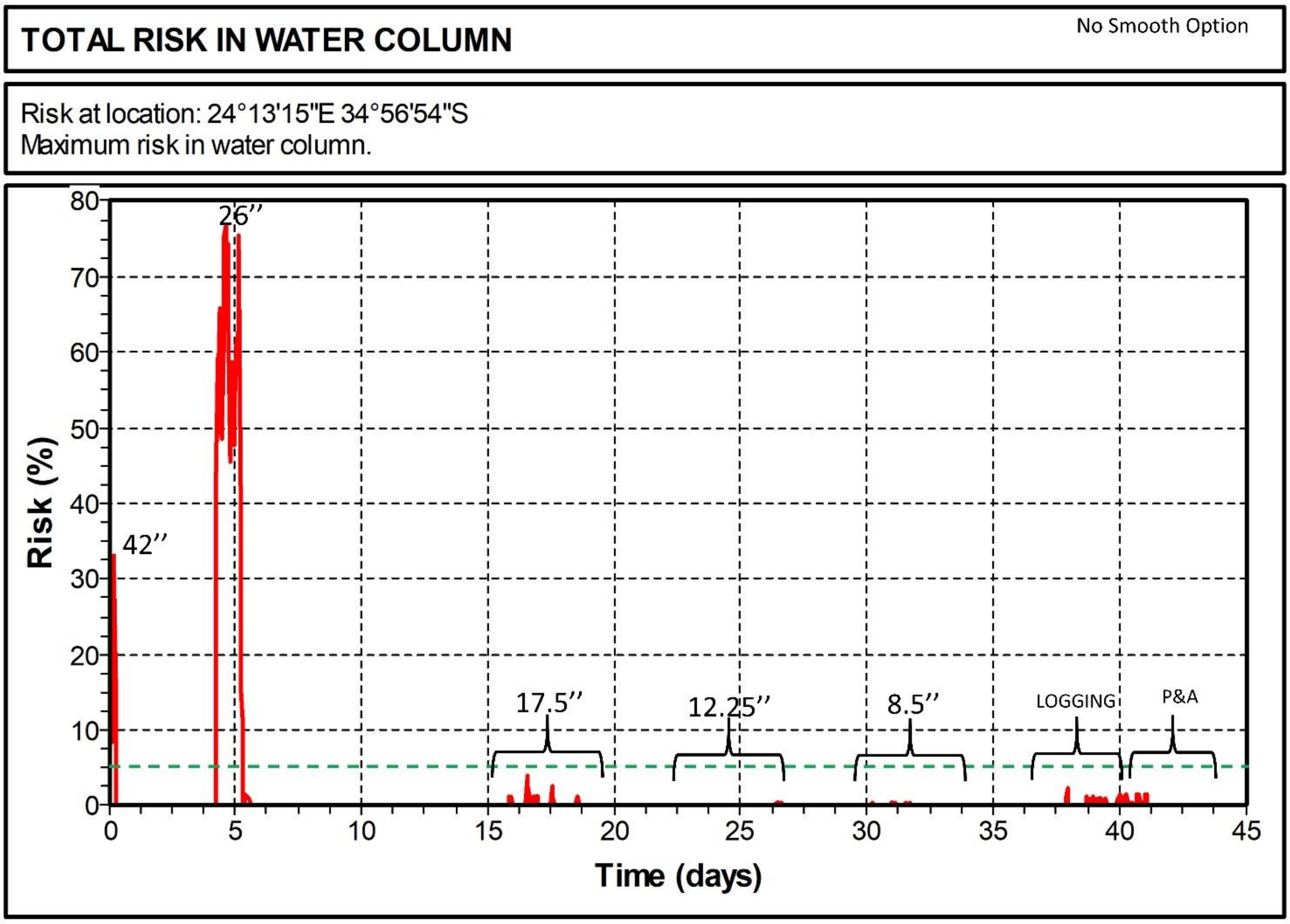


Figure 21: Maximum risk of drilling operations close to the discharge point over the time for the scenario 2 (the green dashed line symbolizes the 5% threshold) (Start Time March 1st)

Figure 22 shows the main contributors over the time for the different sections. In this case, the particulates compounds released (barite) contribute the most to the total environmental risk.

The Barite (component A and B) used in the WBM Pad Mud of the 42” and 26” sections is the main contributor to the total environmental risk to the water column, representing 93% of the total risk.

The hydrochloric acid present in the Clayseal Plus (corresponding to the CLAYSEAL PLUS_B in the Figure) is the main contributor to the total risk in the water column during the discharge of the sections drilled with a riser, contributing to 1% of the total risk.

These results will be further discussed in the following sections.

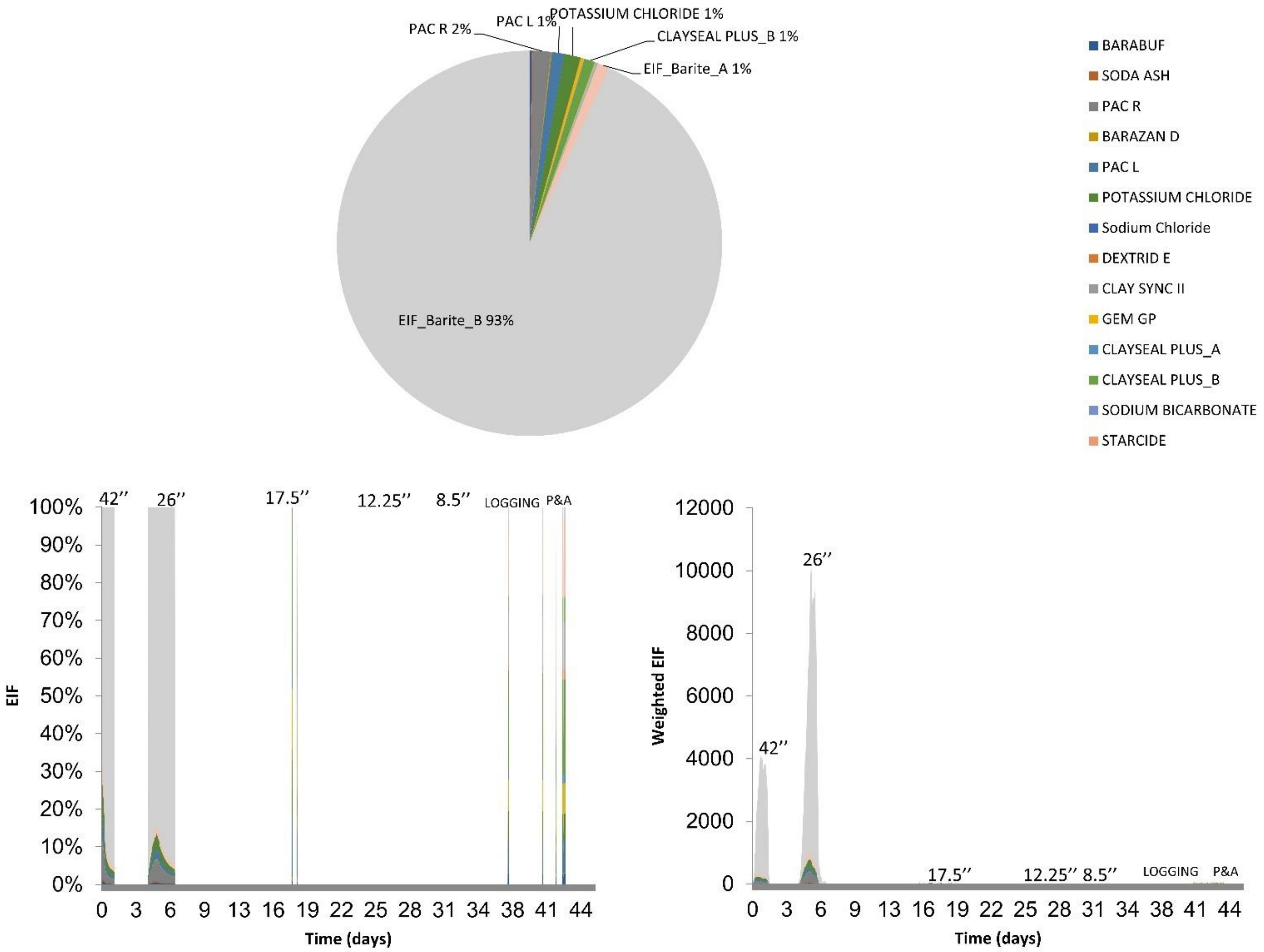


Figure 22: Main contributors to the risk of drilling operations in the water column for the scenario 2 and main contributors to the risk over the time (Start March 1st)

3.1.1.2.2 Discharge concentrations

Figure 23 and Figure 24 show the concentrations of the total discharge and of the main contributors to the environmental risk in the plume around the discharge point (including cuttings and chemicals).

During the discharge of all the sections, the maximum concentrations were as described below (without the smoothing option):

- 42” section: up to 17 ppm (cuttings + chemicals)
- 26’’ section: up to 30 ppm (cuttings + chemicals)
- 17.5” section: up to 0.38 ppm (cuttings + chemicals)
- 12.25” section: up to 0.13 ppm (cuttings + chemicals)
- 8.5’’ section: up to 0. 23 ppm (cuttings + chemicals)
- Logging and P&A: up to 0.36 ppm (chemicals only).

Figure 23 also shows that the highest contaminant concentrations are observed at the seabed (maximum 100 m above seabed) for the discharge of the 42” and 26” sections, mainly due to the presence of Barite. The Barite is the main contributor of the risk due to the high amounts released at sea during the discharge of the riserless sections.

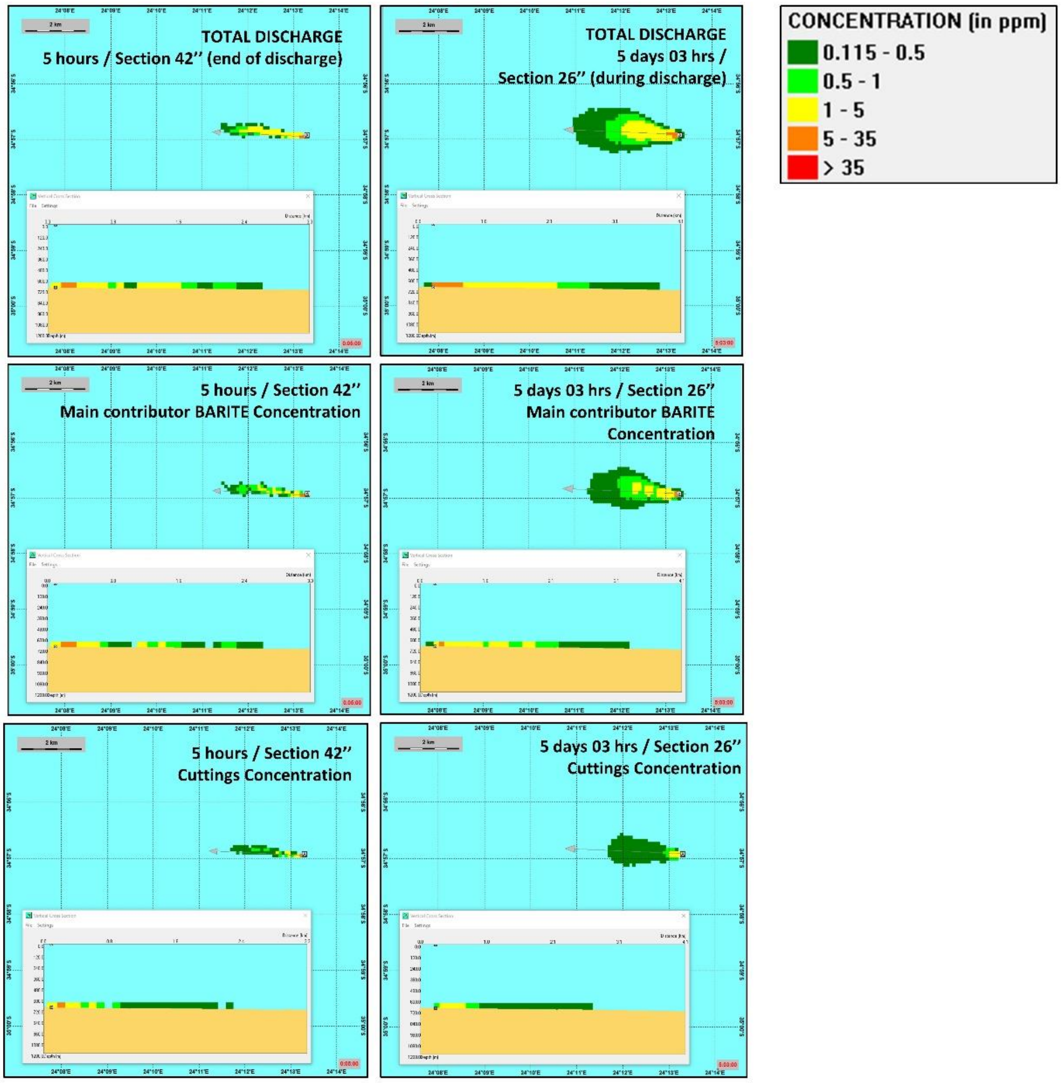


Figure 23: Instantaneous concentrations of total discharge, main contributor (Barite) and cuttings at one time at the end of drilling operations of the 42" and 26" sections (scenario 2)

Figure 24 shows the concentration of the Clayseal Plus_B in the water column during the discharge of the 17.5" section and the logging phase.

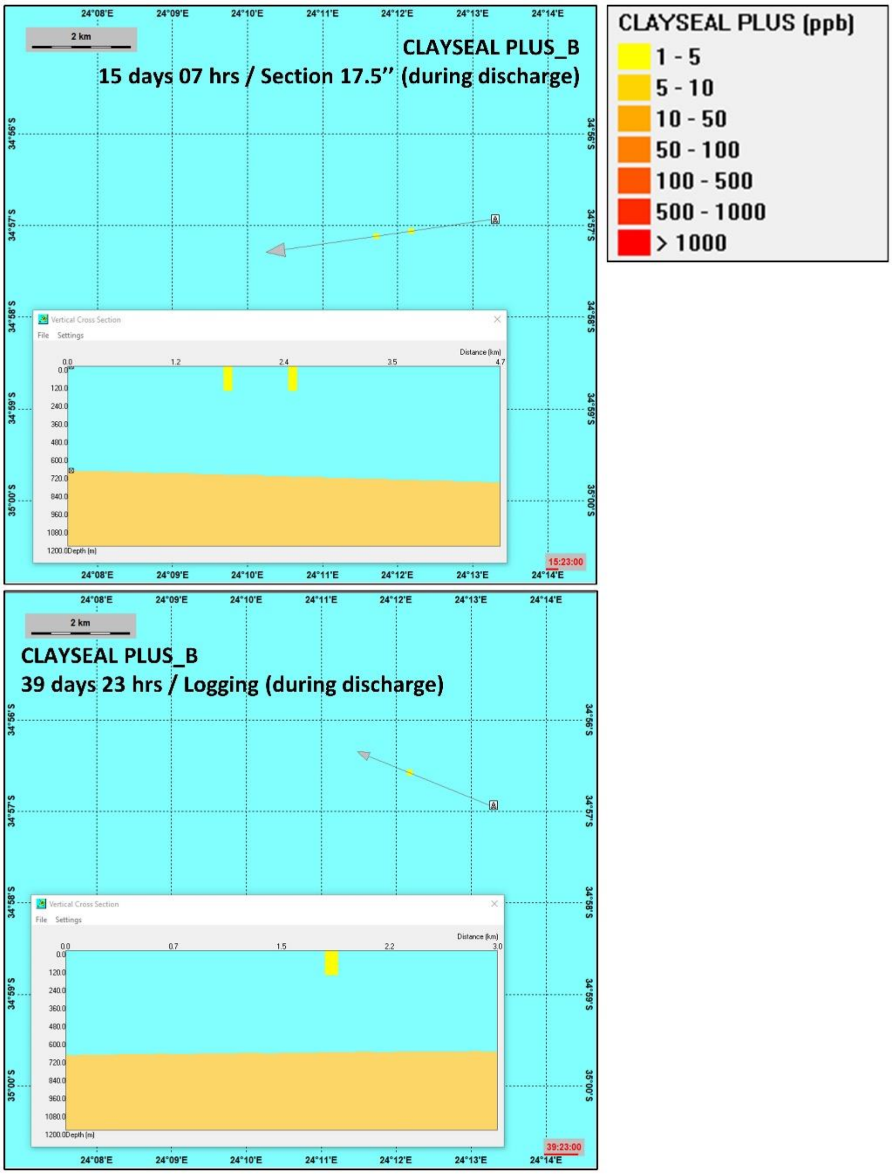


Figure 24: Instantaneous concentrations of Clayseal Plus_B (hydrochloric Acid 10%) above the PNEC (3.25 ppb) during the discharges of the 17.5" section and logging phase (scenario 2)

3.1.1.3 Discharge n°2 - Scenario 3 (Start Time June 1st)

3.1.1.3.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk in the water column associated with the discharge of drilling operations, considering scenario 3, is presented in Figure 25, Figure 26 and Figure 27.

These figures show that the environmental risk is mainly due to the discharge of 42'' and 26'' sections for the seabed and to the discharge of the sections drilled with a riser (17 ½'', 12 ¼'' and 8 ½'') released at sea surface for the upper water column.

These figures show that one part of the total risk is mainly limited to the seabed between 600 m and 700 m for the section drilled riser less (42" and 26"). The maximum risk calculated is up to 90% without smoothing option, very close to the discharge point (Figure 26 and Figure 27).

A significant risk has been calculated in an area of up to 35 km to the West / South-West from the discharge point 5 days after the start of the discharge (Section 26”), corresponding to the maximum risk of the riserless sections (Figure 25).

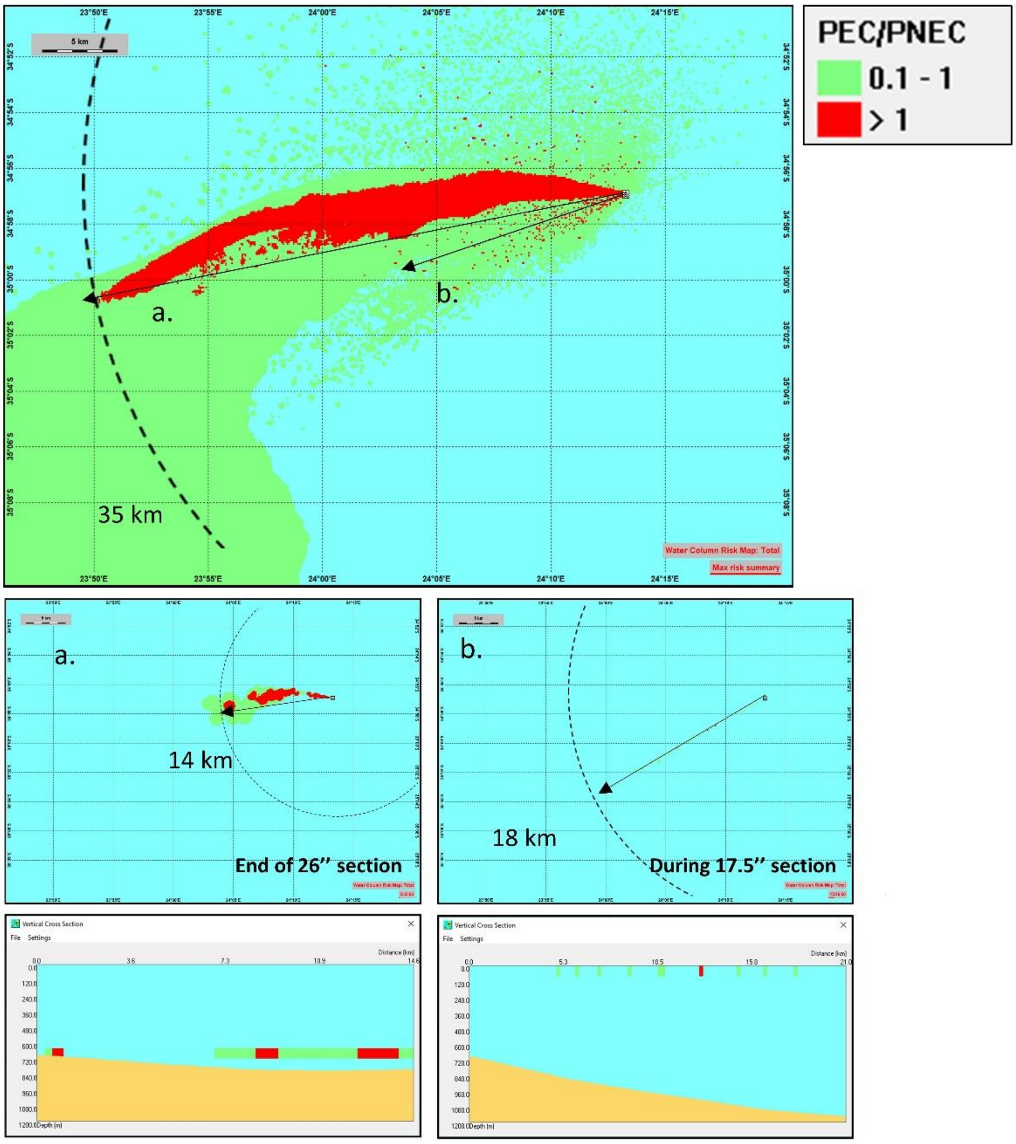


Figure 25: Maximum cumulative risk of drilling operations throughout the water column at any time for the Scenario 3 (Start Time June 1st) - (a) example of the plume corresponding to the instantaneous risk at the end of the 26'' section (riserless) and vertical cross section – (b) example of the plume SW direction corresponding to the instantaneous risk during 17.5” section (discharge at the surface) and vertical cross section.

The risk associated with the discharges of the sections drilled with a riser is located on the first 100 m of the water column from the surface. For those sections drilled with a riser, a significant risk has been calculated to a distance up to 18 km away from the discharge point (between 0 and 100 m depth) to the West/South-West and some patches 21 km North-West. However, during the discharge at the sea surface, the risk is limited both in terms of time and space with only a few tiny patches with significant risk observed around the discharge. The maximum risk reached during the discharge at the sea surface is always between 5 and 10% and most of the time not significant (Figure 26 and Figure 27).

The maximum risk reached during the entire operations is 90% very close to the discharge point without the smoothing option (Figure 27).

This area at risk is not centralized around the discharge point and is orientated along an axis starting from the discharge point towards West / South-West, during the discharge of the riser less sections, following the currents and spread from South-West to the North-West for the discharges at the sea surface. This clearly shows the impact of water column currents on drill cuttings and mud dispersion in the water column.

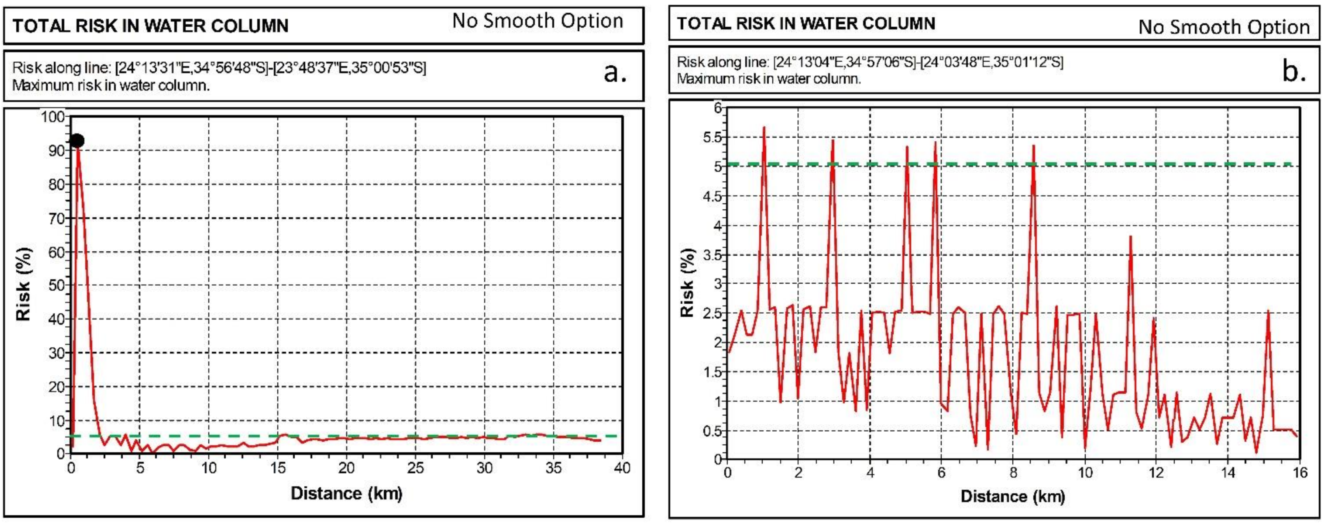


Figure 26: Example of instantaneous risk of drilling operations along a line for the scenario 3 (Start Time June 1st) a. during the discharge of the riserless section (26'') and b. during 17.5" discharge (black dots symbolize the discharge point; the green dashed lines symbolize the 5% threshold)

Figure 27 clearly shows that the risk is not constant throughout the drilling operation. Thus 6 periods are clearly observed during the operations (with the smoothing option):

- A first period corresponding to the discharge of the mud and the cuttings of the 42'' section at the very beginning of the operations leading to significant risk to the environment, with a value of 18%.
- A second period with the maximum significant risk (up to 90%) during the discharge of the mud and the cuttings corresponding to the 26'' section, the maximum risk calculated among the 6 series of discharge.
- A third period with a not significant risk (less than 5 %) calculated during the discharge of the mud and the cuttings corresponding to the 17.5'' section discharge (however tiny patches with significant risk were observed around the discharge)
- A fourth period corresponding to the discharge of the 12.25'' section with a maximum risk of less than 5 %
- A fifth period corresponding to the discharge of the 8.5'' section with a maximum risk of less than 5 %
- A sixth period corresponding to the discharge during logging and P&A with a maximum risk of less than 5 % (however tiny patches with significant risk were observed around the discharge).

Figure 27 also shows for all the sections that the impact of the discharge lasts for the duration of drilling but stops for all sections right after the end of each specific operations. The maximum risk in term of intensity is observed at the seabed for the discharge of the 42" and 26" sections, drilled riserless. There is a risk in the water column until day 43, after the end of the discharge of the P&A discharge but few kilometers form the discharge point (not visible on the graphic representing the risk very close to the discharge point).

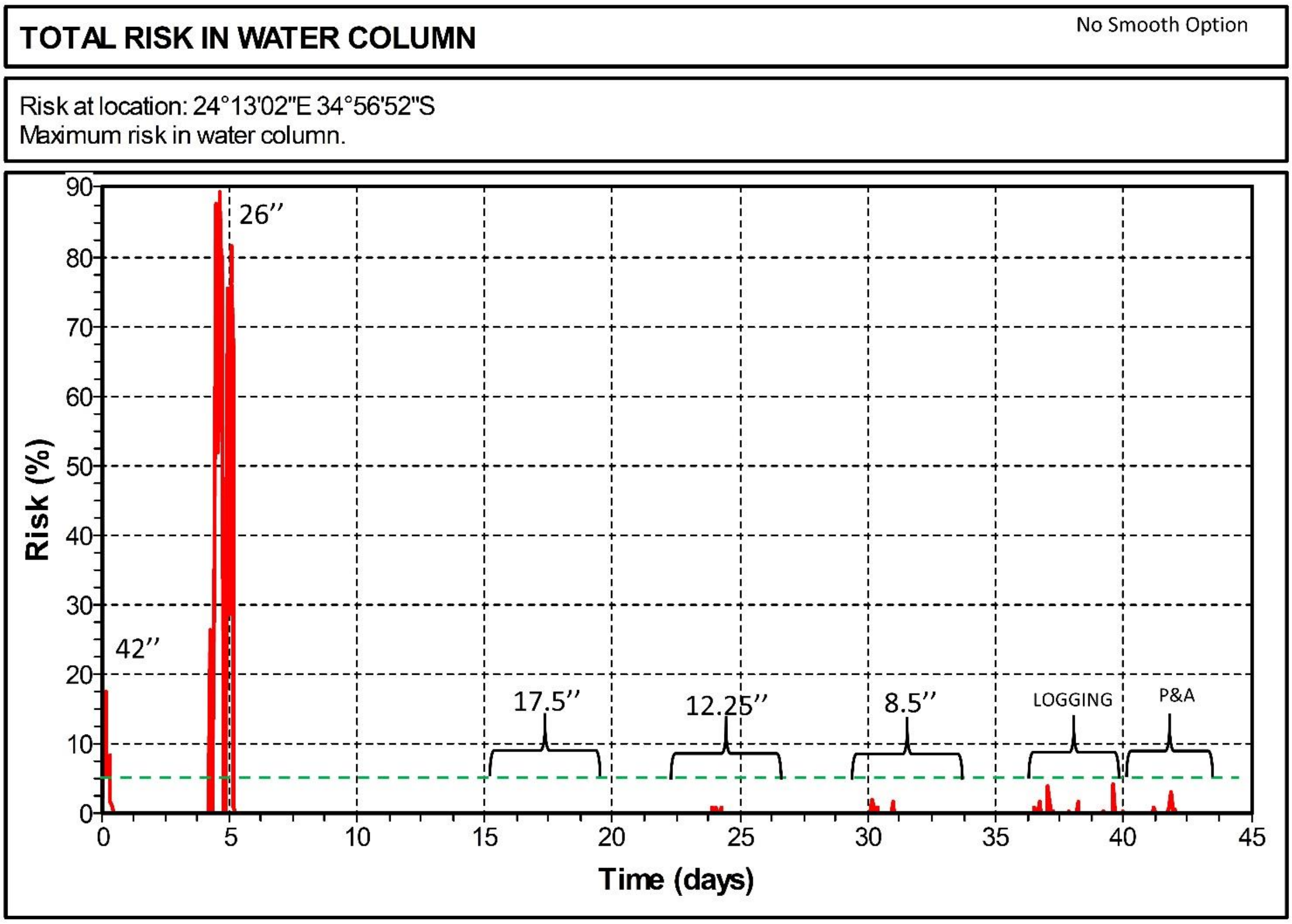


Figure 27: Maximum risk of drilling operations close to the discharge point over the time for the scenario 3 (the green dashed line symbolizes the 5% threshold) (Start Time June 1st)

Figure 28 shows the main contributors over the time for the different sections. In this case, the particulates compounds released (barite) contribute the most to the total environmental risk.

The Barite (component A and B) used in the WBM Pad Mud of the 42" and 26" sections is the main contributor to the total environmental risk to the water column, representing 92% of the total risk.

The hydrochloric acid present in the Clayseal Plus (corresponding to the CLAYSEAL PLUS_B in the Figure) is the main contributor to the total risk in the water column during the discharge of the sections drilled with a riser, contributing to 1% of the total risk.

These results will be further discussed in the following sections.

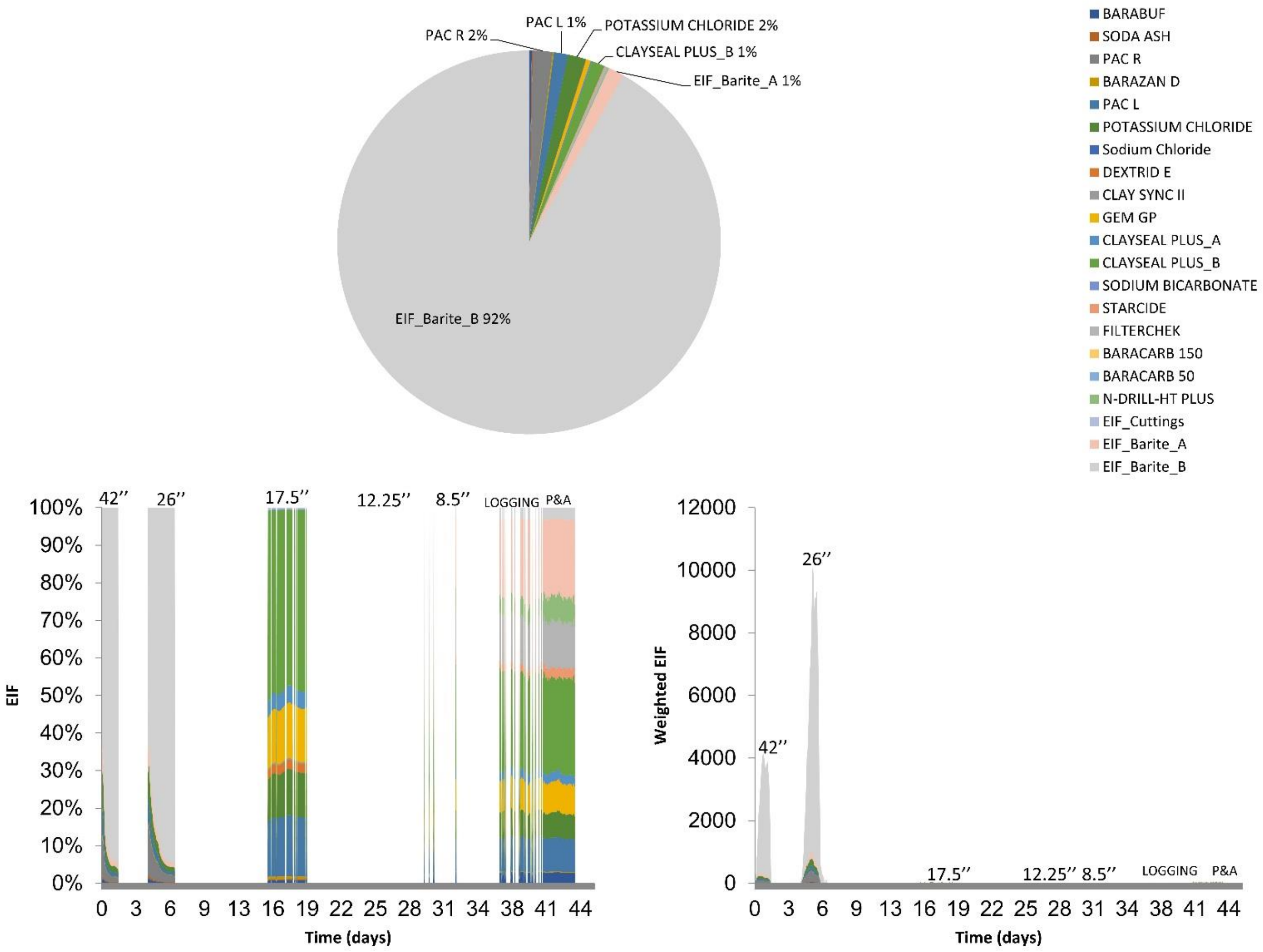


Figure 28: Main contributors to the risk of drilling operations in the water column for the scenario 3 and main contributors to the risk over the time (Start June 1st)

3.1.1.3.2 Discharge concentrations

Figure 29 and Figure 30 show the concentrations of the total discharge and of the main contributors to the environmental risk in the plume around the discharge point (including cuttings and chemicals).

During the discharge of all the sections, the maximum concentrations were as described below (without the smoothing option):

- 42" section: up to 14 ppm (cuttings + chemicals)
- 26'' section: up to 31 ppm (cuttings + chemicals)
- 17.5" section: up to 0.57 ppm (cuttings + chemicals)
- 12.25" section: up to 0.33 ppm (cuttings + chemicals)
- 8.5'' section: up to 0.26 ppm (cuttings + chemicals)
- Logging and P&A: up to 0.72 ppm (chemicals only)

Figure 29 also shows that the highest contaminant concentrations are observed at the seabed (maximum 100 m above seabed) for the discharge of the 42" and 26" sections, mainly due to the presence of Barite. The Barite is the main contributor of the risk due to the high amounts released at sea during the discharge of the riserless sections.

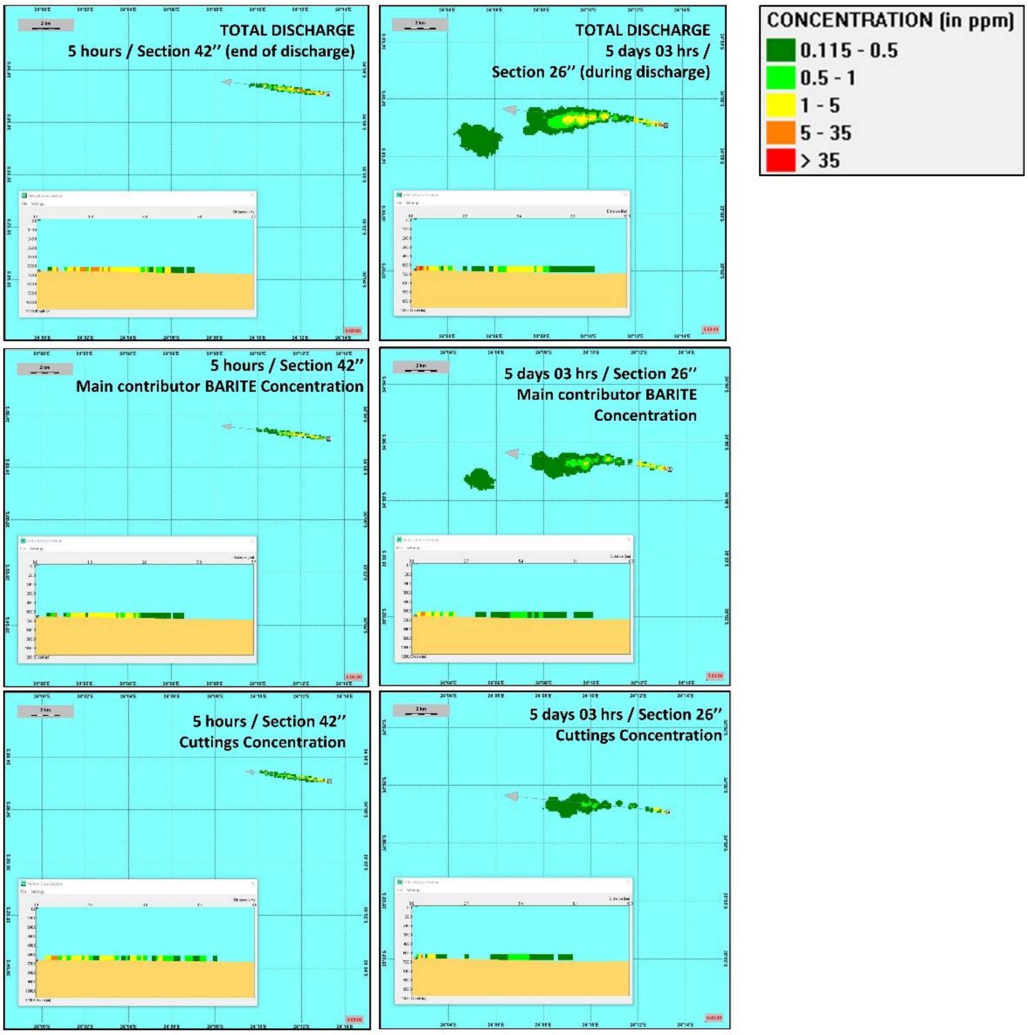


Figure 29: Instantaneous concentrations of total discharge, main contributor and cuttings at one time at the end of drilling operations of the 42" and 26" sections (scenario 3)

Figure 30 shows the concentration of the Clayseal Plus_B in the water column during the discharge of the 17.5" and 12.25" sections.

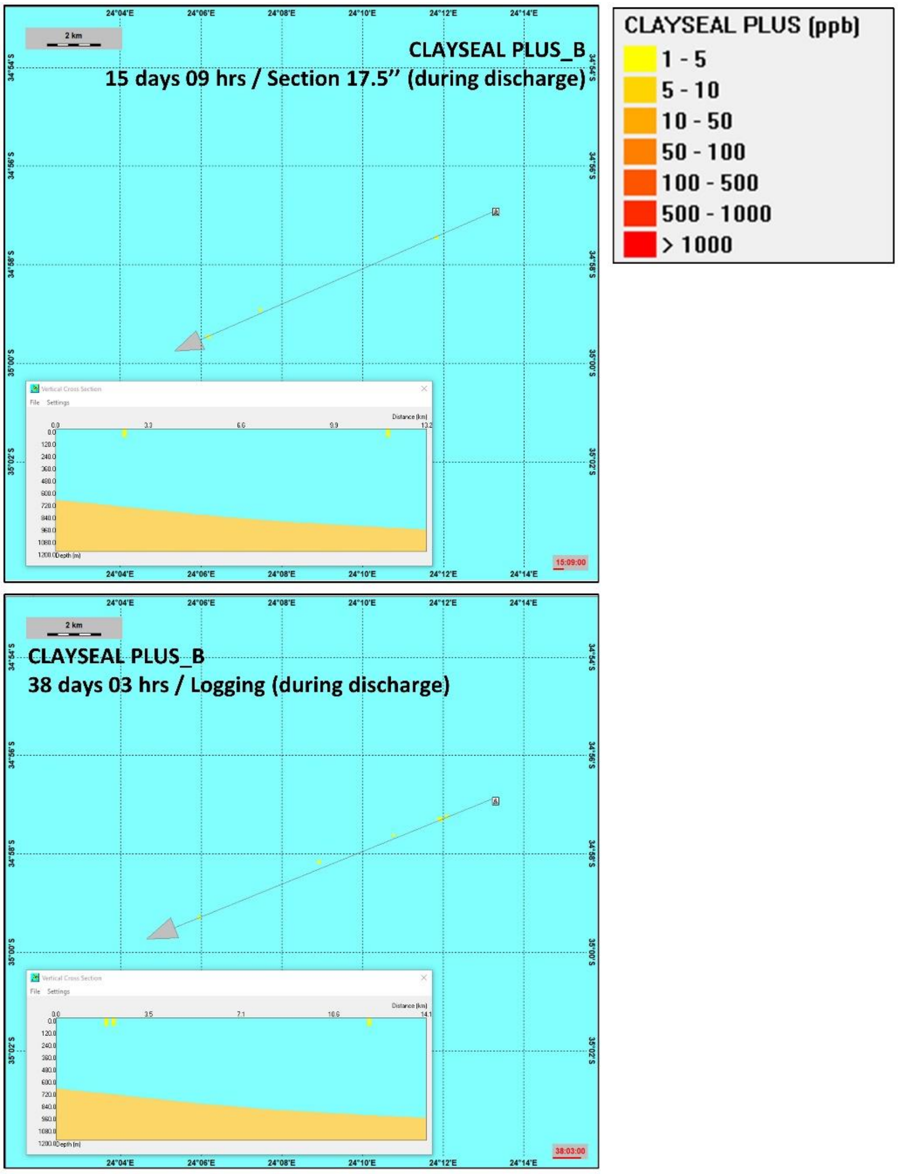


Figure 30: Instantaneous concentrations of Clayseal Plus_B (hydrochloric Acid 10%) above the PNEC (3.25 ppb) during the discharges of the 17.5'' section and logging phase (scenario 3)

3.1.1.4 Discharge n°2 - Scenario 4 (Start Time September 1st)

3.1.1.4.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk in the water column associated with the discharge of drilling operations, considering scenario 4, is presented in Figure 31, Figure 32 and Figure 33.

These figures show that the environmental risk is mainly due to the discharge of 42'' and 26'' sections for the seabed and to the discharge of the sections drilled with a riser (17 ½'', 12 ¼'' and 8 ½'') released at sea surface for the upper water column.

Those figures show that one part of the total risk is mainly limited to the seabed between 600 m and 700 m for the section drilled riser less (42" and 26"). The maximum risk calculated is up to 90% without smoothing option, very close to the discharge point (Figure 32 and Figure 33).

A significant risk has been calculated in an area of up to 12 km West from the discharge point, 1 day after the start of the discharge due to the section 42". Another significant risk has been calculated 5.5 km to the South-East from the discharge point 5 days after the start of the discharge (section 26"), corresponding to the maximum risk of the riserless sections (Figure 31).

