Oil Spill Modelling Report For:

Neptun Deep, Romania

Prepared For:

OMV – Ben Brazier

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Oil Spill Response

OMV Petrom
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Project: PRJ02947 R02

Prepared By: Kate Brown

EXECUTIVE SUMMARY

Two scenarios are presented for the forthcoming development and completion operations at Neptun Deep, offshore Romania. These were a credible-case installation vessel loss resulting in the release of 300m^3 Marine Gas Oil (MGO); and a spill from the drilling rig resulting in the release of 165m^3 MGO. Both scenarios were modelled seasonally through a summer (June-Sept) and winter (Oct-May) period.

A summary of the results for both scenarios are presented in the table below:

Table 1: Summary of model results

	Accidental Spill from the Platform Installation Vessel (300m^3)	Accidental Spill from the Drilling Rig (165m^3)
Surface		
Fastest to maritime boundary	0 days, 22 hours Bulgaria (Winter)	1 days, 3 hours Bulgaria (Winter)
Surface waters with >10% probability of impact	Romania 100% spill originates here, Bulgaria 25%	Romania 100% spill originates here, Bulgaria 15%
Predominant direction of travel	Southwest – up to 150km away during winter and 250km away during summer	Southwest – up to 150km away during winter and 250km away during summer
Fastest to Sensitive Area	0 days, 3 hours Canionul Viteaz (Winter)	0 days, 4 hours Canionul Viteaz (Winter)
Percentage coverage of impact to sensitivity	~75% (Canionul Viteaz)	~70% (Canionul Viteaz)
Shoreline		
Shoreline Oiling	There is no significant shoreline oiling	There is no significant shoreline oiling

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DOCUMENT HISTORY

OSRL Document Number	Revision	Date	Description	Author	Reviewer	Approval
PRJ02947	R01	30-Dec-2022	Draft Modelling Report	KLB	SJB	SJB
PRJ02947	R02	17-Jan-2023	Added drilling rig scenario results. Addressed client comments to R01	SJB	JKM	SJB

KLB – Kate Brown SJB – Simon Blaen JKM – Jenny Mitchell

DISCLAIMERS

- Modelling results are to be used for guidance purposes only and response strategies should not be based on these results alone.
- The resolution / quality of wind and current data vary between regions and models. As with any model, the quality and reliability of the results are dependent on the quality of the input data.

Giving consideration to the above, all advice, modelling, and other information provided is generic and illustrative only and not intended to be relied upon in any specific instance. The recipient of any advice, modelling or other information from, or on behalf of, OSRL acknowledges and agrees that any number of variables may impact on an oil spill and, as such, should be addressed on an individual basis. OSRL has no liability in relation to such advice, modelling or other information and the recipient of such information hereby fully indemnifies and holds harmless OSRL its officers, employees, shareholders, agents, contractors and sub-contractors against any costs, losses, claims or liabilities arising in connection with such advice, modelling, training or other information.

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INTRODUCTION

1.1 Background

Oil spill modelling was completed by Oil Spill Response Ltd. (OSRL) on behalf of OMV Petrom (OMV) to provide OSCAR Oil Spill Modelling services for their forthcoming offshore development and completion operations at Neptun Deep, offshore Romania (Figure 1). The results of this analysis will support the Oil Spill Contingency Plan (OSCP) for the area. The results of two release scenarios are presented in this report[1].

Scenario 1 – Accidental spill of MGO from the platform installation vessel at the Shallow Water Platform. A near instantaneous spill of 300m^3. This is considered the worst case for a range of operations that will occur in the area. These include the bunkering of fuel during drilling, construction and operation stages.

Scenario 2 – Accidental spill of MGO from the drilling rig at the Pelican Drill Centre. A near instantaneous spill of 165m^3 following a collision between the MODU and PSV, resulting in the rupture of 1 tank on each.

The modelling was carried out using SINTEF's Oil Spill Contingency and Response (OSCAR) model. OSCAR is a 3D modelling tool used to predict the movement and fate of oil on the sea surface and throughout the water column (see APPENDIX B for further details).

The modelling assumes no intervention is made to reduce the impact of the spill – for example the use of offshore containment and recovery systems. OMV have access to a range of response services and equipment through membership of Oil Spill Response Limited.

1.2 Aims

The aim of this report is to present the risk to the sea surface and the shoreline by creating spatial maps of:

1. Probability - to estimate how likely an area is to be impacted.
2. Arrival time - to estimate how quickly an area could be impacted; and
3. Emulsion thickness - to estimate how severely an area could be impacted.

The data behind these maps allow us to answer the following questions:

1. How quickly could oil reach nearby shorelines and what mass?
2. Which countries are more likely to be affected by an oil spill from the Neptun Deep operations?
3. Which environmental sensitivities (Figure 2) could be affected by an oil spill from the Neptun Deep operations?

[1] A third release scenario of 3271m^3 MGO has also been considered, representing a complete loss of inventory from the MODU. This has been assessed as having a very low probability of occurrence and therefore not a credible scenario to explore

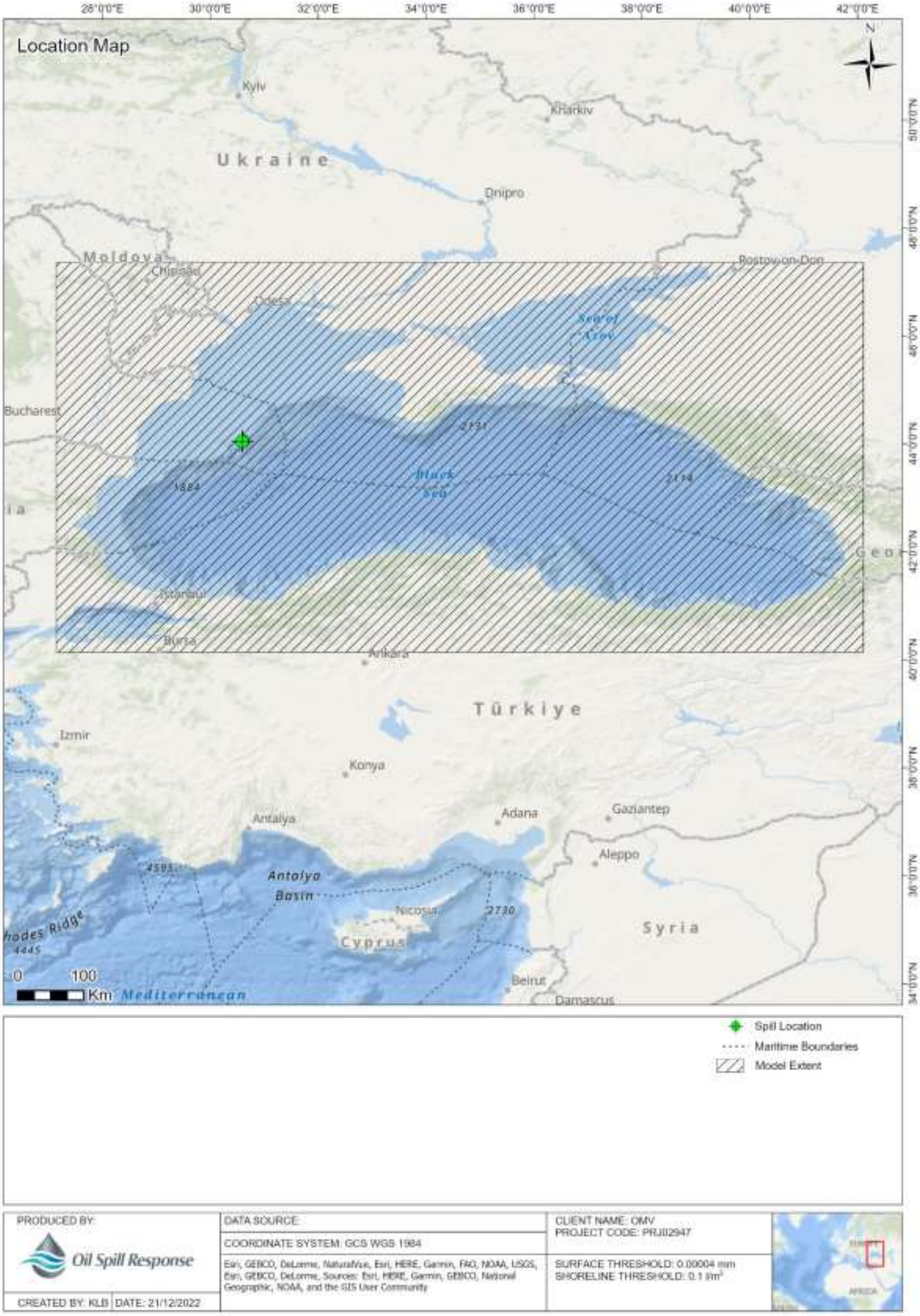

Figure 1 Map showing the release location

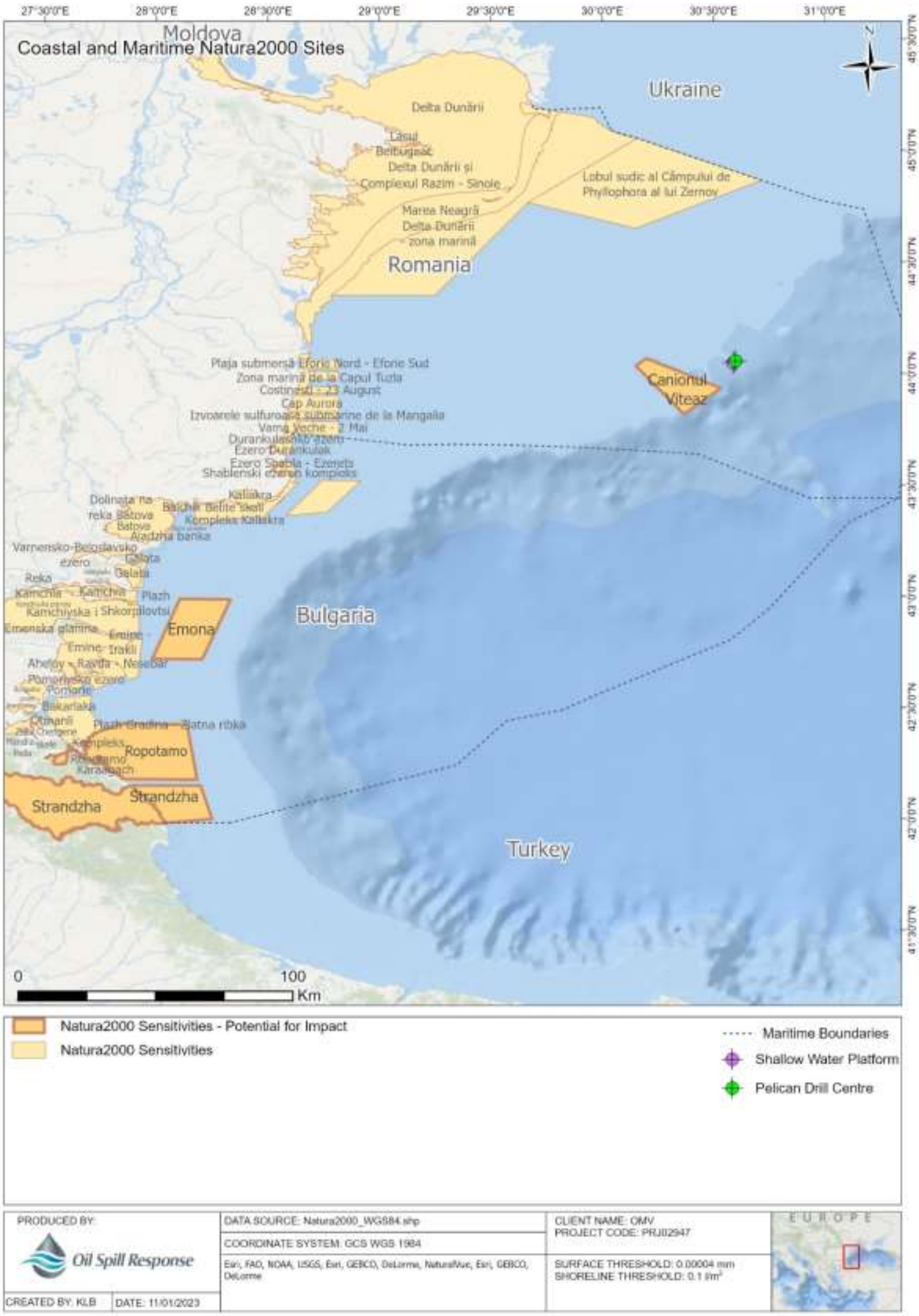

Figure 2: Map showing the location of Natura 2000 sensitivities

1.3 Methodology

Two types of oil spill model have been used to understand fate and effects of an accidental oil spill at the Neptun Deep development.

Stochastic

A stochastic (probabilistic) model demonstrates where an oil spill may impact, with associated probability and minimum arrival time. Stochastic outputs are produced by running a series of trajectories under various wind and current conditions using modelled metocean data. The results of all the simulations are then analysed and statistics generated to summarise the outcomes.

Stochastic results are an excellent tool for assessing risk as they predict the fate of an oil spill under different metocean conditions. These outputs illustrate the waters that are most at risk from oiling and can be used to assess seasonal variability.

Trajectory

A trajectory (deterministic) model predicts the movement and behaviour of an oil spill during a particular scenario and under specific metocean conditions. The trajectory models have been run to show some of the more extreme outcomes that could occur – such as the situation that results in the fastest impact to a maritime boundary. Other less extreme situations could also occur but not all are studied in this detail.

A stochastic output therefore shows the probability of impact over the entire area where oil *could* impact, whereas a trajectory output shows where oil could impact on a given day. A combination of the two types of model gives valuable information for planning purposes.[2]

1.4 Effects of a Marine Gas Oil Spill

The IPIECA guide 'Impacts of Oils Spills on Marine Ecology'[3] provides a comprehensive overview. The below text provides a summary relevant to Marine Gas Oil (MGO) spills.

Crude oils are complex mixtures of hydrocarbons, with small amounts of other compounds and elements that typically include sulphur and other trace elements. Refined products are produced from crude oil through various refining processes to achieve the desired chemical and physical characteristics, like crude oil they also contain a mixture of hydrocarbons. These can vary between very light products, such as gasoline and kerosene, and much heavier products, such as bitumen or heavy fuel oil.