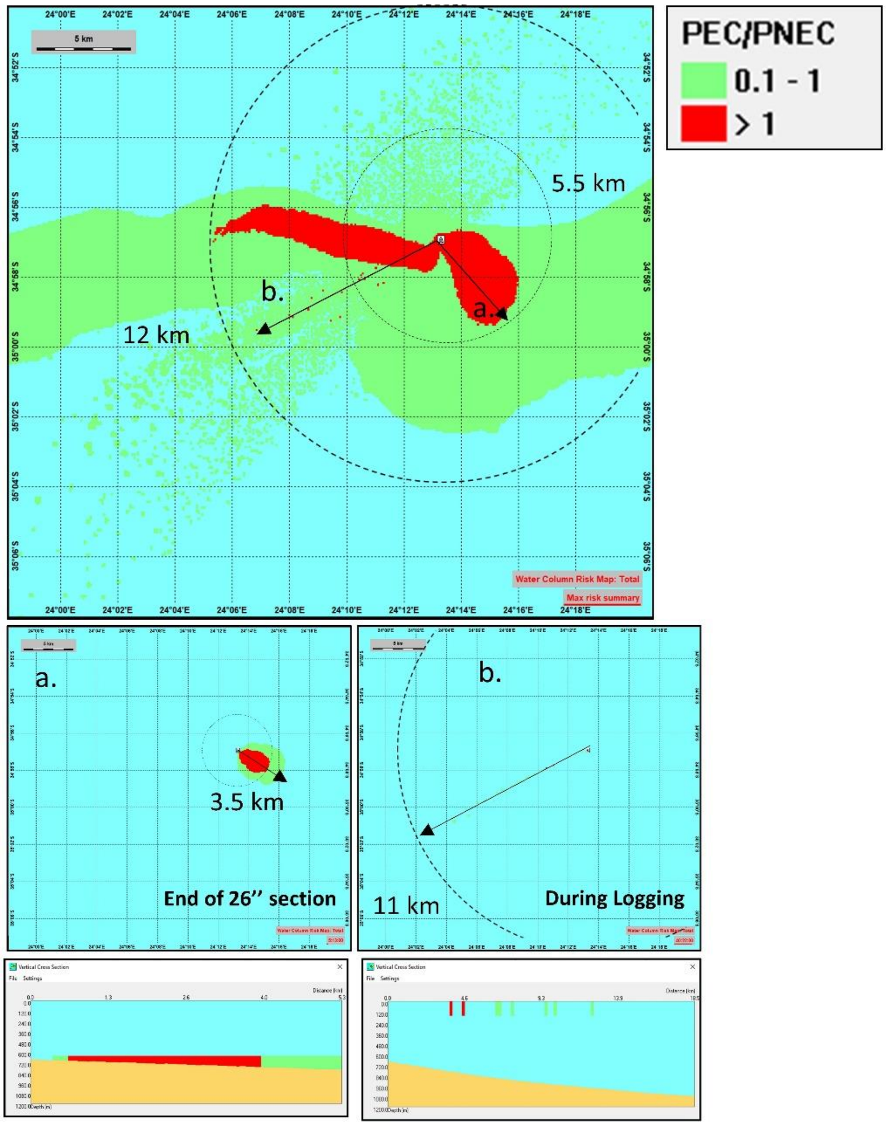


Figure 31: Maximum cumulative risk of drilling operations throughout the water column at any time for the scenario 4 (Start Time September 1st) - (a) example of the plume corresponding to the instantaneous risk at the end of the 26'' section (riserless) and vertical cross section – (b) example of the plume SW direction corresponding to the instantaneous risk during Logging (discharge at the surface) and vertical cross section.

The risk associated with the discharges of the sections drilled with a riser is located on the first 100 m of the water column from the surface. For those sections drilled with a riser, a significant risk has been calculated to a distance up to 11 km away from the discharge point (between 0 and 100 m depth) to the South-West. However, during the discharge at the sea surface, the risk is limited both in terms of time and space with only a few tiny patches with significant risk observed around the discharge. The maximum risk reached during the discharge at the sea surface is always between 5 and 10% and most of the time not significant (Figure 32 and Figure 33).

The maximum risk reached during the entire operations is 90% very close to the discharge point without the smoothing option (Figure 32 and Figure 33).

This area at risk is not centralized around the discharge point and is orientated along three axis starting from the discharge point towards West and South-East during the riserless sections discharge, and South-West during the discharge of the riser less sections, following the currents and spread to South-West for the discharges at the sea surface. This clearly shows the impact of water column currents on drill cuttings and mud dispersion in the water column.

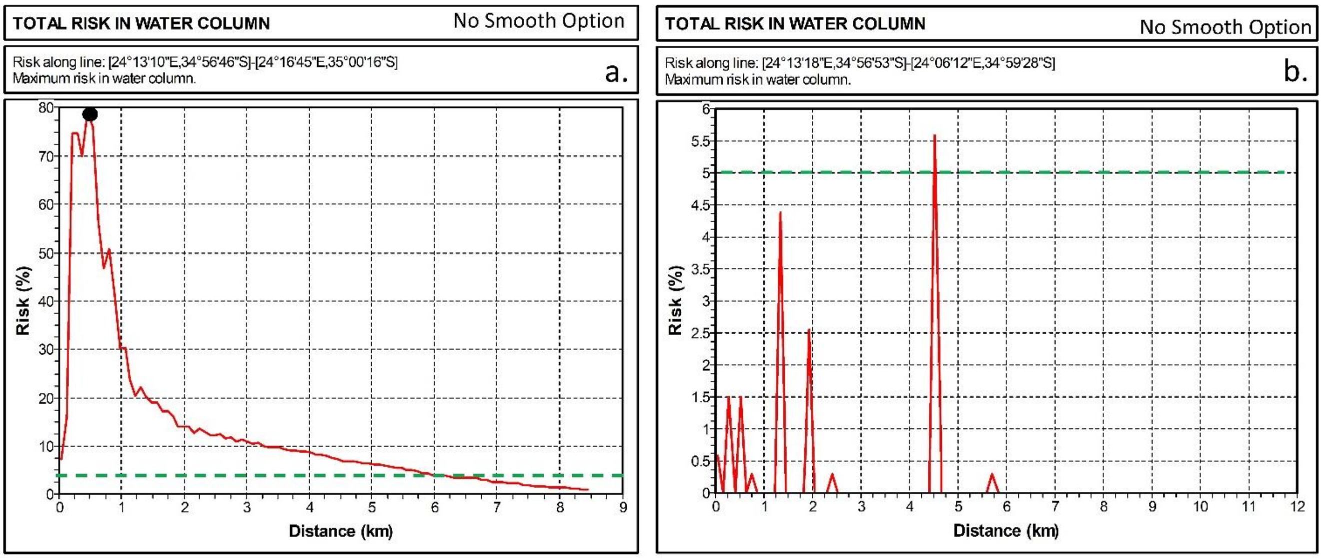


Figure 32: Example of instantaneous risk of drilling operations along a line for the scenario 4 (Start Time June 1st) a. during the discharge of the riserless section (26'') and b. during Logging (black dots symbolize the discharge point, the green dashed lines symbolize the 5% threshold)

Figure 33 clearly shows that the risk is not constant throughout the drilling operations. Thus 6 periods are clearly observed during the operations close to the discharge point (with the smoothing option):

- A first period corresponding to the discharge of the mud and the cuttings of the 42'' section at the very beginning of the operations leading to significant risk to the environment, the maximum risk calculated among the 6 series of discharge, with a value of 36%.
- A second period with a significant risk (up to 90%) during the discharge of the mud and the cuttings corresponding to the 26'' section.
- A third period with a not significant risk (less than 5 %) calculated during the discharge of the mud and the cuttings corresponding to the 17.5'' section discharge (however tiny patches with significant risk were observed around the discharge)
- A fourth period corresponding to the discharge of the 12.25'' section with a maximum risk of less than 5 %
- A fifth period corresponding to the discharge of the 8.5'' section with a maximum risk of less than 5 % (however tiny patches with significant risk were observed around the discharge)
- A sixth period corresponding to the discharge during logging and P&A with a maximum risk of less than 5 % (however tiny patches with significant risk were observed around the discharge).

Figure 33 also shows for all the sections that the impact of the discharge lasts for the duration of drilling but stops for all sections right after the end of each specific operations. The maximum risk in term of intensity is observed at seabed for the discharge of the 42" and 26" sections, drilled riserless. There is a risk in the water column until day 43, after the end of the discharge of the P&A discharge but few kilometers form the discharge point (not visible on the graphic representing the risk very close to the discharge point).

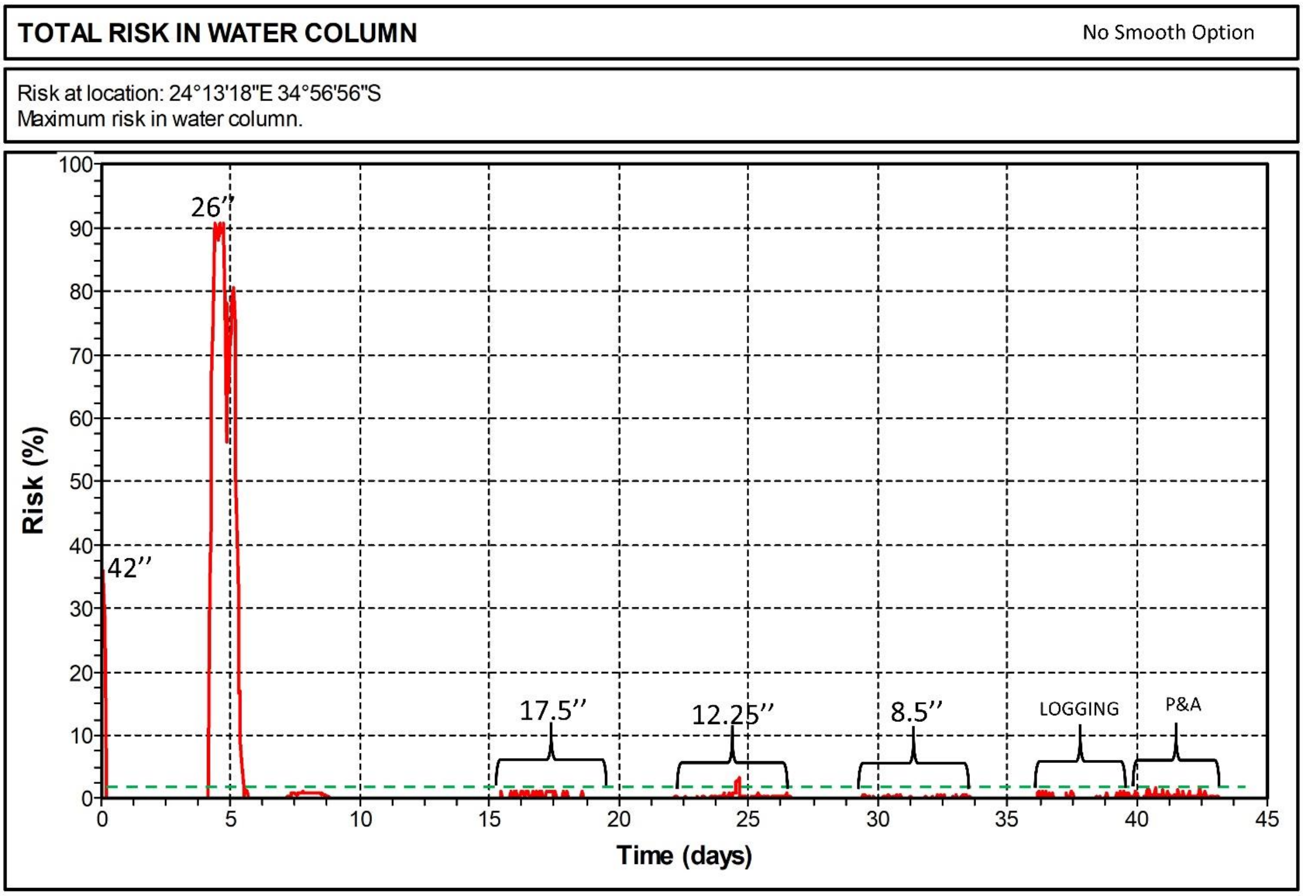


Figure 33: Maximum risk of drilling operations close to the discharge point over the time for the scenario 4 (the green dashed line symbolizes the 5% threshold) (Start Time June 1st)

Figure 34 shows the main contributors over the time for the different sections.

The Barite (component A and B) used in the WBM Pad Mud of the 42" and 26" sections is the main contributor to the total environmental risk to the water column, representing 92% of the total risk.

The hydrochloric acid present in the Clayseal Plus (corresponding to the CLAYSEAL PLUS_B in the Figure) is the main contributor to the total risk in the water column during the discharge of the sections drilled with a riser, contributing to 1% of the total risk.

These results will be further discussed in the following sections.

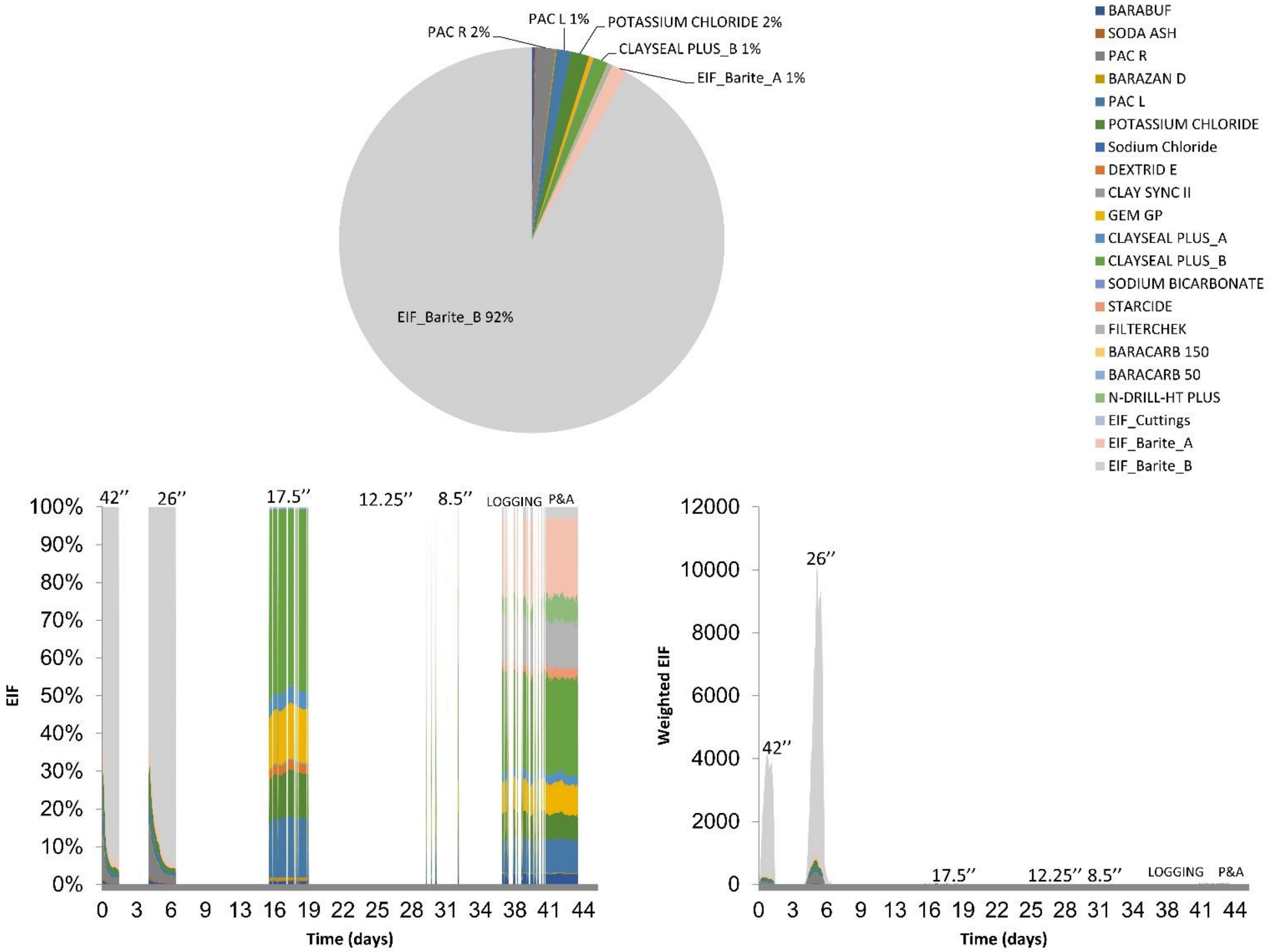


Figure 34: Main contributors to the risk of drilling operations in the water column for the scenario 4 and main contributors to the risk over the time (Start June 1st)

3.1.1.4.2 Discharge concentrations

Figure 35 and Figure 36 show the concentrations of the total discharge and of the main contributors to the environmental risk in the plume around the discharge point (including cuttings and chemicals).

During the discharge of all the sections, the maximum concentrations were as described below (without the smoothing option):

- 42" section: up to 9.6 ppm (cuttings + chemicals)
- 26'' section: up to 34 ppm (cuttings + chemicals)
- 17.5" section: up to 0.21 ppm (cuttings + chemicals)
- 12.25" section: up to 0.50 ppm (cuttings + chemicals)
- 8.5'' section: up to 0.10 ppm (cuttings + chemicals)
- Logging and P&A: up to 0.36 ppm (chemicals only)

Figure 35 also shows that the highest contaminant concentrations are observed at the seabed (maximum 100 m above seabed) for the discharge of the 42" and 26" sections, mainly due to the presence of Barite. The Barite is the main contributor of the risk due to the high amounts released at sea during the discharge of the riserless sections.

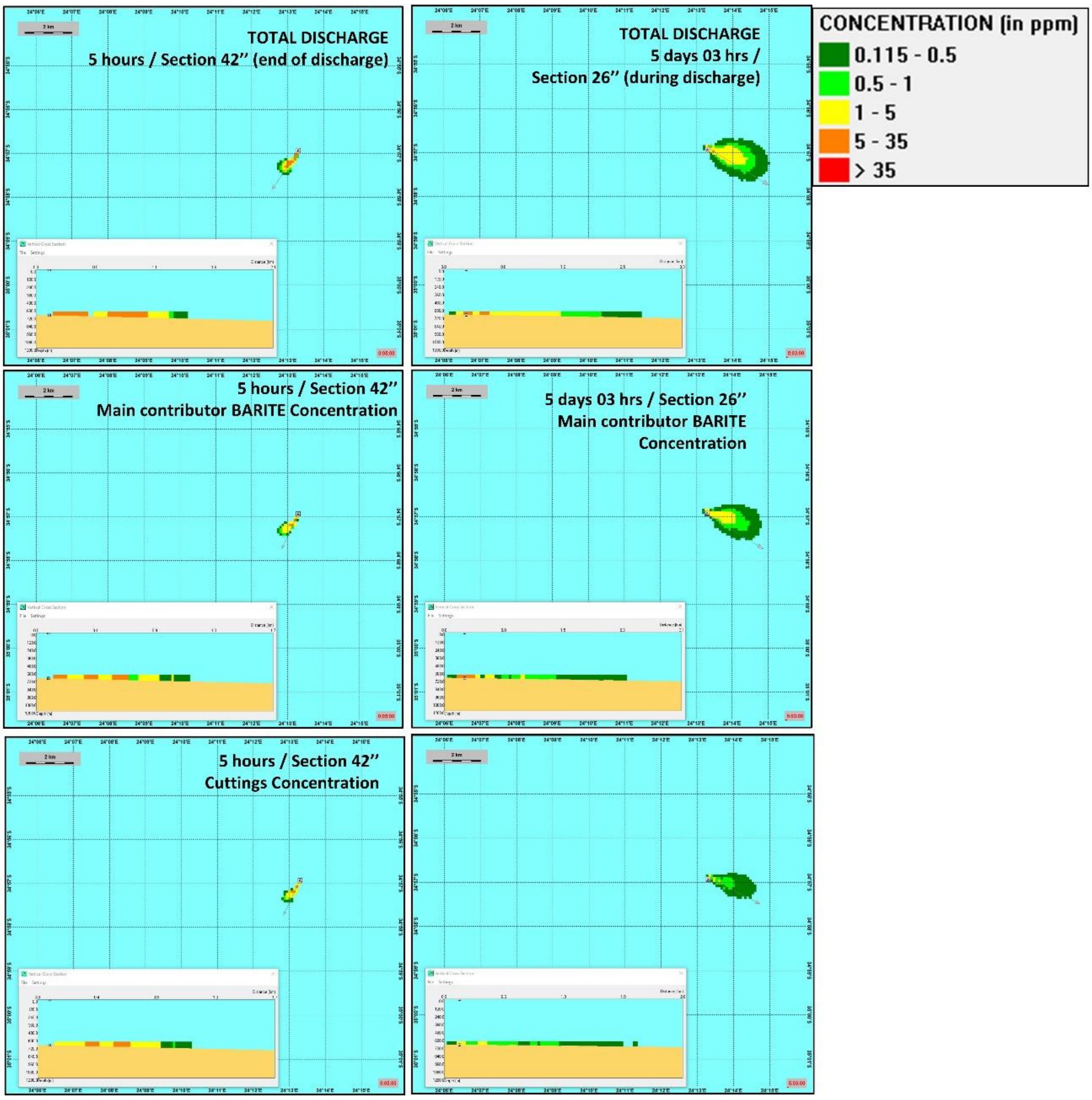


Figure 35: Instantaneous concentrations of total discharge, main contributor (Barite) and cuttings at one time at the end of drilling operations of the 42" and 26" sections (scenario 4)

Figure 36 shows the concentration of the Clayseal Plus_B in the water column during the discharge of the 17.5" section and logging phase.

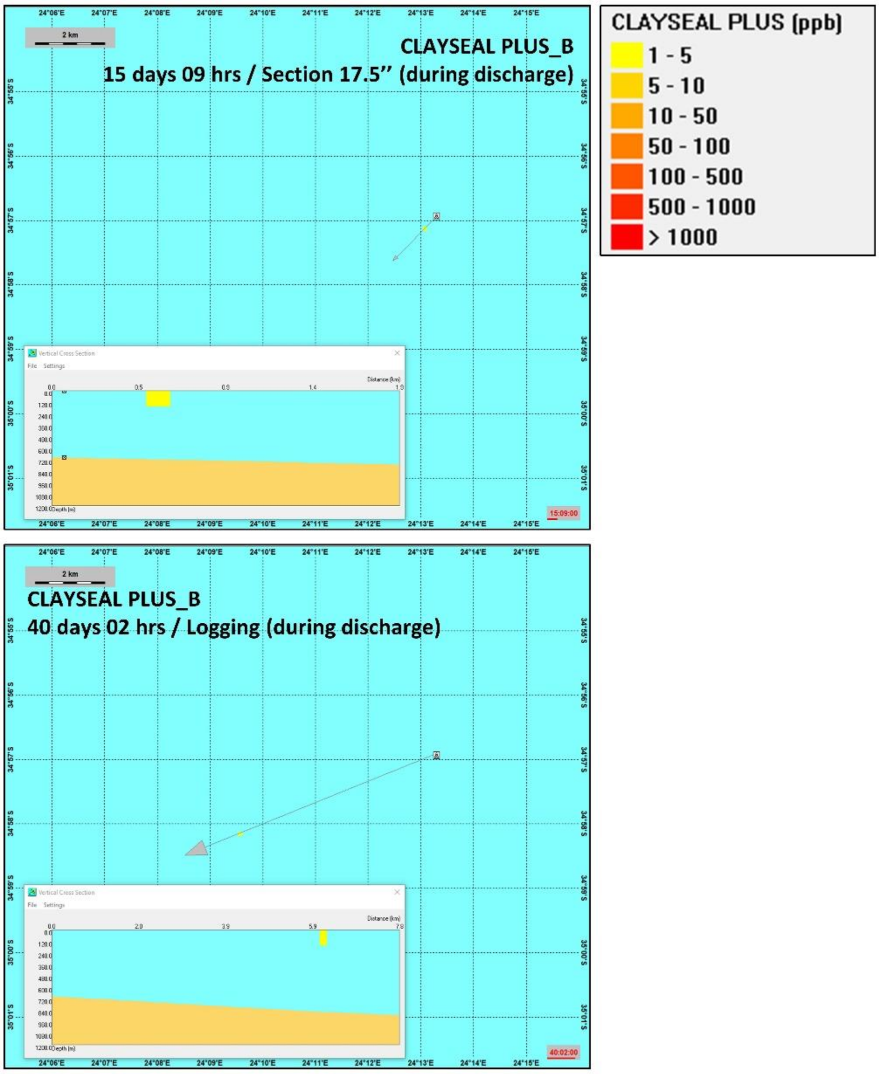


Figure 36: Instantaneous concentrations of Clayseal Plus_B (hydrochloric Acid 10%) above the PNEC (3.25 ppb) during the discharges of the 17.5” and 12.25” sections (scenario 4)

Discharge n°2 - Optional case: scenario 5

3.1.2.1.1 Maximum risk and main contributors

The worst case among the base case (Scenario 1 – 4) is Scenario 3. For the Scenario 5, only the third quarter was therefore modelled. The outcomes of the model for the maximum risk in the water column associated with the discharge of drilling operations, considering Scenario 5, is presented Figure 37, Figure 38 and Figure 39.

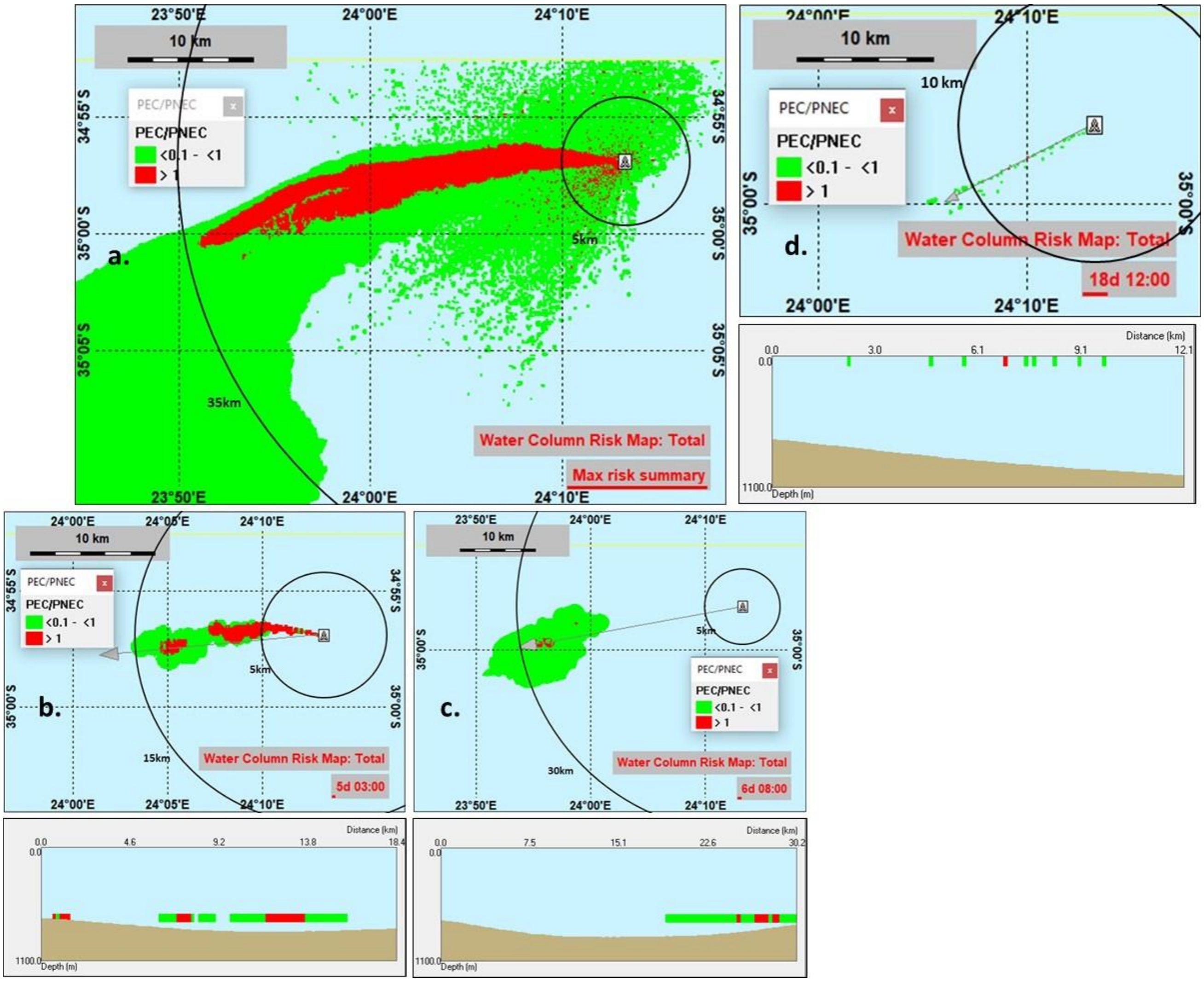


Figure 37: (a) Maximum cumulative risk of drilling operations throughout the water column at any time for Scenario 5 (Start Time June 1st) - (b) example of the plume W direction corresponding to the instantaneous risk at the end of the 26'' section (riserless) and vertical cross section; (c) example of the plume SW direction corresponding to the instantaneous risk 1day after the end of 26'' section and vertical cross section and (d) example of the plume SW direction corresponding to the instantaneous risk during the discharge of the 17.5'' section (discharge at the surface) and vertical cross section.

These figures show that the environmental risk is mainly due to the discharge of 42'' and 26'' sections for the seabed and to the discharge of the sections drilled with a riser (17 ½'', 12 ¼'' and 8 ½'') released at sea surface for the upper water column.

Those figures show that one part of the total risk is mainly limited to the seabed between 625 m and 725 m depth for the section drilled riserless (42" and 26"). The maximum risk calculated is up to 95% without smoothing option, very close to the discharge point (Figure 38 a and Figure 39). A significant risk has been calculated in an area of up to 35 km to the West/West/South West from the discharge point 1.5 days after the start of the discharge, corresponding to the maximum risk of the riserless sections.

The risk associated with the discharges of the sections drilled with a riser is located on the first 100 m of the water column from the surface. For these sections drilled with a riser, a significant risk has been calculated to a distance up to 12 km away from the discharge point (between 0 and 100 m depth) to the South West. However, during the discharge at the sea surface, the risk is limited both in terms of time and space with only a few tiny patches with significant risk observed around the discharge. The maximum risk reached during the discharge at the sea surface is always between 5 and 10% and most of the time not significant.

The maximum risk reached during the entire operations is 95% very close to the discharge point without the smoothing option.

This area at risk is not centralized around the discharge point and is orientated along one main axis starting from the discharge point towards West/West South West during the discharge of the riserless sections, following the currents and spread in all the directions for the discharges at the sea surface. This clearly shows the impact of water column currents on drill cuttings and mud dispersion in the water column.

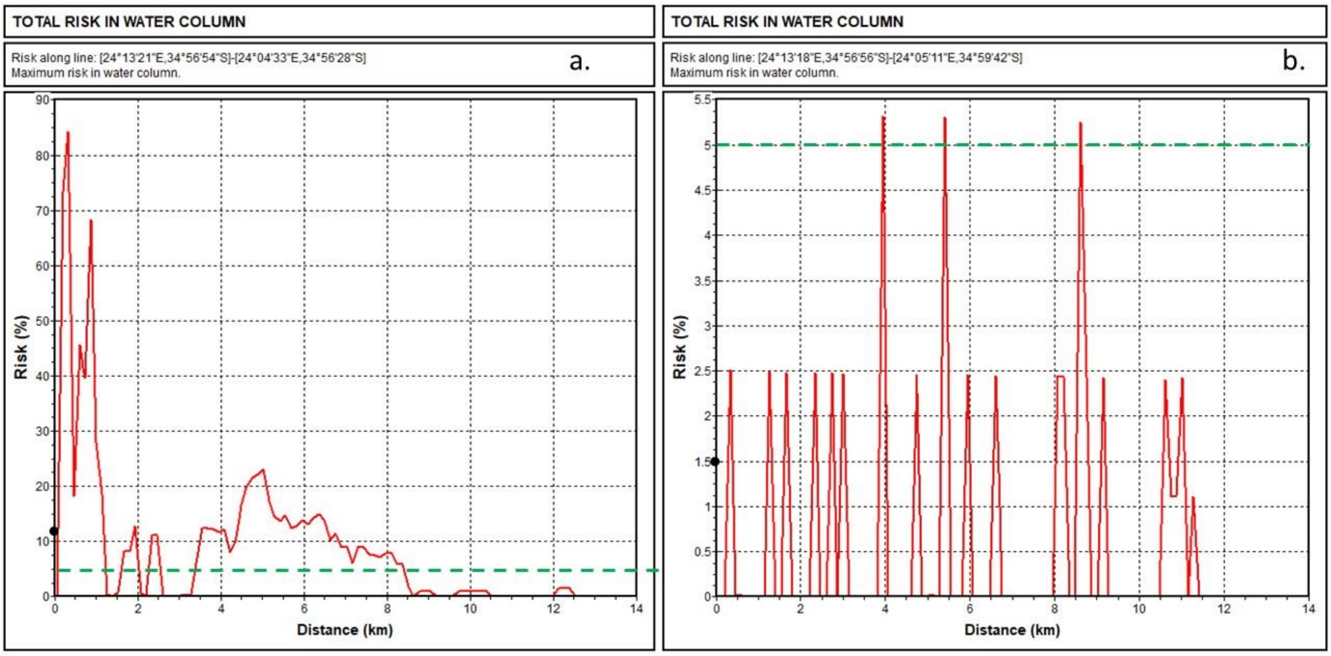


Figure 38: Example of instantaneous risk of drilling operations along a line for the scenario 5 (Start Time June 1st), a. during the discharge of the riserless section (26'') and b. during the discharge of the 17.5'' section(black dots symbolize the discharge point, the green dashed lines symbolize the 5% threshold)

Figure 39 clearly shows that the risk is not constant throughout the drilling operation. Thus, six periods are clearly observed during the operations close to the discharge point (without the smoothing option):

- A first period corresponding to the discharge of the mud and the cuttings of the 42'' section at the very beginning of the operations leading to significant risk to the environment, the maximum risk calculated among the six series of discharge, with a value of 95%

- A second period with a significant risk (up to 95%) during the discharge of the mud and the cuttings corresponding to the 26'' section
- A third period with a maximum risk of less than 5 % most of the time corresponding to the discharge of the mud and the cuttings of the 17.5'' section (however tiny patches with significant risk below 10% were observed around the discharge)
- A fourth period corresponding to the discharge of the 12.25'' section with a maximum risk of less than 5 % (not significant)
- A fifth period corresponding to the discharge of the 8.5'' section with a maximum risk of less than 5 % most of the time (however tiny patches with significant risk below 10% were observed around the discharge)
- A sixth period corresponding to the discharge during logging and P&A with a maximum risk of less than 5 % most of the time (however tiny patches with significant risk below 12% were observed around the discharge).

Figure 39 also shows for all the sections that the impact of the discharge lasts for the duration of drilling but stops for all sections right after the end of each specific operation. The maximum risk, in term of intensity is observed at the seabed for the discharge of the 42" and 26" sections, drilled riserless. There is a risk in the water column until day 60, after the end of the discharge of the P&A discharge.

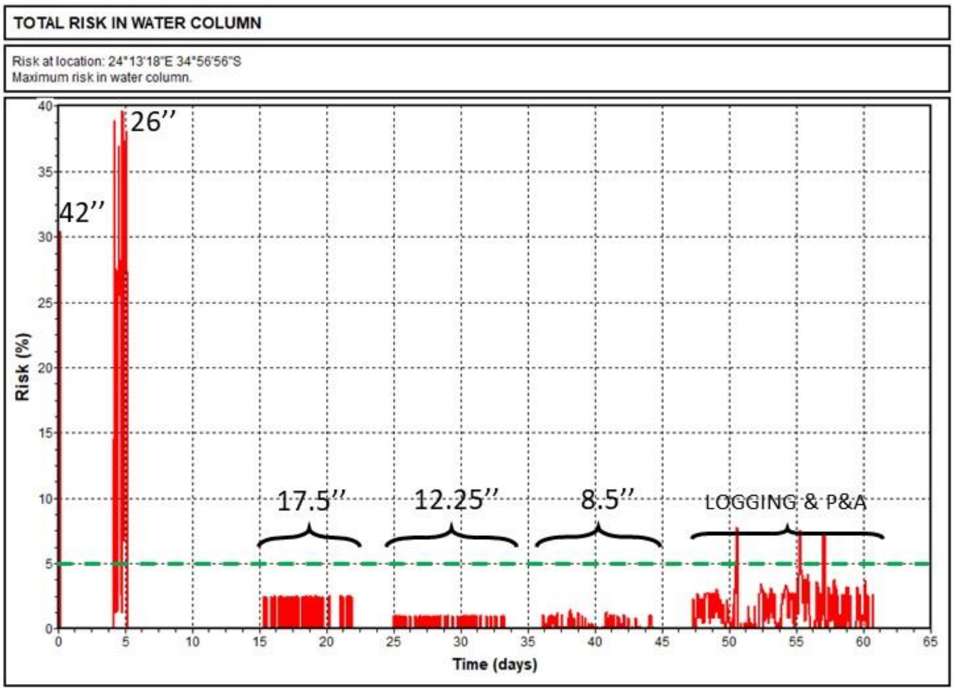


Figure 39: Maximum risk of drilling operations close to the discharge point over the time for the scenario 5 (the green dashed lines symbolize the 5% threshold) (Start Time June 1st)

Figure 40 shows the main contributors over the time for the different sections. In this case, the particulates compounds released (barite) contribute the most to the total environmental risk.

The Barite (component A and B) used in the WBM Pad Mud of the 42" and 26" sections is the main contributor to the total environmental risk to the water column, representing 91% of the total risk.

The hydrochloric acid present in the Clayseal Plus (corresponding to the CLAYSEAL PLUS_B in the Figure) is the main contributors to the total risk in the water column during the discharge of the sections drilled with a riser, contributing to 2% of the total risk.

These results will be further discussed in the following sections.

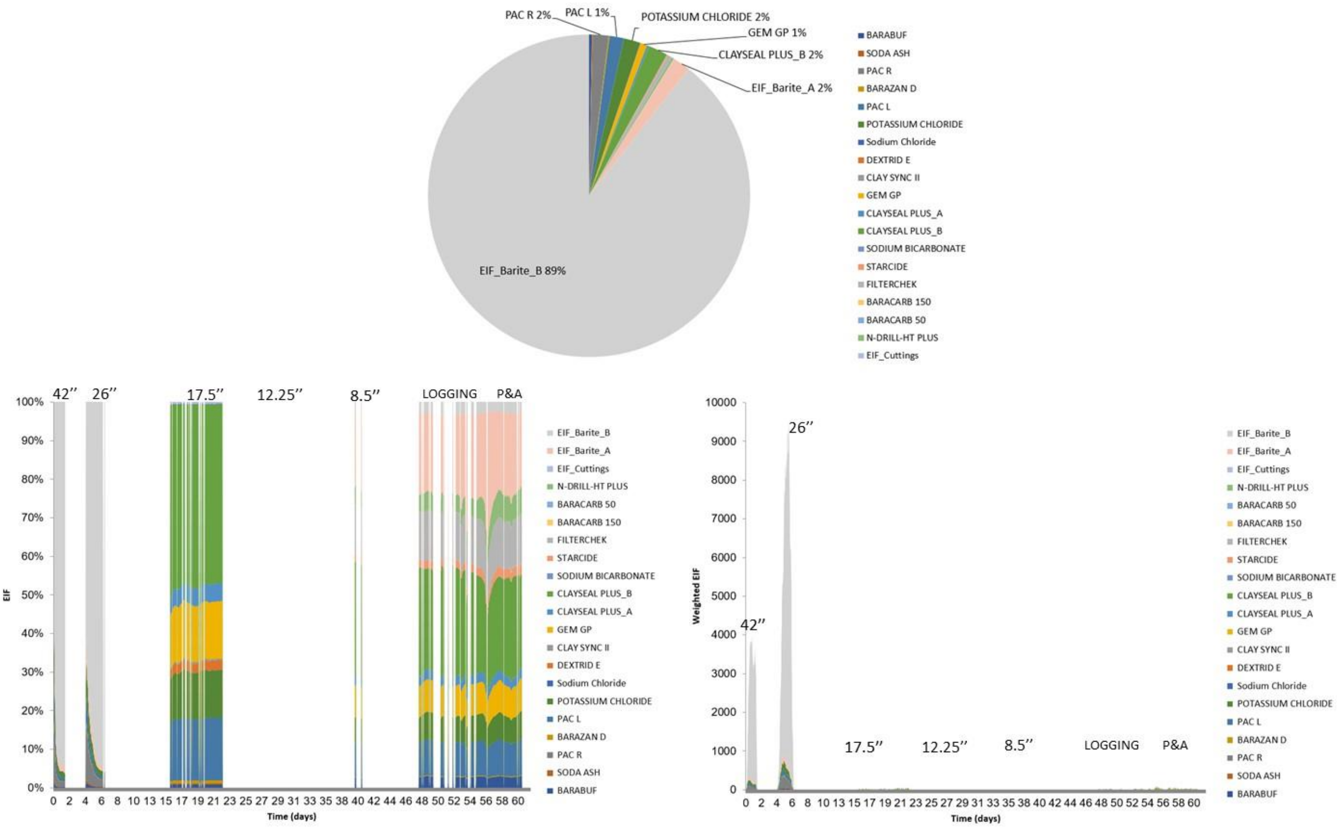


Figure 40: Main contributors to the risk of drilling operations in the water column for Scenario 5 and main contributors to the risk over the time (Start June 1st)

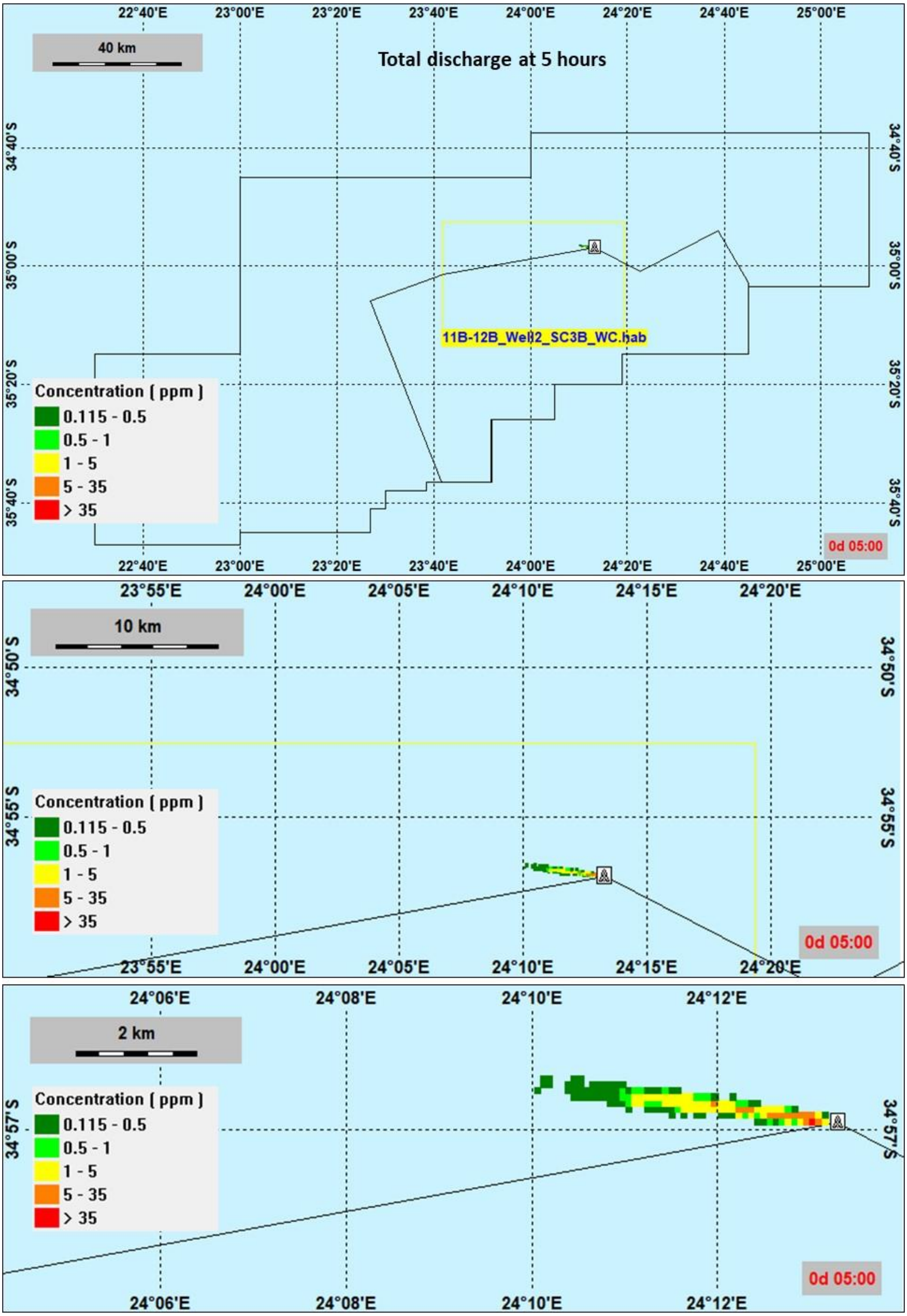
3.1.2.1.2 Discharge concentrations

Figure 41 and Figure 42 show the concentrations of the total discharge and of the main contributor to the environmental risk in the plume around the discharge point (including cuttings and chemicals).

During the discharge of all the sections, the maximum total concentrations were as described below (without the smoothing option):

- 42" section: up to 78 ppm (cuttings + chemicals)
- 26'' section: up to 59 ppm (cuttings + chemicals)
- 17.5" section: up to 1.18 ppm (cuttings + chemicals)
- 12.25" section: up to 0.59 ppm (cuttings + chemicals)
- 8.5'' section: up to 0.38 ppm (cuttings + chemicals)
- Logging and P&A: up to 1.17 ppm (chemicals only)

Figure 41 also shows that the highest contaminant concentrations are observed at the seabed (maximum 100 m above seabed) for the discharge of the 42" and 26" sections, mainly due to the presence of Barite. The Barite is the main contributor to the total risk due to the high amounts released at sea during the discharge of the riserless sections.


Total discharge at 5 hours
40 km
10 km
2 km
11B-12B_Well2_SC3B_WC.hab
Concentration (ppm)
0.115 - 0.5
0.5 - 1
1 - 5
5 - 35
> 35
0d 05:00
22°40'E
23°00'E
23°20'E
23°40'E
24°00'E
24°20'E
24°40'E
25°00'E
34°40'S
35°00'S
35°20'S
35°40'S
23°55'E
24°00'E
24°05'E
24°10'E
24°15'E
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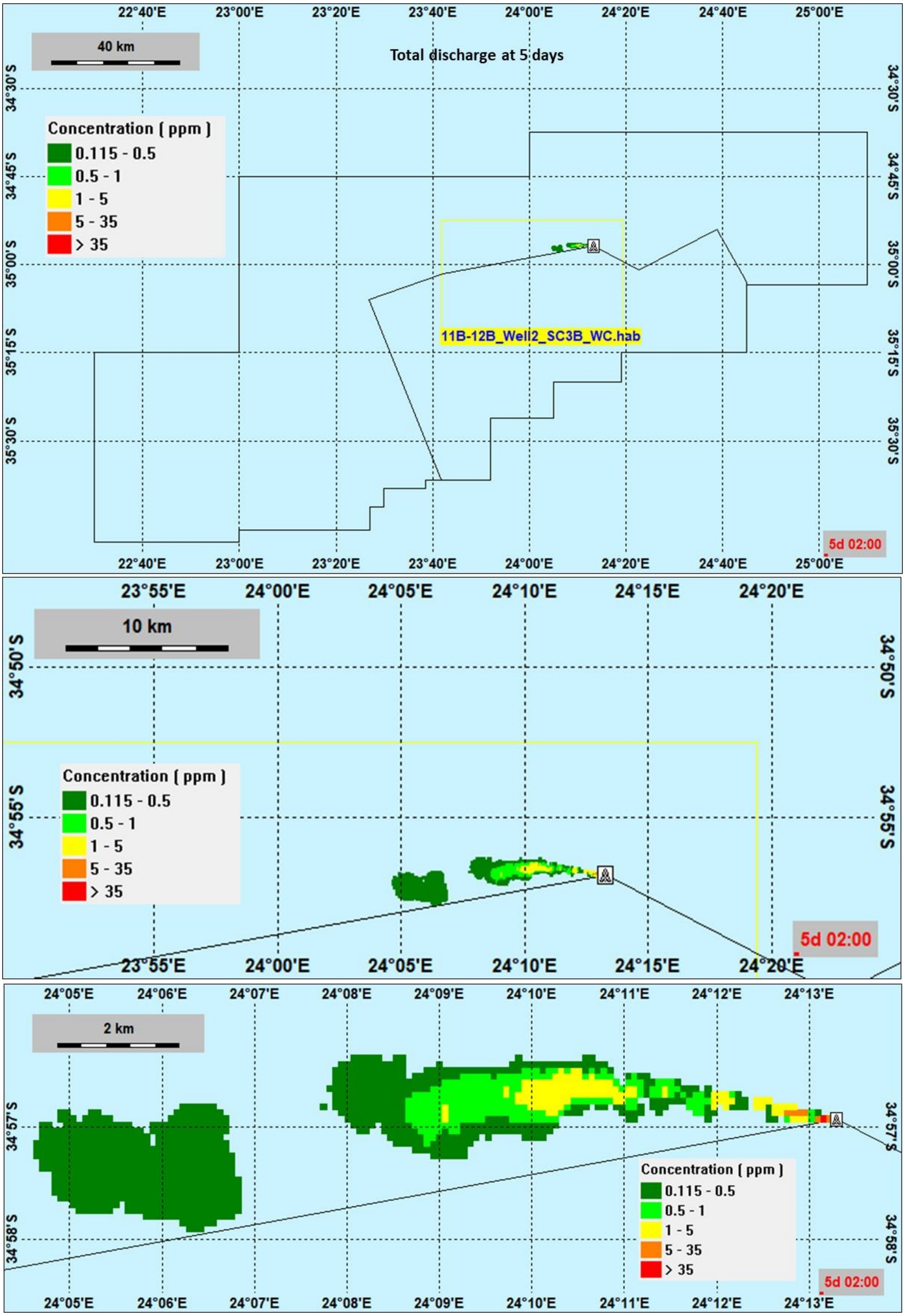
24°10'E
24°12'E
34°57'S


Total discharge at 5 days
40 km
Concentration (ppm)
0.115 - 0.5
0.5 - 1
1 - 5
5 - 35
> 35
11B-12B_Well2_SC3B_WC.hab
5d 02:00
10 km
Concentration (ppm)
0.115 - 0.5
0.5 - 1
1 - 5
5 - 35
> 35
5d 02:00
2 km
Concentration (ppm)
0.115 - 0.5
0.5 - 1
1 - 5
5 - 35
> 35
5d 02:00

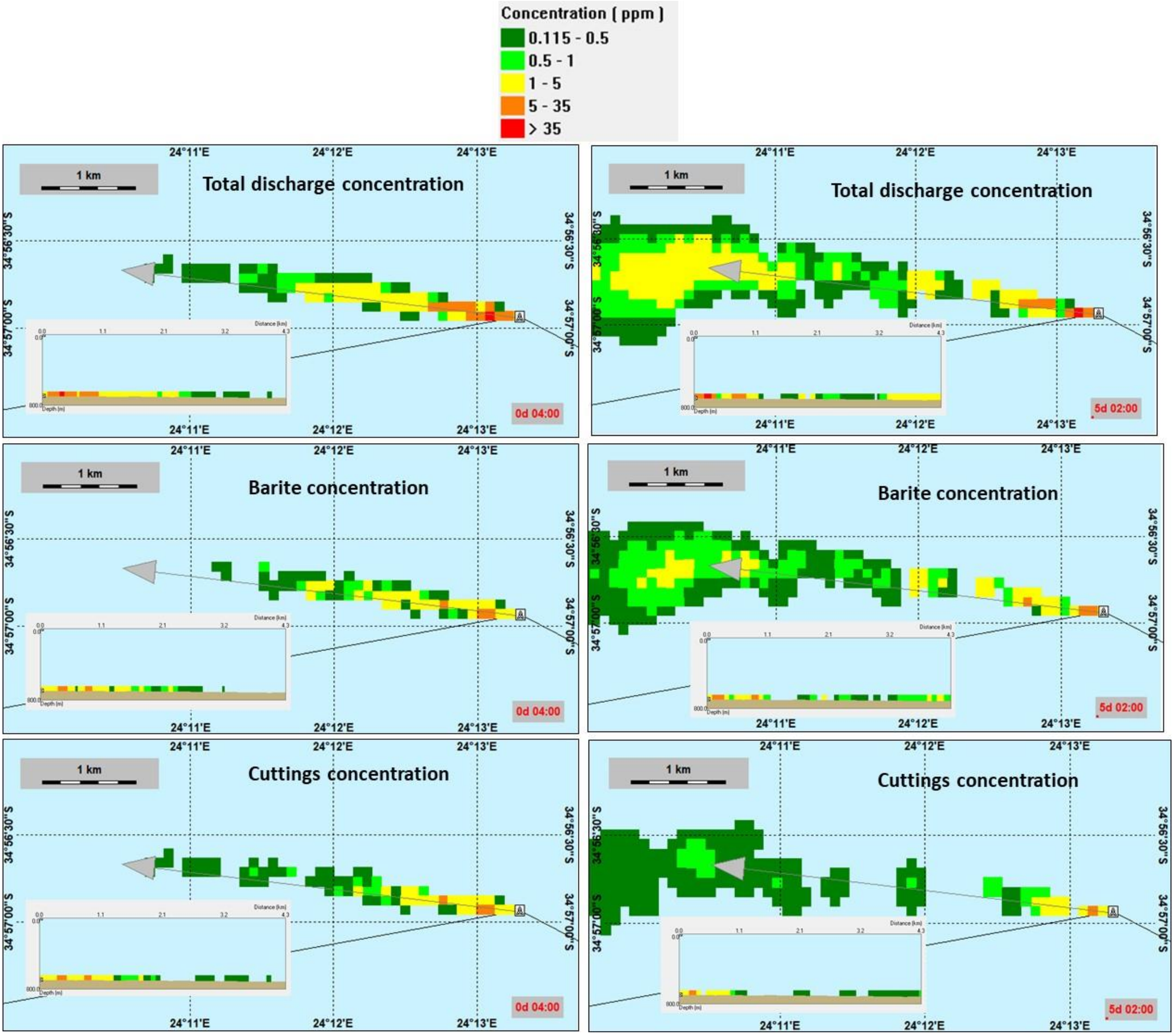


Figure 41: Instantaneous concentrations of total discharge, main contributor (Barite) and cuttings at one time at the end of drilling operations of the 42" and 26" sections (scenario 5)

Figure 42 shows the concentration of the Barite in the water column during the discharge of the 42" and 26" sections.

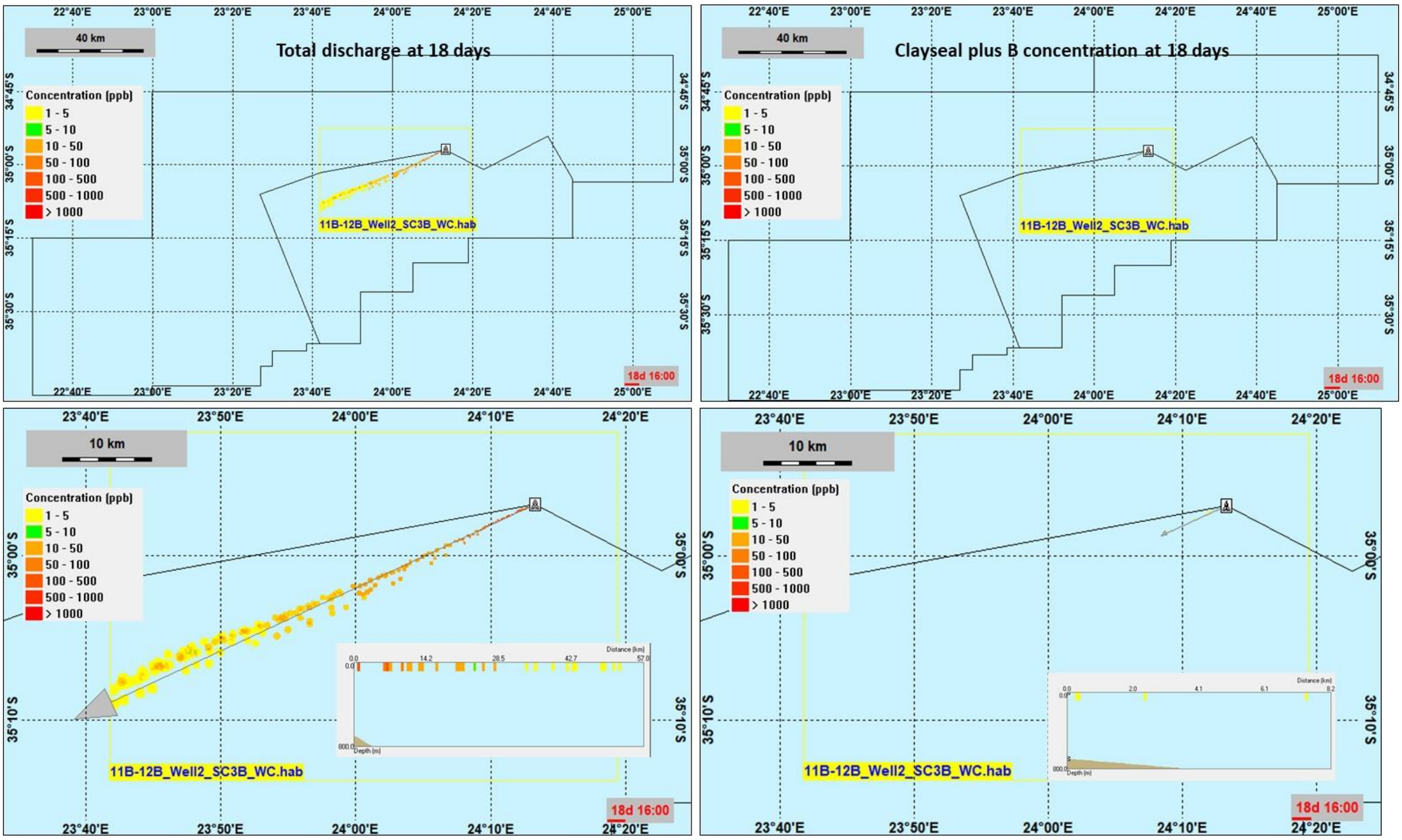


Figure 42: Instantaneous concentrations of total discharge and main contributor (Clayseal Plus_B: hydrochloric Acid 10%) during the 17.5" sections (scenario 5)

3.1.3 Synthesis for the water column for Discharge n°2

The results obtained for all the scenarios ran for the water column are presented in Table 9 below.

Table 10: Result synthesis for the water column

	Base case				Optional case
	Scenario1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Maximum total discharge concentration in the water column (ppm)	31 ppm	30 ppm	31 ppm	34 ppm	78 ppm
Maximum cuttings discharge concentration in the water column (ppm)	18 ppm (always < 35ppm among the 45 days)	8.7 ppm (always < 35ppm among the 45 days)	13 ppm (always < 35 ppm among the 45 days)	6 ppm (always < 35ppm among the 45 days)	30 ppm (always < 35ppm among the 62 days)
Maximum Barite_B discharge concentration in the water column (ppm)	23.7 ppm	21.3 ppm	27 ppm	26 ppm	35 ppm
Chemicals concentrations	All chemical concentrations are below PNEC except: **Pac R**: max.=6700 ppb (>80.86 ppb (PNEC) 28 hours among 45 days) **Pac L**: max.=350 ppb (>80.86 ppb (PNEC) 33 hours among 45 days) **Potassium Chloride**: max.=6000 ppb (>1000 ppb (PNEC) 40 hours among 45 days)	All chemical concentrations are below PNEC except: **Pac R**: max.=685 ppb (>80.86 ppb (PNEC) 9 hours among 45 days) **Pac L**: max.=210 ppb (>80.86 ppb (PNEC) 33 hours among 45 days) **Potassium Chloride**: max.=6100 ppb (>1000 ppb (PNEC) 30 hours among 45 days)	All chemical concentrations are below PNEC except: **Pac R**: max.=725 ppb (>80.86 ppb (PNEC) 30 hours among 45 days) **Pac L**: max.=350 ppb (>80.86 ppb (PNEC) 24 hours among 45 days) **Potassium Chloride**: max.=6200 ppb (>1000 ppb (PNEC) 29 hours among 45 days)	All chemical concentrations are below PNEC except: All chemical concentrations are below PNEC except: **Pac R**: max.=750 ppb (>80.86 ppb (PNEC) 30 hours among 45 days) **Pac L**: max.=375 ppb (>80.86 ppb (PNEC) 33 hours among 45 days) **Potassium Chloride**: max.=6500 ppb (>1000 ppb (PNEC) 30 hours among 45 days)	All chemical concentrations are below PNEC except: **Pac R**: max.=1020 ppb (>80.86 ppb (PNEC) 31 hours among 62 days) **Pac L**: max.=502 ppb (>80.86 ppb (PNEC) 28 hours among 62 days) **Potassium Chloride**: max.=8841 ppb (>1000 ppb (PNEC) 30 hours among 62 days) **Clayseal Plus B:** max.= 4.6 ppb (>3.25 ppb (PNEC) 7 hours among 62 days)

Max instantaneous risk (EIF)	11016	11168	10136	12000	9504
Time Averaged Risk EIF* (10^5 m^3)	380	337	250	355	17
Duration in days with EIF > 0	15.9/45	4.2/45	12.2/45	4.7/45	19.2/62
Last detection of the risk >5% in the water column (days)	43	43	43	43	61
Maximum distance at risk around the discharge point (km)	30 km (one main patch for riserless section) 24 km (small patches for riser)	15 km (one main patch for riserless section) 10 km (small patches for riser)	35 km (one main patch for riserless section) 21 km (small patches for riser)	12 km (one main patch for riserless section) 11 km (small patches for riser)	35 km (one main patch for riserless section) 12 km (small patches for riser)
Main contributors to the risk	Barite: 90%	Barite: 93%	Barite: 92%	Barite: 92%	Barite: 89%

*1 EIF for water column = 100 m x 100 m x 10 m = 10^5 m^3

The approach used by the model for risk calculation is based on the PEC/PNEC calculation. Basically, concentration calculated taking into account the dilution factor (PEC) is compared to toxic threshold (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 because it tends to protect 95 % of species in any ecosystem without taking into account local specificity. For instance, coastal ecosystems usually show higher biodiversity and biomass and such a difference is not considered when using the PEC/PNEC approach.

The risk calculation must be balanced taking into account knowledge of environmental specialist for the study area (presence or absence of sensitive species/habitats should be considered).

3.2 Sediments compartment

Given the characteristics of the release, the environmental impact on the sediments will be due solely to the thickness of the sediment deposit and to the change in particle size of the medium.

The oxygen depletion in the sediment contributing to the risk is equal to zero for all the scenarios, because it is directly related to the biodegradation of the chemicals in the sediment, which is zero in all cases due to the physical and chemical properties of the chemicals used (either particulates for weighting agents or below kow 1000 for liquid chemicals).

3.2.1 Base case (scenario 1 – 4)

3.2.1.1 Discharge n°2 - Scenario 1 (Start Time January 1st)

3.2.1.1.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk associated with the discharge of drilling operations for the sediments, considering Scenario 1, is presented in Figure 43, Figure 44 and Figure 45. The total risk presents a cumulative picture of all stressors contributing to the risk from the sediments.

These figures show that a significant risk above 5% is observed around the well to be drilled. A Maximum risk of 63% has been calculated without the smoothing option. However, the spatial risk is relatively limited. A significant risk has been calculated in an area of up to 175 m radius around the discharge point just after the end of drilling operations (170 m).

The risk is not completely centralized around the discharge point and Figure 43 shows that risk above 5% is orientated towards West. This clearly shows the impact of seabed current on drill cuttings dispersion and settlement in the sediments.

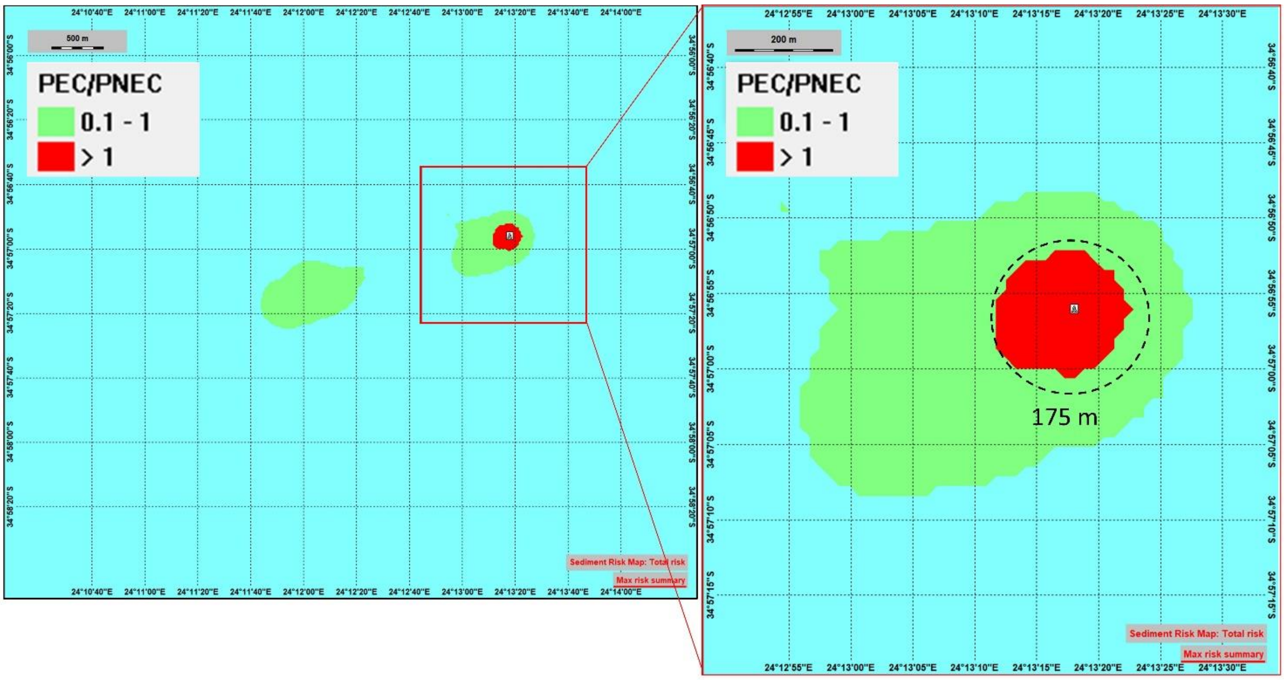


Figure 43: Maximum risk of drilling operations in the sediments for the Scenario 1 (with smoothing) at the end of drilling operations (45 days)

Figure 44 shows that a significant risk is observed in an area with a length of up to 170 m from the discharge point.

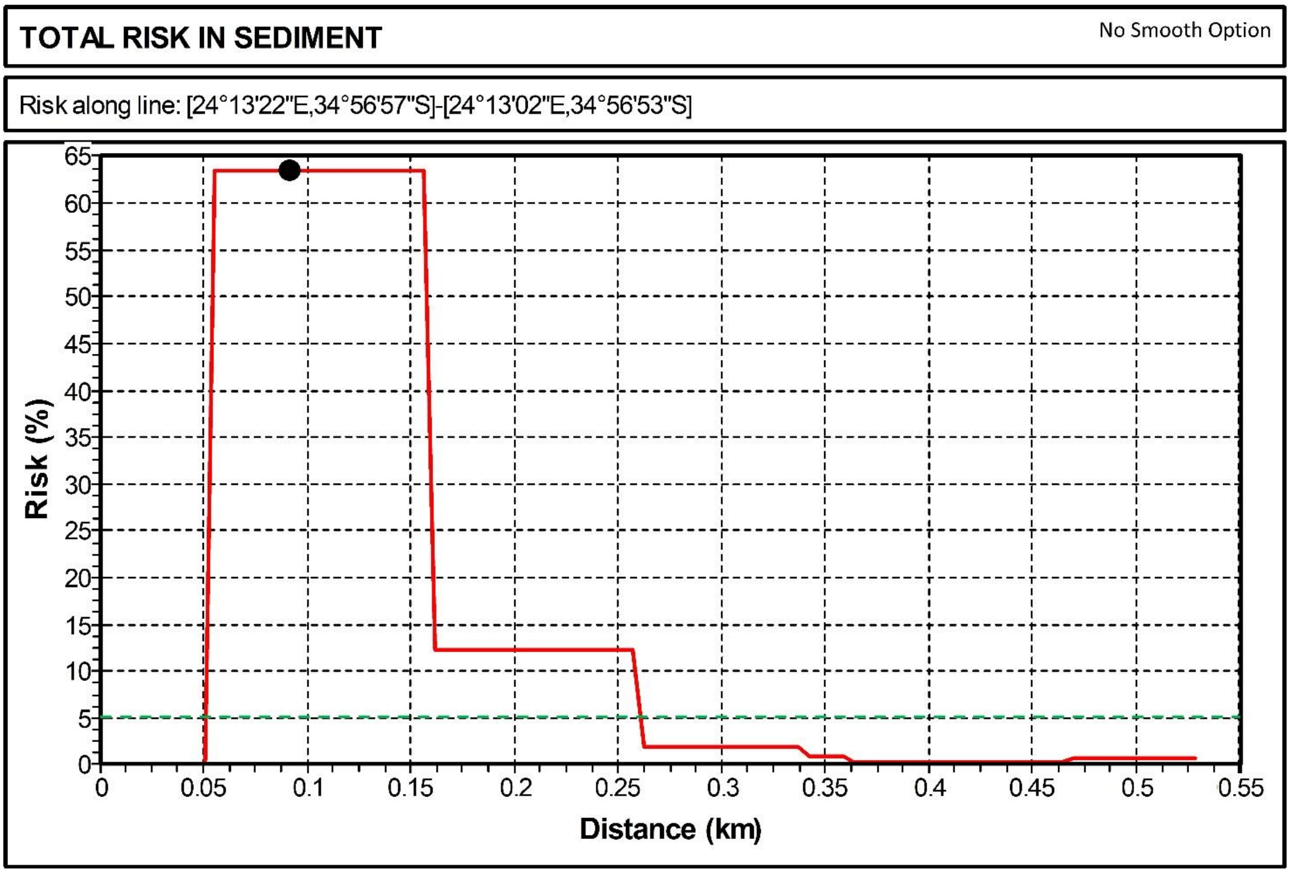


Figure 44: Maximum risk of drilling operations along a line for the Scenario 1 (black dot symbolizes the discharge point; the green dashed line symbolizes the 5% threshold)

Figure 45 shows that the risk decreases over the time in the sediments at the discharge point from the end of the drilling operations to insignificant values approximately 1500 days after the beginning of the operations.
There is no more environmental risk in the sediment 4 years after the operations.

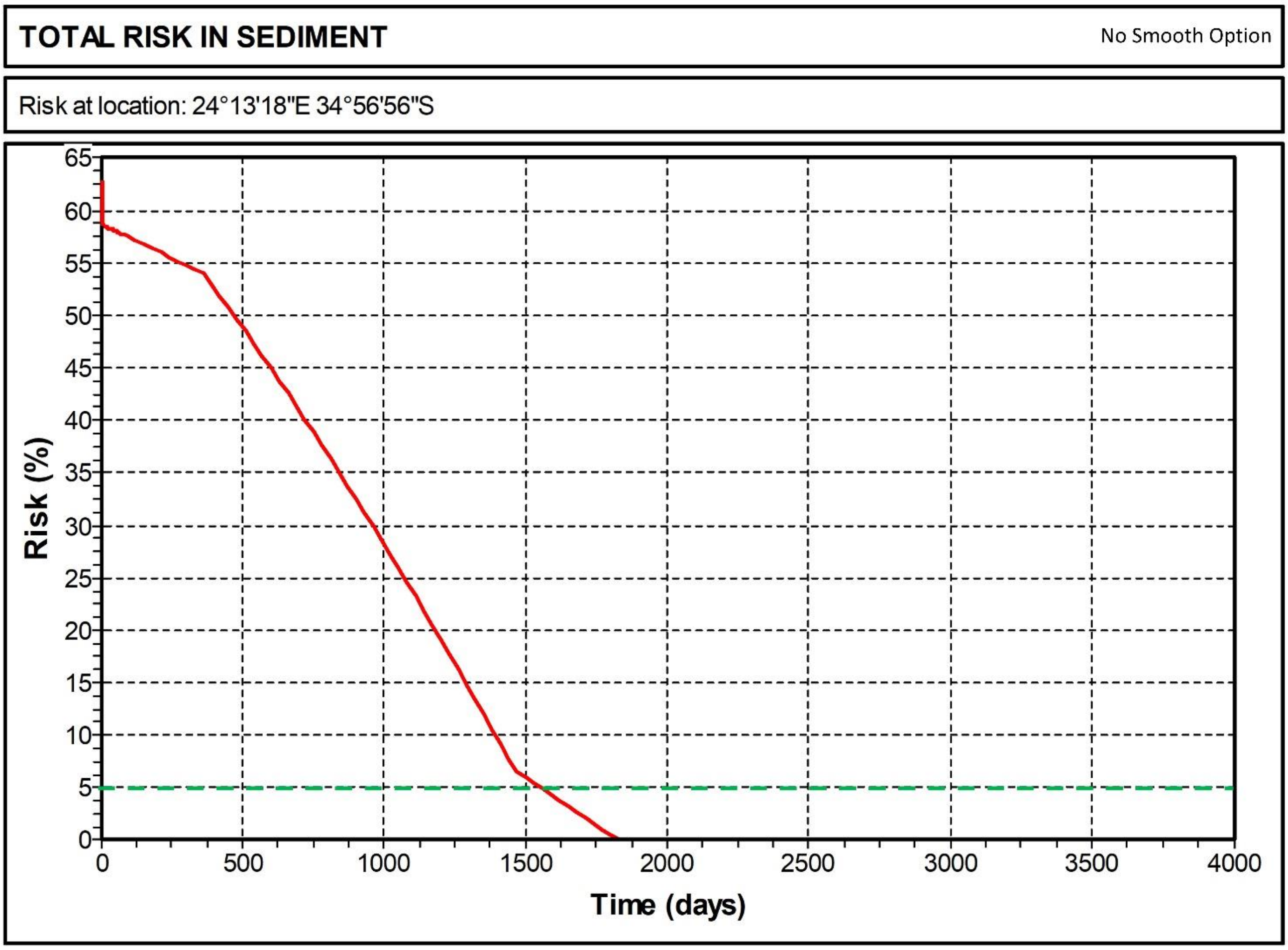


Figure 45: Maximum risk of drilling operations close the discharge point over the time for the Scenario 1 (the green dashed line symbolizes the 5% threshold)

Figure 46 shows the main contributors to the risk in the sediments for the Scenario 1. The main contributors to the total risk are physical, due to the grain size change of the natural sediment and the thickness of the deposit, contributing respectively to 76% and 24% of the total environmental risk for the sediment.

Figure 46 shows that the contribution of the different stressors to the total risk changes over the time with a significant increase of the grain size change 17 days after the start of the discharge.

These results will be further discussed in the following sections.

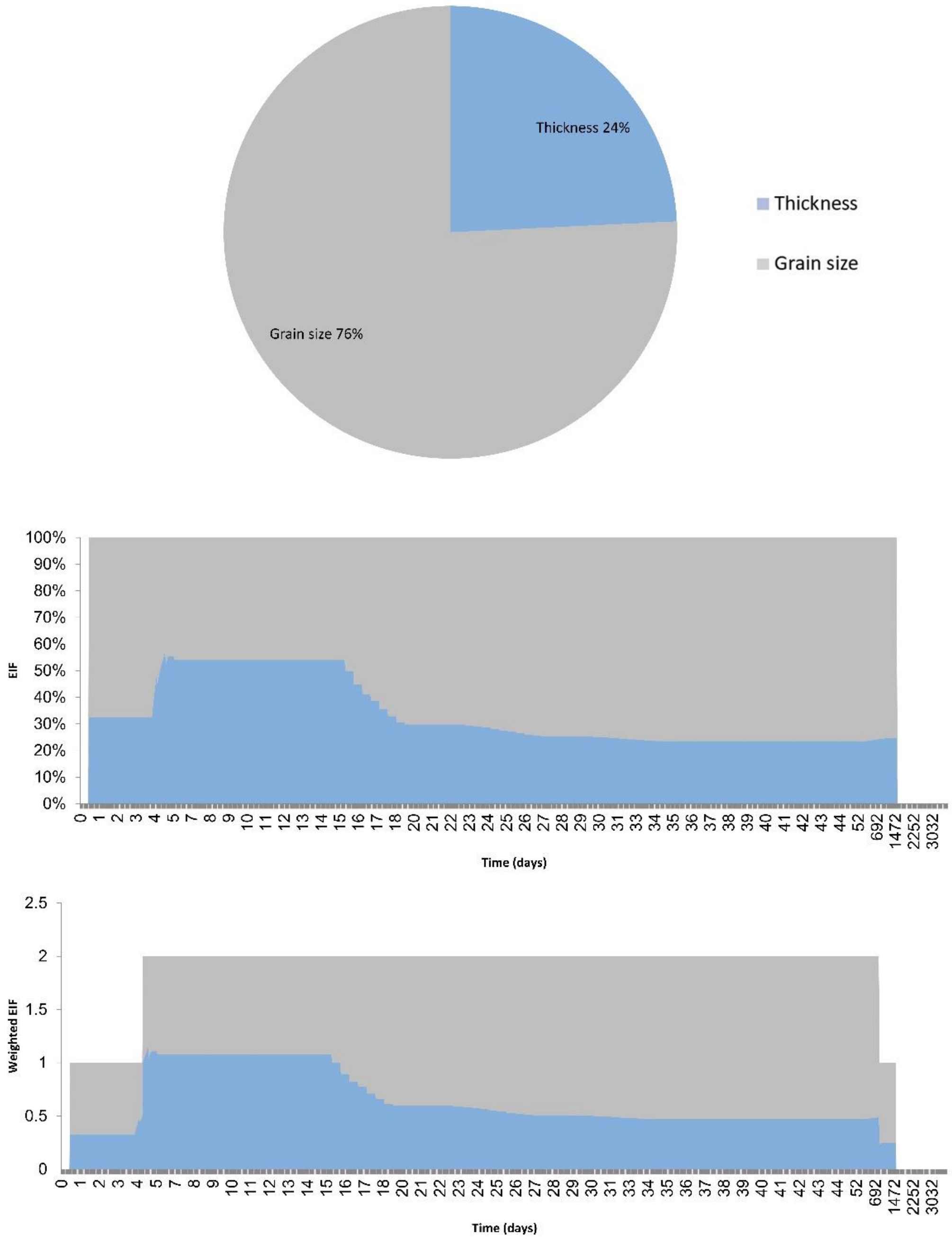


Figure 46: Main contributors to the risk of drilling operations for the Scenario 1

Figure 46 shows that grain size variation on the sediments and sediment thickness change over the time. No more risk corresponding to this contributor is observed after approximately 1500 days.

3.2.1.1.2 Grain Size Variation

Figure 47 and Figure 48 show grain size variation on the sediments at the end of drilling operations. One main area with significant sediment grain size changes is observed around the well due to the release of the 42'' and 26'' sections. The maximum grain size variation observed was up to 210 % on a 100 m radius around the discharge point without the smoothing option (200 m on the map with the smoothing option).

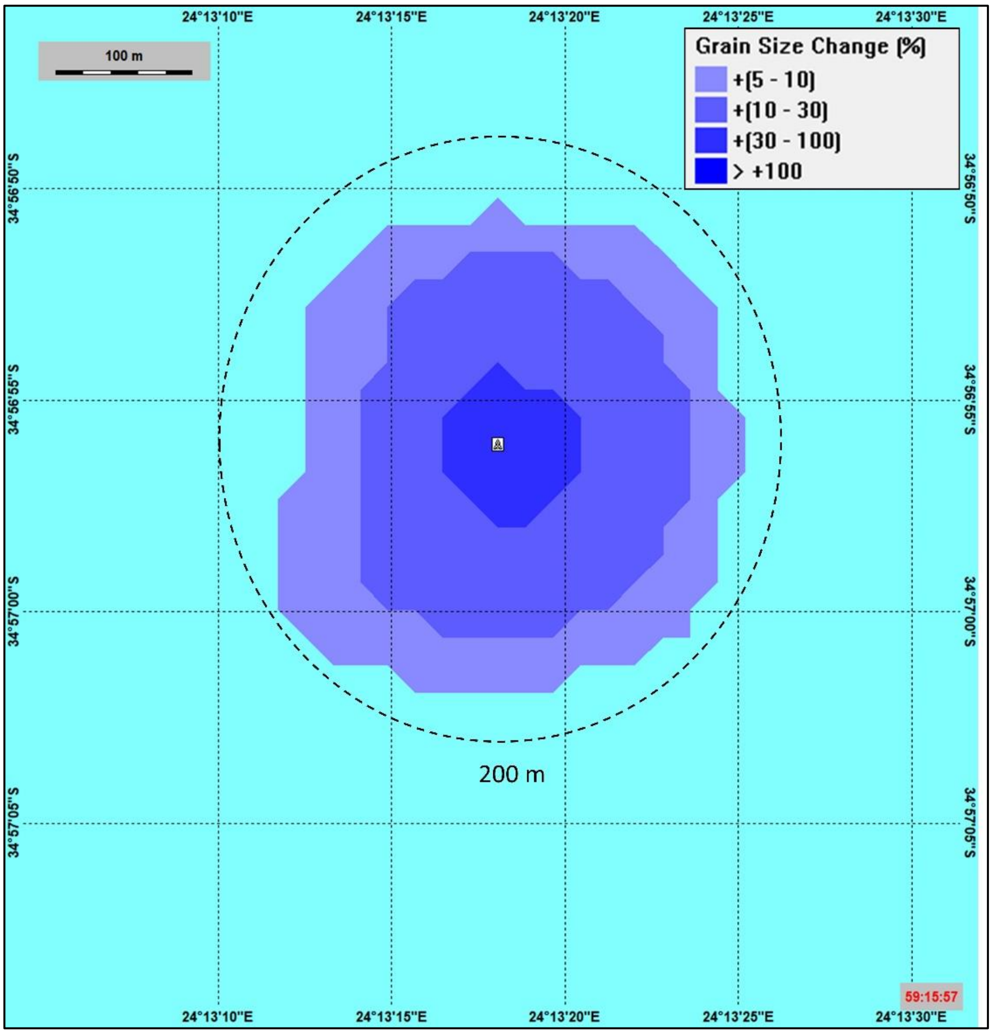


Figure 47: Grain size variations in the superficial section of seabed sediments at the end of drilling operations (Scenario 1)

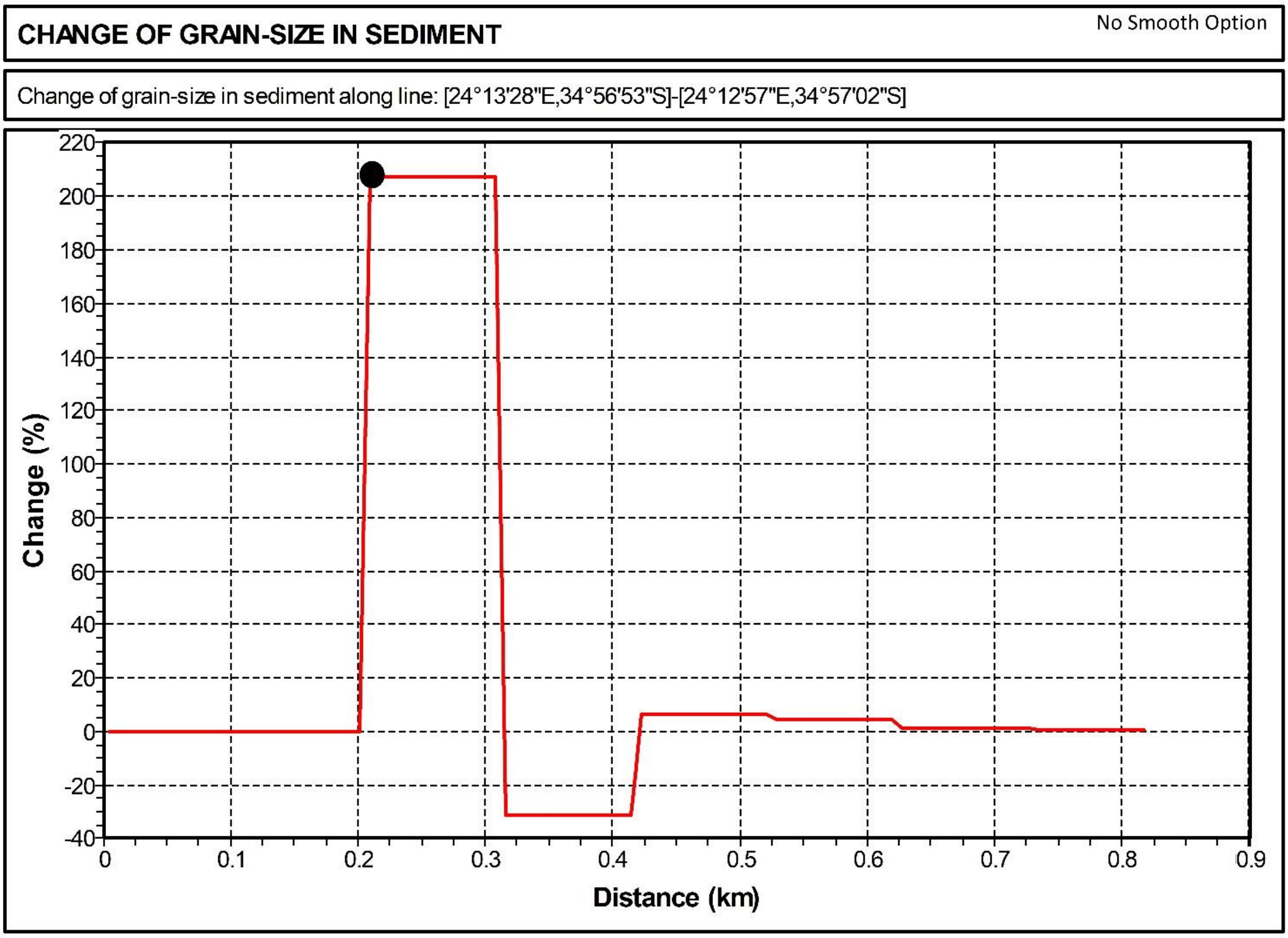


Figure 48: Grain size variations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 1) (black dot symbolizes the discharge point)

3.2.1.1.3 Thickness Deposits

Figure 49 and Figure 50 show cuttings thickness deposits at the end of drilling operations. The sediment deposit area is not centralized around the discharge point and is orientated South-West from the discharge point. This clearly shows the impact of seabed currents on sediment deposition.

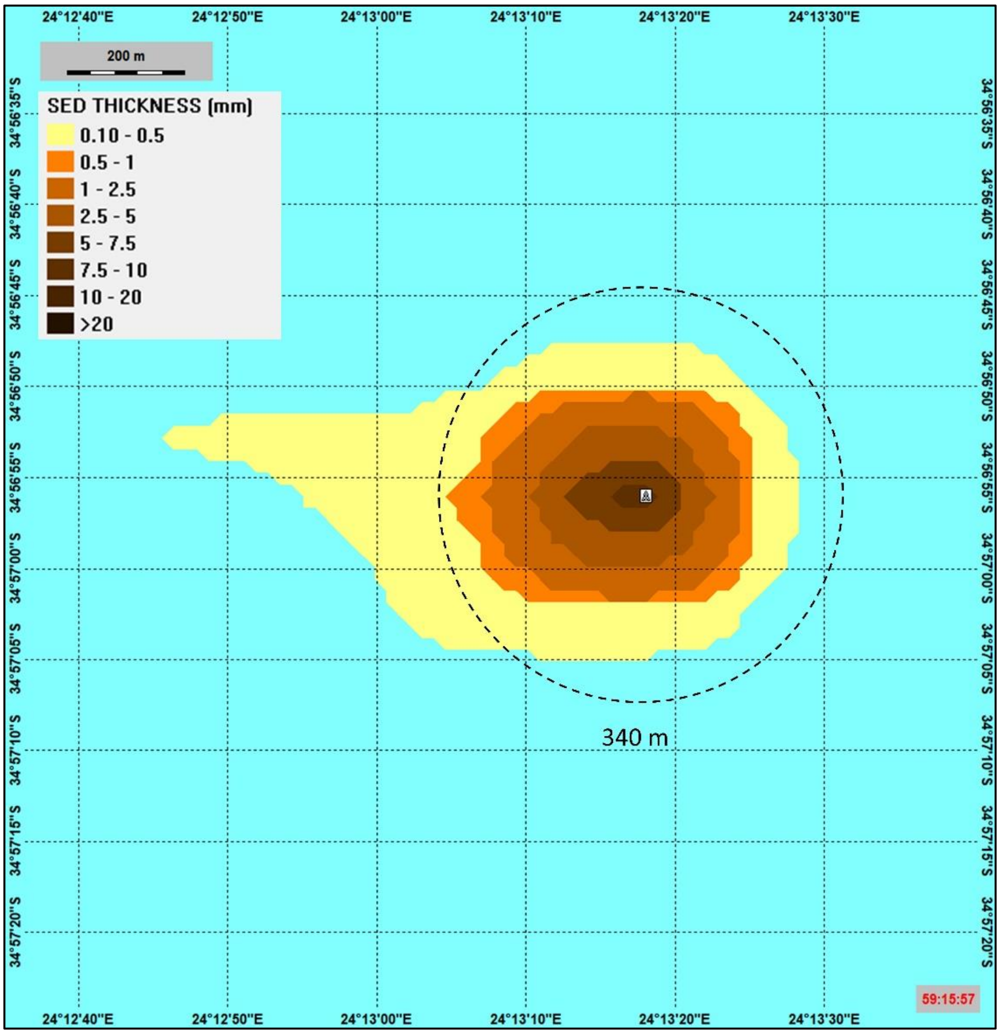


Figure 49: Cuttings thickness deposit on sediment at the end of drilling operations (Scenario 1)

Figure 50 shows that the maximum sediment thickness observed was up to 30 mm on a 175 m radius around the discharge point without the smoothing option activated (and up to 340 m with the smoothing on the map).