The environmental effects of all hydrocarbons are determined by the nature and proportion of each component part.

Lighter refined products contain a high proportion of low molecular weight hydrocarbons. These usually have a lower boiling point and higher volatility than most hydrocarbons. These components display high solubility and therefore higher bioavailability. They often result in

[2] This is further discussed in the IPIECA Good Practice Guide for Contingency planning for oil spills on water. https://www.ipieca.org/resources/good-practice/contingency-planning-for-oil-spills-on-water/ Page 18

[3] https://www.ipieca.org/resources/good-practice/impacts-of-oil-spills-on-marine-ecology/

acute toxicity, but on the surface of the sea they evaporate so quickly that their contribution to marine impacts is generally small.

Heavier refined products contain a high proportion of usually high molecular weight compounds. They have a higher boiling point and lower volatility. Their solubility is low so whilst they may be present in the environment, their bioavailability is low. The evaporation rate is generally low and so persistence is high. The physical effects of smothering are more relevant than the toxicity

MGO sits towards the lighter end of the spectrum, but not at the extreme, containing a higher proportion of low weight molecular compounds than many other oils. The primary environmental impact will come through acute toxicity rather than physical smothering effects. All release scenarios considered result in a surface release, this is likely to lessen the environmental impact as much of the oil will quickly evaporate. Within the water column, the concentration of oil is likely to be greatest nearest the surface, and reduce with depth.

2 SCENARIO SETUP

2.1 Modelling Setup

Two stochastic simulations were run for each of the release scenarios (Table 2), with a total of 150 individual trajectories post-processed for each season to create the stochastic results. Each trajectory began on a different start date, so that each oil spill was simulated using a range of wind and current conditions.

Further explanation on the approach used and the different types of model used are included in Section 1.3 and APPENDIX B.

Table 2: Summary of stochastic setup for spill scenarios

Scenario Reference	Scenario 1	Scenario 2
Description	Accidental spill from the platform installation vessel	Accidental spill of fuel from the drilling rig – Worst credible case
Location	44° 02' 51" N 030° 35' 14" E	44° 03' 19" N 030° 35' 56" E
Timeframe	Winter – October to May Summer – June to September	Winter – October to May Summer – June to September
Depth of Release	0m (Surface)	0m (Surface)
Release Rate	300 m^3/hr	41.25 m^3/hr
Duration of Release	1 hour	4 hours
Total Volume Released	300 m^3	165 m^3
Total Mass Released	264 MT	146 MT
Total Run Duration	14 days	14 days
Diameter of Release Hole	n/a	n/a
Gas to Oil ratio (GOR)	n/a	n/a
Oil Temperature	Winter - 11.6°C Summer - 23.6°C	Winter - 11.6°C Summer - 23.6°C
Total Number of Trajectories	150	150
Time Between Trajectories	8 days, 2 hours	4 days, 1 hour
Nearest Shoreline	~117 km, Sfântu Gheorghe, Romania	~117 km, Sfântu Gheorghe, Romania

2.2 Metocean Data

Five of hydrodynamic data were used as model inputs. See APPENDIX A for more information on the model setup.

Table 3: Metocean data used in study

Metocean Data		
Dataset	**Current** - Black Sea Physics Reanalysis	**Wind** - CFSR
Spatial Resolution	3 km	16 km
Temporal Resolution	24 hr	1 hr
Date period	May 2015 – May 2020	May 2015 – May 2020
Number of vertical layers	31	1

The Black Sea Physics Reanalysis dataset for ocean currents has been selected as the most appropriate option for modelling. Covering only the Black Sea, the hydrodynamic model is optimised for the local area which gives more confidence in the data providing an accurate representation of real world conditions.

2.3 Model Extent

OSCAR requires the user to setup a habitat grid which contains the oil spill. Habitat grids are the model domain; if oil travels outside of this domain, it will be classified as "outside" and not be included in any further calculation. As such, oil "outside" the domain will not be included in shoreline statistics or other analyses. There are a maximum of 1000 x 1000 spatial grid cells. So, if the oil covers a 1000 km x 1000 km area, the smallest spatial resolution (or surface grid cell) is 1 km x 1 km. Habitat grids that cover large areas will typically provide coarser results than habitat grids that cover smaller areas

Table 4: Model Extent

Domain Extent			
Number of Cells		**Cell Resolution**	
East to West	**North to South**	**East to West**	**North to South**
600	400	1,200km	800 km
Domain Size			
East to West		**North to South**	
2 km		2 km	

2.4 Oil Characteristics

Oil Matching

Lab tested oils were selected for this modelling study based on the information provided by OMV. The properties of the modelled oil are shown in Table 5.

Table 5: Properties of the modelled oil

Name	API	Specific Gravity	Viscosity	Pour Point[4]*	Wax Content	Asphaltenes
MGO	30	0.876	1.7 – 4.5 cSt @ 40°C	-	-	-
Modelled Oil	28.4	0.885	12 cSt@ 13°C	-36°C	3.11 %	0.02 %

2.5 Thresholds

Thresholds define the point below which data are no longer informative. For example, when surface emulsion thickness is less than 0.04 µm, the oil is no longer visible to the naked eye so may be considered insignificant to a response. The thresholds applied to this study are given in Table 6.

Table 6: Thresholds used in the modelling

Threshold	Value	Description
Surface	0.04 µm	The Bonn Agreement Oil Appearance Code (BAOAC) defines five oil layer thicknesses based on their optic effects and true colours. 0.04 µm is the minimum thickness that can be seen with the naked eye.
Shoreline	0.1 litres/m^2	Lower threshold for light oiling from the ITOPF document “Recognition of oil on shorelines”. A concentration of 0.1litres/m^2 is assumed to be the lethal threshold for invertebrates on hard substrates and sediments in intertidal habitats. Shoreline oiling greater than 0.1litres/m^2 would be enough to coat the animal and impact it’s survival and reproductive capacity. [5]

The thickness key used in the surface emulsion thickness maps throughout this document is derived from the Bonn Agreement Oil Appearance Code.

The thickness key used in the shoreline maps throughout this document is derived from the ITOPF Technical Information Paper (TIP) No. 6 “Recognition of oil on shorelines” (ITOPF, 2011b). Very light oiling is deemed insignificant by ITOPF[6], no practical response is required for a very lightly oiled shoreline, apart from monitoring the oil spill**.**

4 Due to the algorithms in the model, Pour Point is of lesser importance when oil matching.

[5] French-McCay, Deborah. (2009). State-of-the-Art and Research Needs for Oil Spill Impact Assessment Modeling. Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response. 2.

[6] ITOPF 2011b, The International Tanker Owners Pollution Federation Limited (ITOPF) (n.d.) ‘Technical Information Paper 06: Recognition of oil on shorelines’, accessible online via: https://www.itopf.org/fileadmin/uploads/itopf/data/Documents/TIPS_TAPS_new/TIP_6_Recognition_of_Oil_on_Shorelines.pdf last accessed 29th August 2022.

3 RESULTS

3.1 Interpreting Model Results

The following information is provided to help with the interpretation of the stochastic and trajectory (deterministic) model results presented below.

Stochastic

Stochastic model results are made up of 100+ individual simulations which are then analysed to present statistics summarising the results. It is important to remember that they show a combination of many simulations, and no one spill will result in all the outcomes displayed. Thresholds are applied to the results to determine the point at which an area is considered to be ‘impacted’. Further details on the thresholds are given in Section 2.5

Surface – Probability of impact

This shows the probability that an area of water will be impacted by surface oil at some point during the simulation. The exposure time is not considered - the surface impact may last for 1 hour, or may last for the entire simulation duration. Similarly, oil of any thickness above the threshold of 0.04µm will be counted.

This output is useful to understand the likelihood of impact to a given area, as well as the predominant direction of travel during each season.

Surface – Minimum arrival time

This shows the shortest time, after the start of the simulation, that surface oil reached the location. Other simulations will have resulted in a longer time to first impact. It is reasonable to assume this oil should not arrive at this location sooner than the ‘minimum arrival time’ and in most cases it will take longer, or not arrive at all.

This output is useful to help determine the positioning and response time of resources that will be mobilised to assist in the response.

Surface – Maximum emulsion thickness

This shows the thickest layer of oil that is experienced at that location at some point during any of the simulations. Other simulations will have impacted the area with a thinner layer of oil. It is reasonable to assume that oil should not be found at this location in thicknesses greater than that of the ‘Maximum emulsion thickness’.

This output is useful to inform the type of response techniques that may be appropriate in each location.

Shoreline – Probability

This shows the probability that an area of coastline will be impacted at some point during the simulation.

This output is useful to understand the likelihood of shoreline impact to a given area, it can be used to inform the level of shoreline response planning required, and in what areas.

The modelling results included in this study showed no impact to the shoreline during any simulation

Statistical Analysis

This is applied to both countries and to the Natura2000 sensitive areas. This gives the probability and minimum arrival time to the entire area of the country/sensitive area, rather than one of the individual computational cells within the area.

For countries especially, the overall probability of impact is often higher than that the highest individual probability of a computational cell shown on the surface probability map.

This output is useful for determining the overall likelihood and speed of impact to the area.

Trajectory (Deterministic)

Whilst the stochastic results show a summary of many simulations, each trajectory run shows one particular outcome of the spill in more detail. It should be remembered that notable outcomes have been selected to be run as trajectory models, and many other outcomes are also possible.

Surface – Maximum Thickness

This shows the maximum thickness of surface oil experienced at some point during the simulation. It shows where the oil has travelled to. Not all areas are impacted at the same time, and not always at the thickness indicated.

This output can be used to illustrate where different response techniques may be viable options.

Surface – Daily Position

This shows the position of surface oil at 24 hour intervals. Oil position has been extracted after 24 hours, 48 hours, etc. In between these times the oil may impact other areas not shown. The 'maximum thickness' output provides a complete picture on all areas impacted during the simulation.

This output is useful to understand the area that may be impacted at any one time and also to understand the speed of spill movement.

Mass Balance Graph

This output shows the change in state of the oil within the model. The oil starts the simulation at the sea surface but over time it will be transferred to other states as weathering processes occur.

This output is useful to understand the expected fate of the spill.

3.2 Scenario 1 – Accidental Spill from the Platform Installation Vessel

Stochastic Maps

The stochastic results for the Platform Installation Vessel scenario were calculated from 150 trajectories per season. The scenario involves the instantaneous release of 300m^3 of MGO in both winter and summer seasons at the shallow water platform. The oil is tracked for a further 14 days.

The following results are presented:

Sea Surface

Figure 3: Probability that a surface cell could be impacted.

Figure 4: Minimum arrival time of surface oil.

Figure 5: Maximum emulsion thickness of surface oil.

Shoreline

Figure 6: Probability that a shoreline cell could be impacted.

SURFACE MAPS

Accidental Spill of Fuel from the Platform Installation Vessel

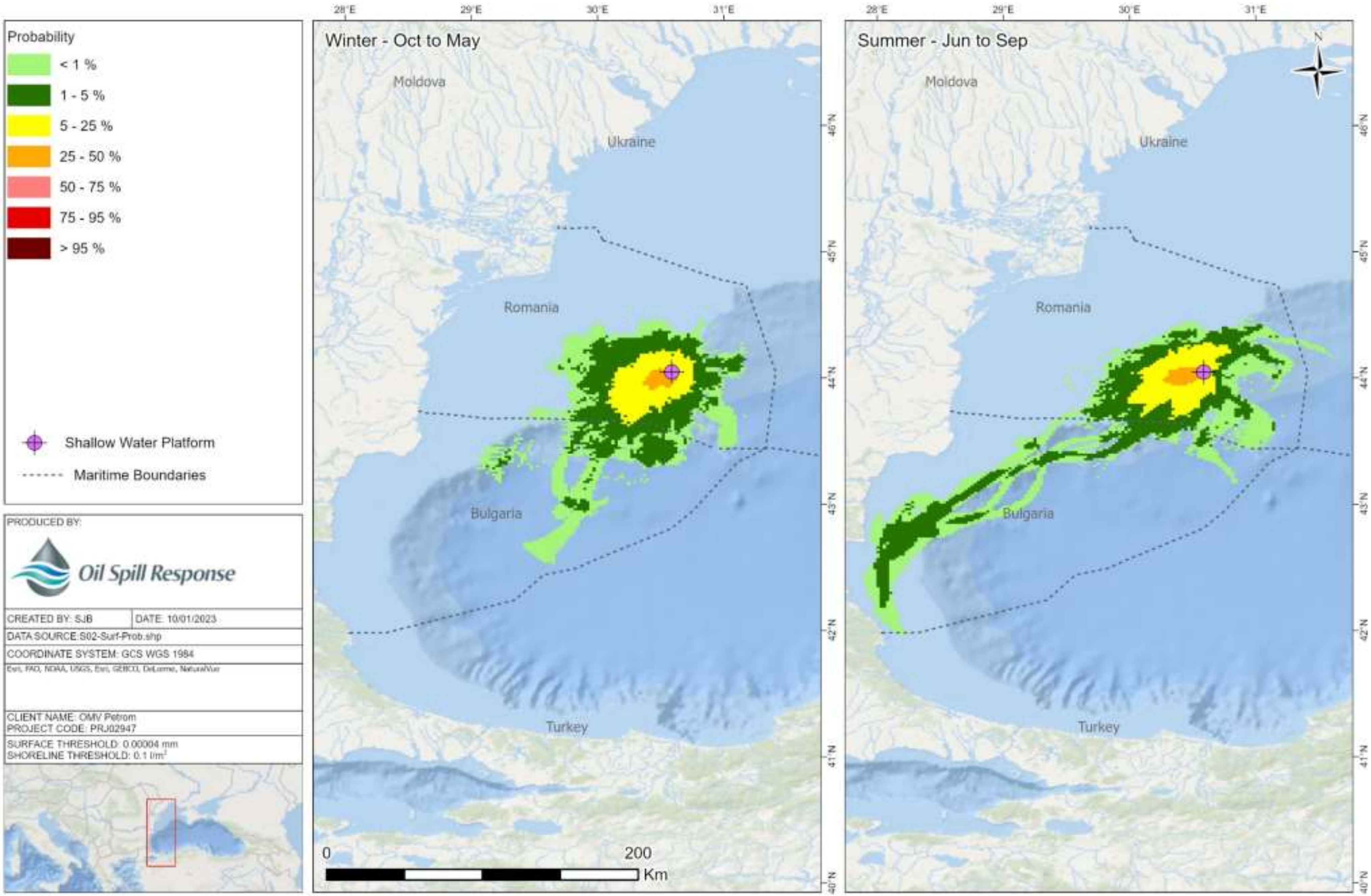

Figure 3: Probability that a surface cell could be impacted.