Figure 49 clearly shows that the highest sediment deposit concentrations are localized very close to the discharge point. The highest cuttings deposit is mainly due to the discharge of the top-hole sections (42'' and 26'') contributing to 28 mm among the total 30 mm deposit at the end of all operations without the smoothing. For the other sections (17.5'', 12.25'' and 8.5'') discharged at sea surface, the cuttings are more spread in the water column towards West leading to lower thickness at the seabed.

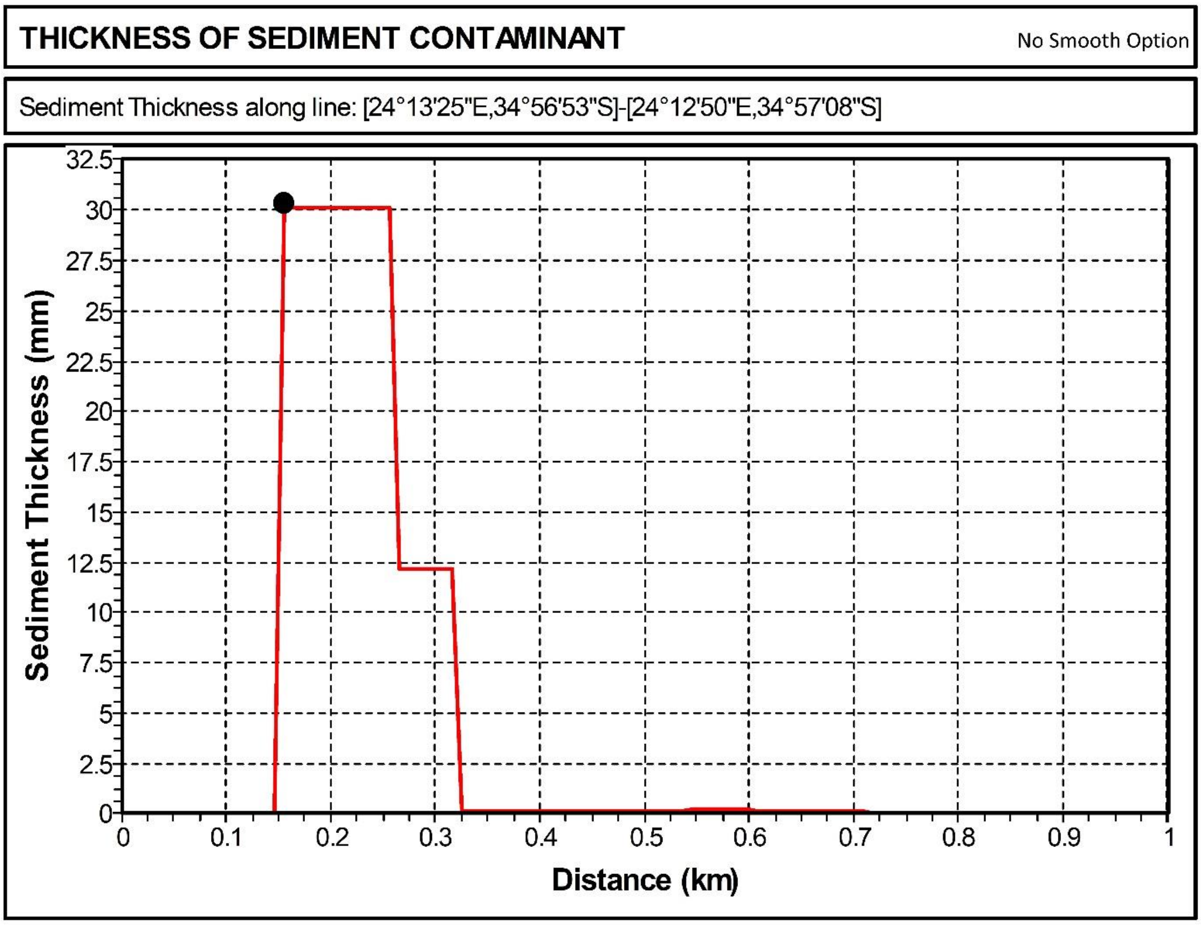


Figure 50: Cuttings thickness deposit on sediment around the discharge point along a line at the end of drilling operations (Scenario 1) (black dot symbolizes the discharge point)

3.2.1.1.4 Contaminants Concentration

Figure 50 and Figure 51 show the total discharge (cuttings and mud) concentrations on the superficial sediments at the end of drilling operations. High concentrations of discharge, i.e. 1000 g/L without smoothing, is observed in the top sediments but, as discuss previously, mainly particulate compounds (cuttings and barite, i.e. non-soluble chemicals used during drilling operation) account for the total concentrations of the discharge in the sediments.

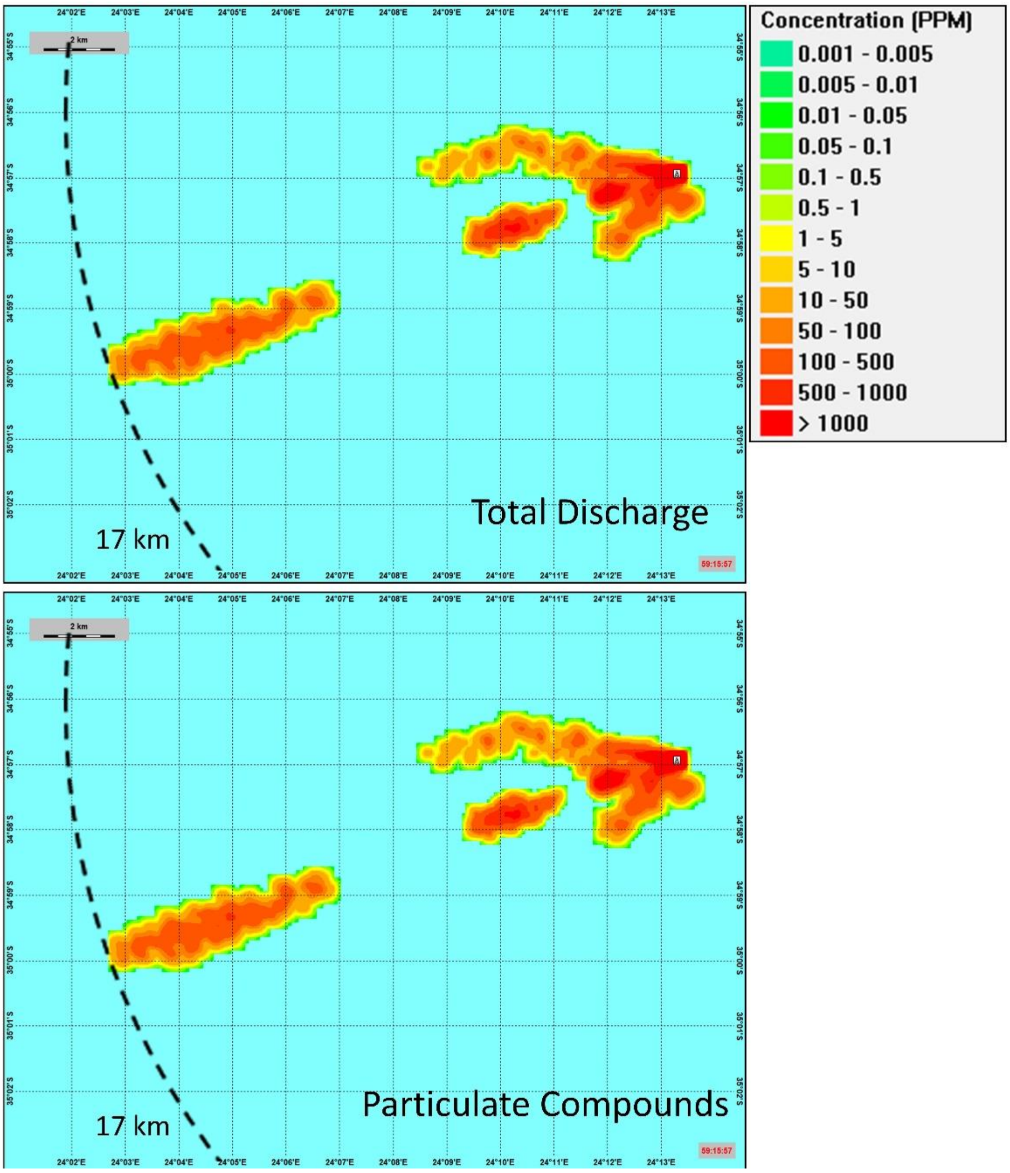


Figure 51: Concentrations of total discharge, and only particulate compounds in the superficial layer of seabed sediments at the end of drilling operations (Scenario 1)

The area with detected discharged chemicals is not centralized around the discharge point and is orientated along an axe starting from the discharge point towards South-West. This clearly shows the impact of seabed currents on sediment deposition.

Figure 52 clearly shows that the highest discharged concentrations in the sediments is localized very close to the discharge point, up to 100 m around the discharged point.

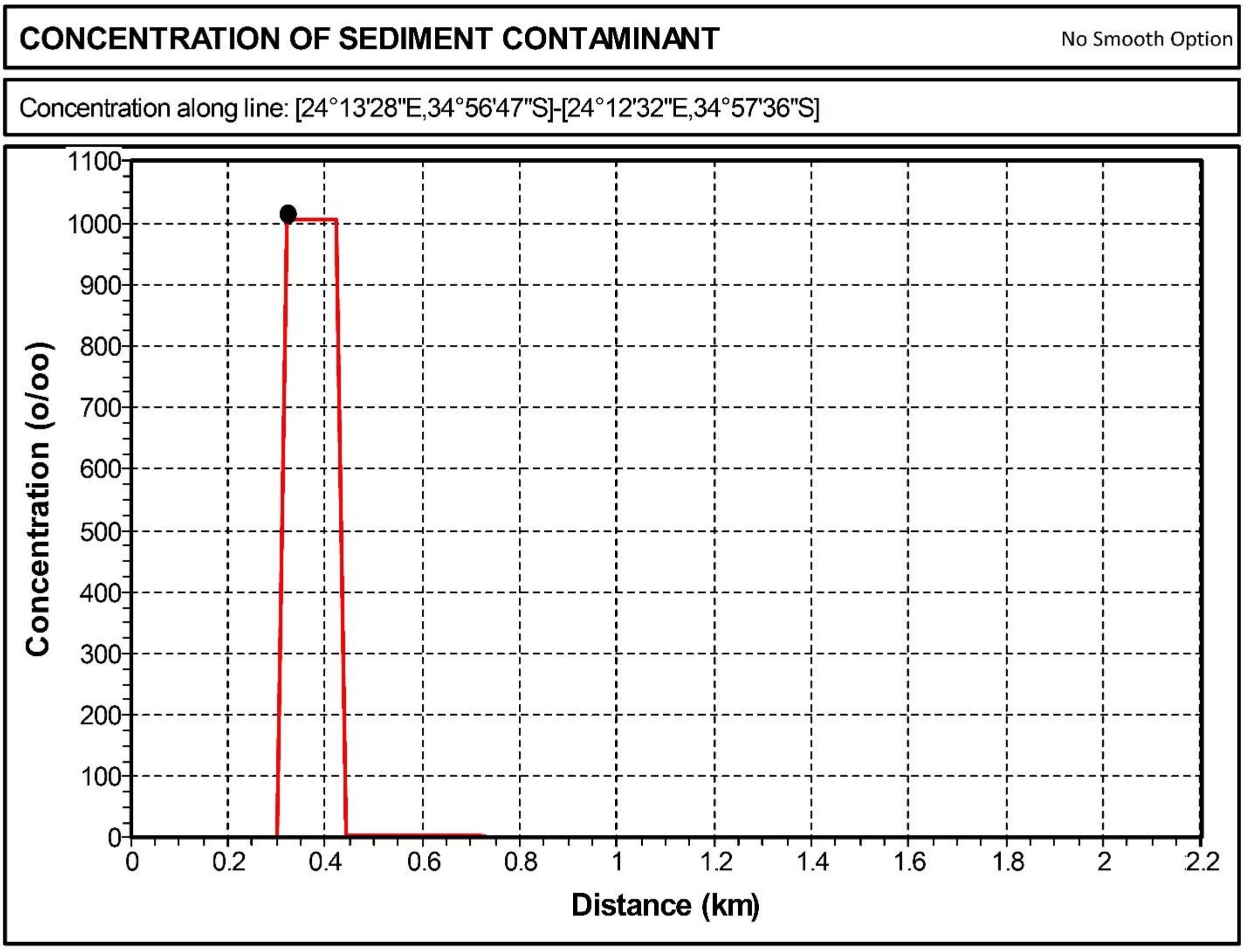


Figure 52: Total discharge concentrations in the superficial section of seabed sediments along a line at the end of drilling operations (40 days) (Scenario 1) (black dot symbolizes the discharge point)

3.2.1.2 Discharge n°2 - Scenario 2 (Start Time March 1st)

3.2.1.2.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk associated with the discharge of drilling operations for the sediments, considering Scenario 2, is presented in Figure 53, Figure 54 and Figure 55. The total risk presents a cumulative picture of all stressors contributing to the risk from the sediments.

These figures show that a significant risk above 5% is observed around the well to be drilled. A Maximum risk of 67% has been calculated without the smoothing option. However, the spatial risk is relatively limited. A significant risk has been calculated in an area of up to 280 m radius around the discharge point to the West South-West just after the end of drilling operations (400 m maximum without smoothing option).

The risk is nearly centralized around the discharge point.

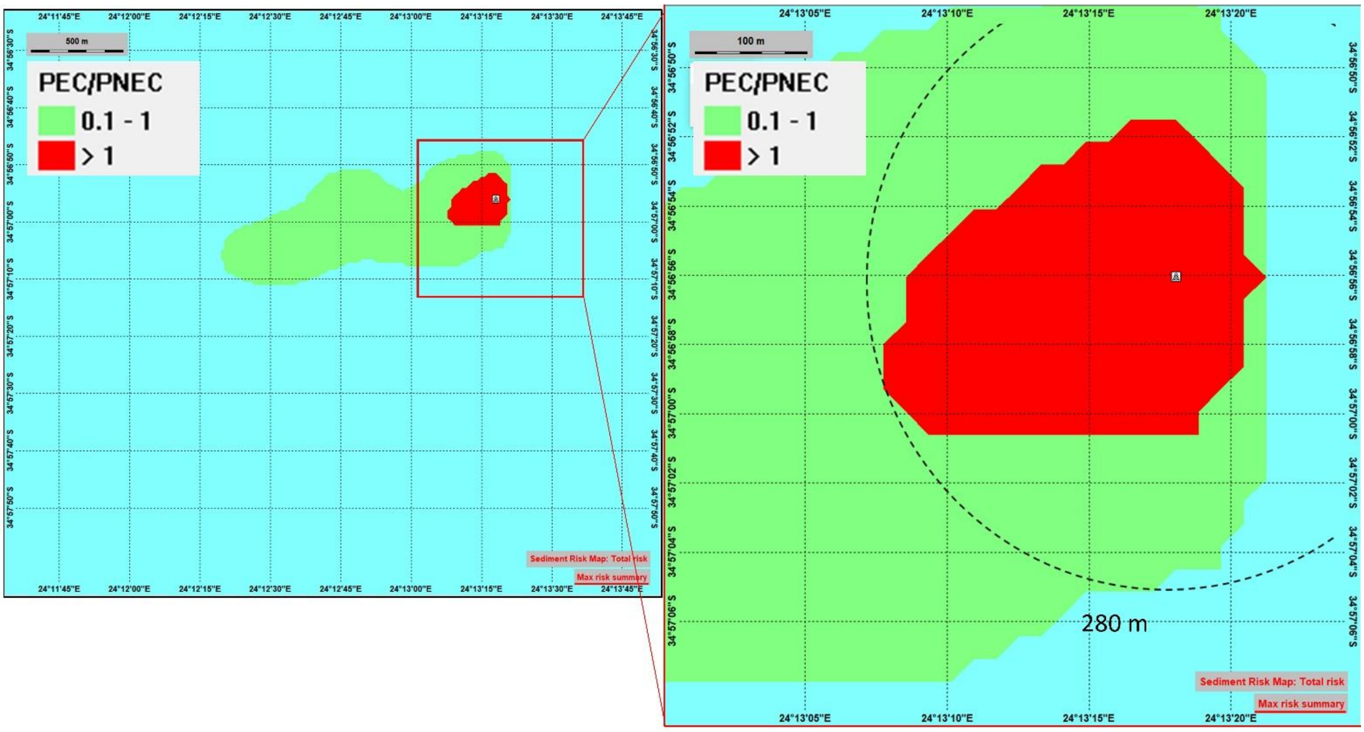


Figure 53: Maximum risk of drilling operations in the sediments for the Scenario 2 (with smoothing) at the end of drilling operations (45 days)

Figure 54 shows that a significant risk is observed in an area with a length of up to 400 m from the discharge point without smoothing option.

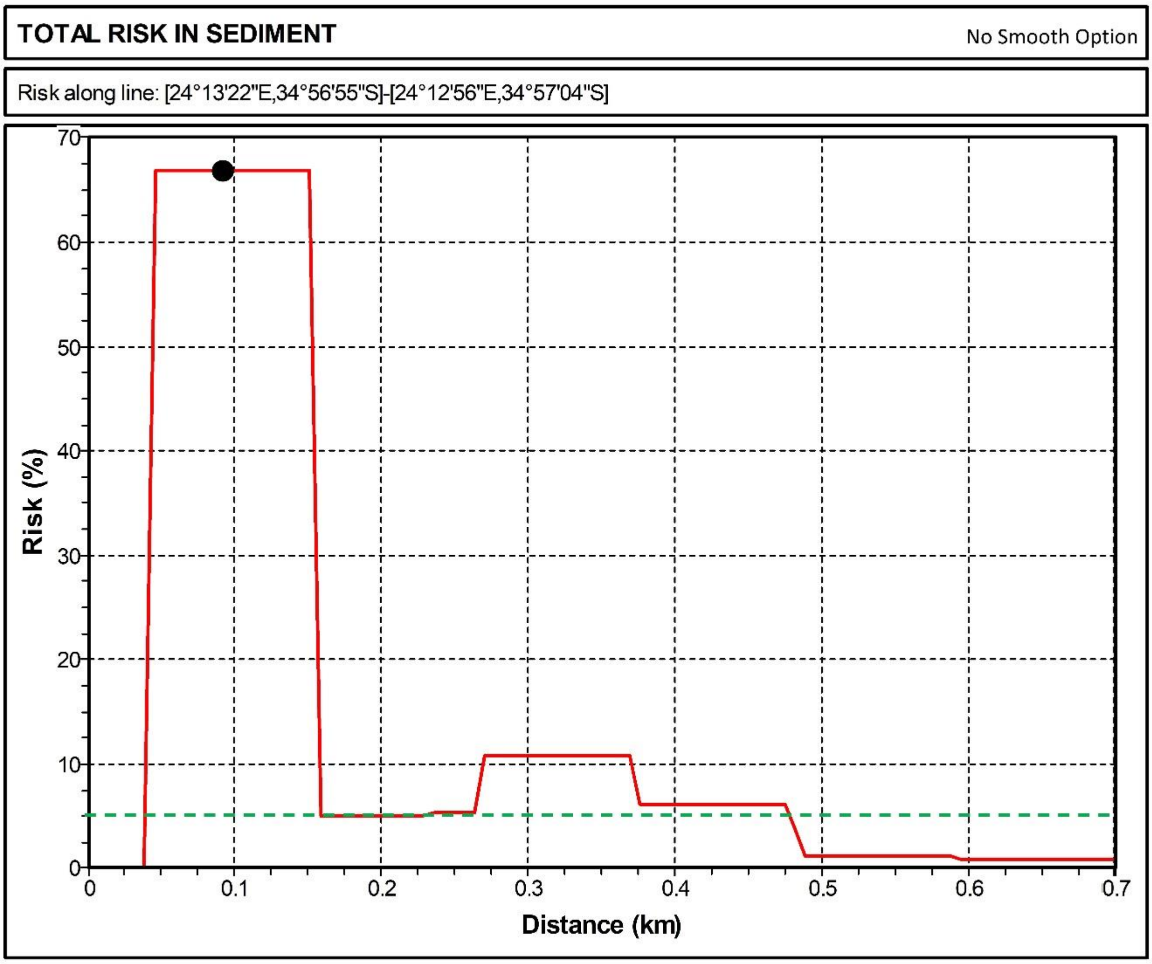


Figure 54: Maximum risk of drilling operations along a line for the Scenario 2 (black dot symbolizes the discharge point; the green dashed line symbolizes the 5% threshold)

Figure 55 shows that the risk decreases over the time in the sediments at the discharge point from the end of the drilling operations to insignificant values approximately 1500 days after the beginning of the operations.
There is no more environmental risk in the sediment 4 years after the operations.

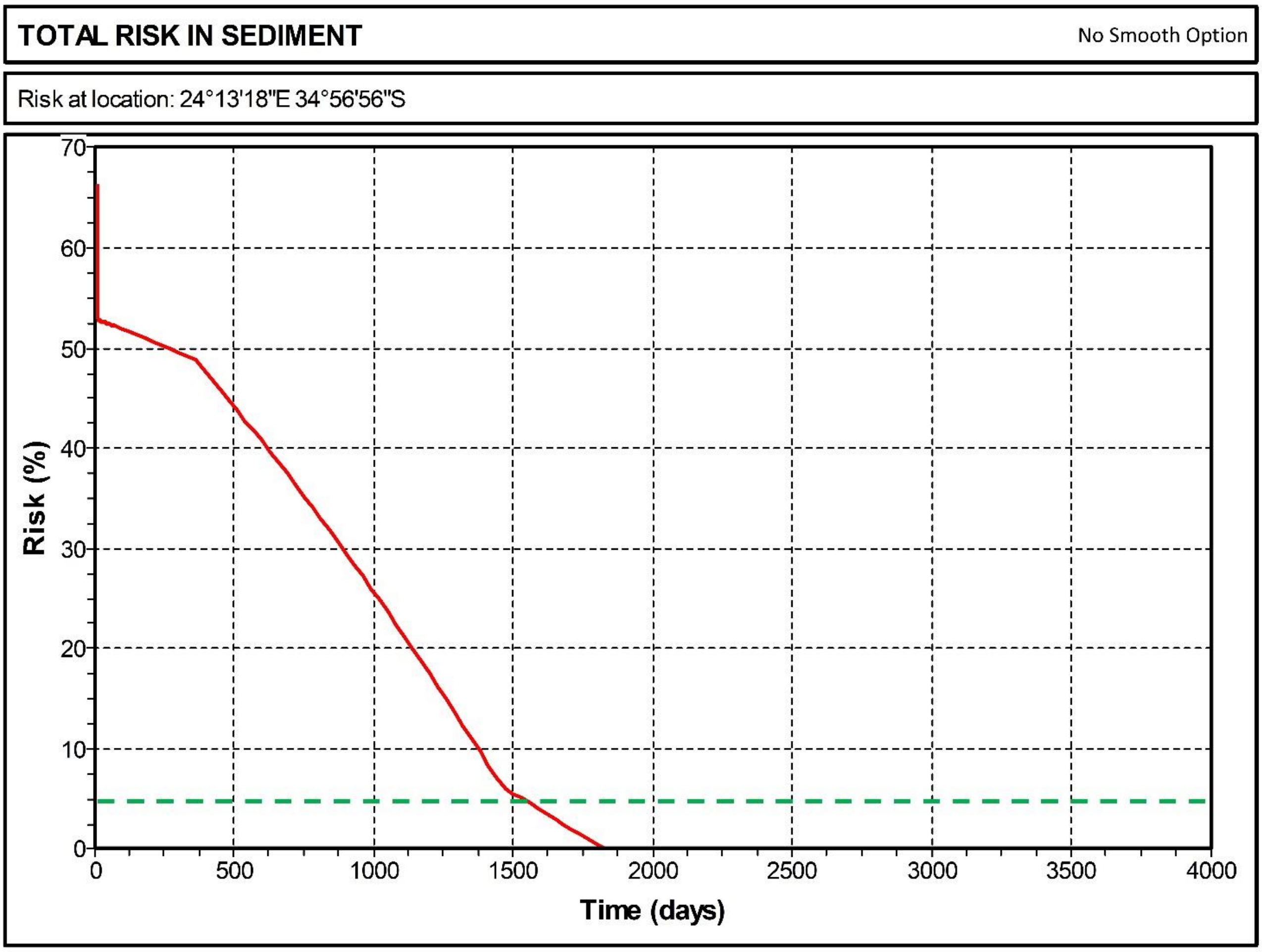


Figure 55: Maximum risk of drilling operations close the discharge point over the time for the Scenario 2 (the green dashed line symbolizes the 5% threshold)

Figure 56 shows the main contributors to the risk in the sediments for the Scenario 2. The main contributors to the total risk are physical, due to the grain size change of the sediment and the thickness of the deposit, contributing respectively to 77% and 23% of the total environmental risk for the sediment.

Figure 56 shows that the contribution of the different stressors to the total risk changes over the time with a significant increase of the grain size change 16 days after the start of the discharge.

These results will be further discussed in the following sections.

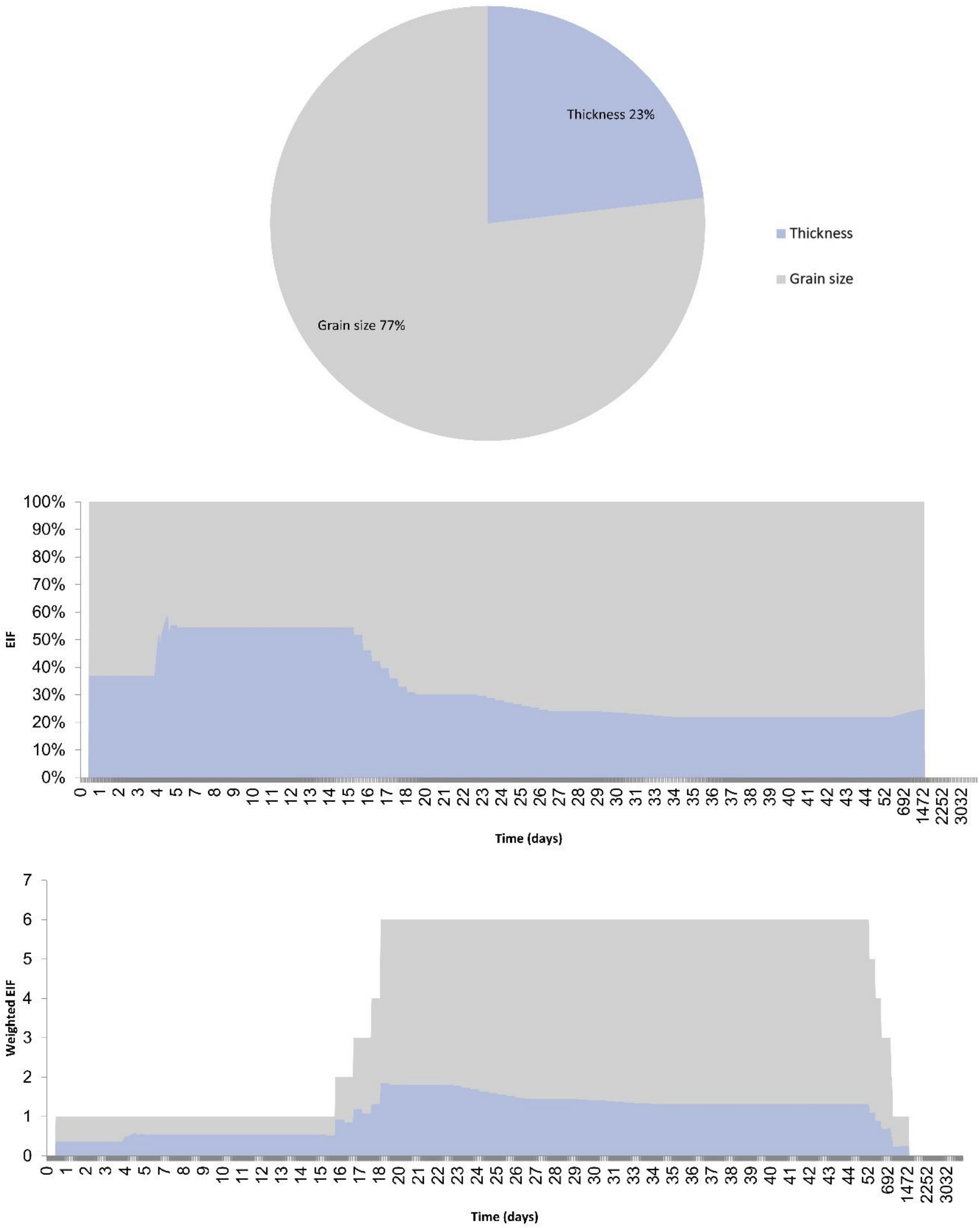


Figure 56: Main contributors to the risk of drilling operations for the Scenario 2

Figure 56 shows that grain size variation on the sediments and sediment thickness change over the time. No more risk corresponding to this contributor is observed after approximately 1500 days.

3.2.1.2.2 Grain Size Variation

Figure 57 and Figure 58 show grain size variation on the sediments at the end of drilling operations. One main area with significant sediment grain size changes is observed (to the South-West) due to the discharge of the 42'' and 26'' sections. The maximum grain size variation observed was up to 87 % on a 120 m radius around the discharge point without the smoothing option (360 m with the smoothing option).

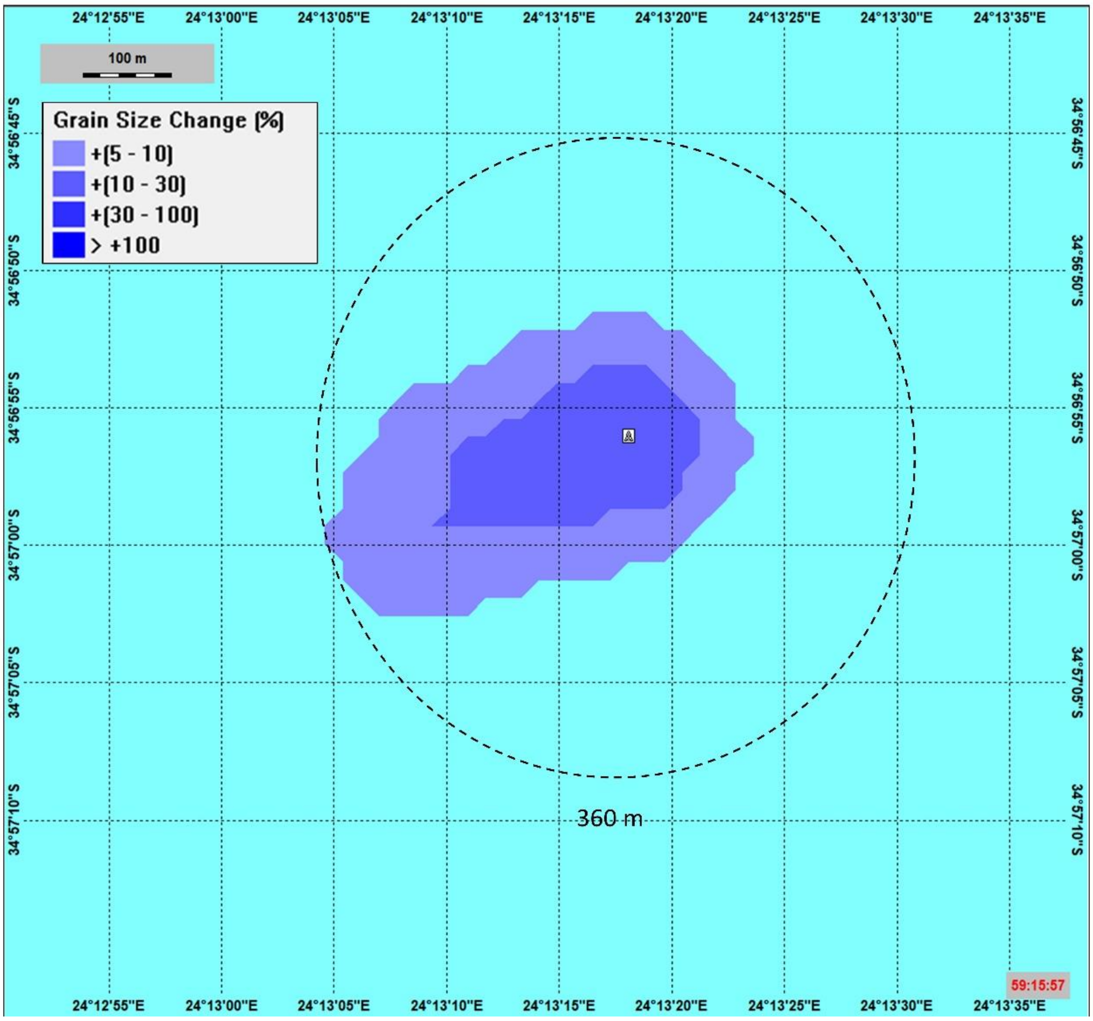


Figure 57: Grain size variations in the superficial section of seabed sediments at the end of drilling operations (Scenario 2)

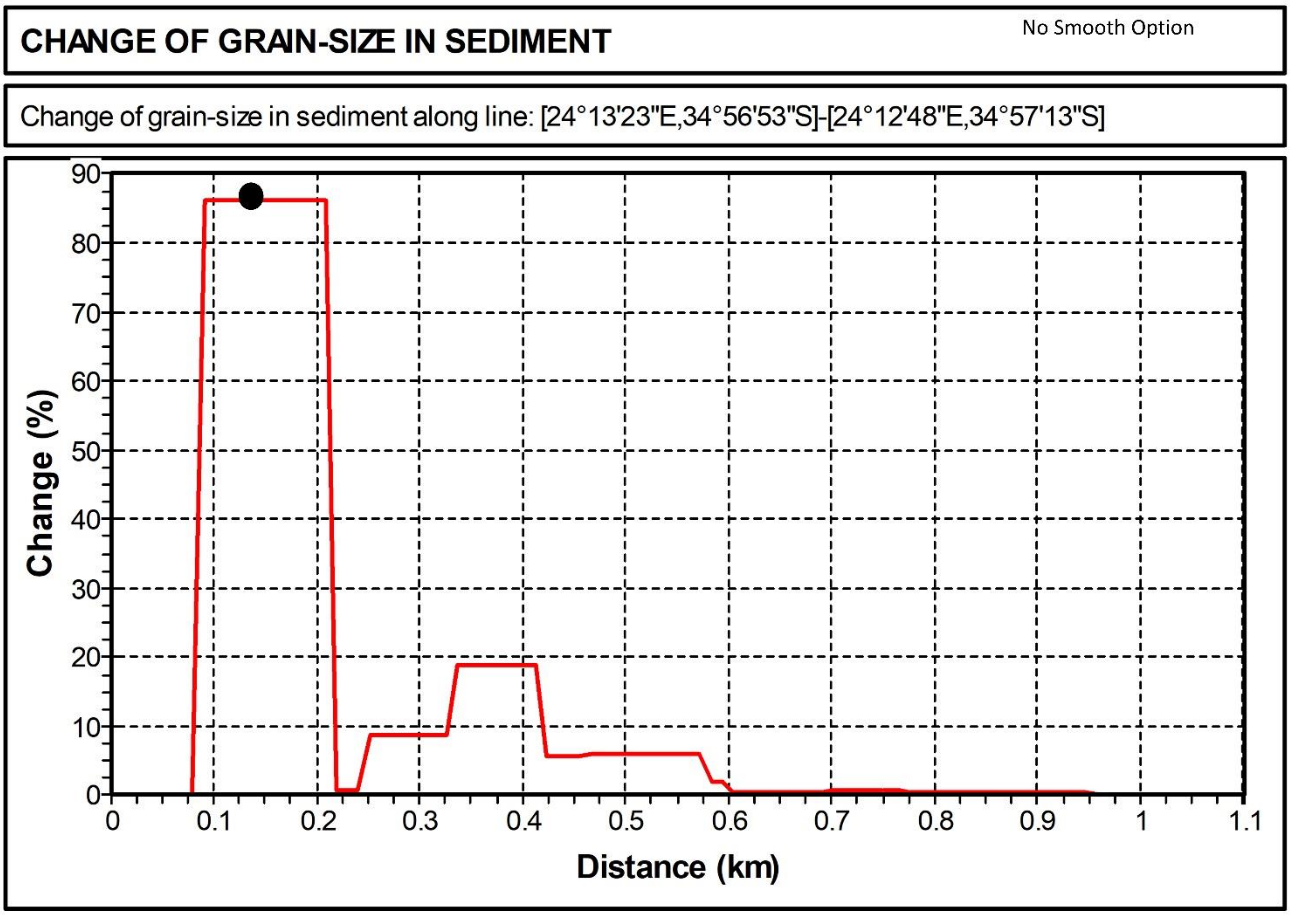


Figure 58: Grain size variations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 2) (black dot symbolizes the discharge point)

3.2.1.2.3 Thickness Deposits

Figure 59 and Figure 60 show cuttings thickness deposits at the end of drilling operations. The sediment deposit area is not centralized around the discharge point and is orientated South-West from the discharge point. This clearly shows the impact of seabed currents on sediment deposition.

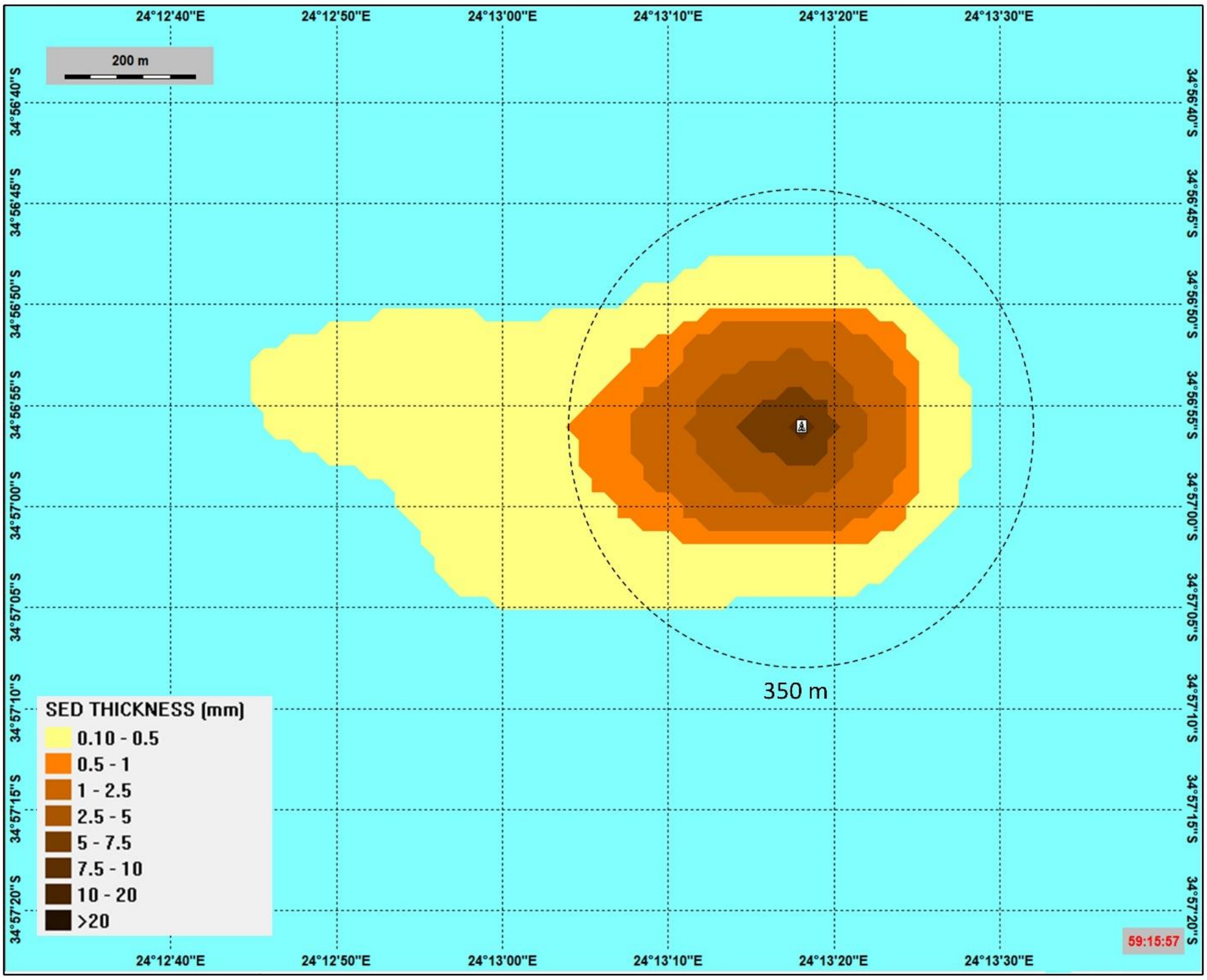


Figure 59: Cuttings thickness deposit on sediment at the end of drilling operations (Scenario 2)

Figure 59 and Figure 60 show that the maximum sediment thickness observed was up to 30 mm on 105 m radius around the discharge point without the smoothing option activated (and up to 350 m with the smoothing option on the map).

Figure 60 clearly shows that the highest sediment deposit concentrations are localized very close to the discharge point. The highest cuttings deposit is mainly due to the discharge of the top-hole sections (42'' and 26'') contributing to 28 mm among the total 30 mm deposit at the end of all operations without the smoothing. For the other sections (17.5'', 12.25'' and 8.5'') discharged at sea surface, the cuttings are more spread within the water column towards West leading to lower thickness at the seabed.

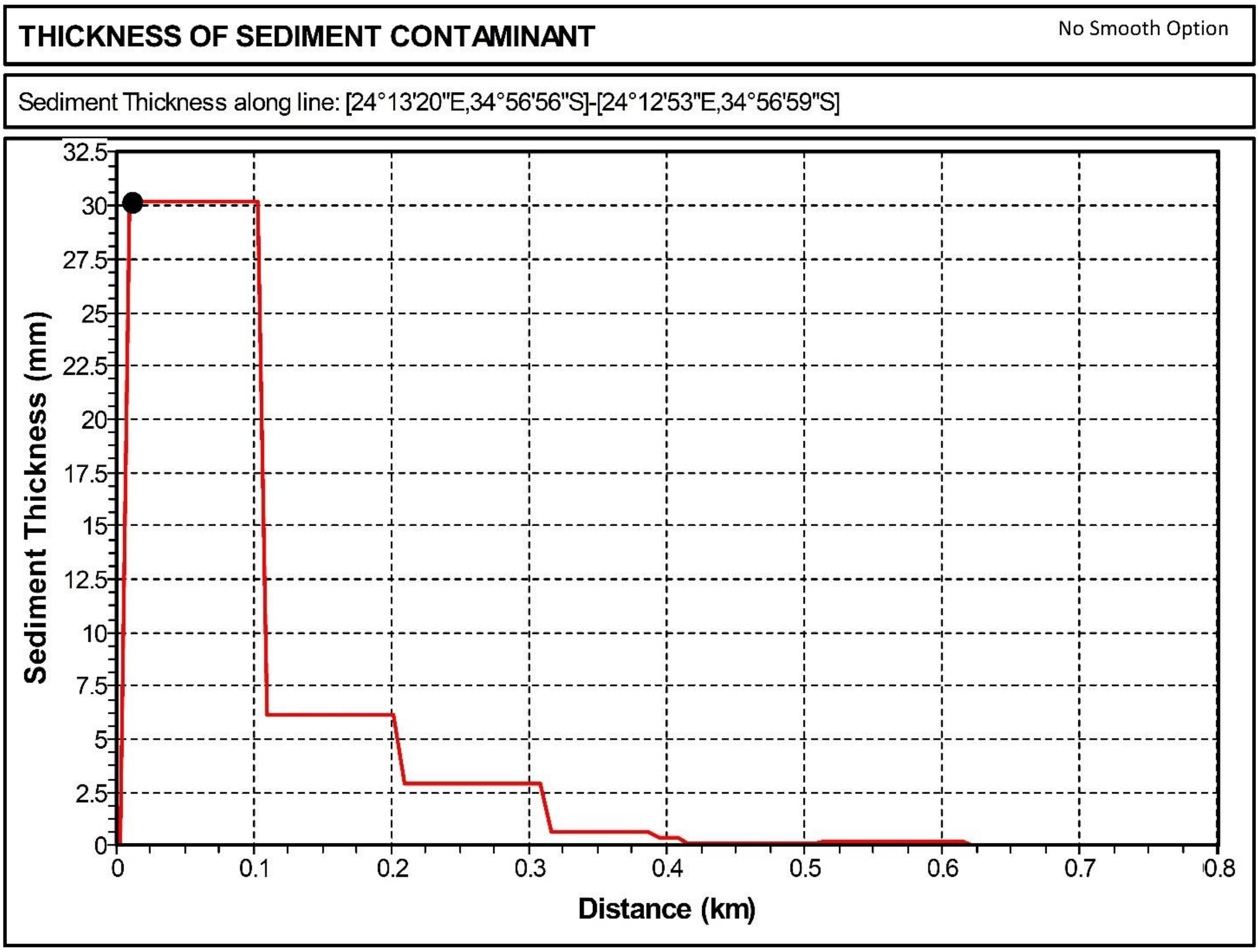


Figure 60: Cuttings thickness deposit on sediment around the discharge point along a line at the end of drilling operations (Scenario 2) (black dot symbolizes the discharge point)

3.2.1.2.4 Contaminants Concentration

Figure 61 and Figure 62 show the total discharge (cuttings and mud) concentrations on the superficial sediments at the end of drilling operations. High concentrations of discharge, i.e. 1000 g/L without smoothing is observed in the top sediments but, as discuss previously, mainly particulate compounds (cuttings and barite, i.e. non-soluble chemicals used during drilling operation) account for the total concentrations of the discharge in the sediments.