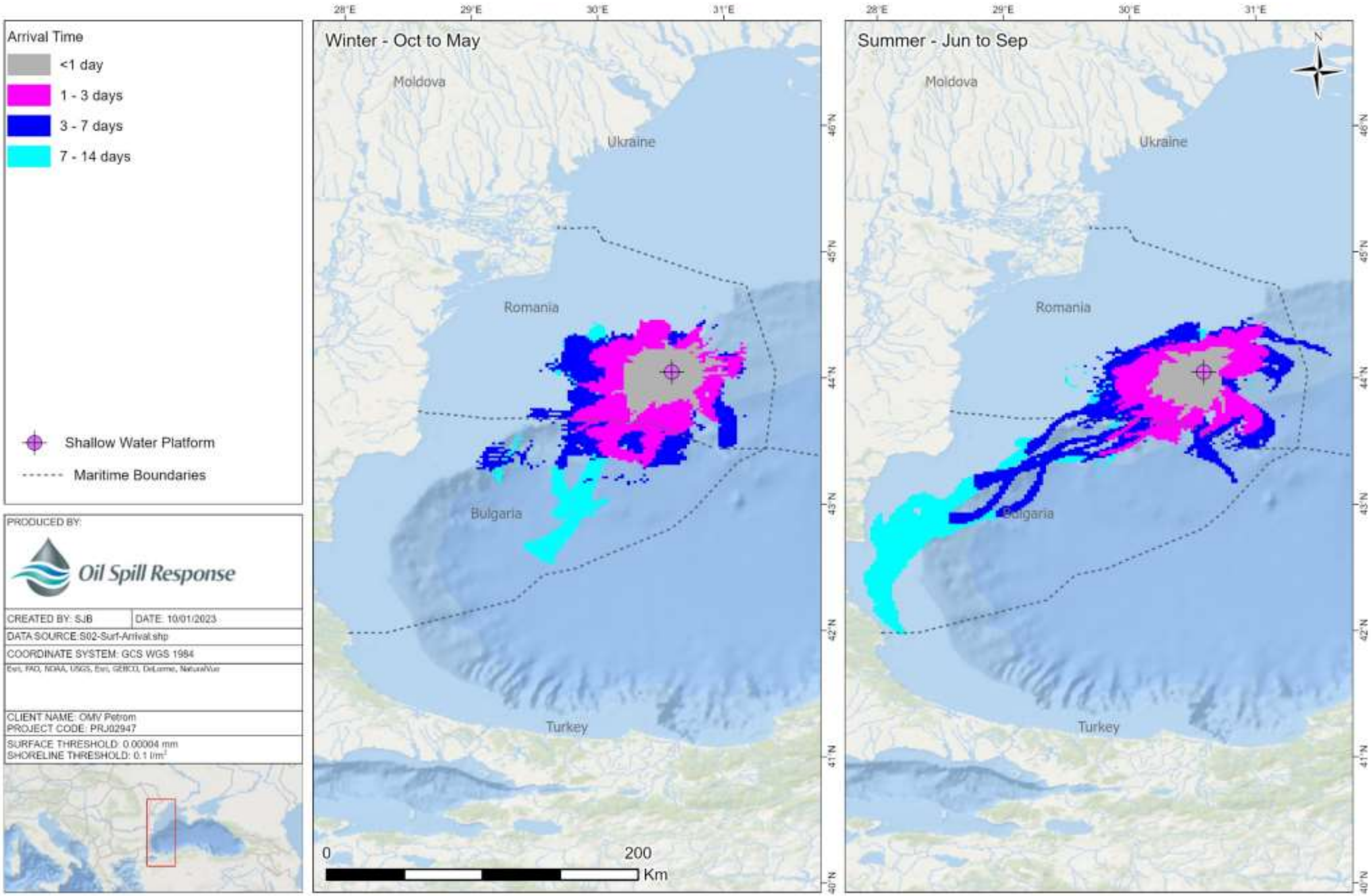

Figure 4: Minimum arrival time of surface oil.

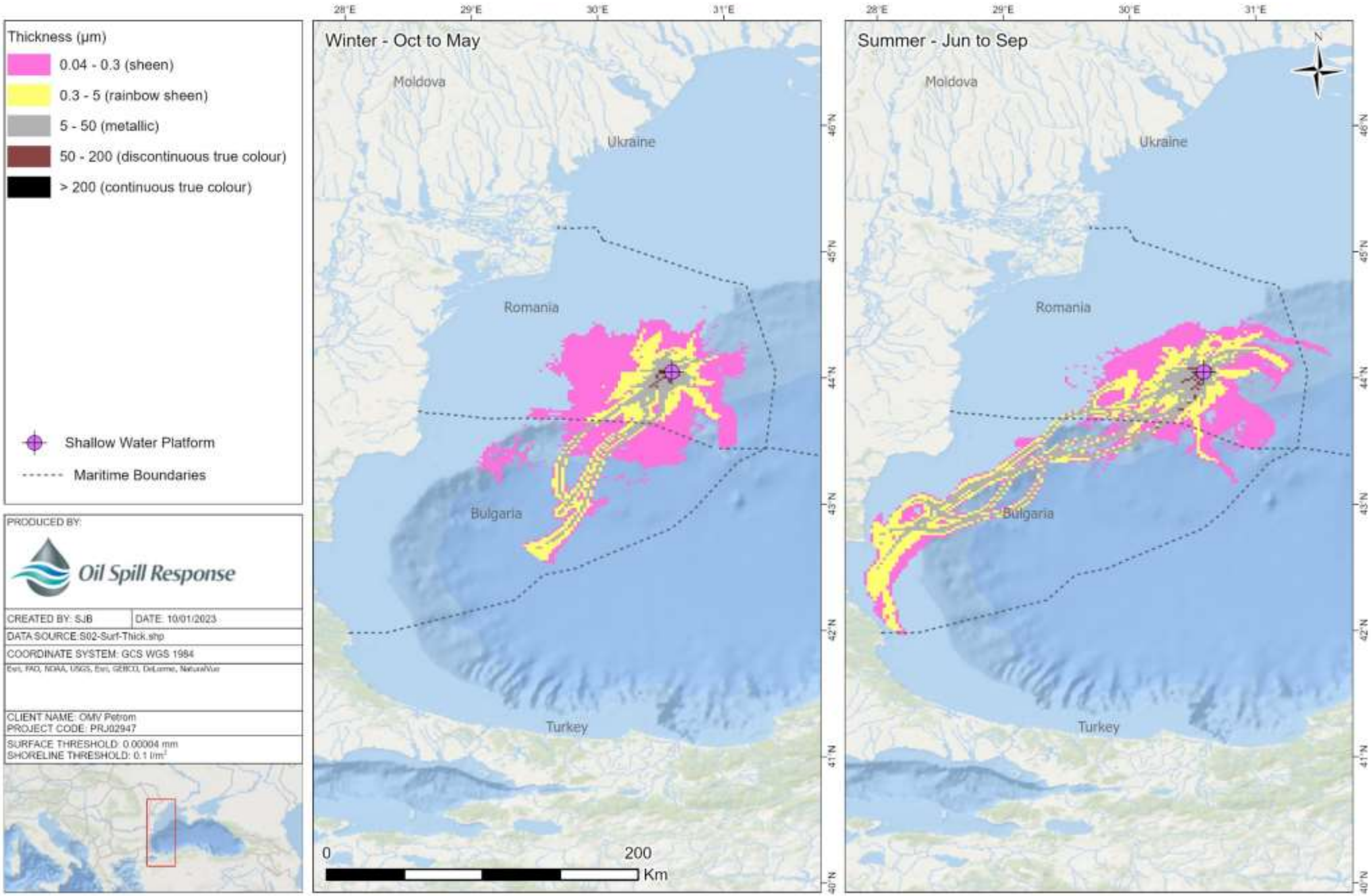

Figure 5: Maximum emulsion thickness of surface oil.

SHORELINE MAPS

Accidental Spill of Fuel from the Platform Installation Vessel

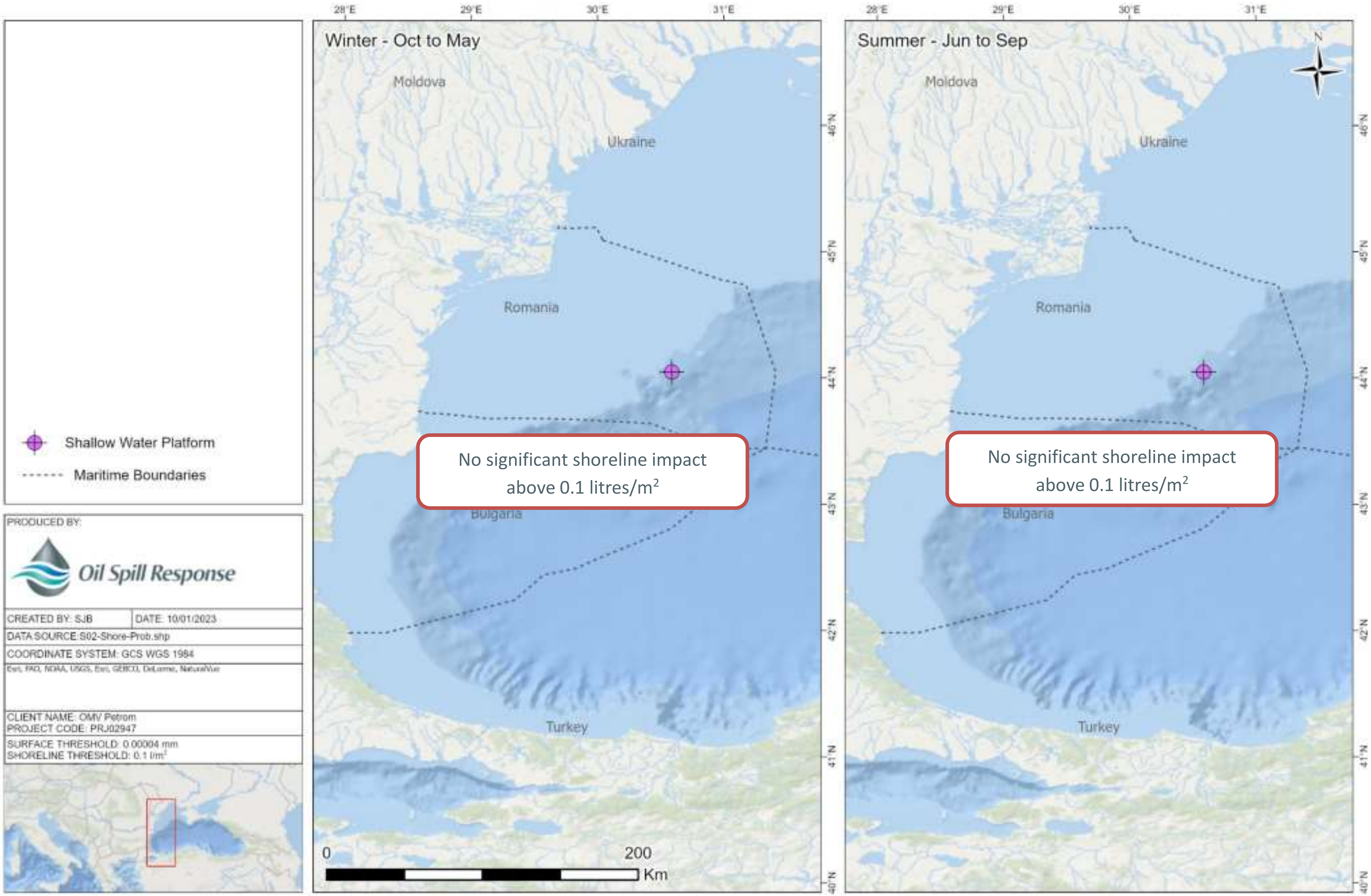

Figure 6: Probability that a shoreline cell could be impacted.

Statistical Analysis

Table 7: Statistical Analysis - Surface

Oil Spill Modelling Summary[7]		
Spill Scenario/Description	Platform Installation Vessel	Scenario 1
Median Crossing		
Identified Median Line	**Probability and Shortest Time to Reach Median Line**	
	Winter	**Summer**
Bulgaria	25% 0 days, 22 hrs	21% 1 day, 2 hrs
Romania	Spill originates in Romania	
Turkey	0% n/a	<1% 13 days, 20 hrs
Ukraine	0% n/a	<1% 4 days, 16 hrs

Table 8: Statistical Analysis – Key Sensitivities

Sensitive Area		
Identified Sensitivity[8] (Natura2000)	**Probability and Shortest Time to Reach Sensitivity**	
	Winter	**Summer**
Canionul Viteaz	71% 0 days, 3 hrs	71% 0 days, 5 hrs
Emona	0% n/a	3% 10 days, 0 hrs
Ropotamo	0% n/a	1% 12 days, 2 hrs
Strandzha	0% n/a	<1 % 13 days, 0 hrs

[7] Whilst the stochastic maps present the probability of an individual “cell” being impacted, the stochastic statistics calculate the probability of impact to any part of a country’s coastline or median line. Therefore, the stats and visual representation of the data on the maps may differ. The stochastic statistics should always supersede the maps representation of the data.

[8] Figure 2 shows the location of each site. For more details, please refer to https://ec.europa.eu/environment/nature/natura2000/index_en.htm

Trajectory Results

Trajectory results are generated by simulating a single spill scenario under specific conditions on a particular date. Worst-case trajectories were selected, from each pool of trajectories that make up the stochastic figures in Section 3.2, to investigate the fate and behaviour of oil during the course of the simulation in more detail.

In this scenario, the worst-case trajectories are defined as:

- The trajectory that results in the **widest impact of oil to a neighbouring country (Bulgaria) (Most)**
- The trajectory that results in the **fastest oil to (Bulgarian) maritime boundary**
- The trajectory that results in the **widest impact of oil to (Canionul Viteaz) sensitivity (Most)**
- The trajectory that results in the **fastest oil to (Canionul Viteaz) sensitivity**

The environmental conditions (wind and currents) on and after the simulation start dates listed below produced the worst case outcomes described above.

The trajectories selected for the platform installation vessel loss are given in Table 9 and the main results are summarised in Table 10 and Table 11

Table 9: Worst-case trajectories following an Accidental Spill from the Platform Installation Vessel

Scenario	Worst-case	Trajectory Number	Simulation Start Date [UTC]
Platform Installation Vessel Loss	Most Oil to Neighbouring Country	117	14-Sept-2018 17:00
	Fastest Oil to Maritime Boundary	48	15-Feb-2017 15:00
	Most Oil to Sensitivity	129	01-Dec-2019 07:00
	Fastest Oil to Sensitivity	48	15-Feb-2017 15:00

Table 10: Key results from an Accidental Spill from the Platform Installation Vessel Most Oil

Trajectory 117 of 150	Most Oil to Neighbouring Country
Release Location	Neptun Deep
Surface Area Impacted within Bulgaria	2,692km^2
Time taken to reach Maritime Boundary	2 days, 5 hours
Trajectory 129 of 150	**Most Oil to Sensitivity**
Release Location	Neptun Deep
Surface Area Impacted to Sensitivity	264 km^2
Percentage of Sensitivity affected	75%
Time taken to reach Sensitivity	0 days, 10 hours

Table 11: Key results from an Accidental Spill from the Platform Installation Vessel Fastest Oil

Trajectory 48 of 150	Fastest Impact to Sensitivity and Maritime Boundary[9]
Release Location	Neptun Deep
First Impact to Maritime Boundary	0 days, 22 hours
First Impact to Sensitivity	0 days, 3 hours

[9] The fastest trajectory to reach the identified sensitivity and the maritime boundary happen to be the same trajectory, this is likely due to the direction of oil travelling south west towards both identified areas.

Worst-case trajectories allow further investigation into the oil fates and behaviour. Mass balance can be scrutinised, and probability and likelihood of oil impact better understood.

The following figures are presented:

<u>Trajectory resulting in most oil to Bulgarian waters</u>

Figure 7: Mass balance plot – Most oil to Neighbouring Country

Figure 8: Overall area impacted– Most oil to Neighbouring Country

Figure 9:Daily Position– Most oil to Neighbouring Country

<u>Trajectory resulting in fastest impact to the Bulgarian maritime boundary</u>

Figure 10: Mass balance plot – Fastest oil to Maritime Boundary

Figure 11:Overall area impacted– Fastest oil to Maritime Boundary

Figure 12:Daily Position– Fastest oil to Maritime Boundary

<u>Trajectory resulting in most oil to the Canionul Viteaz Sensitivity</u>

Figure 13: Mass balance plot – Most oil to Sensitivity

Figure 14: Overall area impacted – Most oil to Sensitivity

Figure 15: Daily Position – Most oil to Sensitivity

<u>Trajectory resulting in the fastest oil to the Canionul Viteaz Sensitivity</u>