The area with detected discharged chemicals is not centralized around the discharge point and is orientated along an axe starting from the discharge point towards South-West. This clearly shows the impact of seabed currents on sediment deposition.

Figure 62 clearly shows that the highest discharged concentration in the sediments is localized very close to the discharge point up to 100 m around the discharged point.

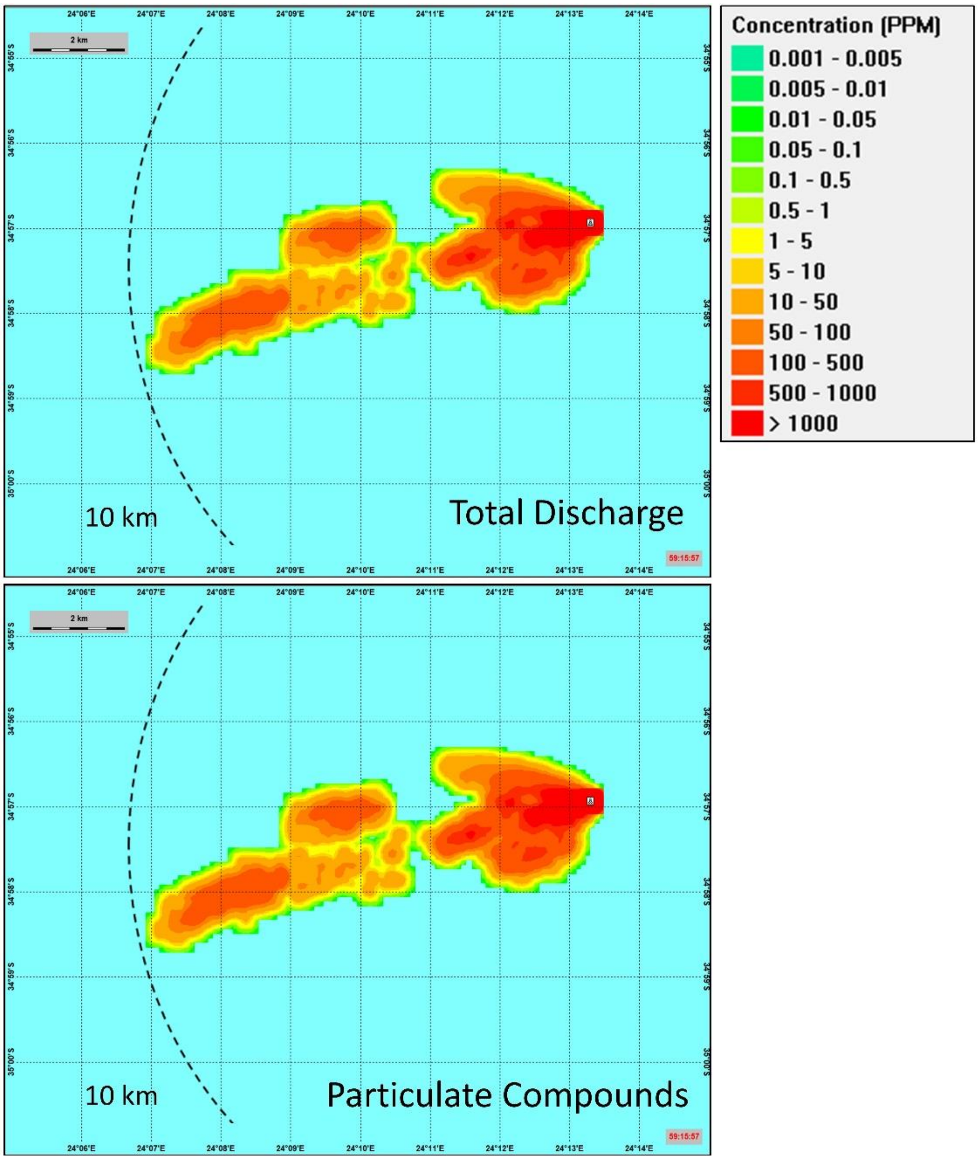


Figure 61: Concentrations of total discharge, and only particulate compounds in the superficial layer of seabed sediments at the end of drilling operations (Scenario 2)

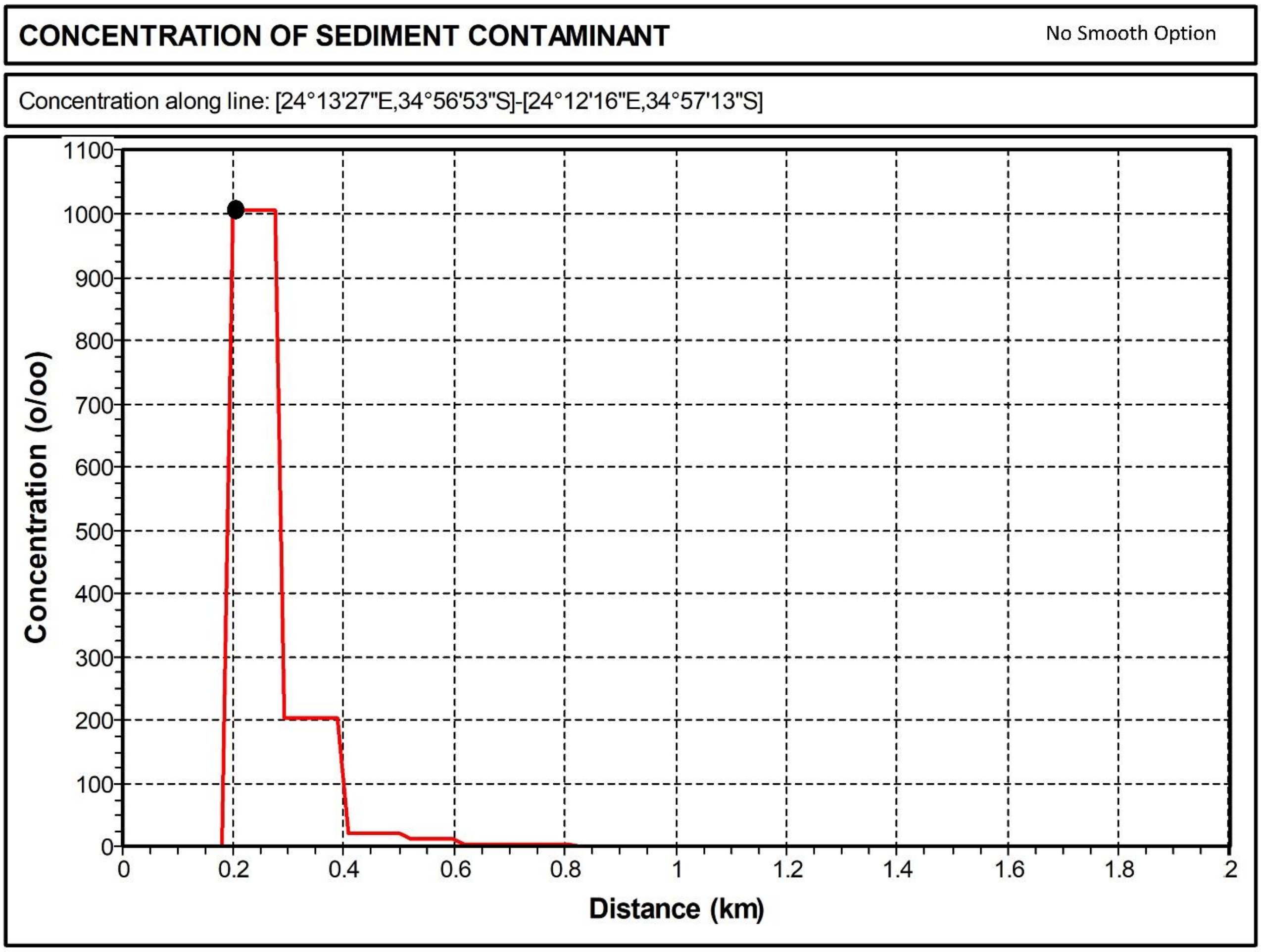


Figure 62: Total discharge concentration in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 2) (black dot symbolizes the discharge point)

3.2.1.3 Discharge n°2 - Scenario 3 (Start Time June 1st)

3.2.1.3.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk associated with the discharge of drilling operations for the sediments, considering Scenario 3, is presented in Figure 63, Figure 64 and Figure 65. The total risk presents a cumulative picture of all stressors contributing to the risk from the sediments.

These figures show that a significant risk above 5% is observed around the well to be drilled. A Maximum risk of 65% has been calculated without the smoothing option. However, the spatial risk is relatively limited. A significant risk has been calculated in an area of up to 165 m radius around the discharge point just after the end of drilling operations (200 m maximum without smoothing option).

The risk is approximately centralized around the discharge point.

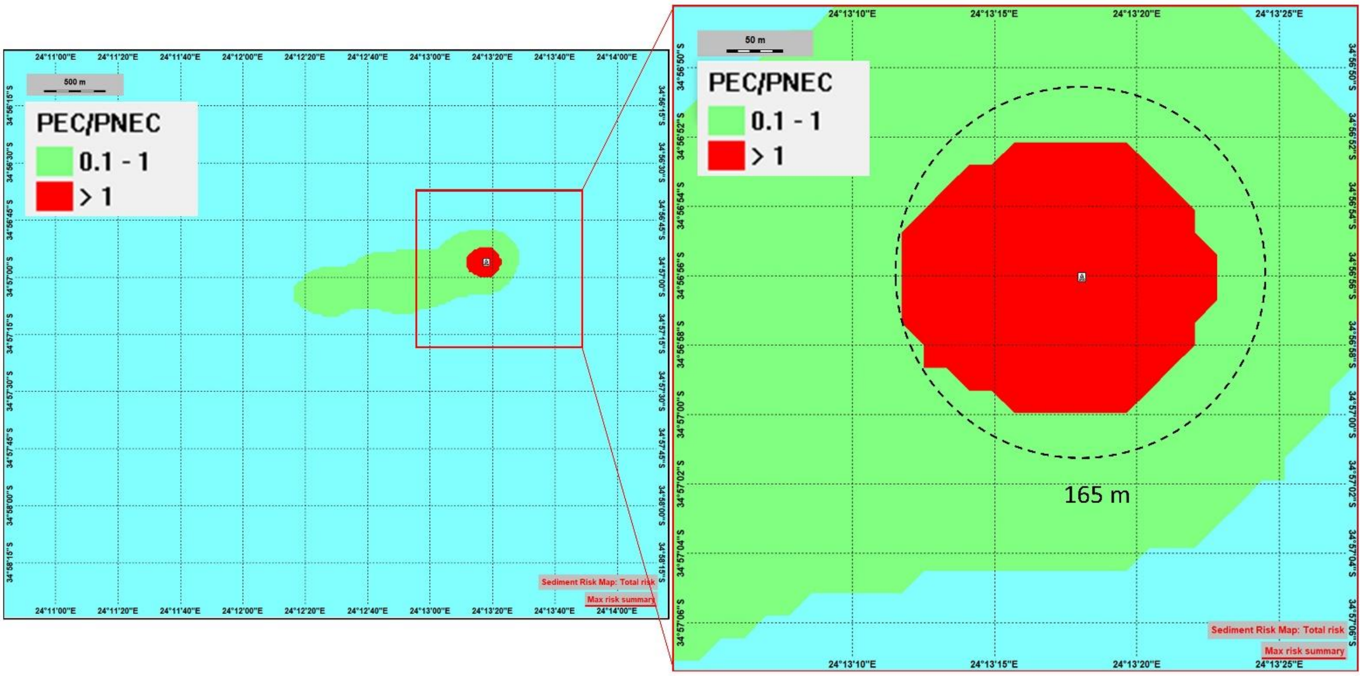


Figure 63: Maximum risk of drilling operations in the sediments for the Scenario 3 (with smoothing) at the end of drilling operations (45 days)

Figure 64 shows that a significant risk is observed in an area with a length of up to 170 m from the discharge point.

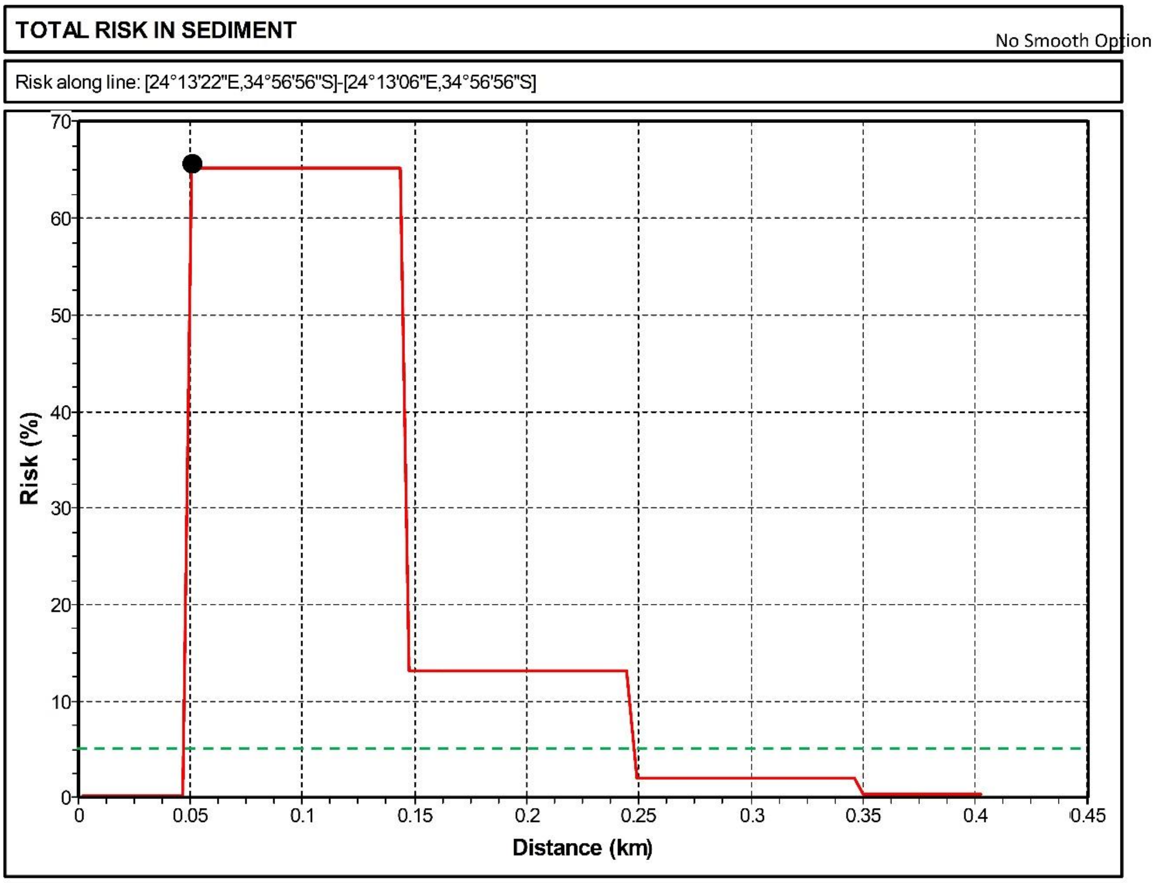


Figure 64: Maximum risk of drilling operations along a line for the Scenario 3 (black dot symbolizes the discharge point; the green dashed lines symbolize the 5% threshold)

Figure 65, shows that the risk decreases over the time in the sediments at the discharge point from the end of the drilling operations to insignificant values approximately 1500 days after the beginning of the operations.
There is no more environmental risk in the sediment 4 years after the operations.

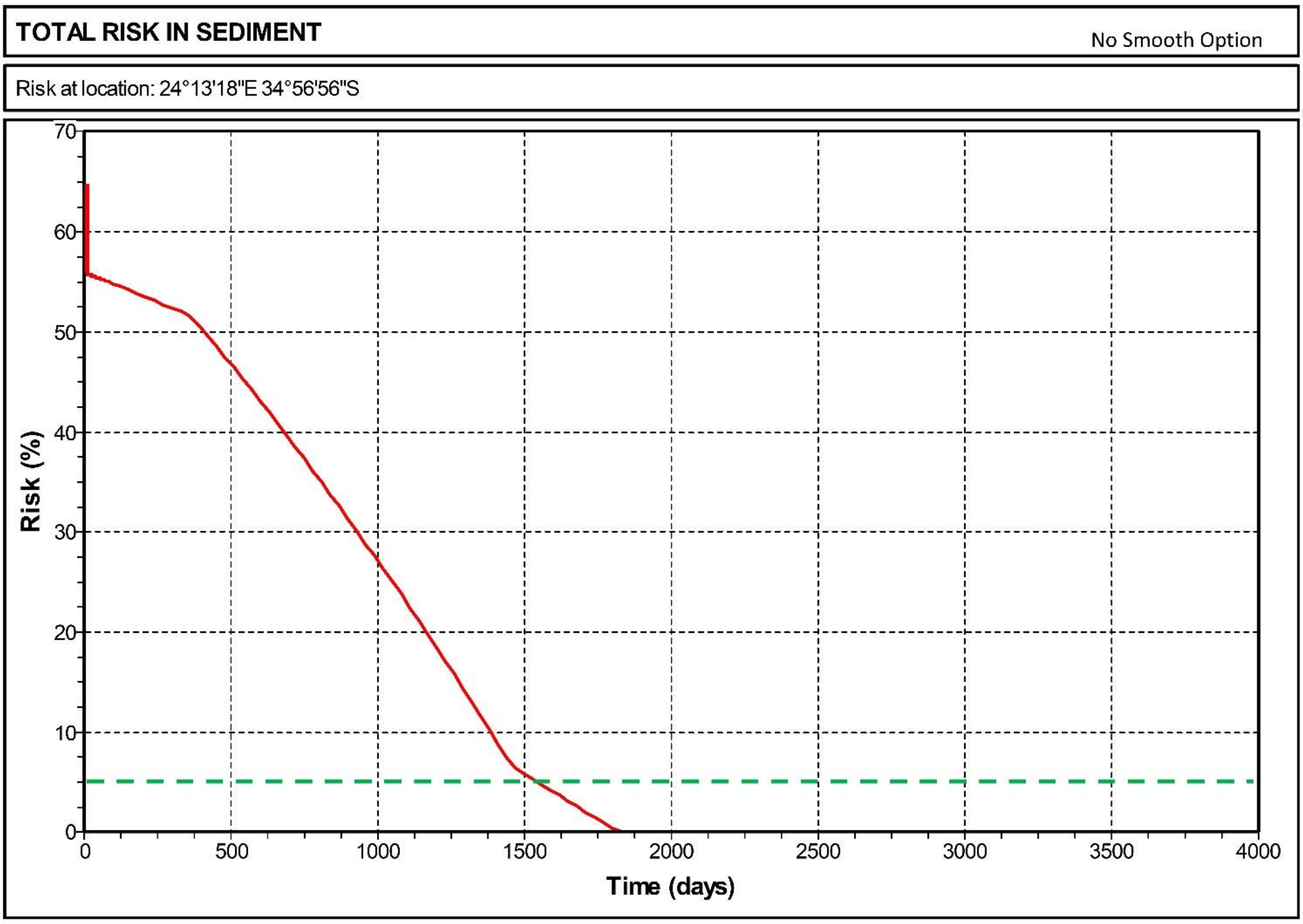


Figure 65: Maximum risk of drilling operations close the discharge point over the time for the Scenario 3 (the green dashed line symbolizes the 5% threshold)

Figure 66 shows the main contributors to the risk in the sediments for the Scenario 3. The main contributors to the total risk are physical, due to the grain size change of the natural sediment and the thickness of the deposit, contributing respectively to 75% and 25% of the total environmental risk for the sediment.

Figure 66 shows that the contribution of the different stressors to the total risk changes over the time with a significant increase of the grain size change 16 days after the start of the operations corresponding to the start of the discharge of the sections drilled with a riser.

These results will be further discussed in the following sections.

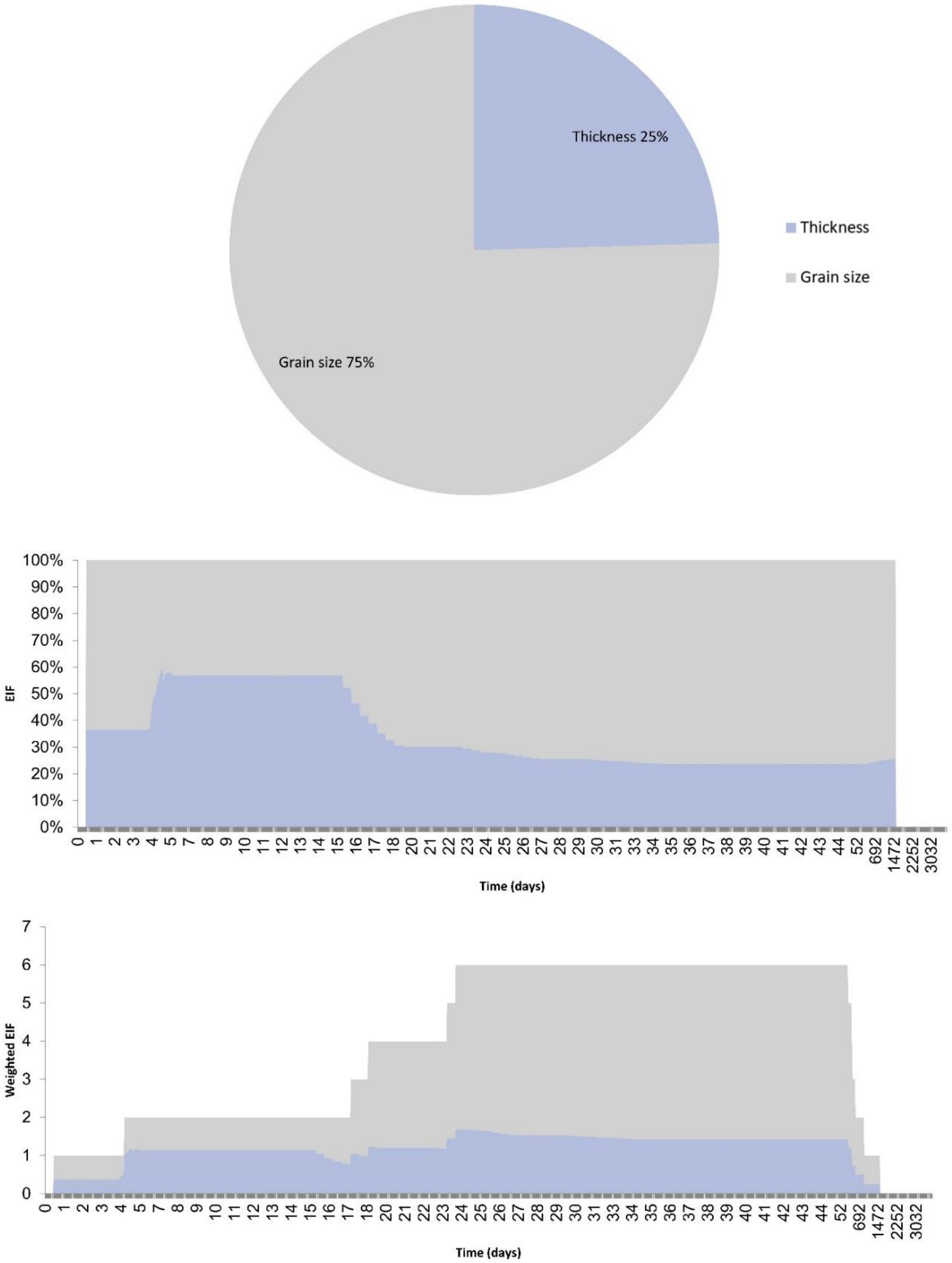


Figure 66: Main contributors to the risk of drilling operations for the Scenario 3

Figure 66 shows that grain size variation on the sediments and sediment thickness change over the time. No more risk corresponding to this contributor is observed after approximately 1500 days.

3.2.1.3.2 Grain Size Variation

Figure 67 and Figure 68 show grain size variation on the sediments at the end of drilling operations. One main area with significant sediment grain size changes is observed around the discharge point due to the discharge of the 42'' and 26'' sections. The maximum grain size variation observed was up to 130 % on a 105 m radius around the discharge point without the smoothing option (160 m with the smoothing option on the map, with a very low change patch until 870 m from the release point, but with very low value <10%).

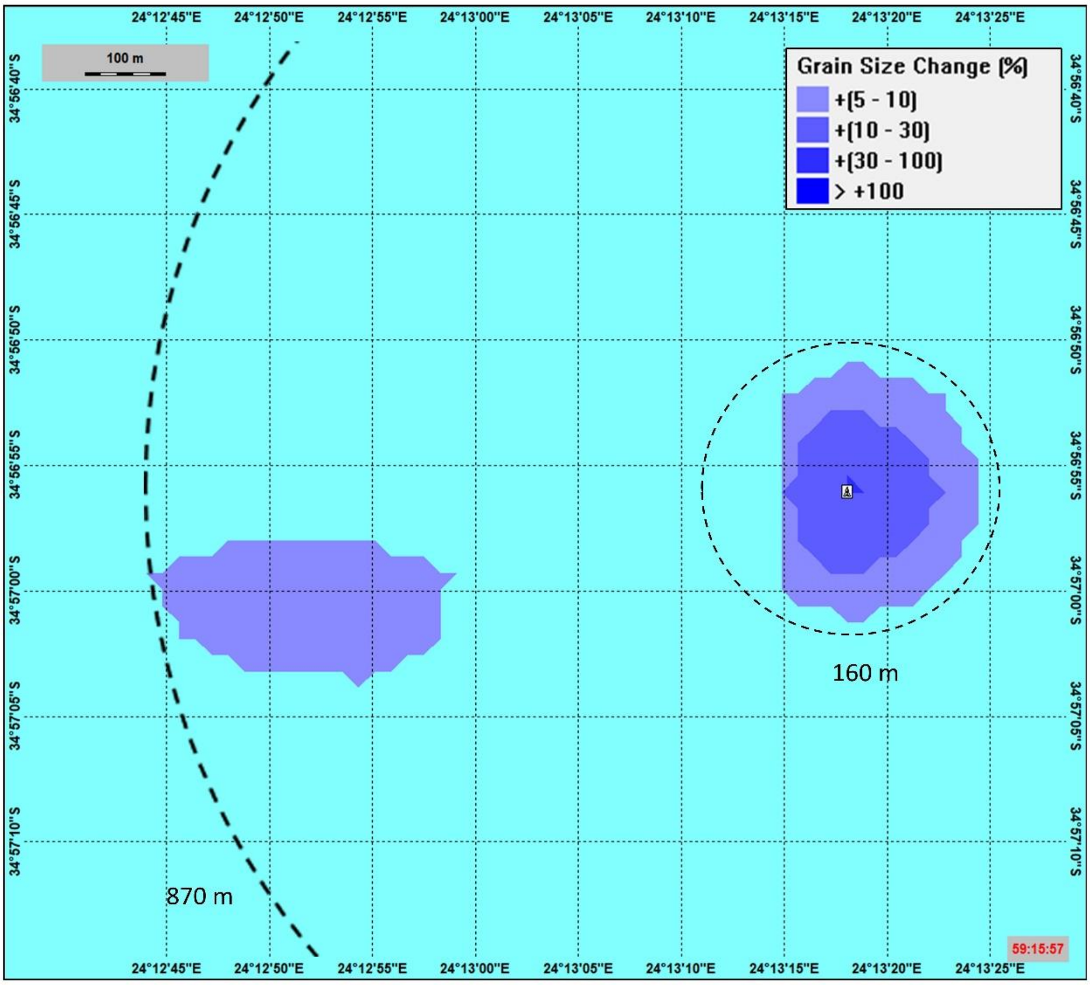


Figure 67: Grain size variations in the superficial section of seabed sediments at the end of drilling operations (Scenario 3)

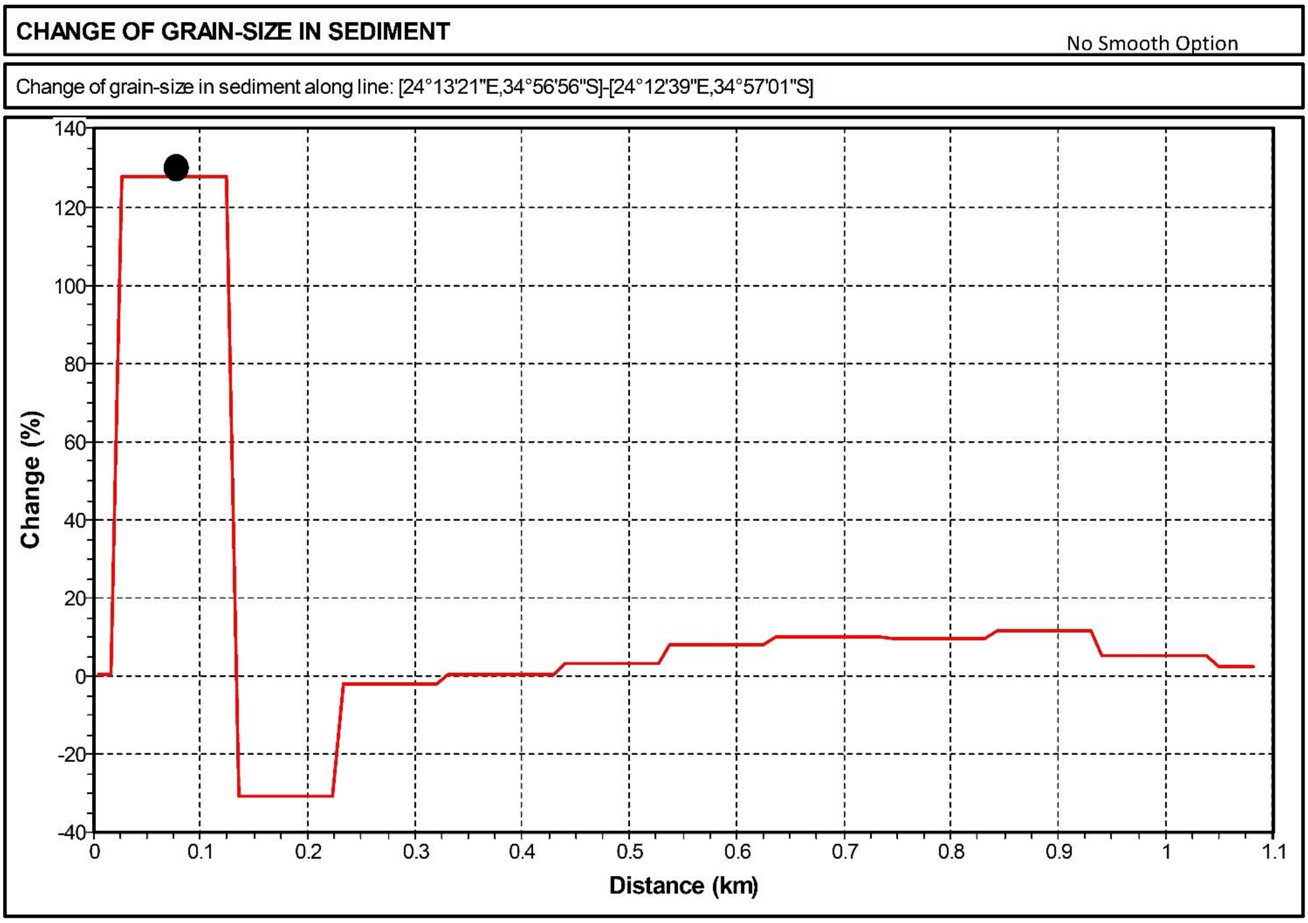


Figure 68: Grain size variations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 3) (black dot symbolizes the discharge point)

3.2.1.3.3 Thickness Deposits

Figure 69 and Figure 70 show cuttings thickness deposits at the end of drilling operation. The sediment deposit area is not centralized around the discharge point and is orientated West South-West from the discharge point. This clearly shows the impact of seabed currents on sediment deposition.

Figure 69 and Figure 70 show that the maximum sediment thickness observed was up to 29 mm on 100 m radius around the discharge point without the smoothing option activated (and up to 335 m with the smoothing option on the map).

Figure 69 clearly shows that the highest sediment deposit concentrations are localized very close to the discharge point. The highest cuttings deposit is mainly due to the discharge of the top-hole sections (42'' and 26'') contributing to 28 mm among the total 29 mm deposit at the end of all operations without the smoothing. For the other sections (17.5'', 12.25'' and 8.5'') discharged at sea surface, the cuttings are more spread within the water column towards West leading to lower thickness at the seabed.

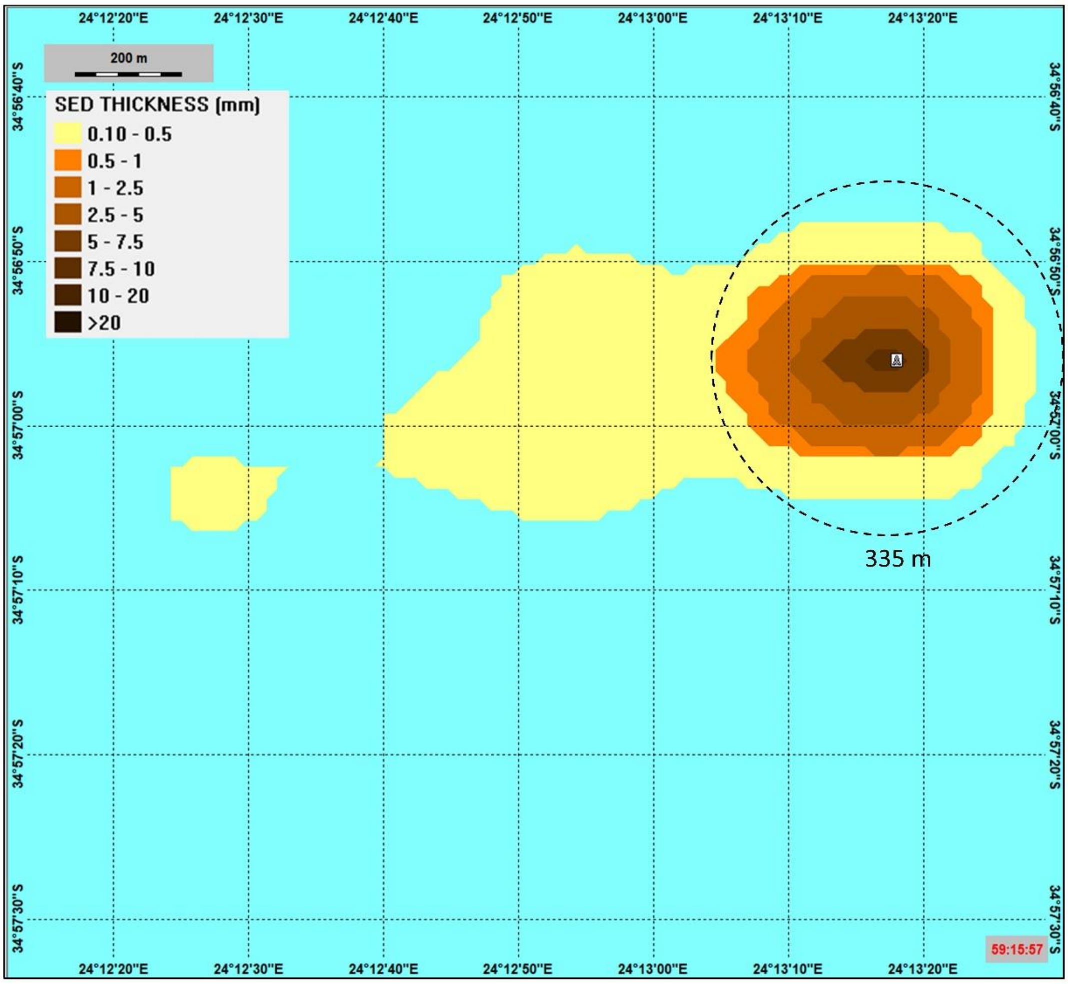


Figure 69: Cuttings thickness deposit on sediment at the end of drilling operations (Scenario 3)

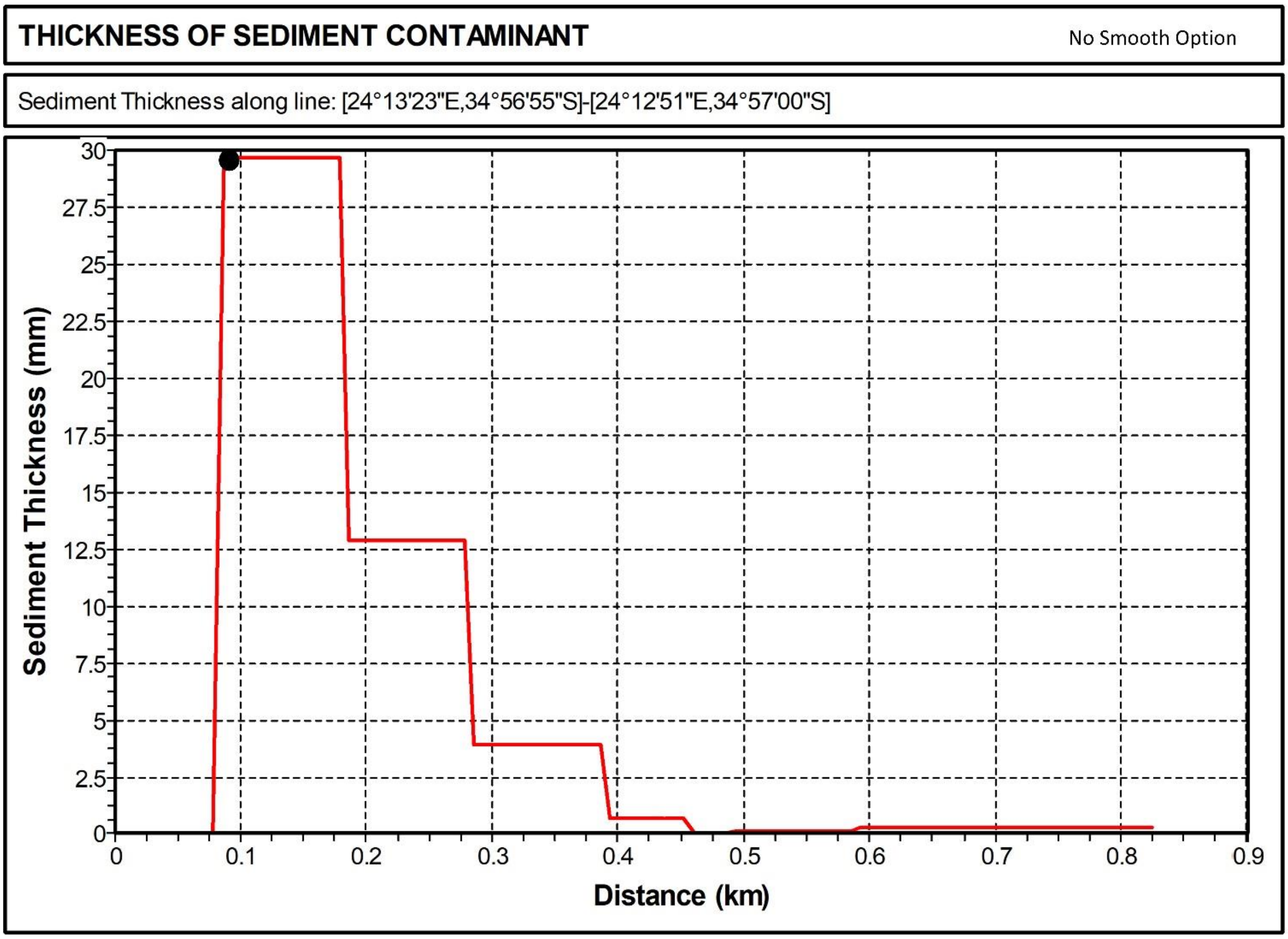


Figure 70: Cuttings thickness deposit on sediment around the discharge point along a line at the end of drilling operations (Scenario 3) (black dot symbolizes the discharge point)

3.2.1.3.4 Contaminants Concentration

Figure 71 and Figure 72 show the total discharge (cuttings and mud) concentrations on the superficial sediments at the end of drilling operations. High concentrations of discharge, i.e. 990 g/L without smoothing is observed in the top sediments but, as discuss previously, mainly particulate compounds (cuttings and barite, i.e. non-soluble chemicals used during drilling operations) account for the total concentrations in the sediments.

The area with detected discharged chemicals is not centralized around the discharge point and is orientated along an axe starting from the discharge point towards West South-West. This clearly shows the impact of seabed currents on sediment deposition.

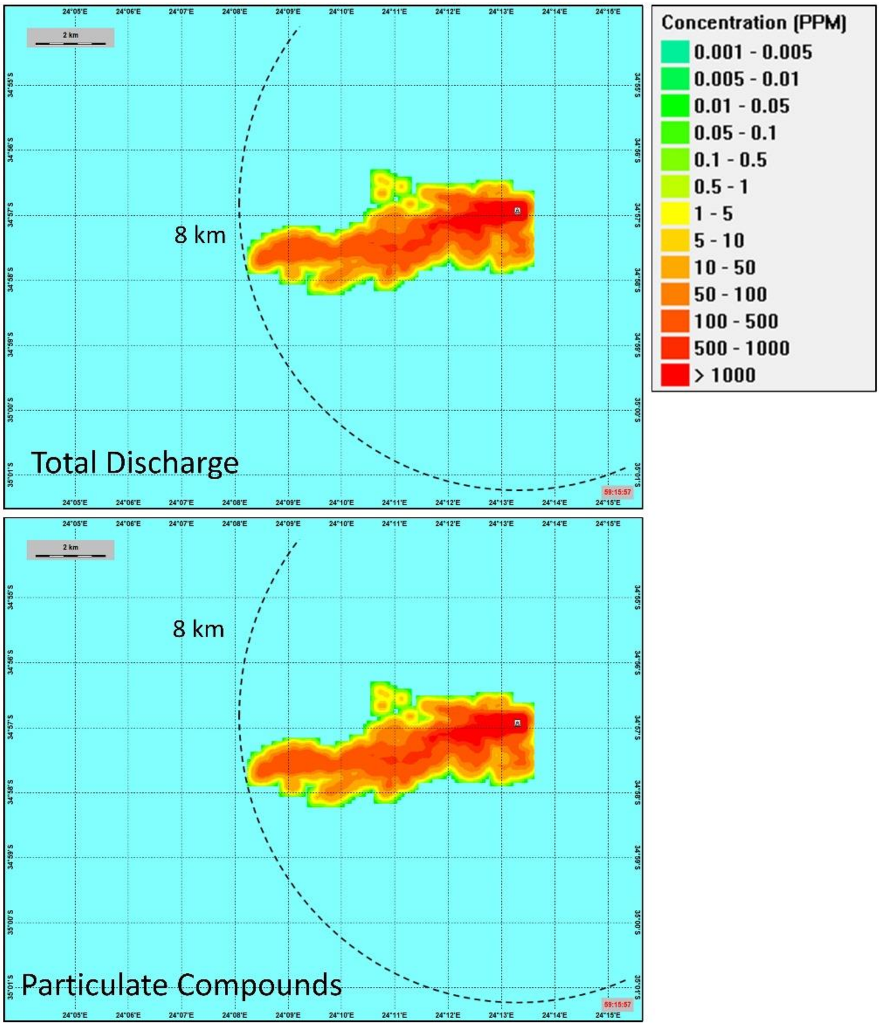


Figure 71: Concentrations of total discharge, and only particulate compounds in the superficial layer of seabed sediments at the end of drilling operations (Scenario 3)

Figure 72 clearly shows that the highest discharged concentrations in the sediments is localized very close to the discharge point, up to 200 m around the discharged point.