Figure 16: Mass balance plot - Fastest oil to Sensitivity

Figure 17: Overall area impacted – Fastest oil to Sensitivity

Figure 18: Daily Position – Fastest oil to Sensitivity

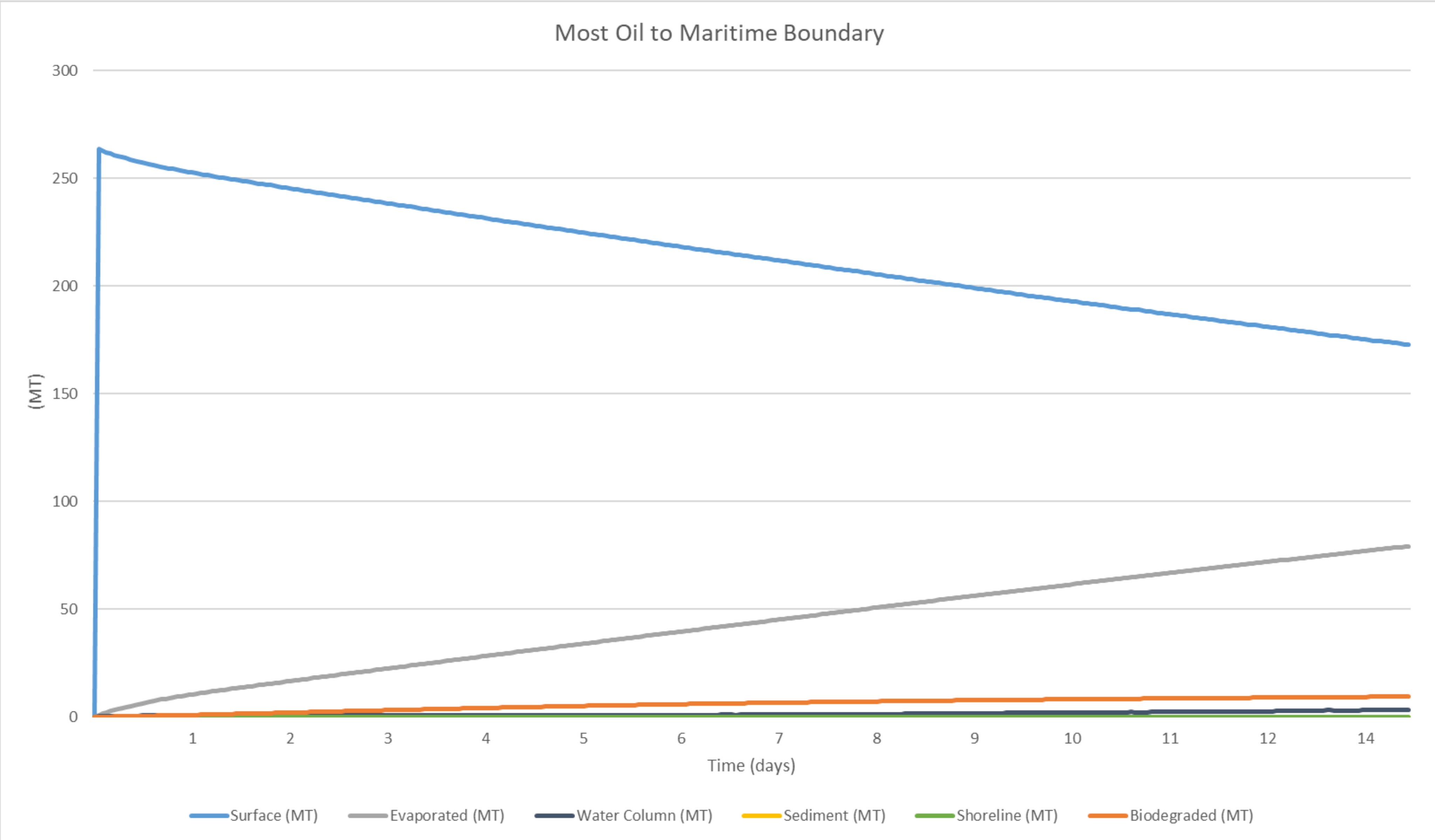

Figure 7: Mass balance plot – Most oil to Neighbouring Country

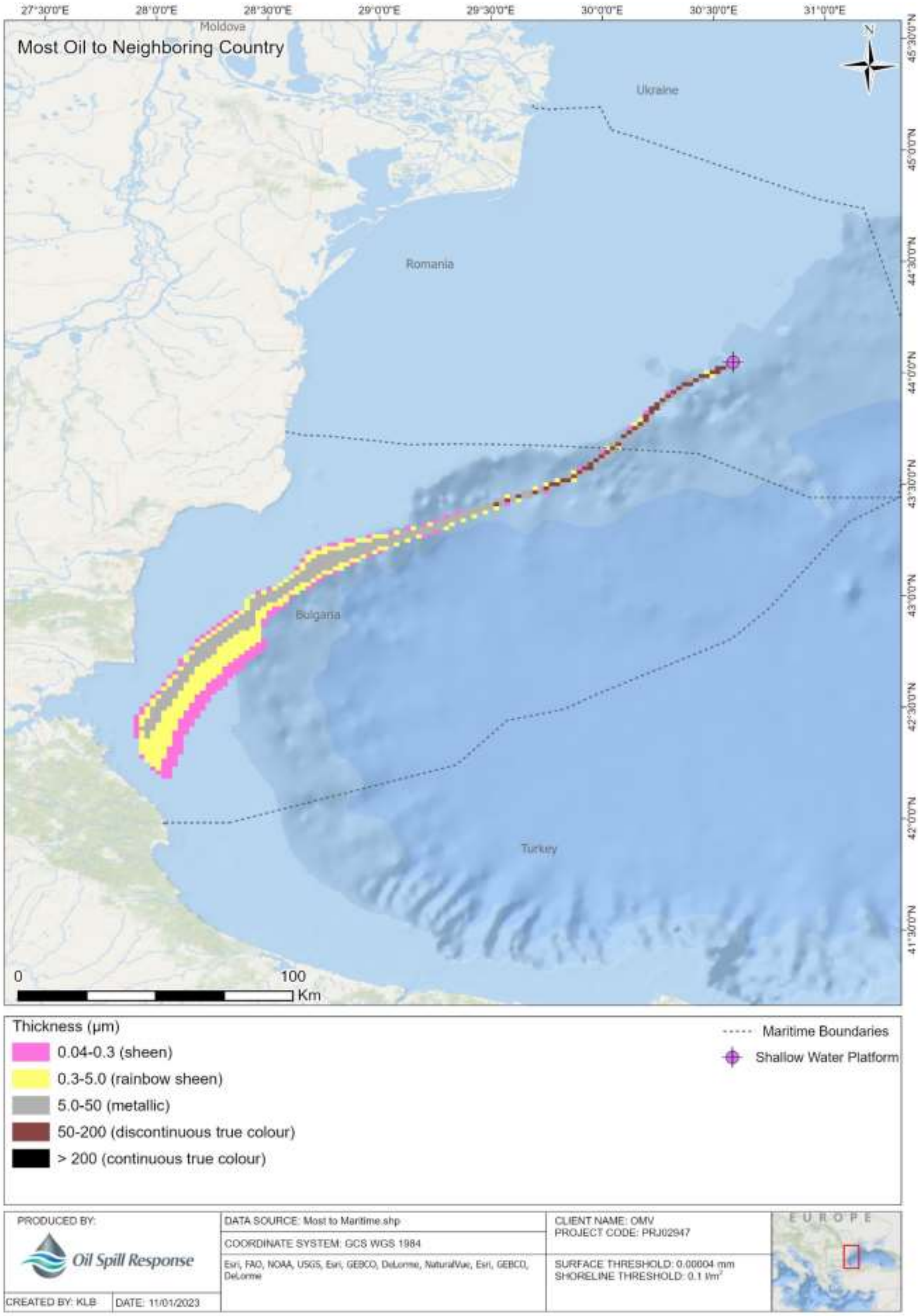

Figure 8: Overall area impacted– Most oil to Neighbouring Country

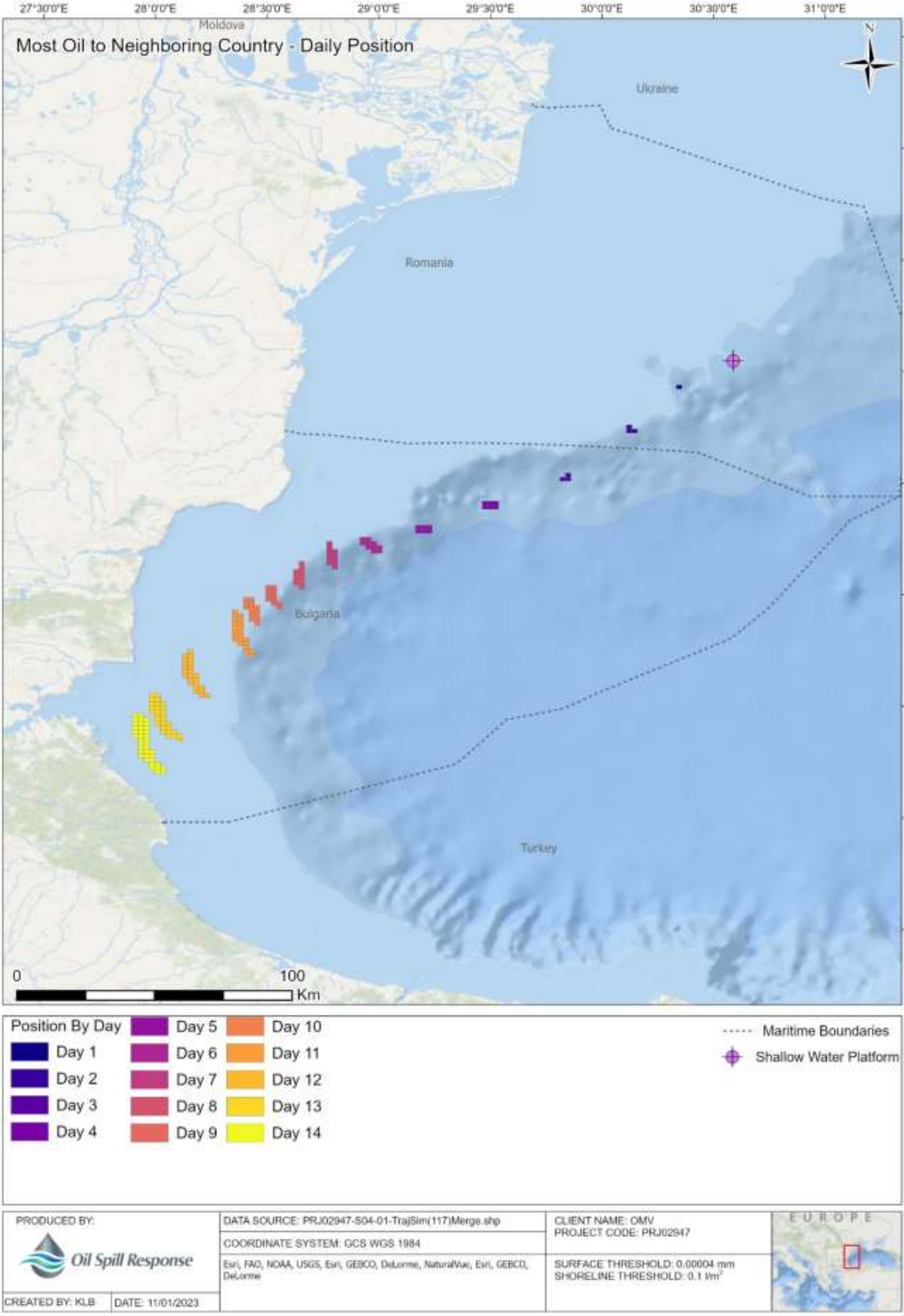

Figure 9:Daily Position– Most oil to Neighbouring Country

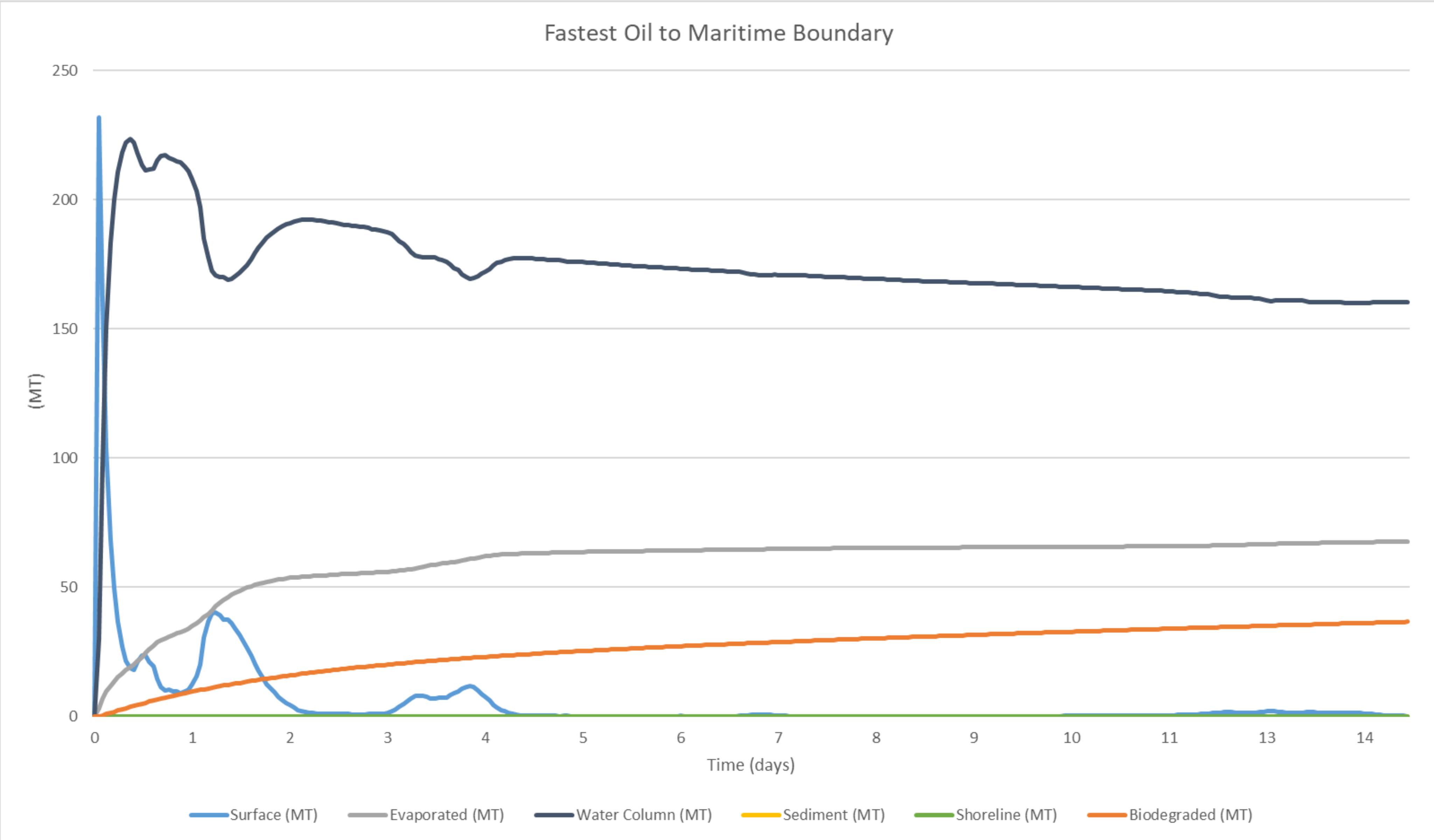

Figure 10: Mass balance plot – Fastest oil to Maritime Boundary

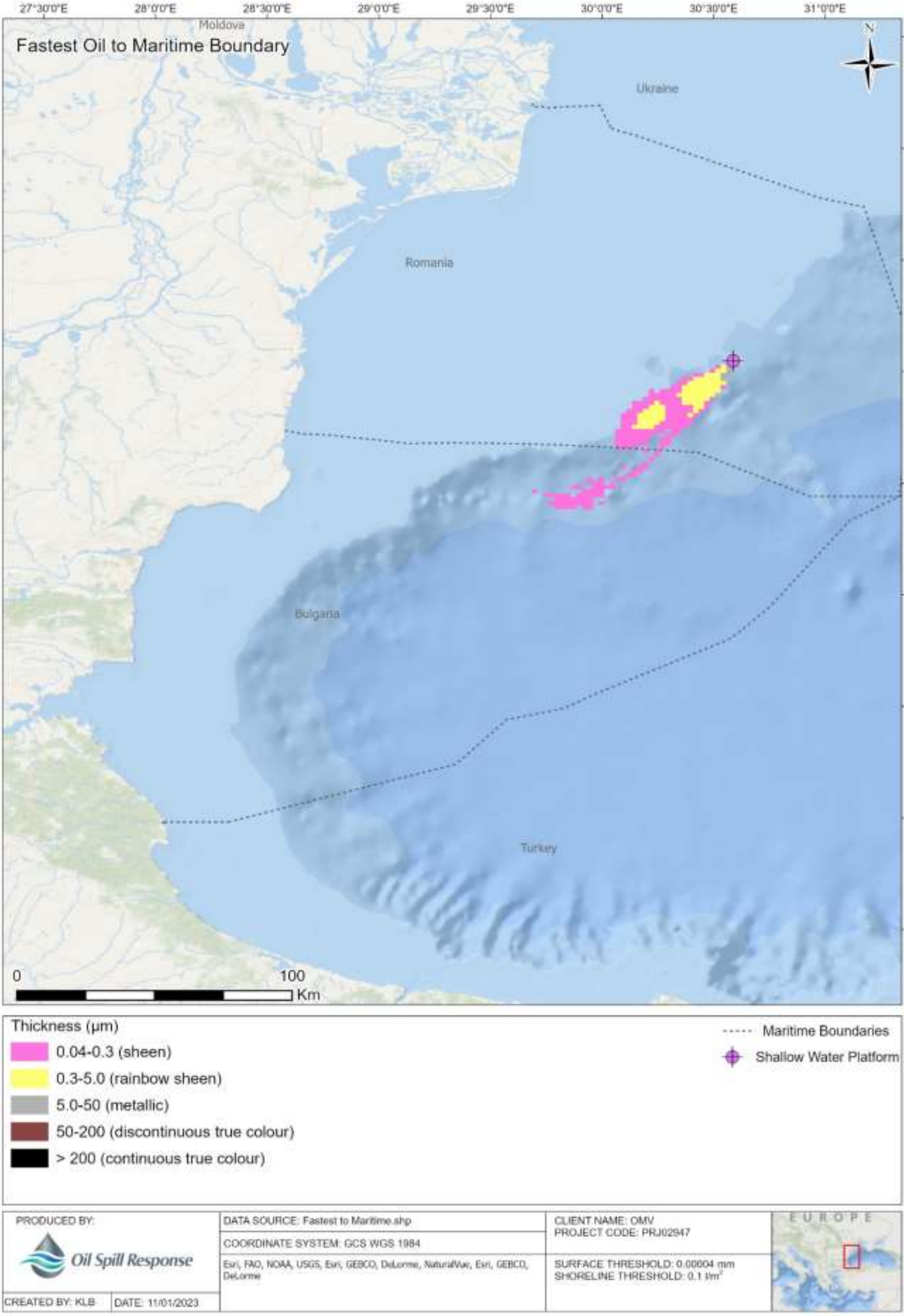

Figure 11:Overall area impacted– Fastest oil to Maritime Boundary

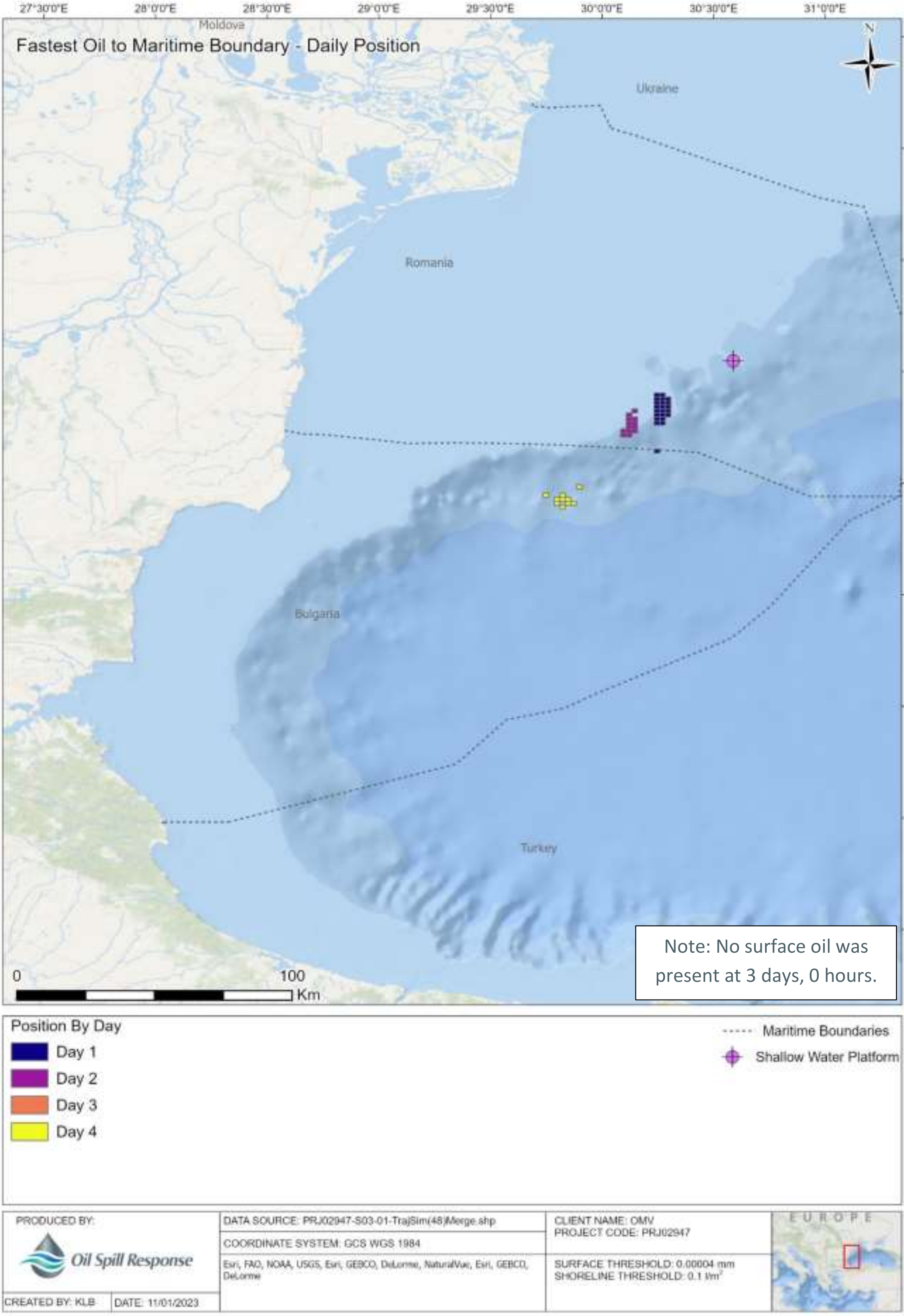