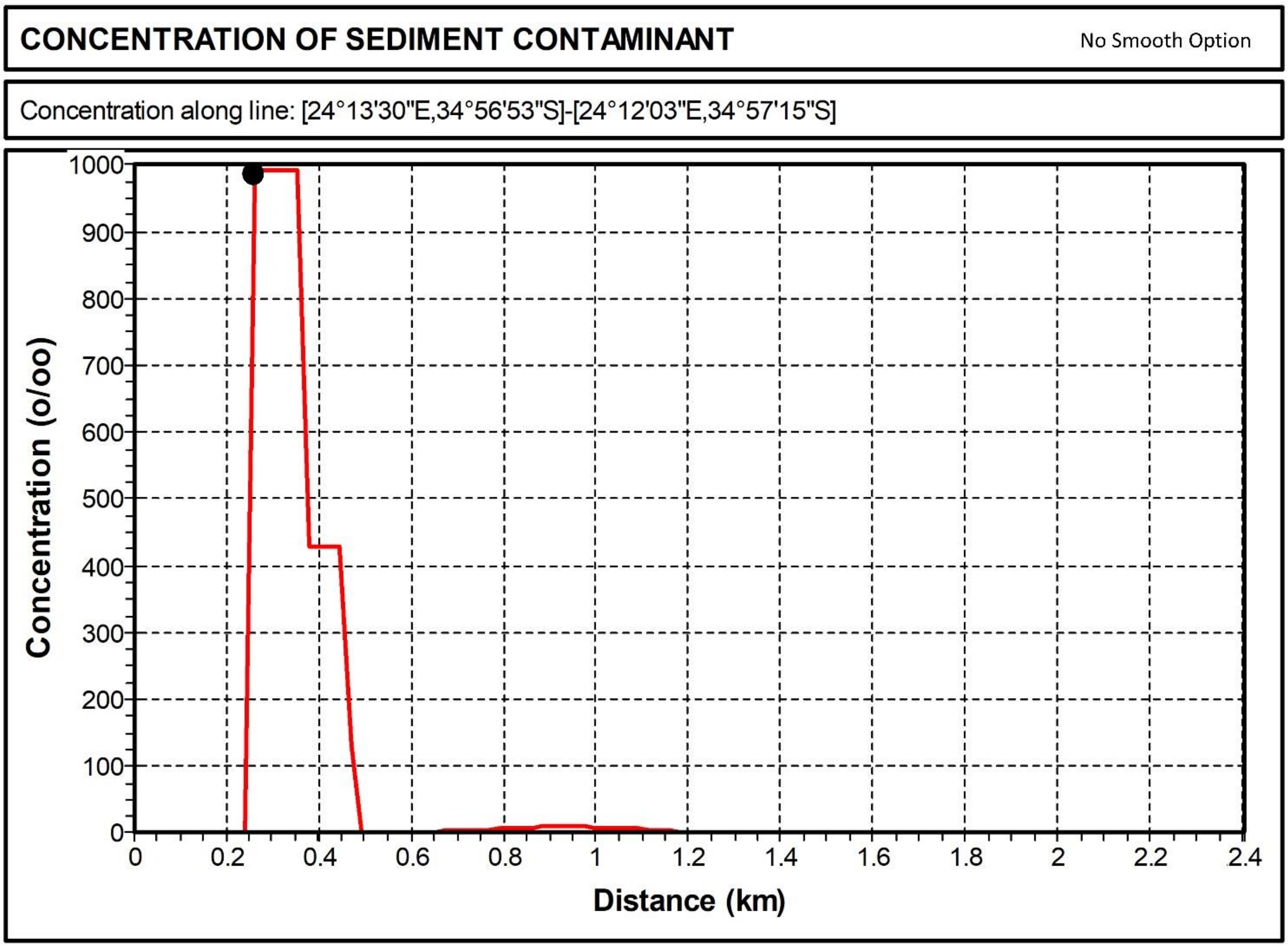


Figure 72: Total discharge concentrations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 3) (black dots symbolize the discharge point)

3.2.1.4 Discharge n°2 - Scenario 4 (Start Time September 1st)

3.2.1.4.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk associated with the discharge of drilling operations for the sediments, considering Scenario 4, is presented in Figure 73, Figure 74 and Figure 75. The total risk presents a cumulative picture of all stressors contributing to the risk from the sediments.

Those figures show that a significant risk above 5% is observed around the well to be drilled. A Maximum risk of 66% has been calculated without the smoothing option. However, the spatial risk is relatively limited. A significant risk has been calculated in an area of up to 150 m radius around the discharge point just after the end of drilling operations without smoothing option (160 m maximum with smoothing option on the map).

The risk is approximately centralized around the discharge point.

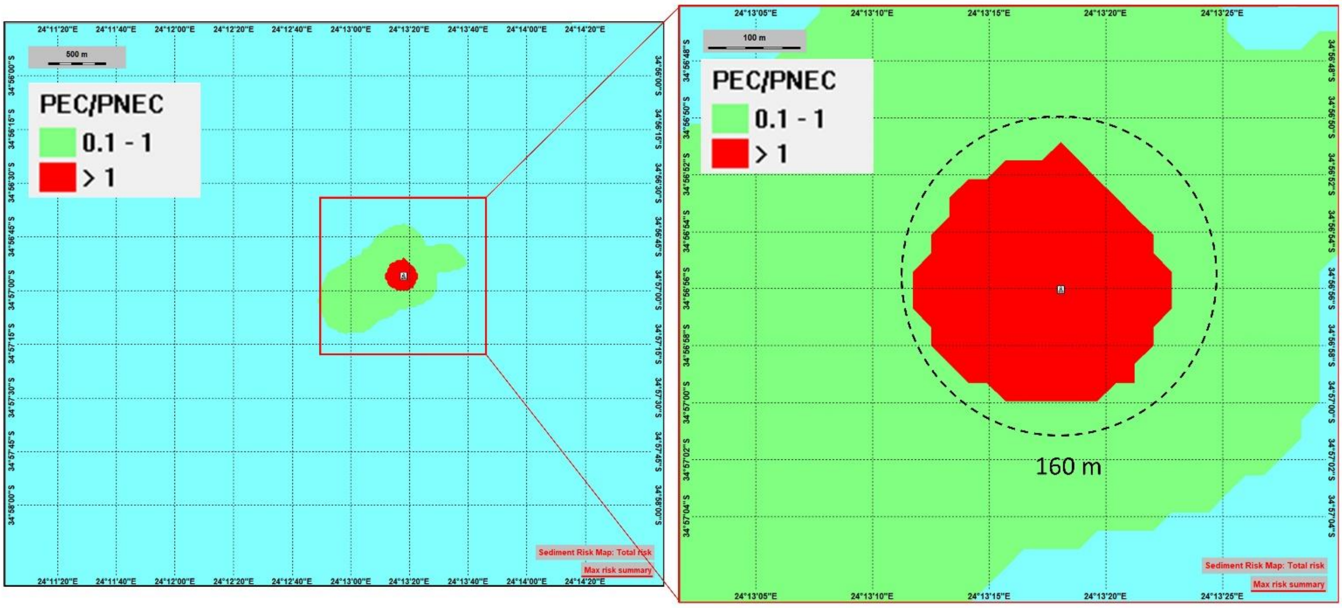


Figure 73: Maximum risk of drilling operations in the sediments for the Scenario 4 (with smoothing) at the end of drilling operations (45 days)

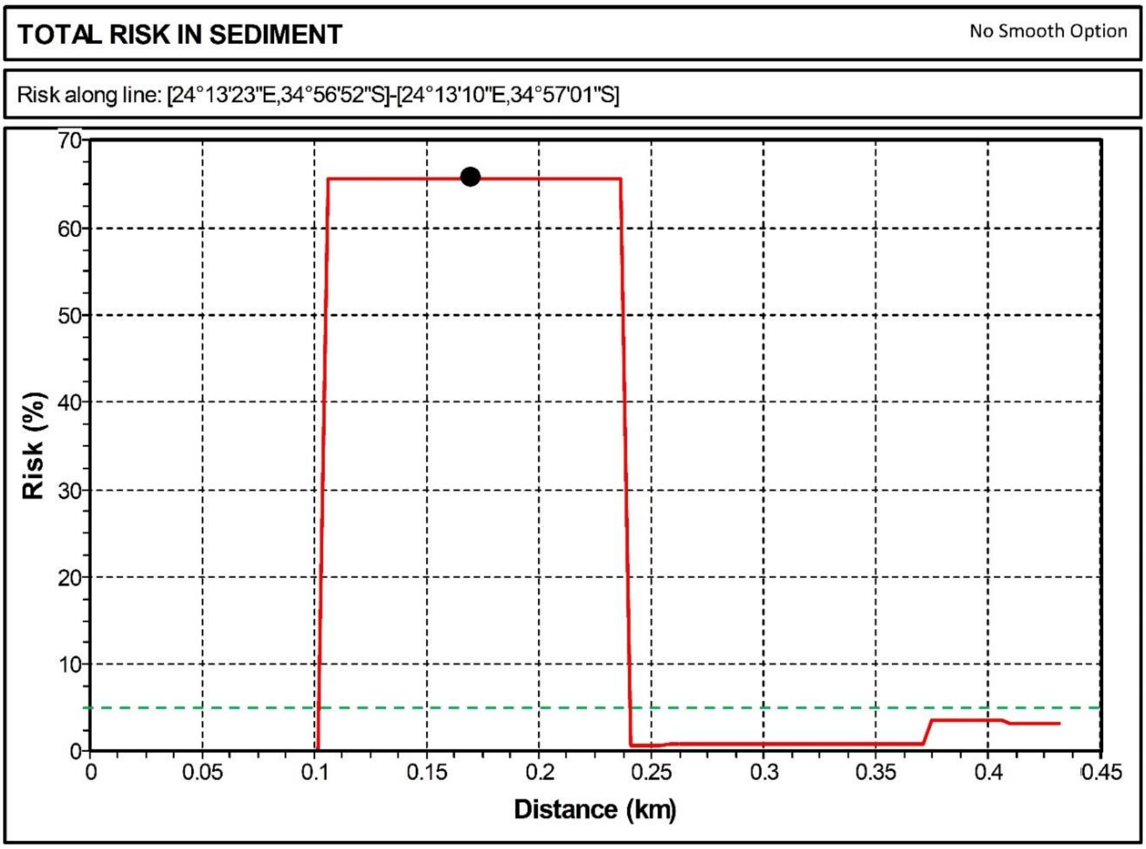


Figure 74: Maximum risk of drilling operations along a line for the Scenario 4 (black dot symbolizes the discharge point; the green dashed line symbolizes the 5% threshold)

Figure 74 shows that a significant risk is observed in an area with a length of up to 80 m from the discharge point without smoothing.

Figure 75, shows that the risk decreases over the time in the sediments at the discharge point from the end of the drilling operations to insignificant values approximately 1500 days after the beginning of the operations.

There is no more environmental risk in the sediment 4 years after the operations.

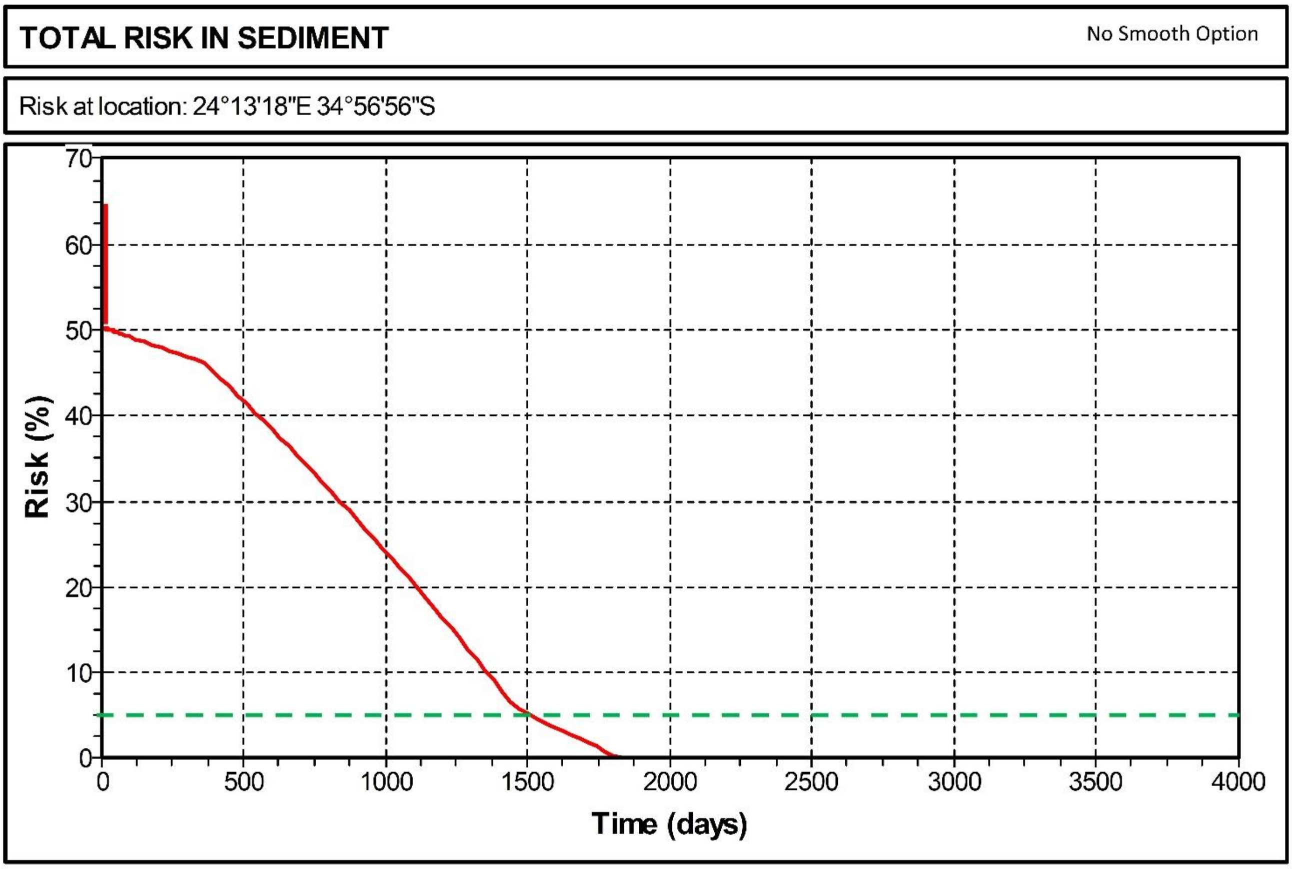


Figure 75: Maximum risk of drilling operations close the discharge point over the time for the Scenario 4 (the green dashed line symbolizes the 5% threshold)

Figure 76 shows the main contributors to the risk in the sediments for the Scenario 4. The main contributors to the total risk are physical, due to the grain size change of the natural sediment and the thickness of the deposit, contributing respectively to 80% and 20% of the total environmental risk for the sediment.

Figure 76 shows that the contribution of the different stressors to the total risk changes over the time with a increase of the grain size change 16 days after the start of the discharge, and a significant increase from day 30.

These results will be further discussed in the following sections.

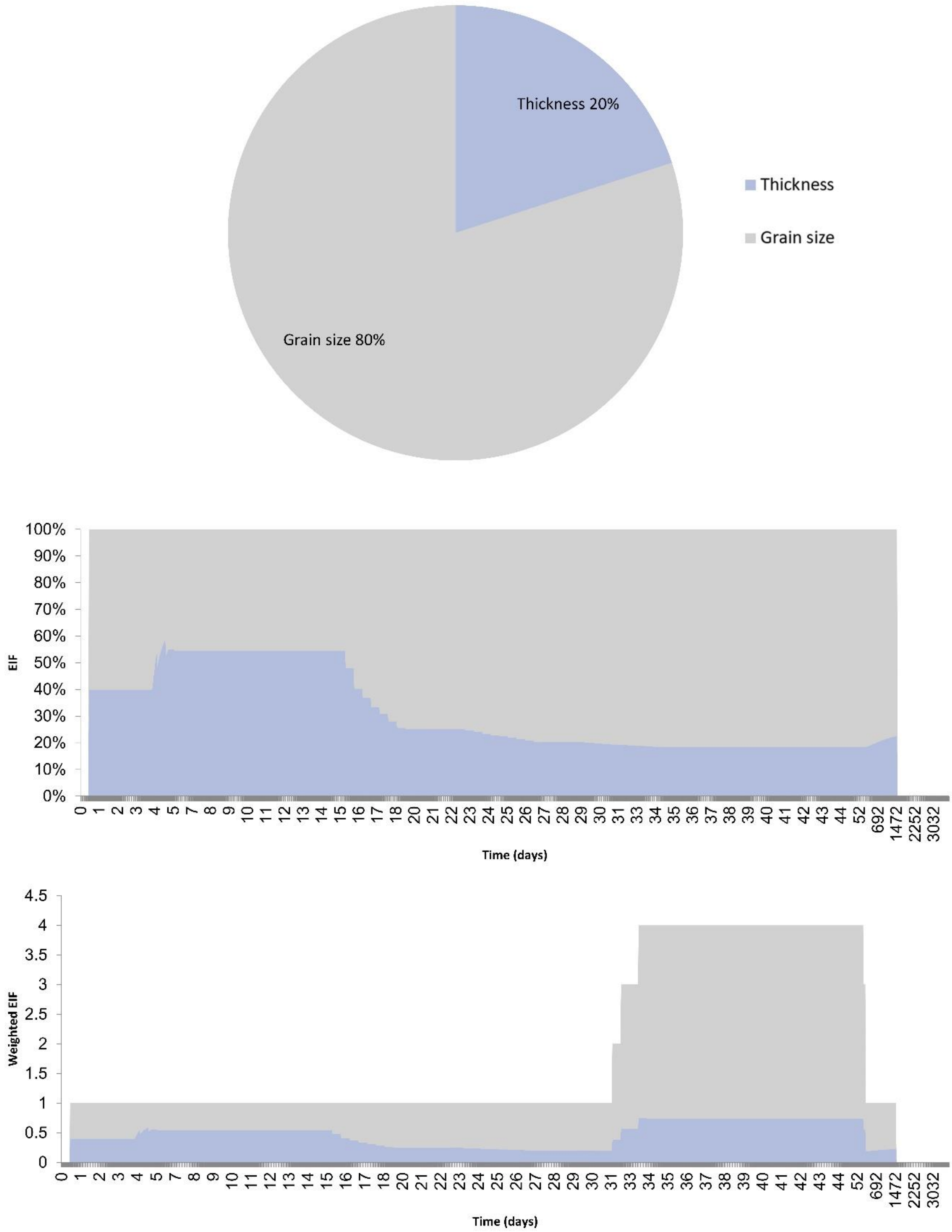


Figure 76: Main contributors to the risk of drilling operations for the Scenario 4

Figure 76 shows that grain size variation on the sediments and sediment thickness change over the time. No more risk corresponding to this contributor is observed after approximately 1500 days.

3.2.1.4.2 Grain Size Variation

Figure 77 and Figure 78 show grain size variation on the sediments at the end of drilling operations. One main area with significant sediment grain size changes is observed around the discharge point due to the discharge of the 42'' and 26'' sections. The maximum grain size variation observed was up to 65 % on a 100 m radius around the discharge point without the smoothing option (80 m with the smoothing option on the map, showing also a larger patch with very low change values until 470 m).

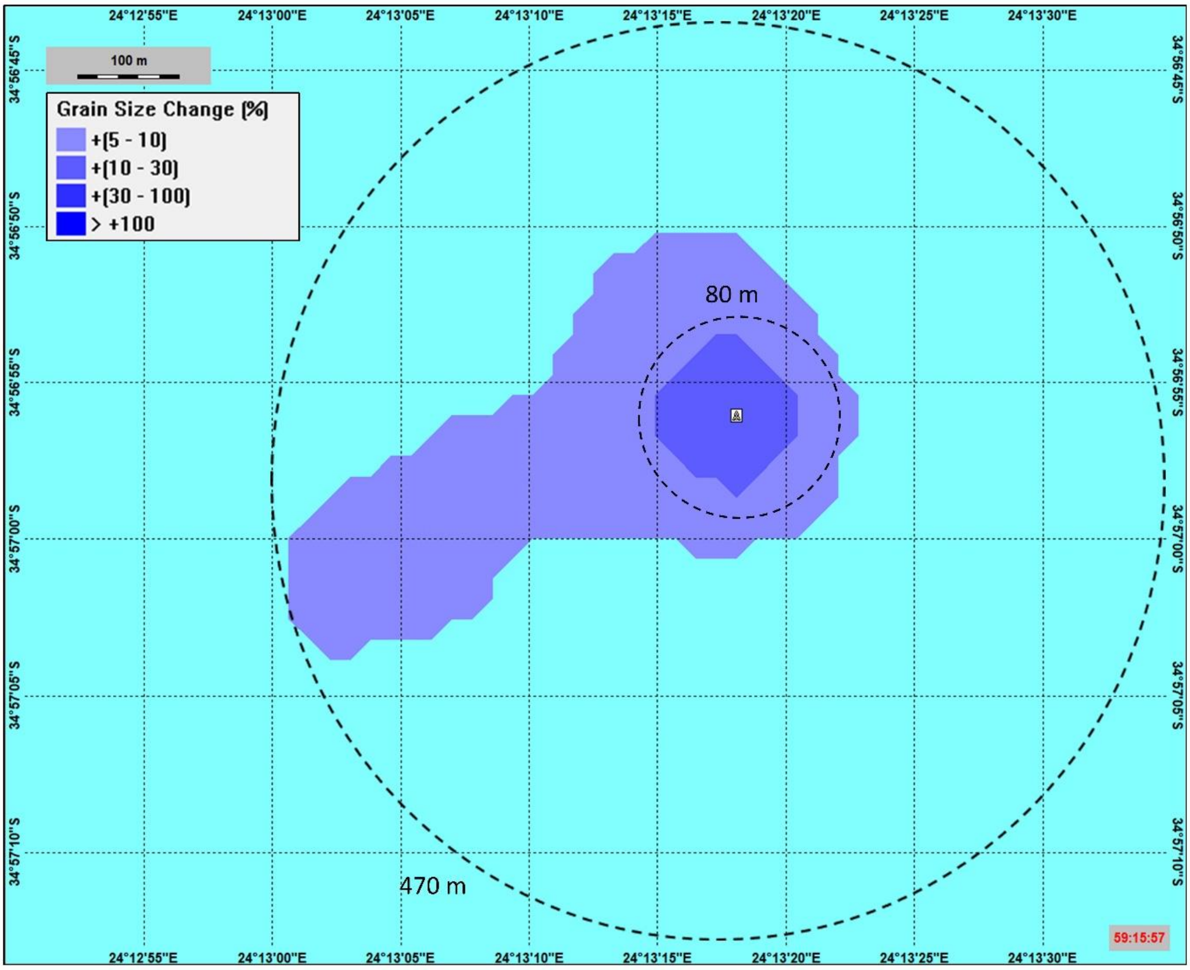


Figure 77: Grain size variations in the superficial section of seabed sediments at the end of drilling operations (Scenario 4)

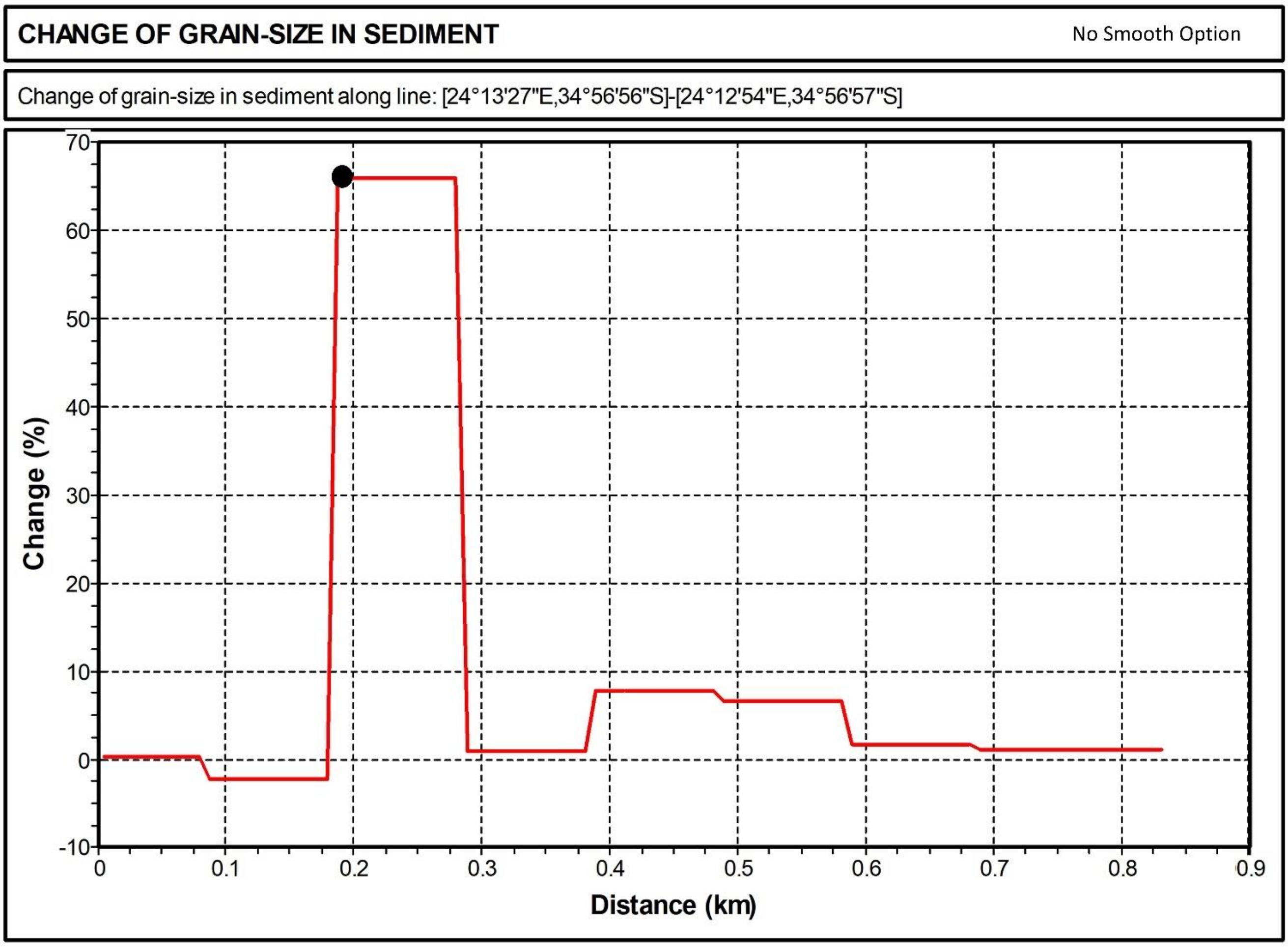


Figure 78: Grain size variations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 4) (black dot symbolizes the discharge point)

3.2.1.4.3 Thickness Deposits

Figure 79 and Figure 80 show cuttings thickness deposits at the end of drilling operations. The sediment deposit area is not centralized around the discharge point and is orientated South-West from the discharge point. This clearly shows the impact of seabed currents on sediment deposition.

Figure 79 and Figure 80 show that the maximum sediment thickness observed was up to 30 mm on a 100 m radius around the discharge point without the smoothing option activated (and up to 235 m with the smoothing option on the map).

Figure 80 clearly shows that the highest sediment deposit concentrations are localized very close to the discharge point. The highest cuttings deposit is mainly due to the discharge of the top-hole sections (42'' and 26'') contributing to 28 mm among the total 30 mm deposit at the end of all operations without the smoothing. For the other sections (17.5'', 12.25'' and 8.5'') discharged at sea surface, the cuttings are more spread within the water column towards South-West leading to lower thickness at the seabed.

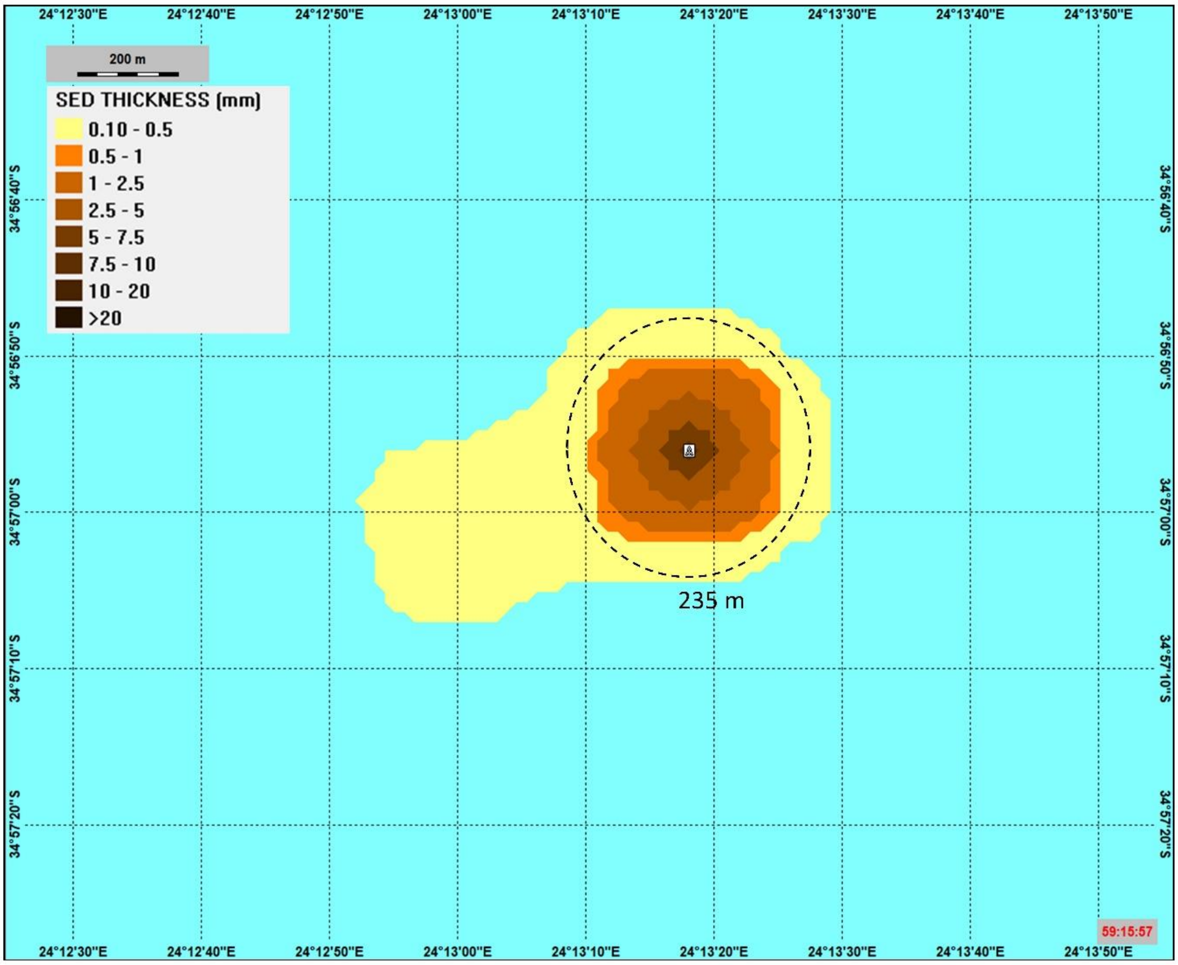


Figure 79: Cuttings thickness deposit on sediment at the end of drilling operations (Scenario 4)

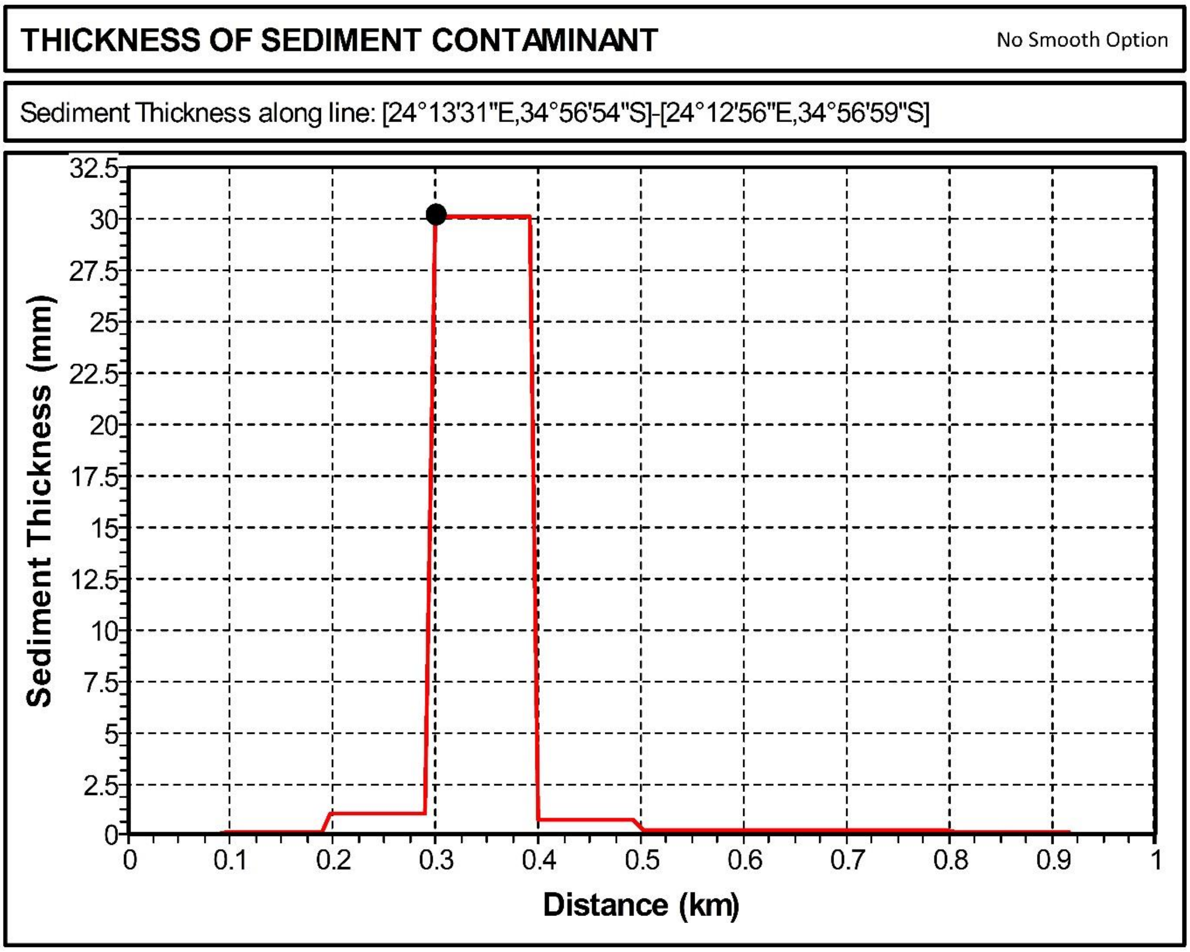


Figure 80: Cuttings thickness deposit on sediment around the discharge point along a line at the end of drilling operations (Scenario 4) (black dot symbolizes the discharge point)

3.2.1.4.4 Contaminants Concentration

Figure 81 and Figure 82 show the total discharge (cuttings and mud) concentrations on the superficial sediments at the end of drilling operations. High concentrations of discharge, i.e. 1000 g/L without smoothing is observed in the top sediments but, as discuss previously, mainly particulate compounds (cuttings and barite, i.e. non-soluble chemicals used during drilling operation) account for the total concentrations of the discharge in the sediments.

The area with detected discharged chemicals is not centralized around the discharge point and is orientated along an axe starting from the discharge point towards South-West. This clearly shows the impact of seabed currents on sediment deposition.

Figure 82 clearly shows that the highest effluent discharged concentration in the sediments is localized very close to the discharge point, up to 100 m around the discharged point.

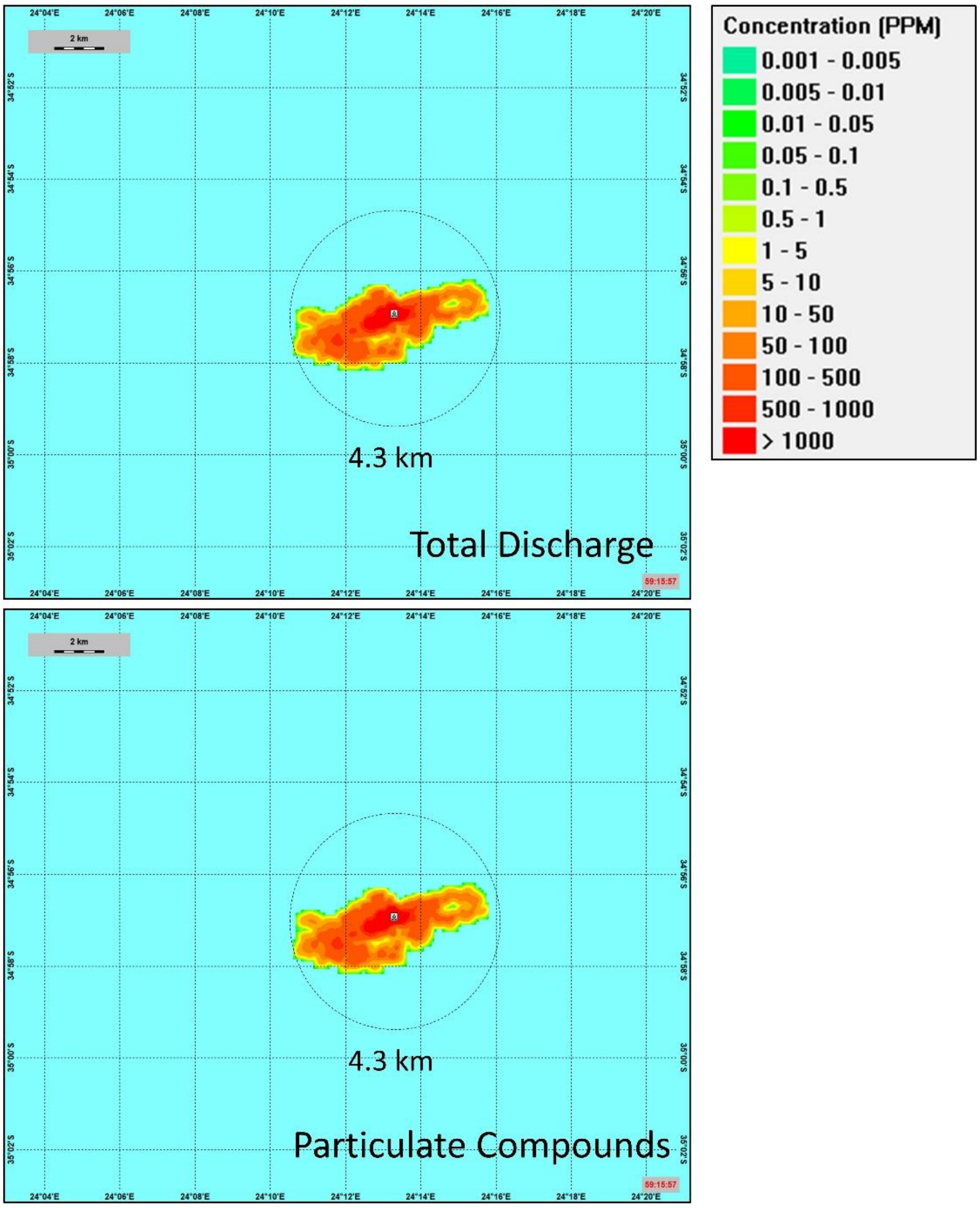


Figure 81: Concentrations of total discharge, and only particulate compounds in the superficial layer of seabed sediments at the end of drilling operations (Scenario 4)

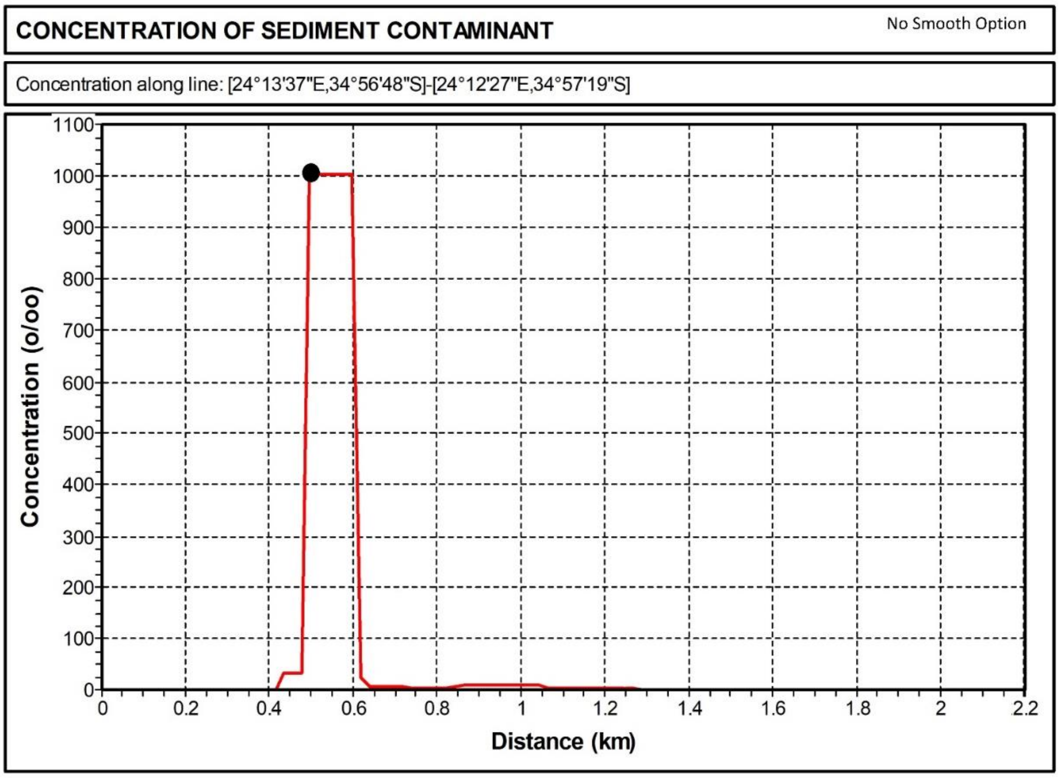


Figure 82: Total effluent concentrations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 4) (black dot symbolizes the discharge point)

3.2.2 Optional case: scenario 5

3.2.2.1.1 Maximum risk and main contributors

The outcomes of the model for the maximum risk associated with the discharge of drilling operations for the sediments, considering Scenario 5, are presented in Figure 83, Figure 84 and Figure 85. The total risk presents a cumulative picture of all stressors contributing to the risk to the sediments.

These figures show that a significant risk above 5% is observed around the well to be drilled. A Maximum risk of 65% has been calculated without the smoothing option. However, the spatial risk is relatively limited. A significant risk has been calculated in an area of up to 325 m radius around the discharge point just after the end of drilling operations (720 m without). A significant risk is observed in an area with a length of up to 720 m from the discharge point. This risk is due to the discharge of the riser less section up to 100 m away from the discharge point. The rest (between 100m and 720 m away from the discharge point) is due to the discharge of the sections to be drilled with a riser.

The significant risk is not centralized around the discharge point and is orientated along an axis starting from the discharge point towards West/South West (Figure 83). This clearly shows the impact of seabed current on drill cuttings dispersion and settlement in the sediments.