Figure 12:Daily Position– Fastest oil to Maritime Boundary

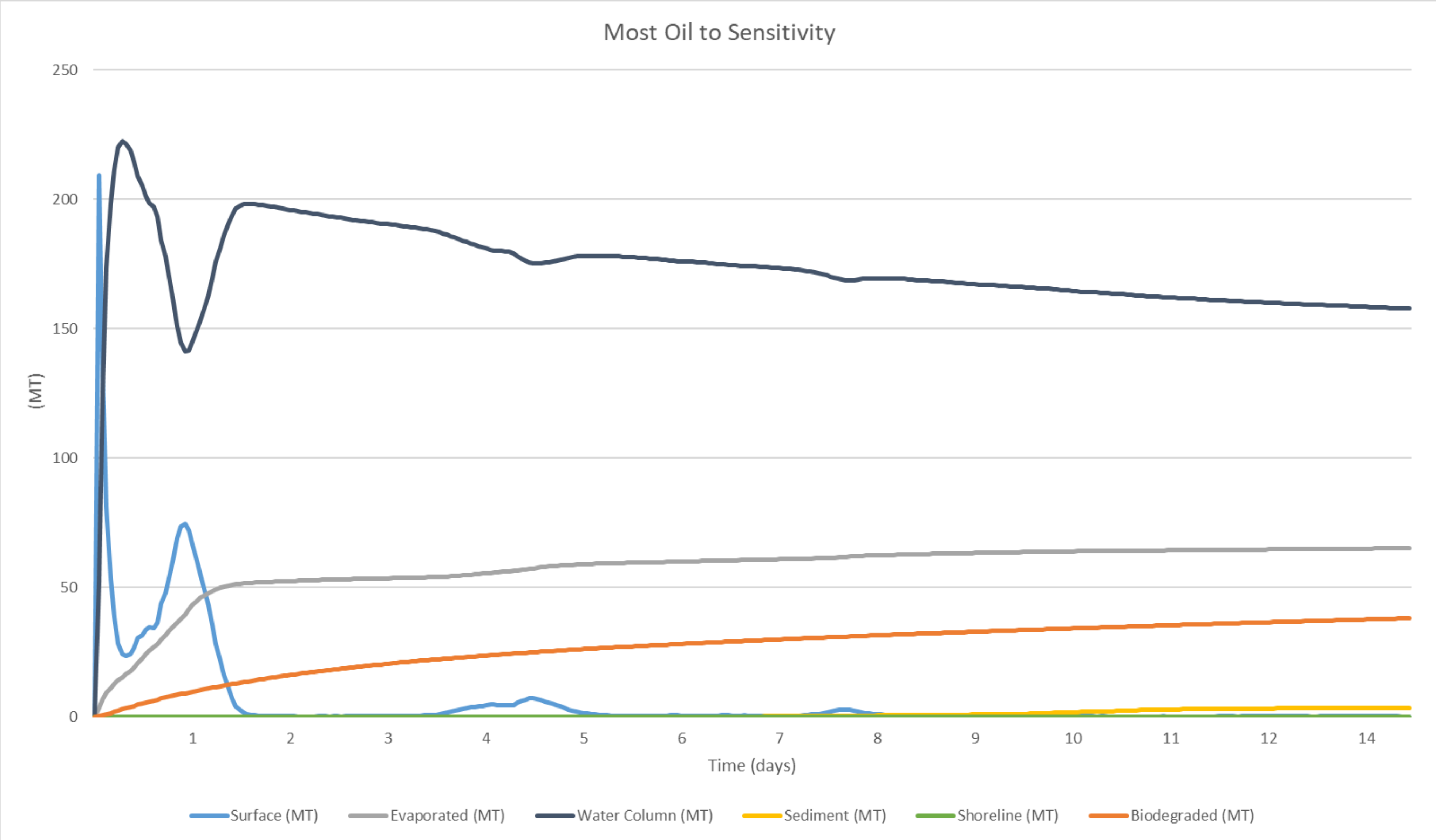

Figure 13: Mass balance plot – Most oil to Sensitivity

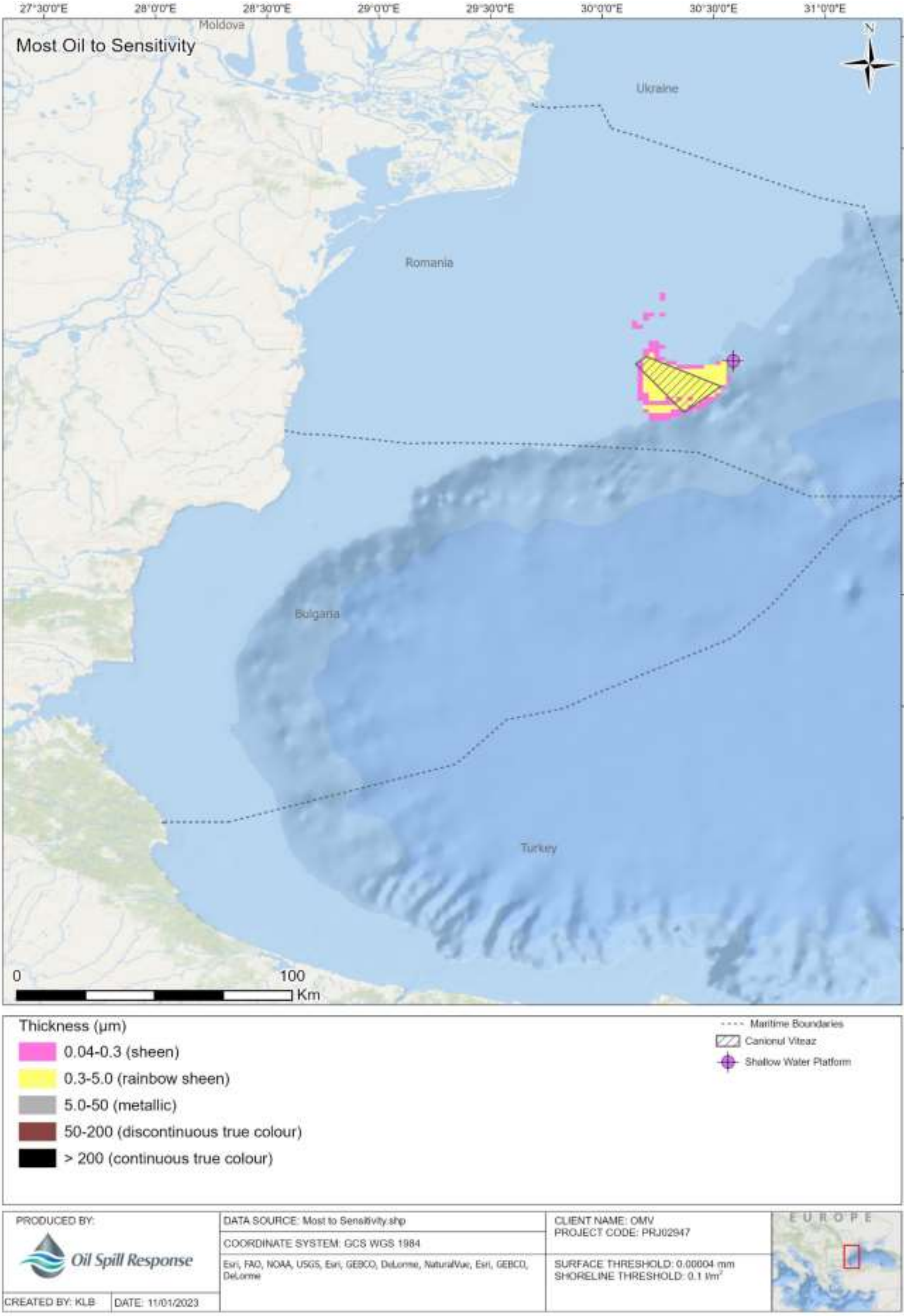

Figure 14: Overall area impacted – Most oil to Sensitivity

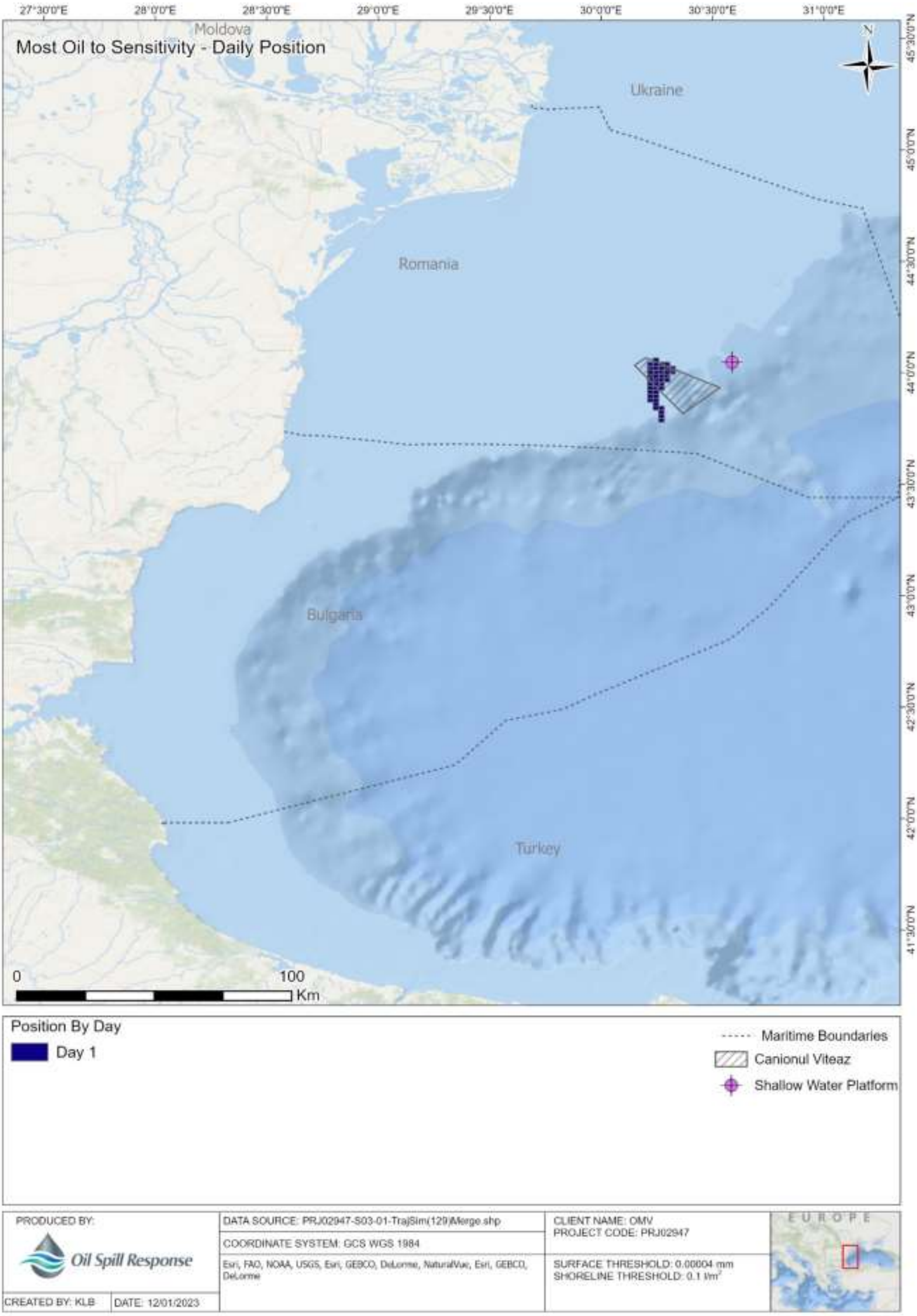

Figure 15: Daily Position – Most oil to Sensitivity

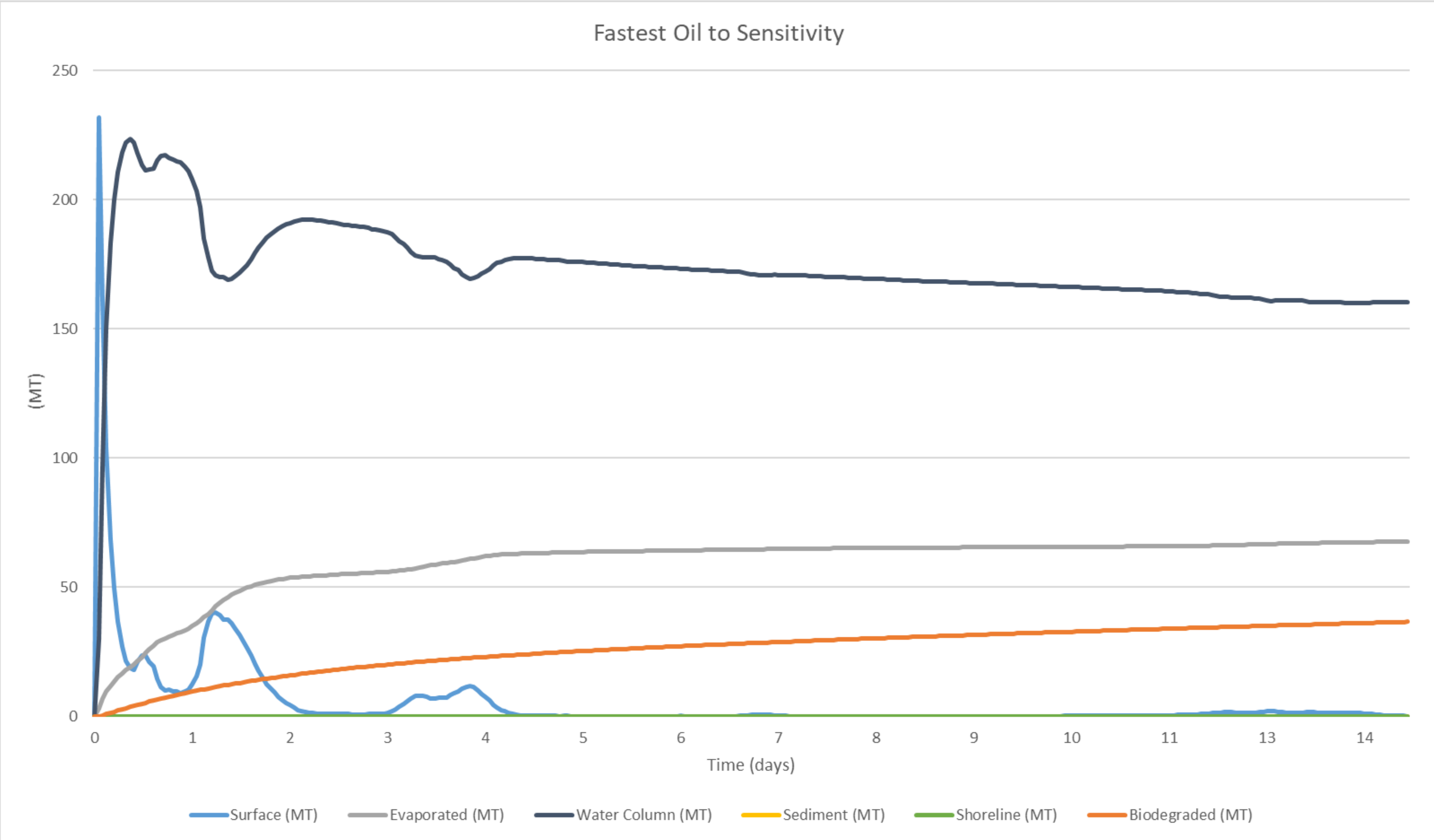

Figure 16: Mass balance plot - Fastest oil to Sensitivity

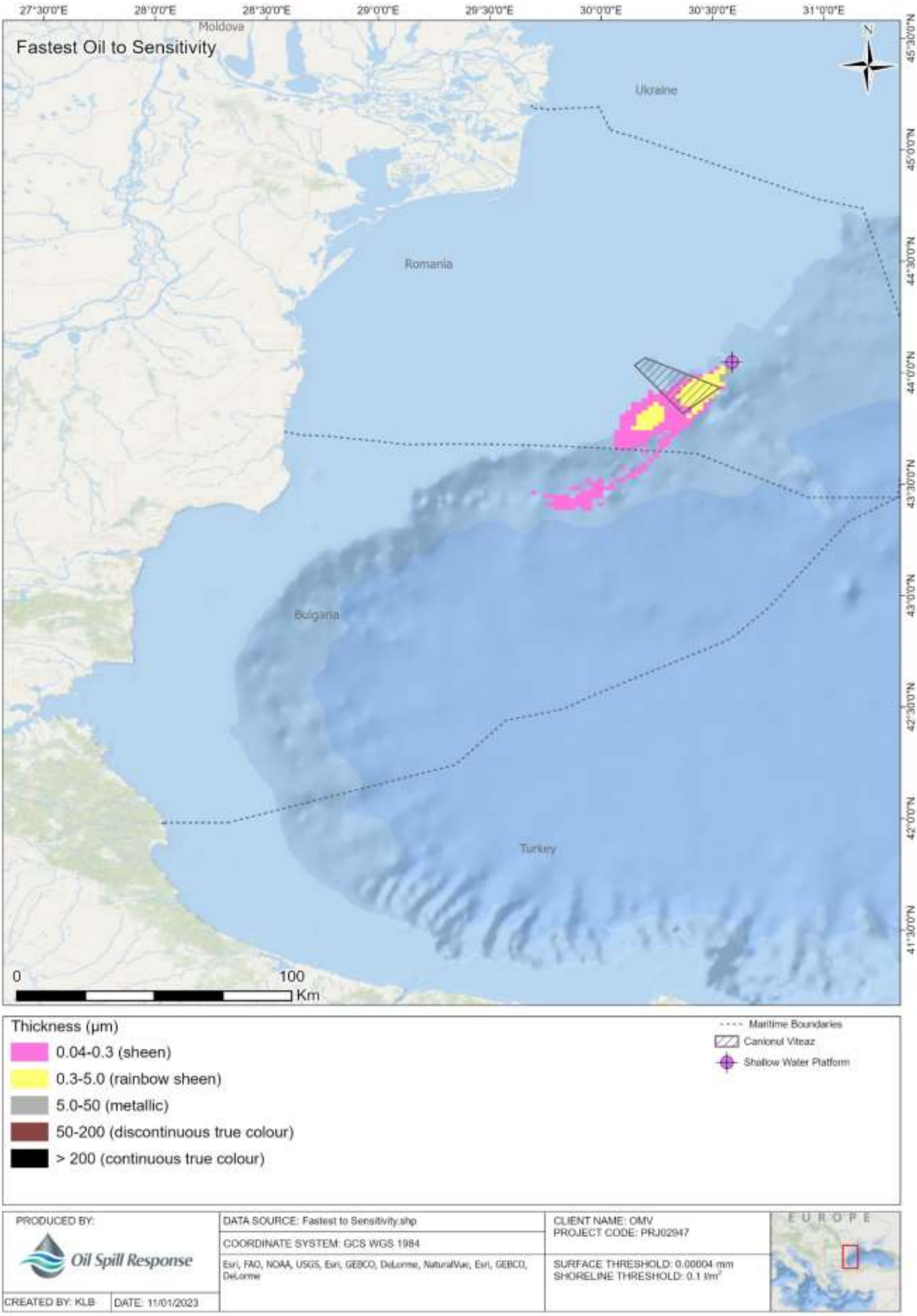

Figure 17: Overall area impacted – Fastest oil to Sensitivity

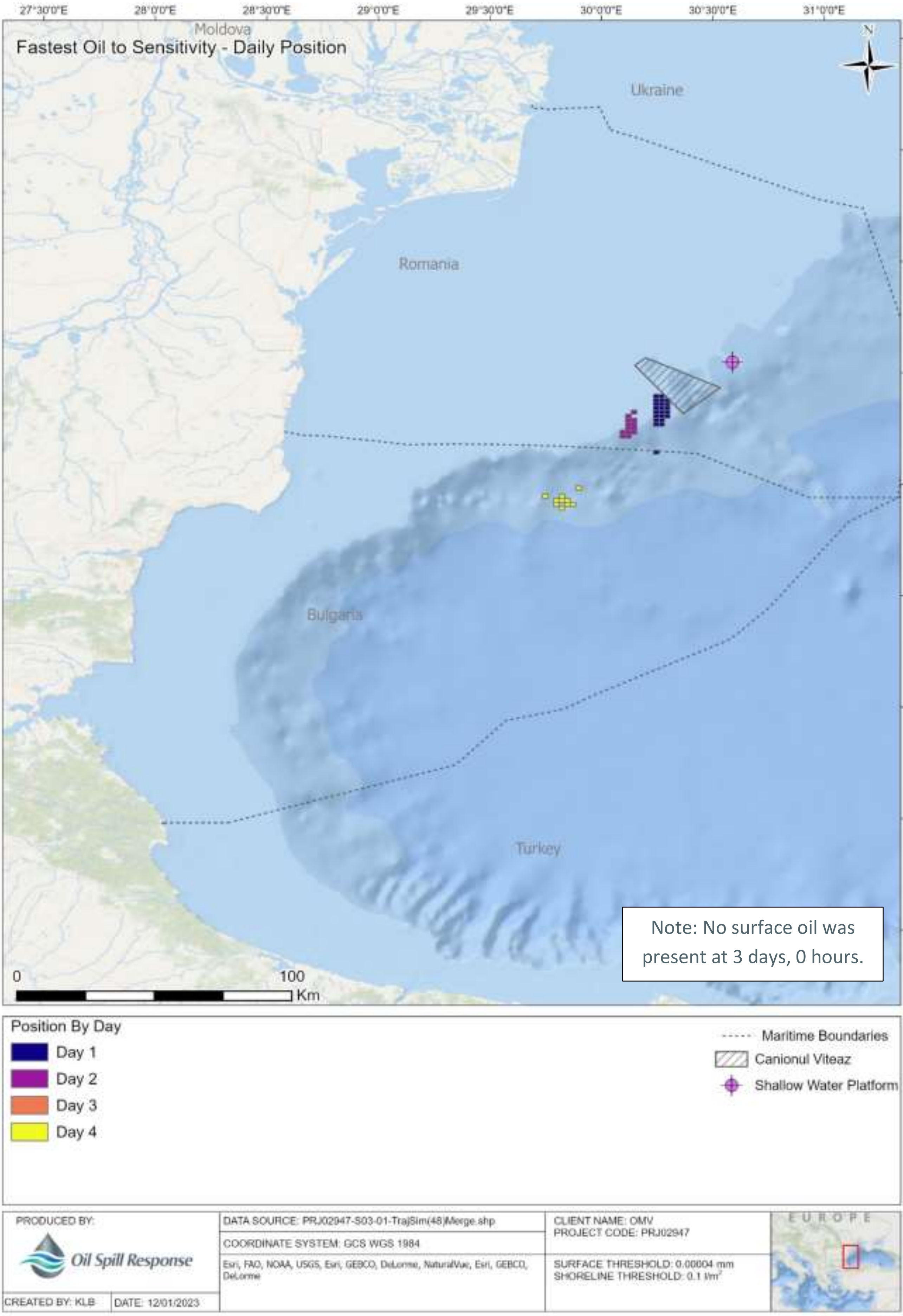

Figure 18: Daily Position – Fastest oil to Sensitivity

3.3 Scenario 2 – Accidental Spill from the Drilling Rig

Stochastic Maps

The stochastic results for the drilling rig scenario were calculated from 150 trajectories per season. The scenario involves the release of 165m^3 of MGO over 4 hours in both winter and summer seasons from the drilling rig at the Pelican drill centre. The oil is tracked for a further 14 days.

The following results are presented:

Sea Surface

Figure 19: Probability that a surface cell could be impacted.

Figure 20: Minimum arrival time of surface oil.

Figure 21: Maximum emulsion thickness of surface oil.

Shoreline

Figure 22: Probability that a shoreline cell could be impacted.

SURFACE MAPS

Accidental Spill from the Dilling Rig

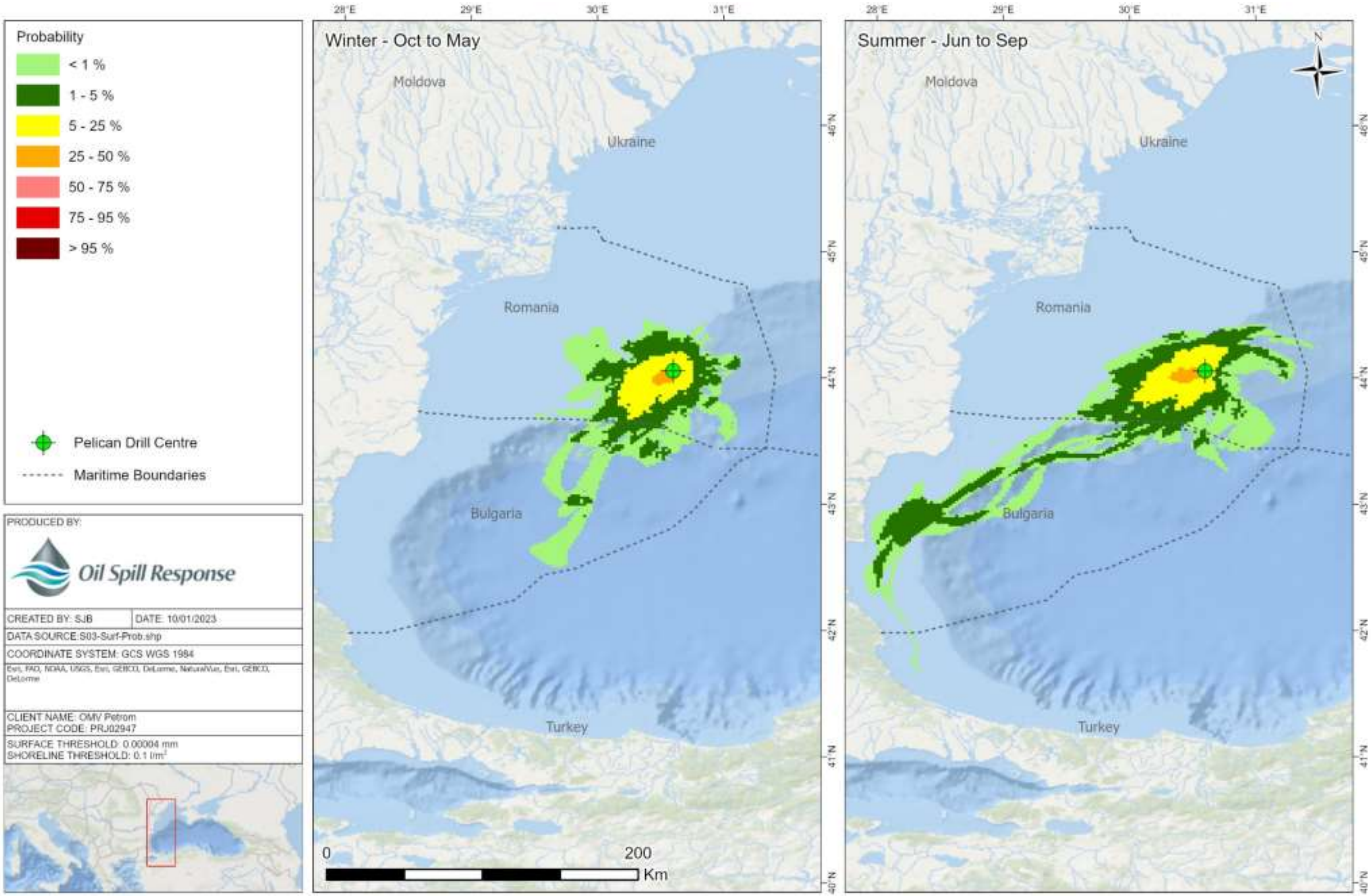

Figure 19: Probability that a surface cell could be impacted.

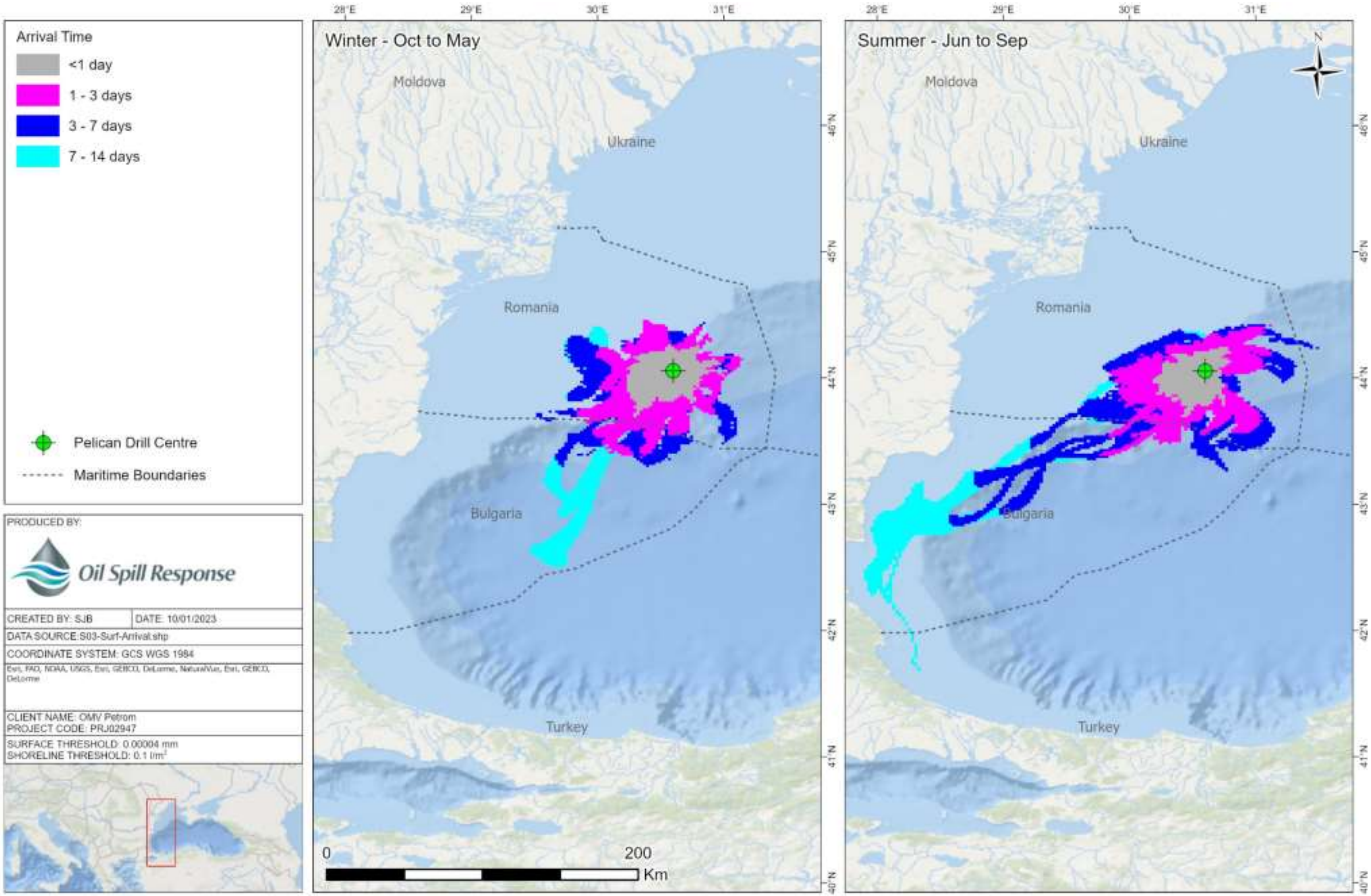

Figure 20: Minimum arrival time of surface oil.