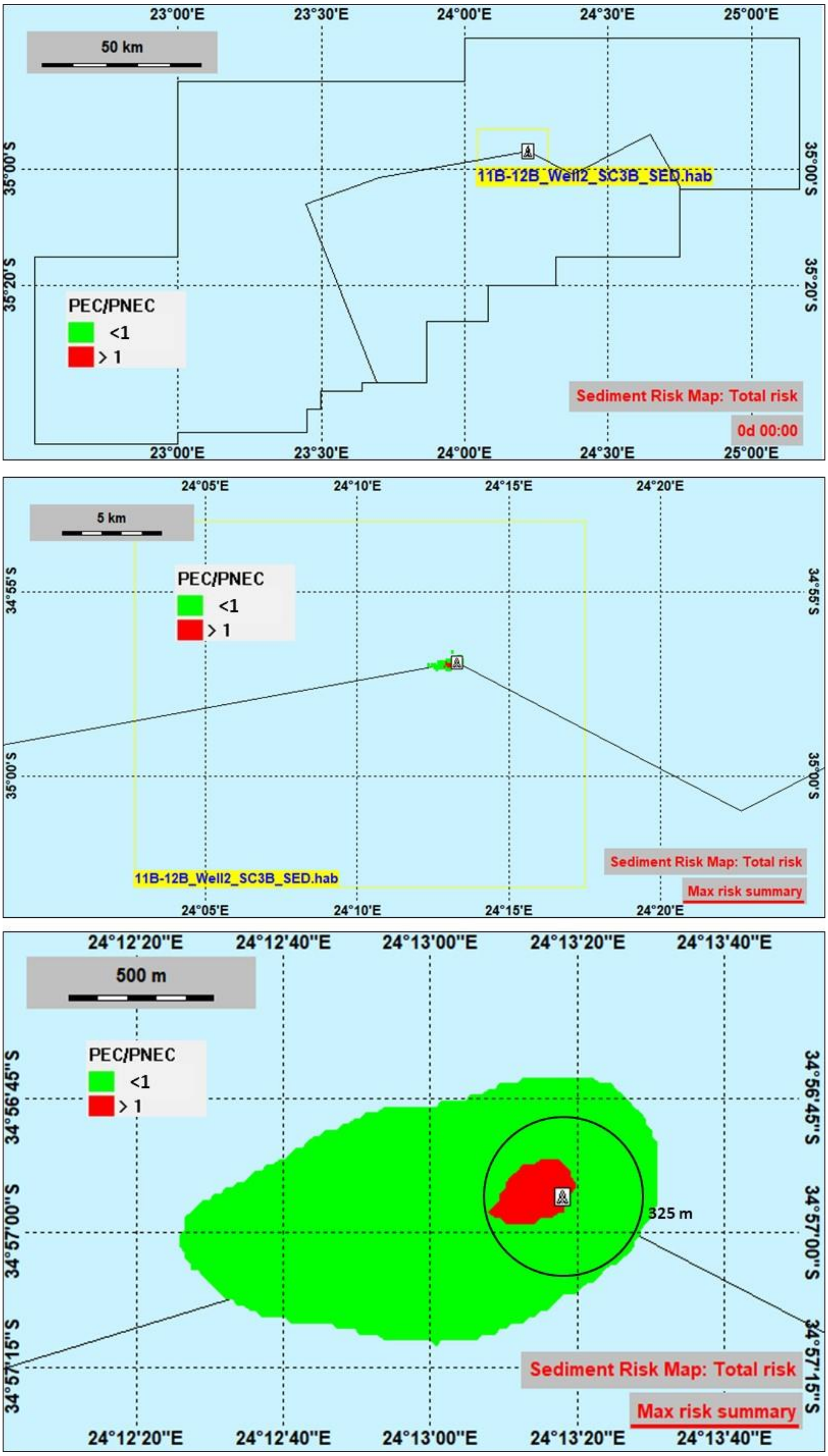


Figure 83: Maximum risk of drilling operations in the sediments for the Scenario 5 (with smoothing)

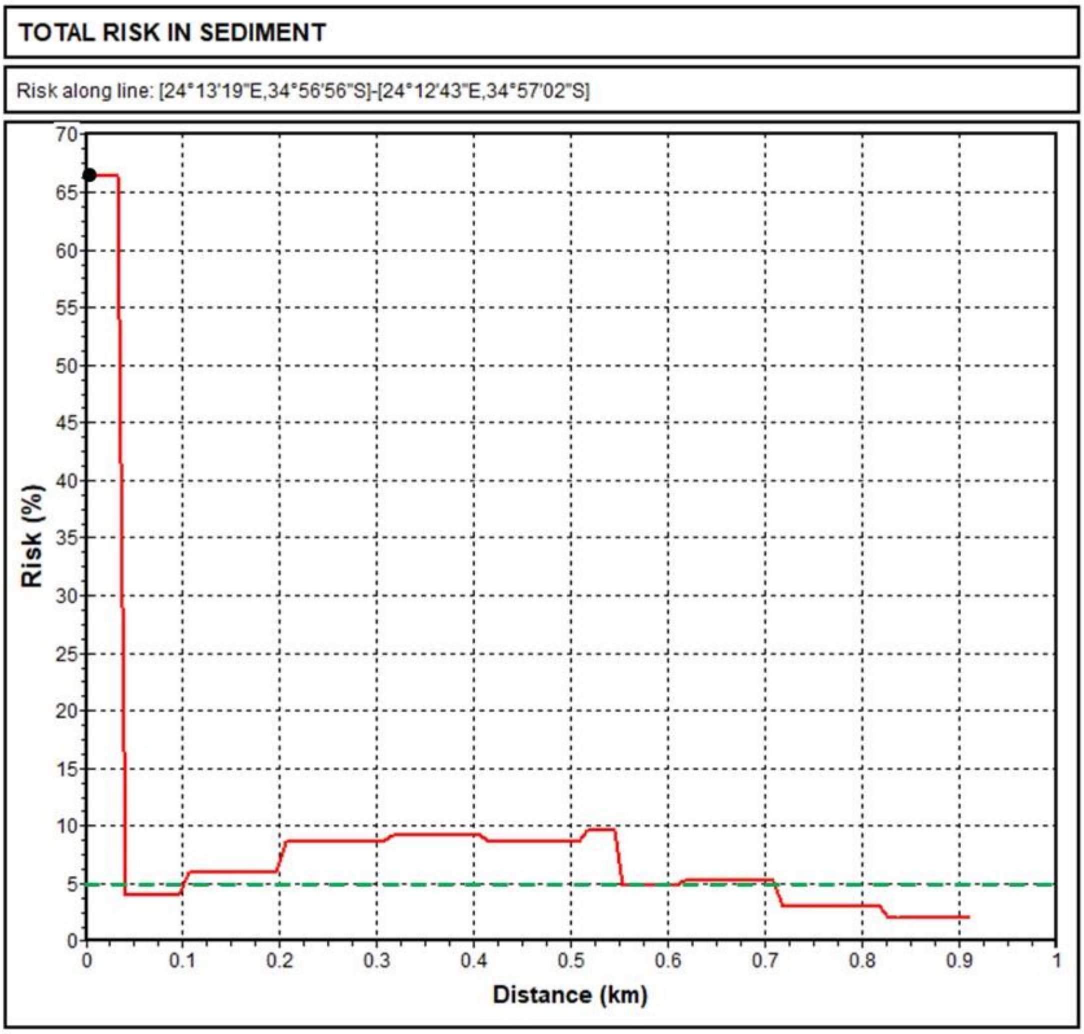


Figure 84: Maximum risk of drilling operations along a line for the Scenario 5 (black dot symbolizes the discharge point; the green dashed line symbolizes the 5% threshold)

Figure 85 shows that the risk decreases over the time in the sediments at the discharge point from the end of the drilling operations to insignificant values approximately 1500 days after the beginning of the operations.
There is no more environmental risk in the sediment 4 years after the end of the operations.

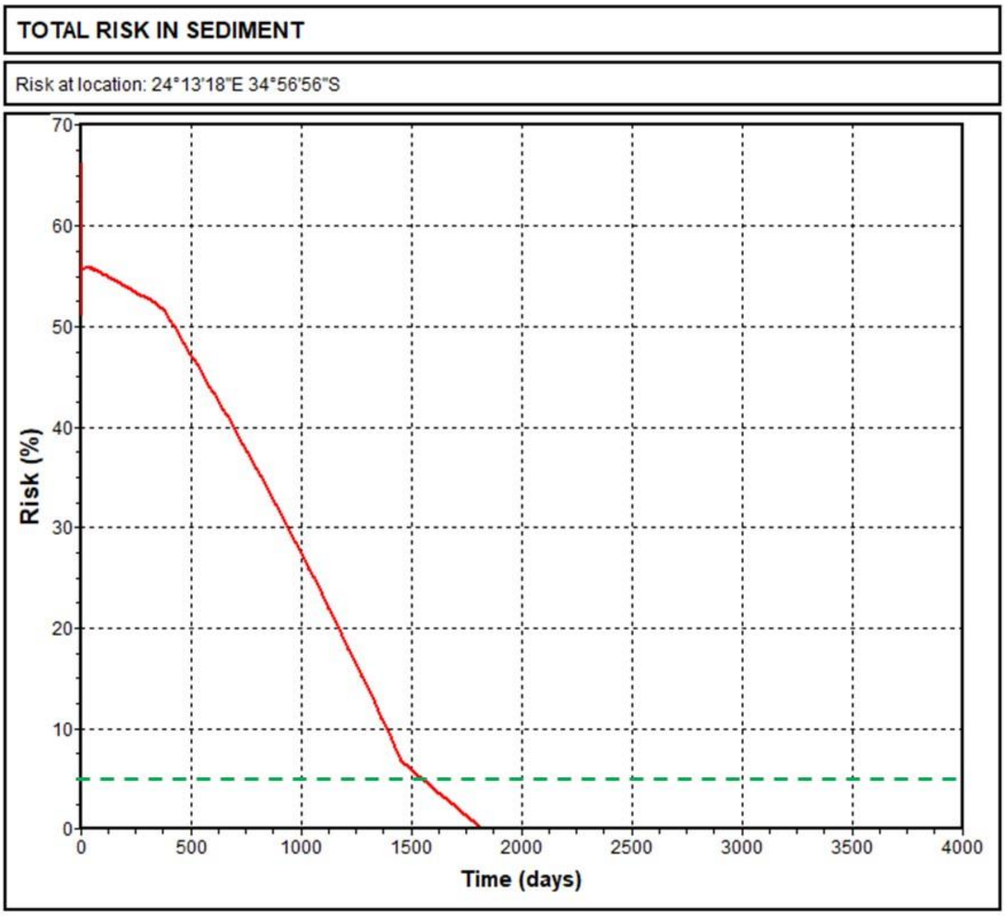


Figure 85: Maximum risk of drilling operations close the discharge point over the time for the Scenario 5 (the green dashed lines symbolize the 5% threshold)

Figure 86 shows the main contributors to the risk in the sediments for the Scenario 5. The main contributors to the total risk are physical, due to the grain size change of the natural sediment and the thickness of the deposit, contributing respectively to 86% and 14% of the total environmental risk to the sediment.

Figure 86 shows that the contribution of the different stressors to the total risk changes over the time with a significant increase of the contribution of the grain size change 18 days after the start of the operations corresponding to the start of the discharge of the sections drilled with a riser.

These results will be further discussed in the following sections.

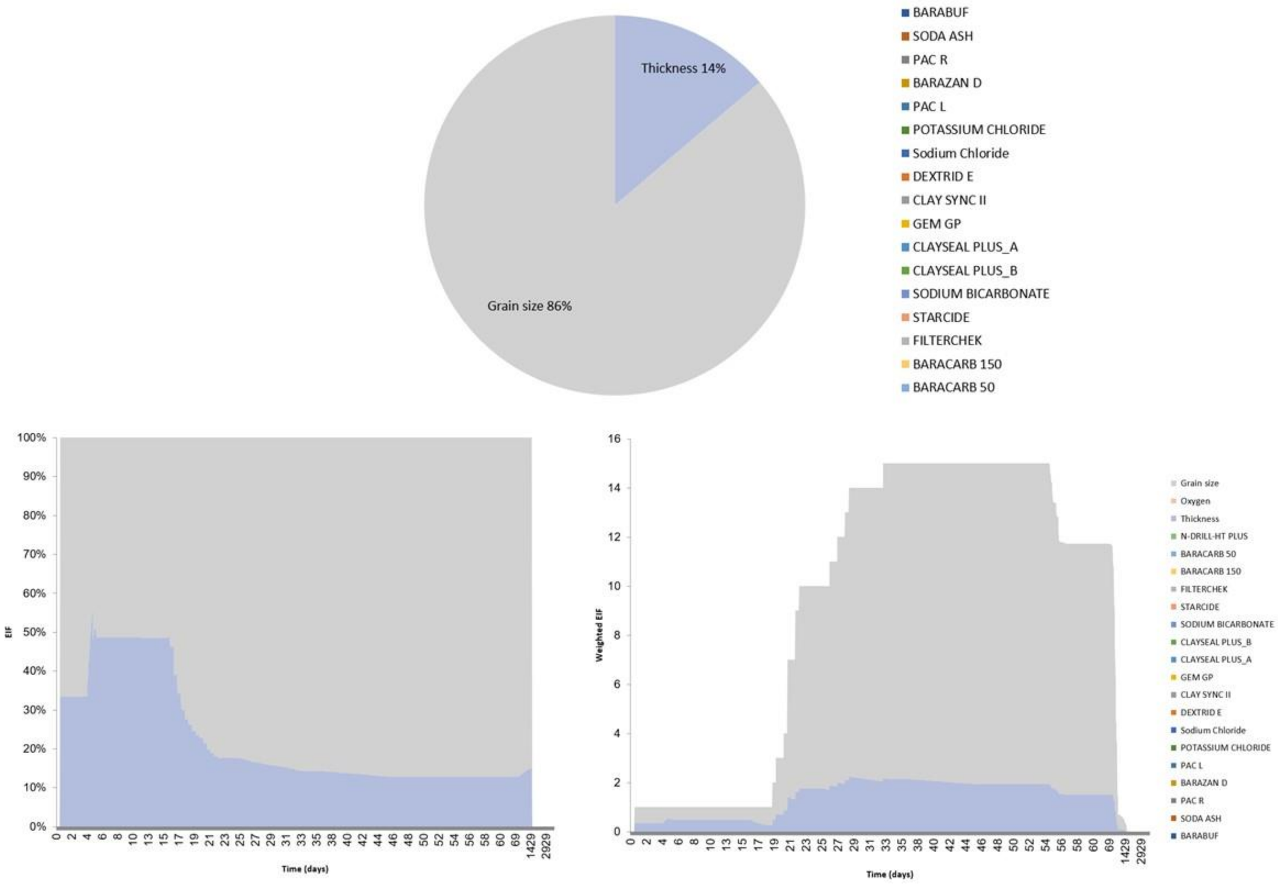


Figure 86: Main contributors to the risk of drilling operations in the sediments for the scenario 5 and main contributors to the risk over the time (Start January 1st)

Figure 86 shows that grain size variation on the sediments and sediment thickness change over the time. No more risk corresponding to this contributor is observed after approximately 1500 days.

3.2.2.1.2 Grain Size Variation

Figure 87 and Figure 88 show grain size variation on the sediments at the end of drilling operations. One main area with significant sediment grain size changes is observed around the discharge point due to the discharge of the 42'' and 26'' sections. The maximum grain size variation observed was up to 156 % on 100 m radius around the discharge point without the smoothing option.

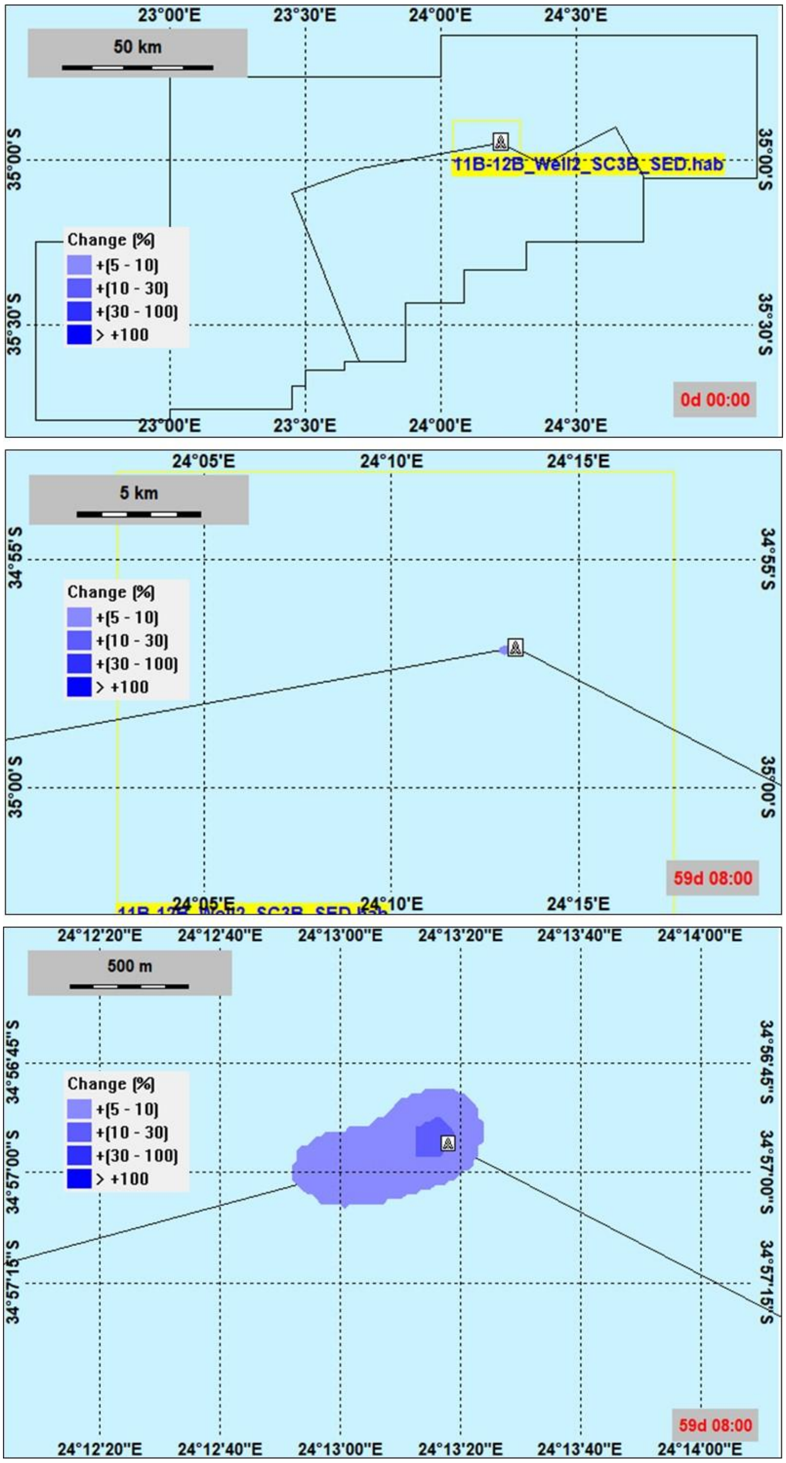


Figure 87: Grain size variations in the superficial section of seabed sediments at the end of drilling operations (Scenario 5)

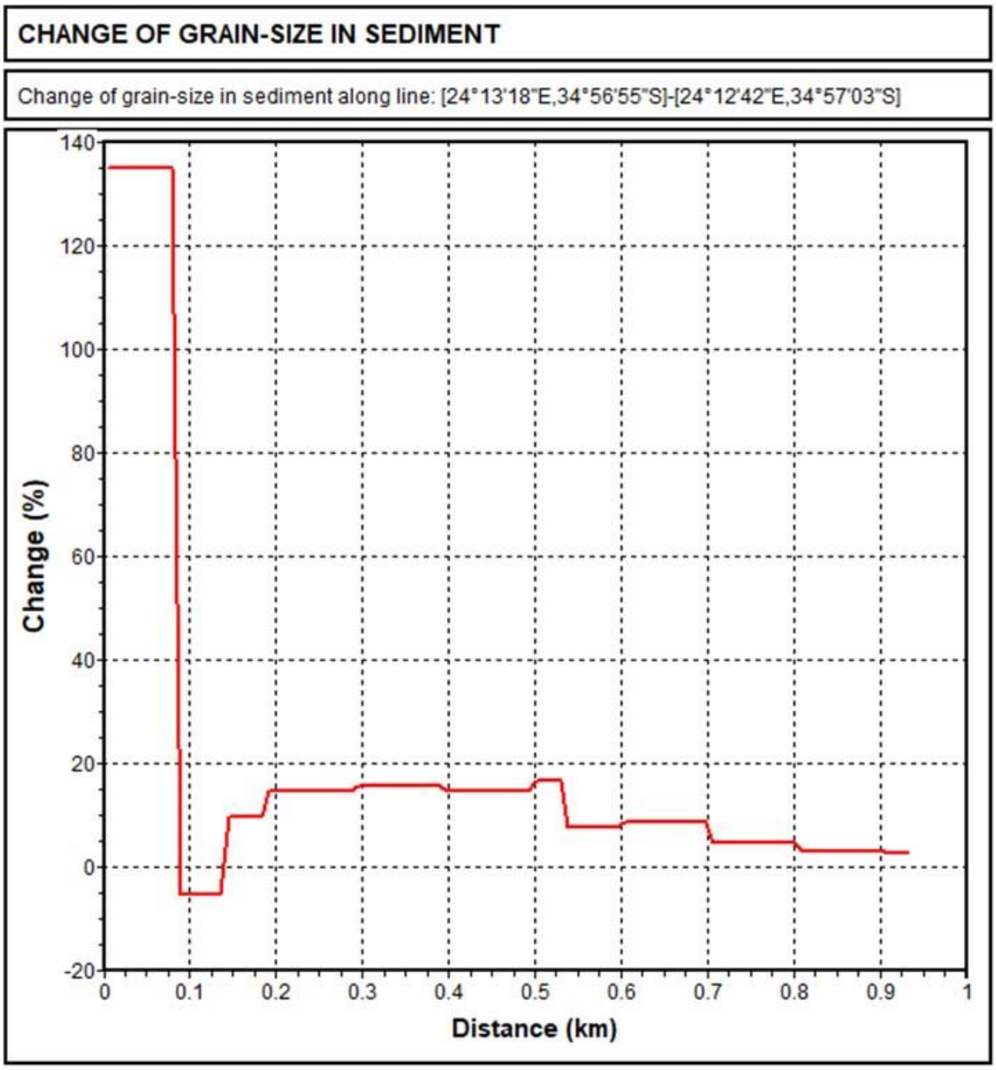


Figure 88: Grain size variations in the superficial section of seabed sediments along a line at the end of drilling operations (Scenario 5) (black dots symbolize the discharge point)

3.2.2.1.3 Thickness Deposits

Figure 89 and Figure 90 show cuttings thickness deposits at the end of drilling operations. The sediment deposit area is not centralized around the discharge point and is orientated West from the discharge point. This clearly shows the impact of seabed currents on sediment deposition.

Figure 90 shows that the maximum sediment thickness observed was up to 48 mm on 100 m radius around the discharge point without the smoothing option activated.

Figure 89 clearly shows that the highest sediment deposit concentrations are localized very close to the discharge point. The highest cuttings deposit is mainly due to the discharge of the top-hole sections (42'' and 26'') contributing to 48 mm among the total 48 mm deposit at the end of all operations without the smoothing. For the other sections (17.5'', 12.25'' and 8.5'') discharged at sea surface, the cuttings are more spread towards West leading to lower thickness at the seabed.

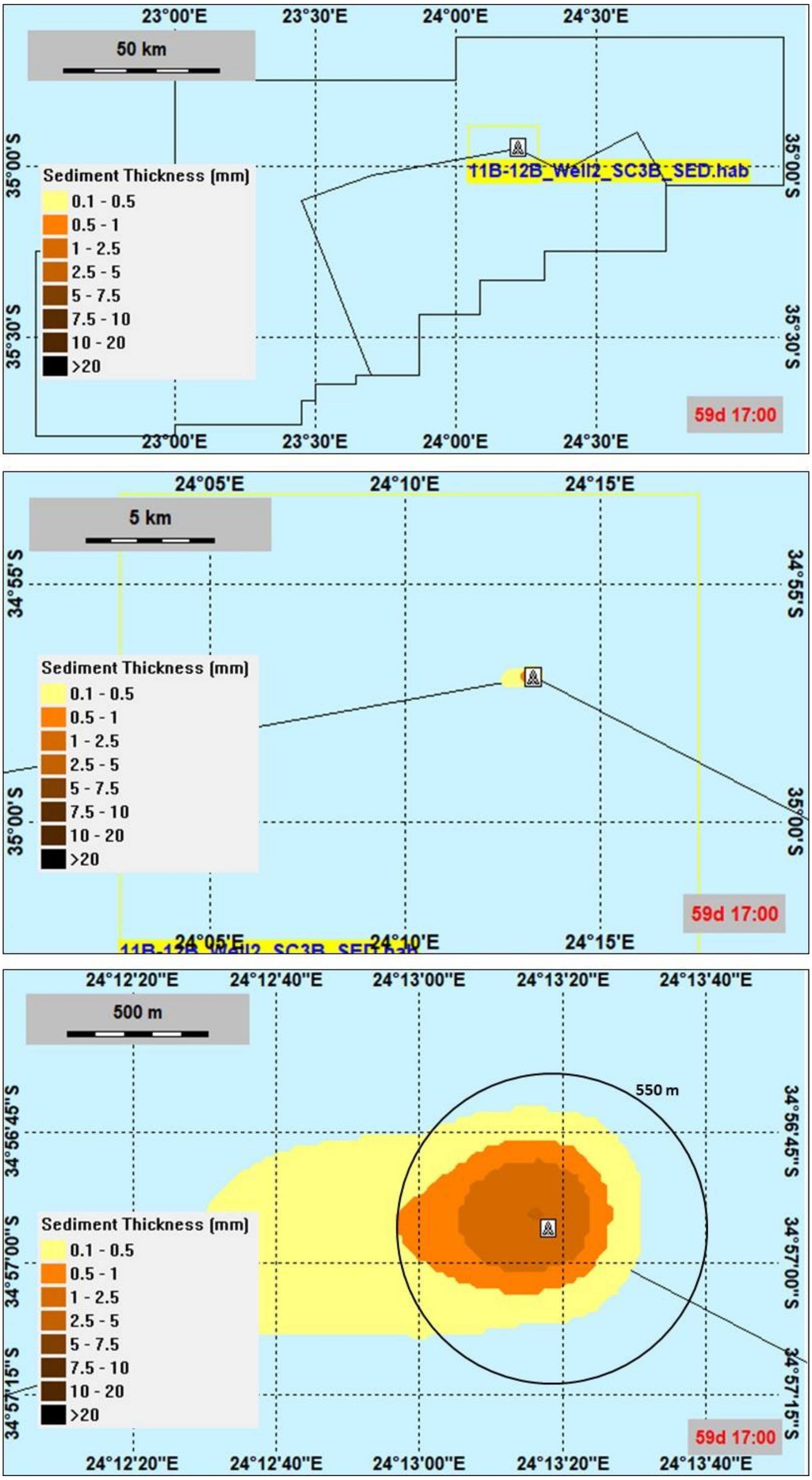


Figure 89: Cuttings thickness deposit on sediment at the end of drilling operations (Scenario 5)

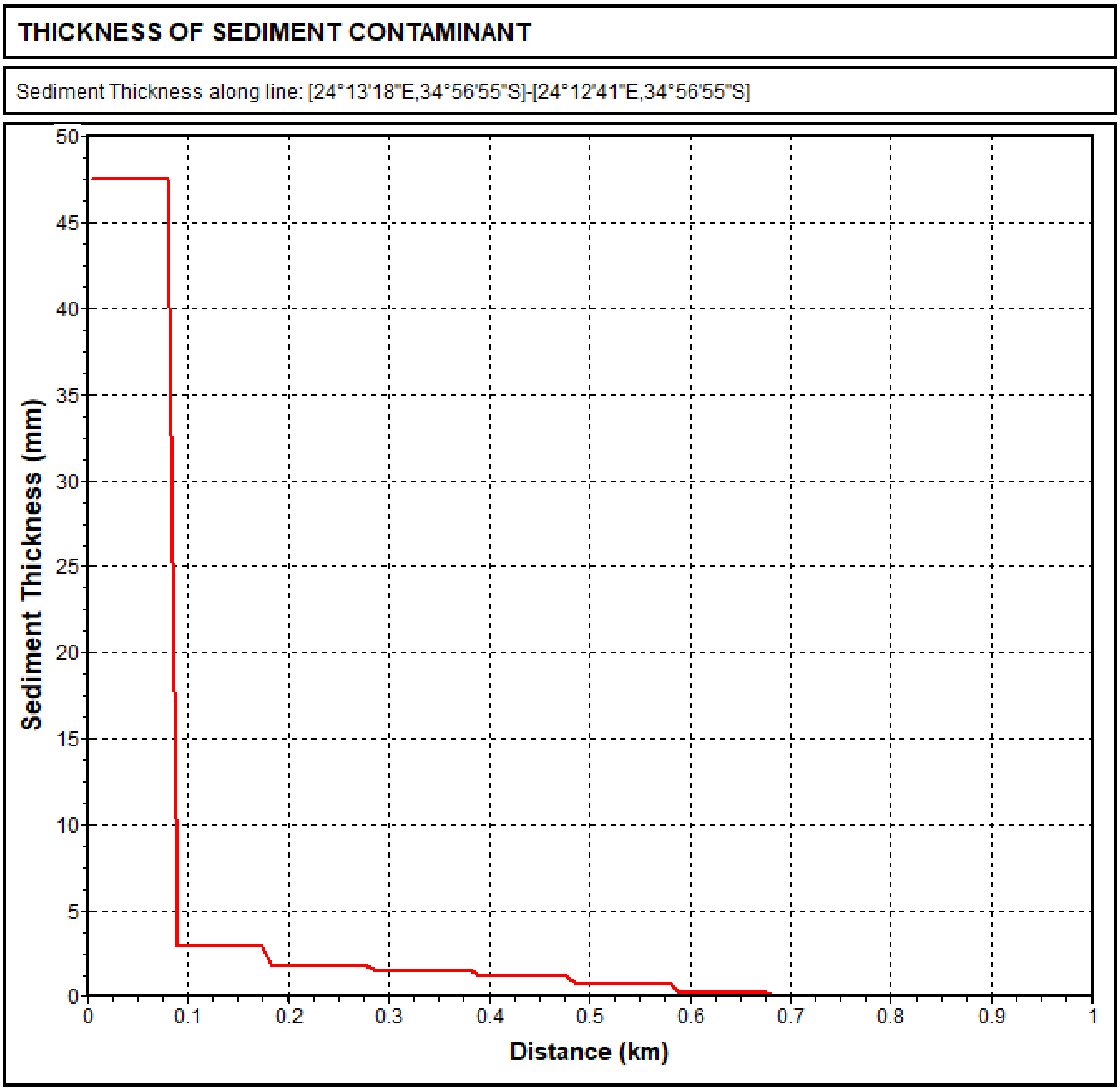


Figure 90: Cuttings thickness deposit on sediment around the discharge point along a line at the end of drilling operations (Scenario 5) (black dots symbolize the discharge point)

3.2.2.1.4 Contaminants Concentration

Figure 90 and Figure 91 show the total discharge (cuttings and mud) concentrations on the superficial sediments at the end of the drilling operations. High concentrations of discharge, i.e. 1586 g/L without smoothing is observed in the top sediments but, as discuss previously, mainly particulate compounds (cuttings and barite, i.e. non-soluble chemicals used during drilling operation) account for the total concentrations of the discharge in the sediments.

The area with discharged chemicals is not centralized around the discharge point and is orientated along an axe starting from the discharge point towards West. This clearly shows the impact of seabed currents on sediment deposition.

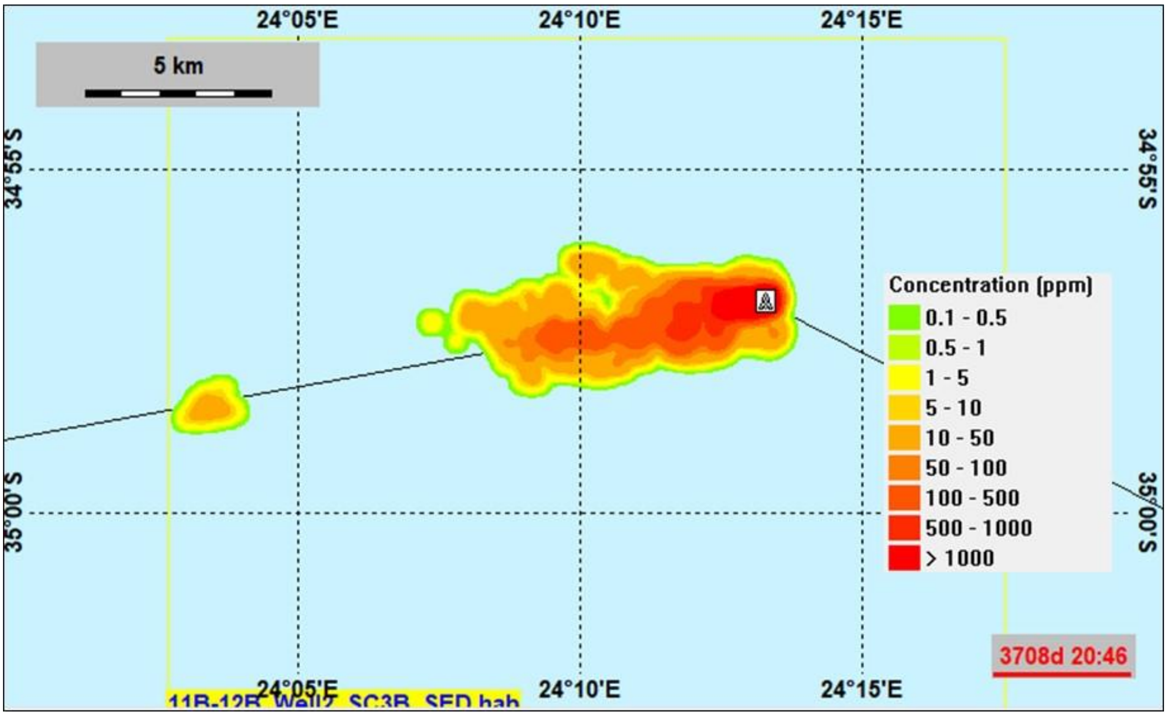


Figure 91: Concentrations of total discharge in the superficial layer of seabed sediments at the end of drilling operations (Scenario 5)

Figure 92 clearly shows that the highest discharged concentration in the sediments is localized very close to the discharge point.

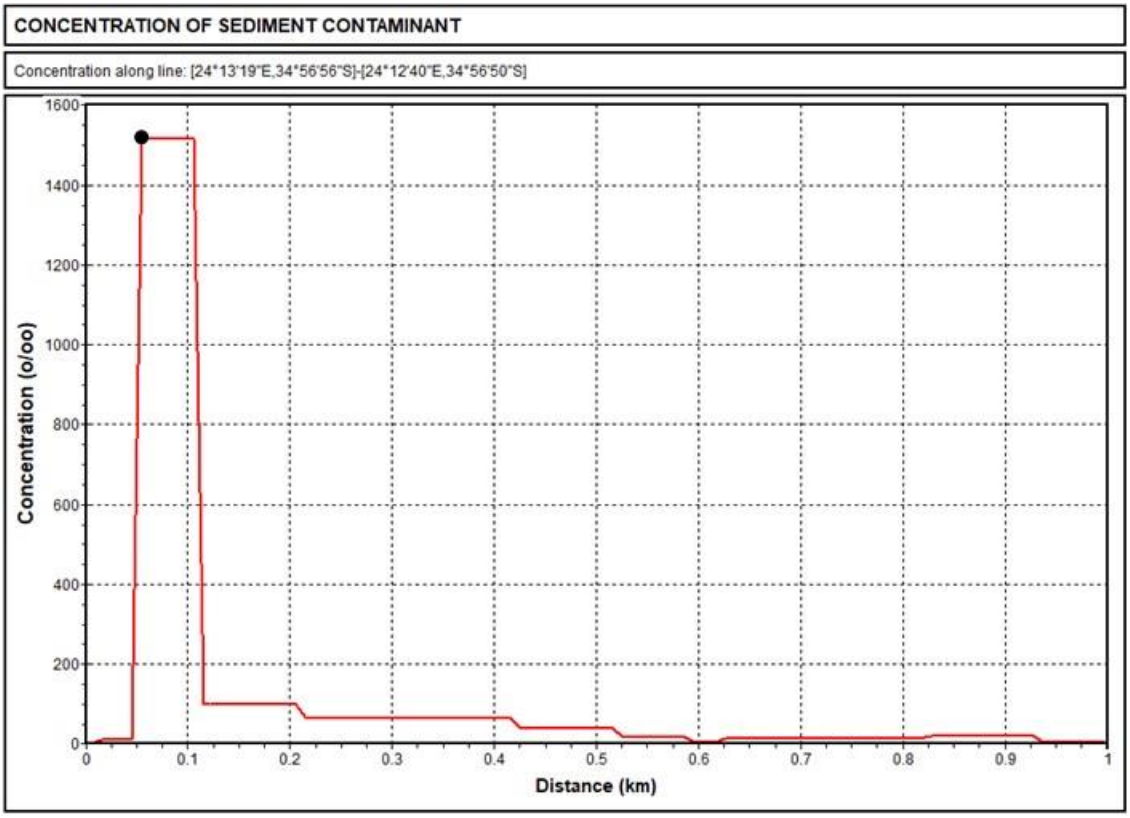


Figure 92: Total discharge concentrations in the superficial section of seabed sediments along a line at the end of drilling operations (60 days) (Scenario 5) (black dots symbolize the discharge point)

3.2.3 Synthesis for the sediments for Discharge n°2

The results obtained for all the scenarios ran for the sediments are presented in Table 11 below.

Table 11: Result synthesis for the sediments

	Base case				Optional case
	Scenario1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Max risk % (EIF*) (10^4 m^2)	2	6	6	4	11
Detection of the risk >5% in the sediments (days)	Day 0 to day 1500	Day 0 to day 1500	Day 0 to day 1500	Day 0 to day 1500	Day 0 to day 1500
Maximum Distance from discharge point with risk above 5% (m)	175 m	400 m	170 m	160 m	720 m
Max sediments thickness (mm)	30 mm	30 mm	29 mm	30 mm	48 mm
Max. Grain size variation (%)	210 % (end of operations)	87 % (end of operations)	130 % (end of operations)	65 % (end of operations)	156% (end of operations)
Max. total discharge concentration at the end of the operations (g/L)	1000	1000	990	1000	1586
Maximum Barite discharge concentration at the end of the operations (g/l)	4.8	8.2	5.6	9.2	7
Risk due to soluble Chemicals in the sediments (%)	0 (no chemicals with log K_{ow} >3 will be discharged)	0 (no chemicals with log K_{ow} >3 will be discharged)	0 (no chemicals with log K_{ow} >3 will be discharged)	0 (no chemicals with log K_{ow} >3 will be discharged)	0 (no chemicals with log K_{ow} >3 will be discharged)
Oxygen depletion in the sediment	Not applicable because no chemicals with log K_{ow} >3 will be discharged	Not applicable because no chemicals with log K_{ow} >3 will be discharged	Not applicable because no chemicals with log K_{ow} >3 will be discharged	Not applicable because no chemicals with log K_{ow} >3 will be discharged	Not applicable because no chemicals with log K_{ow} >3 will be discharged

Main contributors to the risk	PHYSICAL: Grain Size Change (76%) Thickness Deposit (24%)	PHYSICAL: Grain Size Change (77%) Thickness Deposit (23%)	PHYSICAL: Grain Size Change (75%) Thickness Deposit (25%)	PHYSICAL: Grain Size Change (80%) Thickness Deposit (20%)	PHYSICAL: Grain Size Change (86%) Thickness Deposit (14%)

For sediment deposits, no large pile has been observed after the discharge of drill cuttings for any scenario modelled (maximum 48 mm deposit), despite large quantity of particles discharged at the seabed for sections 42” and 26”.

The approach used by the model for risk calculation is based on the PEC/PNEC calculation. Basically, concentration calculated taking into account the dilution factor (PEC) is compared to toxic threshold (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 because tend to protect 95 % of species in any ecosystem without taking into account local specificity. For instance, coastal ecosystems usually show higher biodiversity and biomass and such a difference is not considered when using the PEC/PNEC approach.

The risk calculation must be balanced taking into account knowledge of environmental specialist for the study area (presence or absence of sensitive species/habitats should be considered).

4. Conclusions

The results presented in the report are based on values available at the time of study preparation. Those results are therefore preliminary and subject to scope modification.

The well to be drilled/discharge has been considered in term of architecture using two options:

- Base case scenario
- Optional scenario (deeper drilling with the same mud used for the base case scenario).

Base case scenario:

For the scenario 1, the overall risk calculation shows significant risk in the water column with a spatial extend toward West (up to 30 km away from the discharge point between 600 and 700 m depth), following the deep-sea currents. This risk is mainly due to the quantity of Barite to be used in the mud of the riserless sections.

A significant risk due to the discharge of the sections drilled with a riser has also been observed extending up to 24 km away from the discharge point toward South-West (between 0 and 100 m depth below sea surface). The risk is intermittent and limited in term of volume with only a few tiny patches with significant risk observed around the discharge which disappear after the end of the operations (after 43 days). This risk is mainly due to the hydrochloric acid present in the Clayseal Plus to be used in the sections to be drilled with a riser (17.5”, 12.25”, 8.5”, logging and P&A).

A significant risk has also been observed in the sediments for the **scenario 1** up to 175 m away from the discharge point. The risk observed lasted up to 1500 days (≈ 4 years) after the end of drilling operations. This risk is mainly due to the grain size change of the natural sediment (76% of the risk).

For the scenario 2, the overall risk calculation shows significant risk in the water column with a spatial extend toward West (up to 15 km away from the discharge point between 600 and 700 m depth), following the deep-sea currents. This risk is mainly due to the quantity of Barite to be used in the mud of the riserless sections.

A significant risk due to the discharge of the sections drilled with a riser has also been observed extending up to 10 km away from the discharge point toward South-West (between 0 and 100 m depth below sea surface). The risk is intermittent and limited in term of volume with only a few tiny patches with significant risk observed around the discharge which disappear after the end of the operations (after 43 days). This risk is mainly due to the hydrochloric acid present in the Clayseal Plus to be used in the sections to be drilled with a riser (17.5”, 12.25”, 8.5”, logging and P&A).

A significant risk has also been observed in the sediments for the **scenario 2** up to 400 m away from the discharge point toward West/South-West. The risk observed lasted up to 1500 days (≈ 4 years) after the end of drilling operations. This risk is mainly due to the grain size change of the natural sediment (77% of the risk).

For the scenario 3, the overall risk calculation shows significant risk in the water column with a spatial extend toward West / South-West (up to 35 km away from the discharge point between 600 and 700 m depth), following the deep-sea currents. This risk is mainly due to the quantity of Barite to be used in the mud of the riserless sections.

A significant risk due to the discharge of the sections drilled with a riser has also been observed extending up to 21 km away from the discharge point toward North-West (between 0 and 100 m depth below sea surface). The risk is intermittent and limited in term of volume with only a few tiny patches with significant risk observed around the discharge which disappear after the end of the operations (after 43 days). This risk is mainly due to the hydrochloric acid present in the Clayseal Plus to be used in the sections to be drilled with a riser (17.5”, 12.25”, 8.5”, logging and P&A).

A significant risk has also been observed in the sediments for the **scenario 3** up to 170 m away from the discharge point. The risk observed lasted up to 1500 days (≈ 4 years) after the end of drilling operations. This risk is mainly due to the grain size change of the natural sediment (75% of the risk).

For the scenario 4, the overall risk calculation shows significant risk in the water column with a spatial extend toward 12 km West and 5.5 km South-East (between 600 and 700 m depth), following the deep-sea currents. This risk is mainly due to the quantity of Barite to be used in the mud of the riserless sections.

A significant risk due to the discharge of the sections drilled with a riser has also been observed extending up to 11 km away from the discharge point toward South-West (between 0 and 100 m depth below sea surface). The risk is intermittent and limited in term of volume with only a few tiny patches with significant risk observed around the discharge which disappear after the end of the operations (after 43 days). This risk is mainly due to the hydrochloric acid present in the Clayseal Plus to be used in the sections to be drilled with a riser (17.5”, 12.25”, 8.5”, logging and P&A).

A significant risk has also been observed in the sediments for the **scenario 4** up to 160 m away from the discharge point. The risk observed lasted up to 1500 days (≈ 4 years) after the end of drilling operations. This risk is mainly due to the grain size change of the natural sediment (80% of the risk).

Optional case scenario:

For the scenario 5, the overall risk calculation shows a significant risk in the water column with a spatial extend toward West (up to 35 km away from the discharge point between 625 and 725 m depth), following the deep-sea currents. This risk is mainly due to the quantity of Barite to be used in the mud of the riserless sections.

A significant risk due to the discharge of the sections drilled with a riser has also been observed extending up to 12 km away from the discharge point toward South West between 0 and 100 m depth below sea surface). The risk is intermittent and limited in term of volume with only a few tiny patches with significant risk observed around the discharge which disappear after the end of the operations (after 61 days). This risk is mainly due to the hydrochloric acid present in the Clayseal Plus to be used in the sections to be drilled with a riser (17.5”, 12.25”, 8.5”, logging and P&A).

A significant risk has also been observed in the sediments for the **scenario 5** up to 720 m away from the discharge point toward West/South West. The risk observed lasted up to 1500 days (≈ 4 years) after the end of drilling operations. This risk is mainly due to the grain size change of the natural sediment (86% of the risk).

The approach used by the model for risk calculation is based on the PEC/PNEC calculation. Basically, concentration calculated taking into account the dilution factor (PEC) is compared to toxic threshold (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 because tend to protect 95 % of species in any ecosystem without taking into account local specificity. For instance, coastal ecosystems usually show higher biodiversity and biomass and such a difference is not considered when using the PEC/PNEC approach.

The risk calculation must be balanced taking into account knowledge of environmental specialist for the study area (presence or absence of sensitive species/habitats should be considered).

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Appendix 1: Service Request form

DREAM-PARTRACK MODELLING SETUP – SUMMARY SHEET

IMPORTANT/ Information detailed here must be agreed and validated (signed) by client before commencement of the study

WARNING 1: Any changes to the information mentioned herein after validation will imply an impact on the delivery time and / or costs associated with the service.

WARNING 2: For studies related with preparation and/or updating of OSCP/ESIA, the input data for the study as well as the results, shall be verified by HSE/GCA or PSR/HSE/EP/ES/ENV/PJT, before disclosure to client.

WARNING 3: Report or results being produced are not absolute values and needs to be interpreted by specialists. Reports generated are not intended for external use. Any misunderstanding or misleading interpretation of results provided will be client responsibility.

COUNTRY/AFFILIATE	TEPSA	
BLOCK/WELL	Block11B/12B -- Kloofpadda-1X	
CLIENT/REQUESTOR NAME AND ENTITY	Eduard GROENEWALD, HSE manager	
HEAD OFFICE CORRESPONDANT	☐ TEPSA	☒ ENV/PJT Tatiana Gusachenko
RFS REFERENCE	To be filled	
SERVICE SCOPE OF WORK	☒ EIA support	☐ Operation support
	☐ OSCP	☐ Other ....
NUMBER OF SCENARIOS	1 Scenario	☐ OSR
DEADLINE	Deliverables deadline 30/06 / 20 Draft report 29 /05/ 20 Final report 30/06 / 20 NB : Metocean dataset acquisition 2 weeks Modeling study 8 weeks	
AGREED DELIVERABLES	☒ Technical Report (ESIA purposes)	☒ Power-point presentation (ESIA purposes)
	☐ GIS maps (.nc or .shp)	☐ raw PARTRACK results
METOCEAN DATA	☐ Available	☒ To be purchased
	Area to be covered	*LAT:*
		LON:
CONFIDENTIAL LEVEL	☐ Confidential (internal use)	☒ external use (ESIA purposes)

BASIC INFORMATION – RELEASE LOCATION	
LOCATION 1– CONFIRMED COORDINATES (WGS84)	34° 58' 49,765" S / 24° 42' 3,649" E
LOCATION 2 - CONFIRMED COORDINATES (WGS84)	34° 56' 56,043" S / 24° 13' 18,074" E
SIMULATION PERIOD	Beginning of January (sc1) – Beginning of March –Sc2) – Beginning of June (Sc3) – Beginning of September (Sc4)
NUMBER SCENARIOS & duration of model	**NUMBER OF SCENARIOS & duration of model**

	[redacted]			duration of simulation– water column (days)	duration of simulation– sediments (days)		
	Scenario 1	42"+ 26"+ 17.5"+ 12.25"+8.5"+ plug well		45	45 +10 years		
	Scenario 2	42"+ 26"+ 17.5"+ 12.25"+8.5"+ plug well		45	45 +10 years		
	Scenario 3	42"+ 26"+ 17.5"+ 12.25"+8.5"+ plug well		45	45 +10 years		
	Scenario 4	42"+ 26"+ 17.5"+ 12.25"+8.5"+ plug well		45	45 +10 years		
	Section to be drilled						
Wellbore diameter (")	42"	26"	17.5"	12.25"	8.5" Drilling	8.5" Logging	8.5" P&A
Sections length (m)	83	504	504	504	505		
Drilling rate (m/h)	15-20	15-30	25-40	5-15	5-15	0	0
Mass of cuttings (T)	260	606	253	114	55	0	0
Cuttings discharged (yes/No)	Yes, at Seabed	Yes, at Seabed	Yes, after shaker	Yes, after shaker	Yes, after shaker		
Type of mud used while drilling	Sea Water & Hi-vis Sweep & WBM (PAD mud)	Sea Water & Hi-vis Sweep & WBM (PAD mud)	HydroGuard High Performance Water Base Mud	HydroGuard High Performance Water Base Mud	KCl/Glycol/ Polymer Water Base Mud		
quantity of mud discharged while drilling (T)	768	2521	836	475	326	740	740
Drilling duration (section length/rate) (hours)/ operation duration = discharge duration	4.75	22.4	15.5	50.4	50.5	96	72
Discharge duration	4.75	22.4	3.5 days	4.5 days	4.5 days		
Indicative time before next operation (hours) – (including time to prepare next operation, cementing operation, Liner, casing, pressure tests...)	4 days	10 days	3 days	2.5 days	2.5 days	0	0
Discharge DEPTH (m)	Seabed	Seabed	At mean sea level	At mean sea level	At mean sea level		
Suspension/clean-up/displacement before drilling next section (yes/No)	No	No	No	No	No	No	No
Type of mud used for Suspension/clean-up/displacement	na	na	na	na	na	na	Na
quantity of mud discharged for Suspension/clean-up/displacement (T)	0	0	0	0	na	na	na
Suspension/clean-up/displacement duration (days) – Default value 0.5 days	na	na	na	na	na	na	na
Discharge DEPTH (m)	na	na	na	na	na		

MUD COMPOSITION *MSDS or HOCNF or bioassays results report must be provided to HSE/ENV/OPS, to allow to gather Ecotoxicological data*														
			Input from Fluid team				Input from HSE/ENV/OPS based on MSDS, HOCNF or bioassays results provided by the project team							
Mud type		**name**	**composition**	**Function**	**Concentration (kg/T)**	**Mass (T)**	**PNEC (ppb)**	**KOC**	**solubility**	**density**	**Biodegradation (%)**	**KOW**	**Vapour pressure**	**MW**
42" Sea Water & Hi-vis Sweep & WBM (PAD mud) – 768MT	**Hi-vis Sweep (247 mT)**	PAC R	Polysaccharide	Filtration loss control	9.7	2.4	80.86	1	10000	1.6	60	0	0	
		Barabuf	Not Available	Alkalinity Agent	2.8	0.2	100	1	10 000	3.56	0	0	0	
		Soda ash	Sodium Carbonate	Water Hardness Control	1.2	0.3	242	1	212500	2.52	0	0	0	106
	PAD mud (521mT)	Barazan D	Polysaccharide/Xanthan Gum	Polymeric Viscosifier	2.7	1.4	420	1	100000	1.6	93	0	0	
		PAC L	Polysaccharide	Filtration loss control	3.3	1.7	80.86	1	100000	1.6	60	0	0	
		KCL	Potassium Chloride	Salinity /Inhibition	57.4	29.9	1000	1	355 000	1.98	0	0	0	74.55
		Barabuf	Not Available	Alkalinity Agent	0.4	0.2	100	1	10 000	3.56	0	0	0	
		Soda ash	Sodium Carbonate	Water Hardness Control	0.6	0.3	242	1	212500	2.52	0	0	0	106
		Barite	Crystalline silica, quartz	Weighting Agent	240.9	6.3	440	1	0	2.6	0	0	0	60
			Barium Sulphate			119.2	115	1	3.1	4.5	0	5	0	234.4
26" Sea Water & Hi-vis Sweep & WBM (PAD mud) – 2521 MT	**Hi-vis Sweep (1031 mT)**	PAC R	Polysaccharide	Filtration loss control	9.7	10	80.86	1	10000	1.6	60	0	0	
		Barabuf	Not Available	Alkalinity Agent	0.7	0.7	100	1	10 000	3.56	0	0	0	
		Soda ash	Sodium Carbonate	Water Hardness Control	1.1	1.1	242	1	212500	2.52	0	0	0	106
	PAD mud (1490 mT)	Barazan D	Polysaccharide/Xanthan Gum	Viscosifier	2.7	4	420	1	100000	1.6	93	0	0	
		PAC L	Polysaccharide	Filtration loss control	3.3	4.9	80.86	1	100000	1.6	60	0	0	
		KCL	Potassium Chloride		57.3	85.4	1000	1	355 000	1.98	0	0	0	74.55
		Barabuf	Not Available	Alkalinity Agent	0.5	0.7	100	1	10 000	3.56	0	0	0	

		Soda ash	Sodium Carbonate	Water Hardness Control	0.7	1.1	242	1	212500	2.52	0	0	0	106
		Barite	Crystalline silica, quartz	Weighting Agent	240.8	17.9	440	1	0	2.6	0	0	0	60
			Barium Sulphate			340.9	115	1	3.1	4.5	0	5	0	234.4
17.5" HydroGuard High Performance Water Base Mud – 836 MT	HydroGuard High Performance Water Base Mud (836 MT)	KCL	Potassium Chloride	Salinity/Inhibition	75	62.5	1000	1	355 000	1.98	0	0	0	74.55
		NaCl	Sodium Chloride	Salinity/Inhibition	24	20.3	40000	1	317 000	2.163	0	0	0	
		Barabuf	Not Available	Alkalinity Agent	0.7	0.6	100	1	10 000	3.56	0	0	0	
		Barazan D	Polysaccharide/Xanthan Gum	Viscosifier	3	2.5	420	1	100000	1.6	93	0	0	
		PAC L	Polysaccharide	Filtration loss control	7.9	6.6	80.86	1	100000	1.6	60	0	0	
		Clayseal Plus	Triethylenetetramine, polymer with oxirane (95%)	Encapsulator/Shale Stabilizer	18.7	14.8	562.3	1	10000	1.0561	0	0	0	na
			Hydrochloric acid (5%)			0.8	3.25	1	500000	1.27	100	0	45.6	36.46
		Dextrid E	Modified Starch/Complex carbohydrate	Filtration loss control	18.7	15.6	1000	1	100000	1.5	70%	0	0	
		Clay Sync II	Not Available	Encapsulator/Shale Stabilizer	4.7	3.9	1160	1	100000	1.04	2.8 (21days)	0	0	500000
		GEM GP	Polyethylene glycol butyl ether	Clay Inhibition	28	23.4	310	2.75	989000	0.989	69	2.76	0	
		Soda ash	Sodium Carbonate	Water Hardness Control	0.6	0.5	242	1	212500	2.52	0	0	0	106
		Sodium bicarbonate	Sodium bicarbonate	Buffer	1	0.8	576	1	93400	2.21	0	0	0	
12.25" HydroGuard High Performance Water Base Mud – 475 MT	HydroGuard High Performance Water	KCL	Potassium Chloride	Salinity/Inhibition	75	35.5	1000	1	355 000	1.98	0	0	0	74.55
		NaCl	Sodium Chloride	Salinity/Inhibition	24	11.5	40000	1	317 000	2.163	0	0	0	

	Base Mud (475 MT)	Barabuf	Not Available	Alkalinity Agent	0.6	0.3	100	1	10 000	3.56	0	0	0	
		Barazan D	c	Viscosifier	2.9	1.4	420	1	100000	1.6	93	0	0	
		PAC L	Polysaccharide	Filtration Loss Control	8	3.8	80.86	1	100000	1.6	60	0	0	
		Clayseal Plus	Triethylenetetramine, polymer with oxirane (95%)	Encapsulator/Shale Stabilizer	23.4	8.5	562.3	1	10000	1.0561	0	0	0	na
			Hydrochloric acid (5%)			0.4	0.364	1	500000	1.27	100	0	45.6	36.46
		Dextrid E	Modified Starch/Complex carbohydrate	Filtration loss control	18.7	8.9	1000	1	100000	1.5	70%	0	0	1000
		Clay Sync II	Not Available	Encapsulator/Shale Stabilizer	4.6	2.2	1160	1	100000	1.04	2.8 (21days)	0	0	500000
		GEM GP	Polyethylene glycol butyl ether	Clay Inhibition	28	13.3	310	2.75	989000	0.989	69	2.76	0	
		Sodium bicarbonate	Sodium bicarbonate	Buffer	As required	0.4	576	1	93400	2.21	0	0	0	
		Soda ash	Sodium Carbonate	Water Hardness Control	0.6	0.3	242	1	212500	2.52	0	0	0	106
		Starcide	3, 3'-Methylene bis (5-methyl oxazolidine)	biocide	1.3	0.6	49	0.91	2800000	1.069	90	0.9	0	186.25
8.5" KCl/Glycol/ Polymer Water Base Mud – 1806 MT	KCl/Glycol/ Polymer Water Base Mud (326 MT)	KCL	Potassium Chloride	Salinity/Inhibition	68	22.1	1000	1	355 000	1.98	0	0	0	74.55
		NaCl	Sodium Chloride	Salinity/Inhibition	22	7.2	40000	1	317 000	2.163	0	0	0	
		Barabuf	Not Available	Alkalinity Agent	3	1.0	100	1	10 000	3.56	0	0	0	
		Barazan D	Polyethylene glycol butyl ether	Viscosifier	2	0.6	420	1	100000	1.6	93	0	0	

		PAC L	Polysaccharide	Filtration loss control	7	2.3	80.86	1	100000	1.6	60	0	0	
		Clayseal Plus	Triethylenetetramine, polymer with oxirane (95%)	Encapsulator/Shale Stabilizer	17	5.2	562.3	1	10000	1.0561	0	0	0	na
			Hydrochloric acid (5%)			0.3	3.25	1	500000	1.27	100	0	45.6	36.46
		FilterChek	Not Available	Filtration loss control	12	3.9	100	1	100000	1.5	60	0	0	
		GEM GP	Polyethylene glycol butyl ether	Clay Inhibition	25	8.3	310	2.75	989000	0.989	69	2.76	0	
		BARACARB 150	Calcium Carbonate / Ground Marble	Loss Control Material/LCM	25	8.3	440	1	0	2.7	0	0	0	
		BARACARB 50	Calcium Carbonate / Ground Marble	Loss Control Material/LCM	55	18	440	1	0	2.7	0	0	0	
		Barite	Crystalline silica, quartz (95%)	Weighting Agent	As Required	11.6	440	1	0	2.6	0	0	0	60
			Barium Sulphate (5%)			0.6	115	1	3.1	4.5	0	5	0	234.4
		starcide	3, 3'-Methylene bis (5-methyl oxazolidine)	biocide	1	0.4	49	0.91	2800000	1.069	90	0.9	0	186.25
		N-Drill HT plus	?	Fluid Loss Additive	5	1.7	100	1	100000	1.5	0	0	0	
	KCl/Glycol/ Polymer Water Base Mud (740 MT) - Logging	KCL	Potassium Chloride	Salinity/Inhibition	55	40.6	1000	1	355 000	1.98	0	0	0	74.55
		NaCl	Sodium Chloride	Salinity/Inhibition	18	13.2	40000	1	317 000	2.163	0	0	0	
		Barabuf	Not Available	Alkalinity Agent	3	1.9	100	1	10 000	3.56	0	0	0	
		Barazan D	Polyethylene glycol butyl ether	Viscosifier	1	1.0	420	1	100000	1.6	93	0	0	

	PAC L	Polysaccharide	Filtration loss control	6	4.3	80.86	1	100000	1.6	60	0	0	
	Clayseal Plus	Triethylenetetramine, polymer with oxirane (95%)	Encapsulator/Shale Stabilizer	14	9.6	562.3	1	10000	1.0561	0	0	0	na
		Hydrochloric acid (5%)			0.5	3.25	1	500000	1.27	100	0	45.6	36.46
	FilterChek	Not Available	Filtration loss control	10	7.1	100	1	100000	1.5	60	0	0	
	GEM GP	Polyethylene glycol butyl ether	Clay Inhibition	21	15.2	310	2.75	989000	0.989	69	2.76	0	
	BARACARB 150	Calcium Carbonate / Ground Marble	Loss Control Material/LCM	21	15.2	440	1	0	2.7	0	0	0	
	BARACARB 50	Calcium Carbonate / Ground Marble	Loss Control Material/LCM	45	33	440	1	0	2.7	0	0	0	
	Barite	Crystalline silica, quartz (95%)	Weighting Agent	As Required	21.4	440	1	0	2.6	0	0	0	60
		Barium Sulphate (5%)			1.1	115	1	3.1	4.5	0	5	0	234.4
	starcide	3, 3'-Methylene bis (5-methyl oxazolidine)	Biocide	0.9	0.7	49	0.91	2800000	1.069	90	0.9	0	186.25
	N-Drill HT plus	?	Fluid Loss Additive	4.1	3	100	1	100000	1.5	0	0	0	
KCl/Glycol/ Polymer Water Base Mud (740 MT) - P&A	KCL	Potassium Chloride	Salinity/Inhibition	55	40.6	1000	1	355 000	1.98	0	0	0	74.55
	NaCl	Sodium Chloride	Salinity/Inhibition	18	13.2	40000	1	317 000	2.163	0	0	0	
	Barabuf	Not Available	Alkalinity Agent	2.6	1.9	100	1	10 000	3.56	0	0	0	
	Barazan D	Polyethylene glycol butyl ether	Viscosifier	1.4	1.0	420	1	100000	1.6	93	0	0	

		PAC L	Polysaccharide	Filtration loss control	6	4.3	80.86	1	100000	1.6	60	0	0	
		Clayseal Plus	Triethylenetetramine, polymer with oxirane (95%)	Encapsulator/Shale Stabilizer	14	9.6	562.3	1	10000	1.0561	0	0	0	na
			Hydrochloric acid (5%)			0.5	3.25	1	500000	1.27	100	0	45.6	36.46
		FilterChek	Not Available	Filtration loss control	10	7.1	100	1	100000	1.5	60	0	0	
		GEM GP	Polyethylene glycol butyl ether	Clay Inhibition	21	15.2	310	2.75	989000	0.989	69	2.76	0	
		BARACARB 150	Calcium Carbonate / Ground Marble	Loss Control Material/LCM	21	15.2	440	1	0	2.7	0	0	0	
		BARACARB 50	Calcium Carbonate / Ground Marble	Loss Control Material/LCM	45	33	440	1	0	2.7	0	0	0	
		Barite	Crystalline silica, quartz (95%	Weighting Agent	As Required	21.4	440	1	0	2.6	0	0	0	60
			Barium Sulphate			1.1	115	1	3.1	4.5	0	5	0	234.4
		starcide	3, 3'-Methylene bis (5-methyl oxazolidine)	biocide		0.9	49	0.91	2800000	1.069	90	0.9	0	186.25
		N-Drill HT plus	?	Fluid Loss Additive		4.1	100	1	100000	1.5	0	0	0	

RELEASE PROPER TIES			
ORIENTATION	Vertical		
		RELEASE TEMPERATURE (°C)	Release salinity (g/L)
	Section 1: 42''	15	35.4 psu
	Section 2: 26''	15	35.4 psu
	Section 3: 17.5''	11	50
	Section 4: 12.25''	15	50
	Section 5: 8.5''	15	50

AMBIENT AVERAGE DATA If water profiles are available close to studied area; they should be provided; if ambient measurements are not available, default values or bibliography average values will be considered								
comments	bibliography				EBS values (range)			
	Monthly means values							
	January	March	June	Sept	January	March	June	September
WATER COLUMN TEMPERATURE (°C)	0m: 22.6; 100m: 15.8; 200m: 12.7; 500m: 9.7; 800m: 7.4; 1000m: 5.7; 1500m: 3.4 1600m: 3.1	0m: 22.7; 100m: 15.5; 200m: 12.7; 500m: 8.6; 800m: 6.0; 1000m: 4.6; 1500m: 3.3 1600m: 3.1	0m: 19.5; 100m: 16.7; 200m: 14.7; 500m: 9.7; 800m: 6.4; 1000m: 5.1; 1500m: 3.3 1600m: 3.1	0m: 18.6; 100m: 14.3; 200m: 11.7; 500m: 7.7; 800m: 5.2; 1000m: 5.1; 1500m: 4.1 1600m: 3.1	No info			
SALINITY (%)	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	0m: 35.4; 700m: 34.9 100m: 34.6 2000m: 34.7 2500m: 34.8	No info			
AIR TEMPERATURE (°C)	21.5	21.2	17.6	16.9	No info			
OXYGEN CONTENT (mg/l)	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	0m: 7.68 250m: 7.36 500m: 6.88 1000m: 6.08 1500m: 5.44 2000m: 6.88	No info			
Median GRAIN SIZE (mm)	0.350				No info			
SUSPENDED SEDIMENT (mg/l)	0				No info			

COMMENTS	

Appendix 2: 3D current model calibration and methodology – South Blocks – South Africa

MEMO

Exploration & Production

TEPSA/OPS – TEPSA/2020-0098/OPS.PL

Destinataire : C. MICHEL (EP/AF/A-FE/ZA-TEP/HSEQ) *To* E. GROENEWALD (EP/AF/A-FE/ZA-TEP/HSEQ)	Expéditeur : P. LATTES (EP/AF/A-FE/ZA-TEP/OPS) T. MAJA (EP/AF/A-FE/ZA-TEP/OPS) *From*
Copie : *Copy*	Date : April 21th 2020
Object : 3D current model calibration and methodology – South Blocks - South Africa. *Subject*	Philippe LATTES Signature numérique de Philippe LATTES Date : 2020.06.09 13:20:38 +02'00'

1 Background

Block 11B/12B is characterized by harsh environmental conditions. Total Hs and surface winds show clear seasonality signals with best conditions occurring during austral summer. Another aspect that affects Block 11B/12B is the core of the Agulhas Current. This warm and saline current is formed by several oceanic currents in the Indian ocean and is the second strongest current in the world.

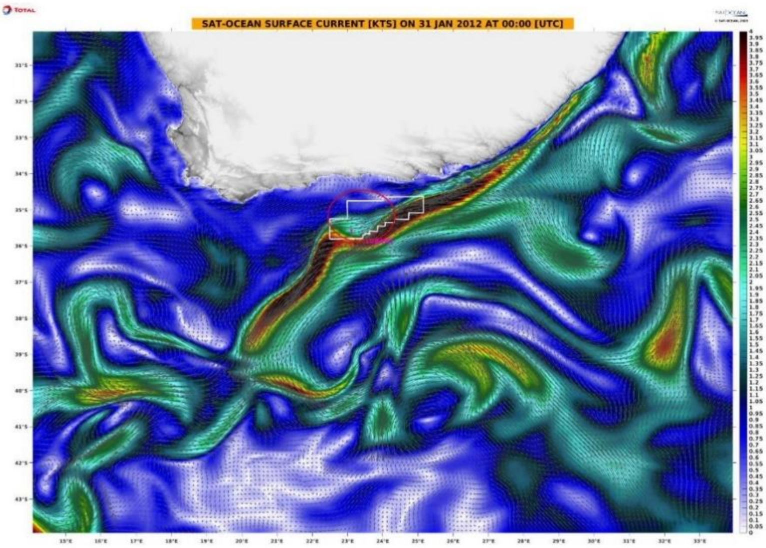

Figure 1: Current speed map of current flow over the southern African region showing the Agulhas Current system for January 2012. A shear edge eddy (red circle) cross the 11B/12B block is demarcated by a white polygon.

TOTAL MEMO

A great portion of the 11B/12B block lies on the pathway of the Agulhas Current, a fast and narrow western boundary current flowing along the eastern and southern coasts of South Africa. The core of the current is generally positioned across the block and is occasionally perturbed by shear edge eddies (see Figure 1) generated upstream south of Port Elizabeth (34° S) and or Natal pulse anomalies generated offshore Durban. During passage of these anomalies, the current speeds over the block are either weakened or reinforced with an associated change in flow direction and depending on the behavior of the anomaly (see Figure 2).

Current speeds of up to and exceeding 6 knots have been recorded within the core of the current associated with meanders. Current direction can change in response to change in winds and or progression of large eddies. The Agulhas Current does not present any seasonality as the anomalies impacting the current flow, in addition to weather, are sporadic and difficult to predict.

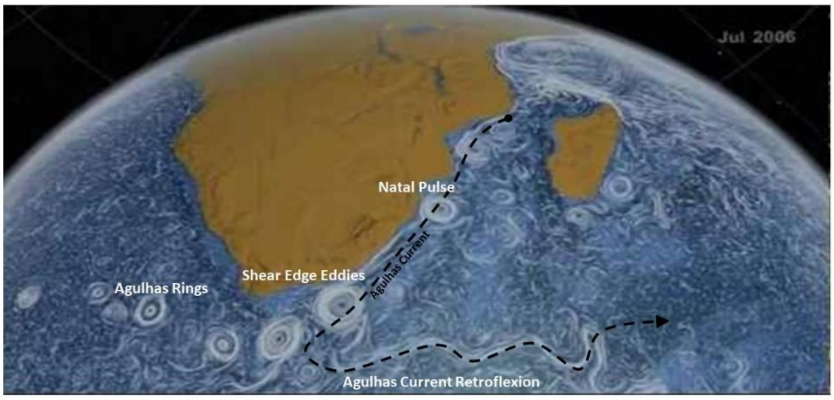

Figure 2 Large current eddies due to shear stress induced by the coast and continental shelf in South Africa

2 SAT-OCEAN Model description

SAT-OCEAN have developed innovative and exclusive technologies based on in-situ, satellite sea surface temperature, wind and altimetric data by which absolute ocean currents and winds are computed, anywhere in the world.

In effect, coupled inverse/direct modeling approaches combined with the data allow us to measure these quantities from space with very high spatial (1/32°) and temporal resolutions (3-hour output time step) over the model emprise (see Figure 1Figure 1: Current speed map of current flow over the southern African region showing the Agulhas Current system for January 2012. A shear edge eddy (red circle) cross the 11B/12B block is demarcated by a white polygon.).

Several studies have shown that upper layer oceanic features can be monitored from satellite measurements over long periods of time. SAT-OCEAN merge up to 9 sensor data sets and produce analyzed SST fields accurate to 0.3°C on average compared to surface drifting buoys' temperature measurements. Monitoring the ocean's surface at such resolutions yields the ability to compute absolute 3-dimensional currents

TOTAL MEMO

worldwide. In addition, SAT-OCEAN model data are cloud free and can be produced up to every 3 hours at a 7-10 km resolution in space from 1998.

SAT-OCEAN inverse/direct model is controlled by very accurate SST analyzed fields, together with wind satellite analyzed data and altimetric data, leading to high resolution current fields. Over several areas of the world including offshore South Africa, this new approach has yielded accurate current estimates with respect to simultaneous on-site measurements (ADCP, HF radars, current meter and buoys' velocities).

SAT-OCEAN also provides high quality analyzed satellite wind data, either in real time or spanning over the past 25 years. The data can be used for design or to assist offshore operations.

3 Satellite observations and Ocean Currents Monitoring

3.1 Satellite data

SAT-OCEAN bases its ocean current computations on several data sets, stemming from scatterometers (for the model forcing winds) as well as from altimeter-based and Sea Surface Temperature satellite observations (to be assimilated in the HYCOM based ocean current model).

3.2 QSCAT and SSMI satellite wind data

Satellite wind scatterometry data are processed for the purpose of forcing the 3D Navier-Stokes direct circulation model.

The data are extracted from the GSFC database (public access), and wind magnitude and direction images are processed (flagged for rainy areas, bad data, projected and calibrated against anemometer data).

The processed data are then merged via objective mapping and spectral fusion. Analyzed wind fields are produced in real time every 3 hours at a 0.125^{o} spatial resolution.

3.3 Geostationary imagery

The geostationary raw data are routinely obtained from the GMS satellite series which cover the area of interest. SAT-OCEAN produces SST images via a methodology analogous to the one described for the AVHRR imagery (section 3.4).

The GOES image series presents a 5 km spatial resolution over the area of concern and 24 to 48 images are available each day, depending on the availability of the data.

3.4 TRMM TMI and AQUA AMSR-E imagery

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The TRMM (Tropical Rainfall Measuring Mission), TMI (TRMM Microwave Imager) and AMSR-E AQUA SST image series are extracted in real time from the GSFC (Goddard Space Flight Center) data base (public access). The SSTs are already computed and the projection, geolocation and error correction are already applied. The TMI and AMSR-E measurement technology is such that the ocean is always visible no matter the cloud coverage, except over regions where it is raining. The TMI and AMSR-E image spatial resolution is about 25 km and the area is covered twice a day.

3.5 Polar Orbiting NOAA Satellite AVHRR imagery

Satellite AVHRR (Advanced Very High Resolution Radiometer) Level 1b high resolution imagery is extracted in real time from the NOAA (US National Oceanographic and Atmospheric Agency) Satellite Active Archive server (public access). The level 1b data is very similar to the Level 0 on-board recorded measurement.

The AVHRR image series presents a 1 km (Local Area Coverage) to 4 km (Global Area Coverage) spatial resolution and 10-12 images are available each day, depending on the number of orbiting satellites.

The raw satellite data are processed in real time at SAT-OCEAN including: channels 1 to 5 linear and non-linear calibrations, geolocation, clock drift and satellite attitude (roll, pitch and yaw) error corrections, Lambert Azimuthal Equal Area projection, multi-channel cloud detection and sea surface temperature (SST) will be computed using split, dual or triple window algorithms from the 5 processed channels.

3.6 Satellite altimeter data

Several altimeters are and have been orbiting with a worldwide coverage. Among those, some are performing measurements in spectral bands dedicated to ocean circulation.

SAT-OCEAN will process the data set over the area of concern for the study, calibrate and cross-calibrate all the data to construct an altimeter-based series over the area.

3.7 HF radars and ADCP

ADCP data have been recorded during seismic campaigns and dedicated surveys over the 11B/12B block and have been used for SAT-OCEAN model calibration. In addition, several HF radars installed and operated by TOTAL located along the coast (between Mossel Bay and Port Elizabeth) allowed to monitor surface current since February 2018 over a large offshore area. These data are available every 30 minutes at 6km resolution. This monitoring allows accurate historical and real time monitoring of the surface currents over the block 11B/12B and has been used for model validation/calibration.

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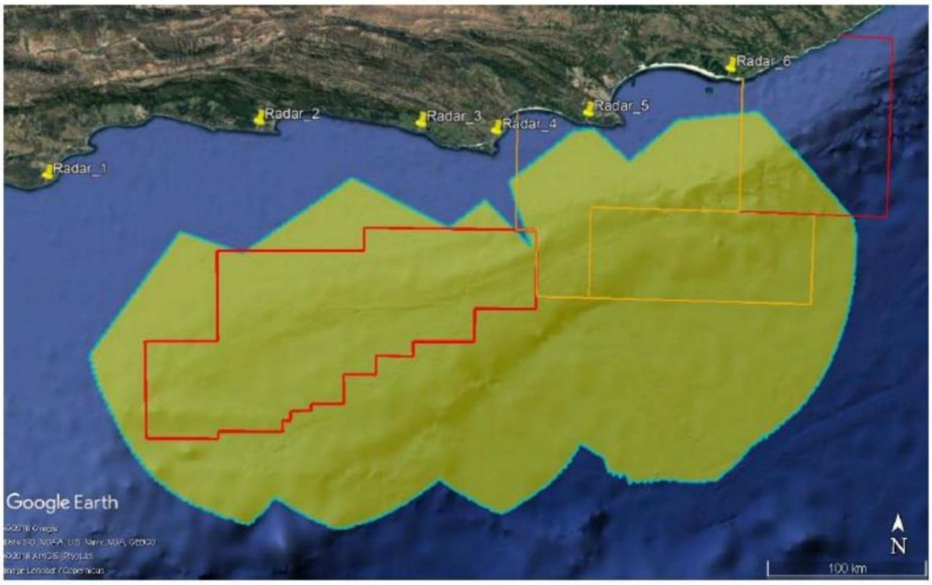

Figure 3 Coverage with 6 radar stations

4 Methodology

4.1 Ocean current computation

SAT-OCEAN ocean current modeling is based on HYCOM (Hybrid Coordinate Ocean Model - Bleck, 2001). HYCOM is a generalized hybrid vertical coordinate model widely recognized as a powerful and efficient tool for ocean modeling. To this state of the art model, SAT-OCEAN brings a significant methodology innovation in using it in an inverse way: the “data” drives the model where the dynamics is fitted onto it to yield 3D absolute ocean currents.

SST cloud-free fields are produced from merged sensor data sets with a very high spatial and temporal resolution and a 0.2°C rms error compared to simultaneous *in situ* measurements. From there, a regression coefficient calculation derived from simultaneous altimetric fields and historical Temperature / Salinity (T/S) profiles yields 3D temperature and salinity, daily: the obtained 3D T/S is called SAT-OCEAN dynamic climatology and represents as closely as possible the 3D state of the ocean over a given region.

The 3D T/S data is then strongly being assimilated in HYCOM/SAT-OCEAN model, strongly in the sense that it is given very little freedom to the model, and are very close to performing an inversion of forcing data, for the ocean circulation (except in the mixed layer which is highly driven by the forcing wind stress). Another way to present this is to say that ocean currents is fitted with high quality 3D satellite data, rather than obtaining current "data" from a model.

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SAT-OCEAN also make a quantitative use of *in situ* data to calibrate the model when available (section 4.2).

A first 1/16° assimilated global model in-house run is used that covers the global ocean domain. Then, a fine resolution 1/32nd degree configuration of the assimilated model will cover a very large target area covering the offshore South Africa area of concern. The run will encompass 34 layers, with an about 10-layer sampling of the thermocline and a 3-hour output time step.

4.2 Calibration

Where TOTAL HF Radar and ADCP *in situ* current measurements are available, SAT-OCEAN performs a calibration and validation of their 3D ocean current model against the field data. Many mooring data as possible are used to perform the model calibration, including previous drilling campaigns and extensive seismic survey-based hull mounted ADCP on site current measurements. However, model calibration and validation at the deeper layers remain always more challenging due to the lack of measurements and are generally less reliable than at the surface where a larger quantity of data measurements are available. For each data set, current speed and direction measurements are extracted at all times and depths from all the provided files, and time-depth arrays are built. Specific procedures are then developed and applied (SVD decomposition, Kalman filtering etc.) to process the data at each measurement site such that it can be used for quantitative comparison and assimilation into the current model.

The pre-processed measurements are then used by SAT-OCEAN to extract the best calibration scheme for obtaining an improved time-depth dataset at each of the mooring sites. The outcome of this approach significantly improves the correlation between the modeled currents and the measurement series. Typically, SAT-OCEAN derive a calibration scheme over a learning data subset and evaluate the result over the remainder set, providing solid ground for the calibration scheme generalization to periods beyond learning periods. The final calibration scheme is applied to the entire ocean current historical/hindcast period to obtain calibrated hindcast datasets at every mooring location.

A calibration of the full South African south blocks dataset is finally performed. Spatial correction fields are derived in order to quantify at all ocean locations the influence of the locally calibrated currents at the mooring sites and of the modeled currents at each grid point of the hindcast domain.

The methodology results in a fully calibrated ocean current data set that takes the best advantage of the HF radar and ADCP on-site data available and of the assimilated model hindcast.

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4.3 Validation: currents and winds

4.3.1 Surface current

The SAT-OCEAN model currents were compared against observational data from HF radar for the purpose of validation. Only currents at the surface could be validated due to limited or no data at the sub-surface and for this exercise, 30 days of surface current observations from a single point were extracted from the HF radar dataset. The comparison of modelled currents with observations offers an opportunity to assess the ability of the SAT-OCEAN model to represent the current variability from the extracted data. Time series data starting from 10/03/2020 and ending on 10/04/2020 is presented in Figure 4 below.

From the visual inspection of the presented time-series in Figure 4 and scatter plots in Figure 5, surface current observations are generally coherent with SAT-OCEAN currents during the 30-day period. The SAT-OCEAN current presents a relative error RMS of 0.32kt. The increasing and decreasing patterns are consistent between the model and observations although there are slight differences in the magnitude of current speeds. The absolute mean bias between the SAT-OCEAN model and HF radar observations generally should not exceed 1 knot and there are occasional and slightly differences in the direction of the surface current flow.

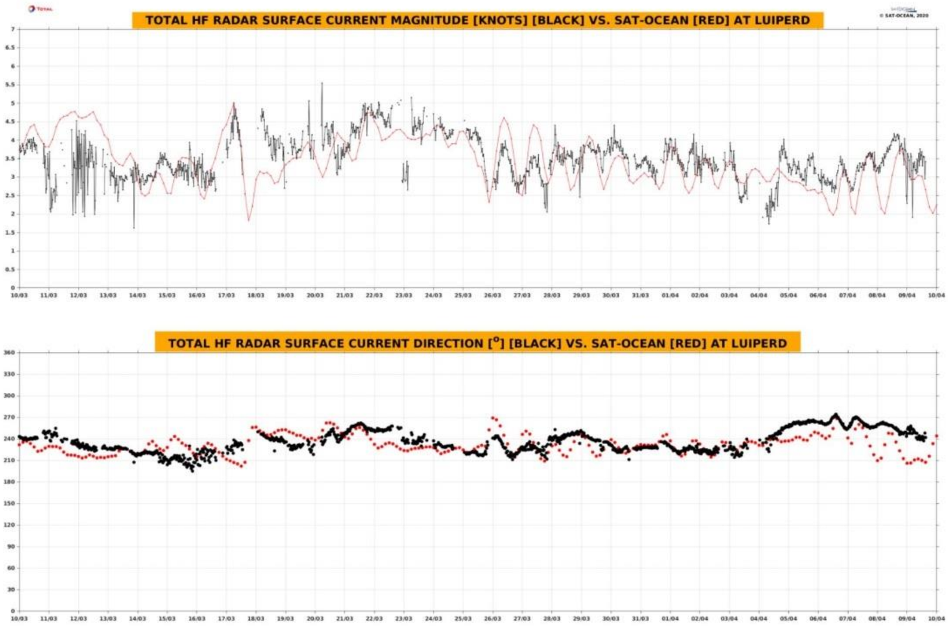

Figure 4: Surface currents time-series from SAT-OCEAN (model) vs HF Radar (observations) for 30 days.

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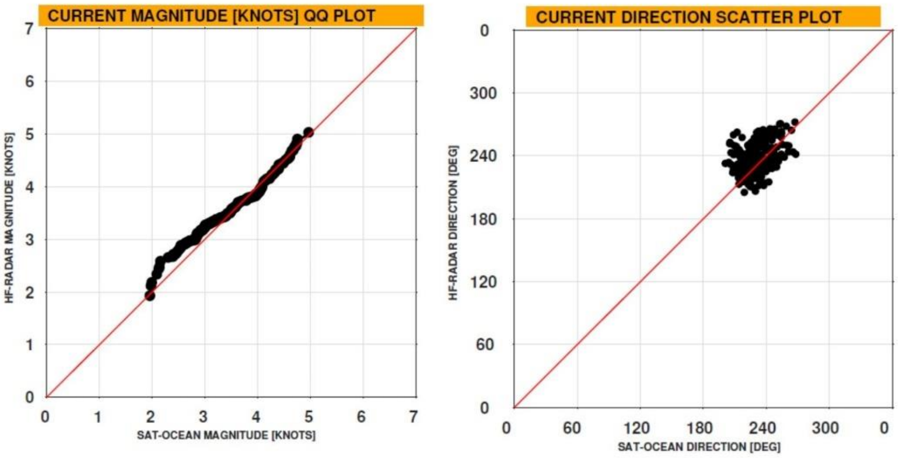

Figure 5 Current speed QQ plot and current direction scatter plot of SATOCEAN model vs observation for the considered period

For the given location, SAT-OCEAN modelled currents performed adequately indicating a reasonably fair representation of the surface current conditions over the 11B/12B block. The performance of the model may vary depending on features impacting the current flow e.g. a meandering core vs jet-regime state. Caution should be exercised when interpreting these results as they only represent validation at a single point within the block area (i.e. the Luiperd well location).

4.3.2 Winds

For the wind model validation, METAR (METeorological Airport Report) wind observations are used as reference to compare with the model output. The comparison is made from a weather station wind dataset from Port Elizabeth which is located north-east outside the11B/12B block along the South African coast. The Port Elizabeth location is within our observation area of interest with HF radars and therefore a relevant position for validation of the wind model. The time series comparison between the dates 10/03/2020 and 10/04/2020 is presented below in Figure 6.

Strong correlation between wind observations and model (see Figure 7) is recorded from the 30-day time series with the model explaining more than 88% of the variability in wind observations (r = 0.94 and rms = 13 kt). The SAT-OCEAN wind model provides coherent and consistent representation of the winds and is accurate in both magnitude and direction. Although the extreme wind conditions at 11B/12B can often exceed that of Port Elizabeth, the SAT-OCEAN model has proven its adequacy in capturing and representing wind conditions over a larger area including the full extent of the 11B/12B block.

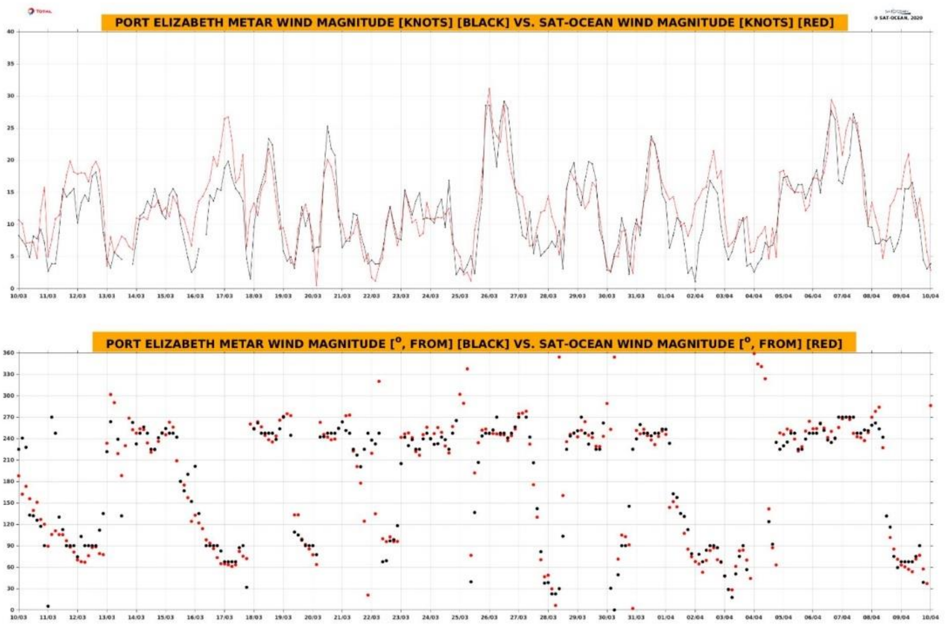

Figure 6 Surface winds time-series from SAT-OCEAN (model) vs METAR (observations) for 30 days.

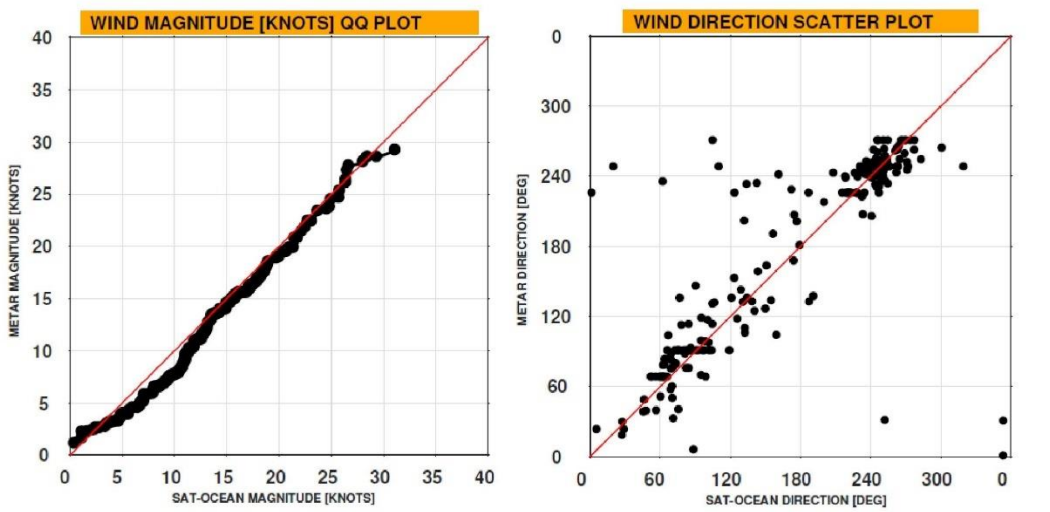

Figure 7 Wind speed QQ plot and wind direction scatter plot of SATOCEAN model vs observation for the considered period