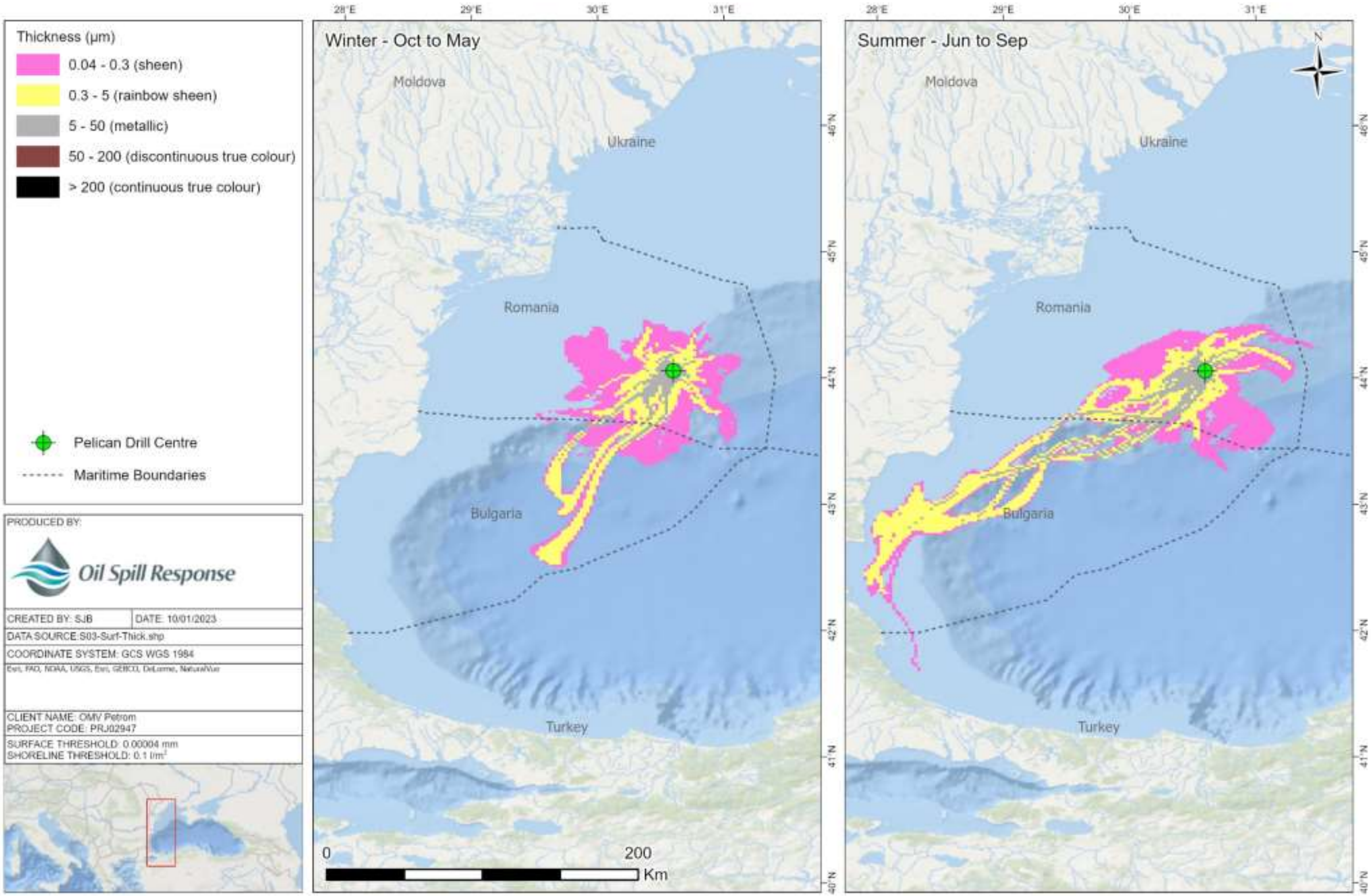

Figure 21: Maximum emulsion thickness of surface oil.

SHORELINE MAPS

Accidental Spill from the Drilling Rig

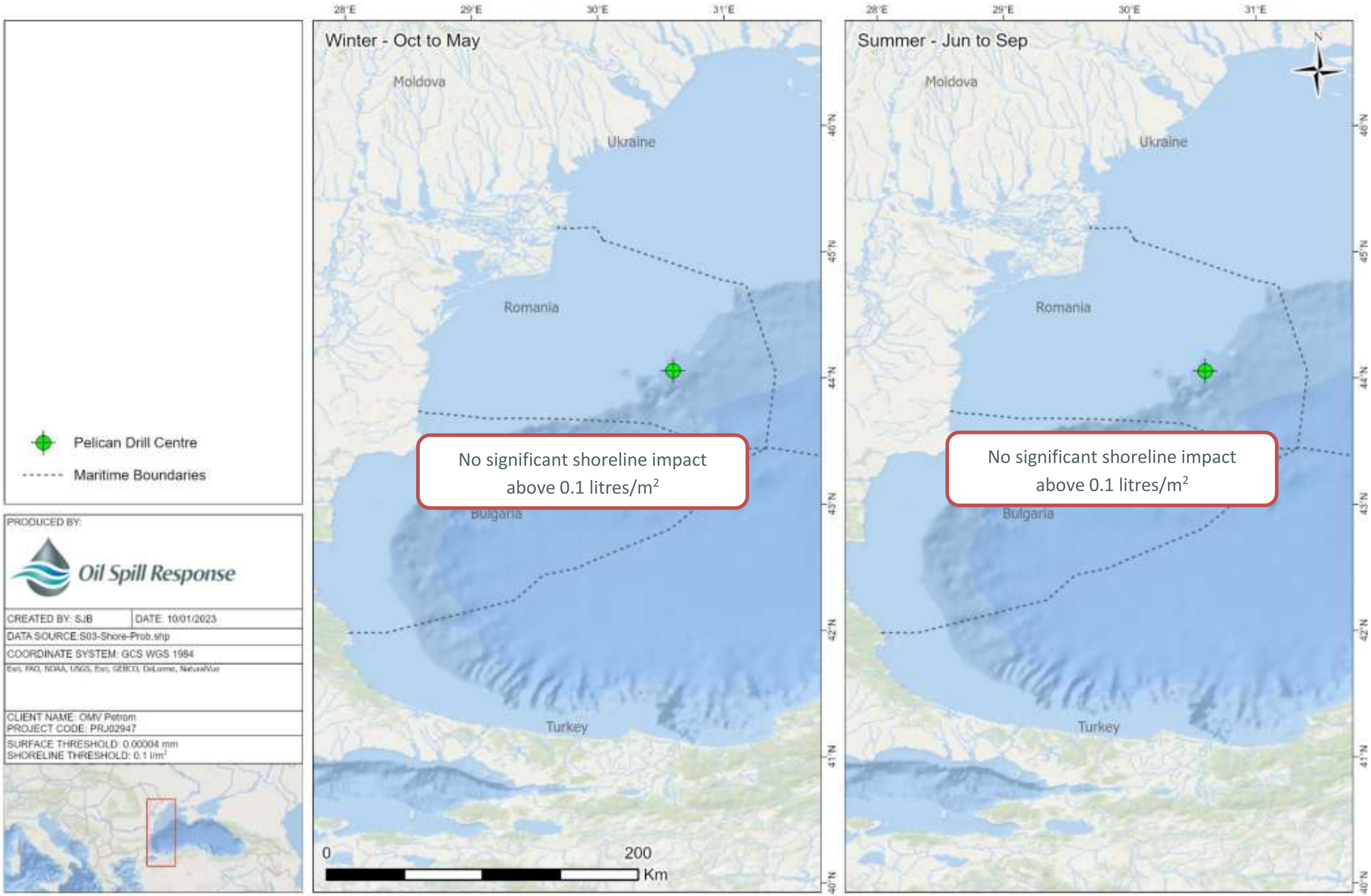

Figure 22: Probability that a shoreline cell could be impacted.

Statistical Analysis

Table 12: Statistical Analysis - Surface

Oil Spill Modelling Summary[10]		
Spill Scenario/Description	Drilling Rig	Scenario 2
Median Crossing		
Identified Median Line	**Probability and Shortest Time to Reach Median Line**	
	Winter	**Summer**
Bulgaria	15% 1 day, 3 hrs	15% 1 day, 5 hrs
Romania	Spill originates in Romania	
Turkey	0% n/a	<1% 12 days, 13 hrs
Ukraine	0% n/a	<1% 4 days, 15 hrs

Table 13: Statistical Analysis – Key Sensitivities

Sensitive Area		
Identified Sensitivity[11] (Natura2000)	**Probability and Shortest Time to Reach Sensitivity**	
	Winter	**Summer**
Canionul Viteaz	59% 0 days, 4 hrs	67% 0 days, 7 hrs
Emona	0% n/a	3% 9 days, 23 hrs
Ropotamo	0% n/a	1% 11 days, 1 hr
Strandzha	0% n/a	<1 % 11 days, 21 hrs

[10] Whilst the stochastic maps present the probability of an individual "cell" being impacted, the stochastic statistics calculate the probability of impact to any part of a country's coastline or median line. Therefore, the stats and visual representation of the data on the maps may differ. The stochastic statistics should always supersede the maps representation of the data.

[11] Figure 2 shows the location of each site. For more details, please refer to https://ec.europa.eu/environment/nature/natura2000/index_en.htm

4 SUMMARY

Two scenarios are presented for the forthcoming development and completion operations at Neptun Deep, offshore Romania. These were a credible-case Installation Vessel loss resulting in the release of 300m^3 MGO; and a spill from the Drilling Rig resulting in the release of 165m^3 MGO. Both scenarios were modelled seasonally through a summer (June-Sept) and winter (Oct-May) period.

A summary of the results is presented in the table below:

Table 14: Summary of model results

	Accidental Spill from the Platform Installation Vessel 300m^3 MGO	Accidental Spill from the Drilling Rig 165m^3 MGO
	Scenario 1	**Scenario 2**
Surface		
Fastest to maritime boundary	0 days, 22 hours Bulgaria (Winter)	1 days, 3 hours Bulgaria (Winter)
Surface waters with >10% probability of impact	Romania 100% spill originates here, Bulgaria 25%	Romania 100% spill originates here, Bulgaria 15%
Predominant direction of travel	Southwest – up to 150km away during winter and 250km away during summer	Southwest – up to 150km away during winter and 250km away during summer
Fastest to Sensitive Area	0 days, 3 hours Canionul Viteaz (Winter)	0 days, 4 hours Canionul Viteaz (Winter)
Percentage coverage of impact to sensitivity	~75% (Canionul Viteaz)	~70% (Canionul Viteaz)[12]
Shoreline		
Shoreline Oiling	There is no significant shoreline oiling	There is no significant shoreline oiling

[12] For scenario 2 this result has not been presented in section 3.3, this is because no trajectories have been run. Percentage of the impacted area is derived from stochastic results and so has been included here to m

Discussion

All the model results have been created with thresholds applied. Thresholds are used to present information that is meaningful, either in terms of responding to the spill, or environmental impact. Further details on the thresholds used are given in Section 2.5.

For ease of reading, the below discussion focusses on scenario 1, many of the comments are applicable to scenario 2 also.

Scenario 1

Stochastic

The stochastic modelling results show that in most situations, the impact to surface waters will remain within Romanian waters. Approximately ¼ (Winter 25%, Summer 21%) of the simulations also resulted in surface oil travelling across the maritime boundary to Bulgaria. It is also possible, but highly unlikely that surface oil could impact the waters of Ukraine and Turkey during the winter season (<1%).

Surface oil could be found up to around 100km away in most directions, apart from a small number of situations where the environmental conditions allow surface oil to persist for long enough to be transported to the south west. This is especially pronounced in the summer season.

The fastest that oil is expected to reach the Bulgarian maritime boundary is around 1 day. Please note that this is the fastest impact out of the 150 simulations per season. Other simulations will either not impact at all, or take longer than 1 day. The surface-arrival time map suggests that, in most simulations there is no surface oil present after 7 days. Only a few simulations show oil persisting beyond 7 days, these are the ones which travel to the south west.

Away from the immediate area of release, oil is expected to spread out into layers of metallic thickness (5-50µm) or less. Many areas experience oil no thicker than silver sheen.

The surface waters at the nearby sensitivity of Canionul Viteaz are impacted in 71% of the simulations. The simulations that impacted the fastest reached the area in 3 hours (winter season). The impact to this site has been explored further with additional trajectory simulations. It should be remembered that 'impact' is counted as occurring when surface oil exceeds the threshold of silver sheen - 0.04µm. This study does not directly comment on how oil on the surface will impact to organisms in the water column and at the sea bed.

Shoreline oiling is not predicted during any of the stochastic simulations. It is possible that a small number of the simulations with impact to the south west could impact the shoreline if the simulation was run for longer than 14 days. However, it should be noted that this modelling assumes no intervention or response actions are used. In reality, actions would have been taken to mitigate the effects of the spill during the intervening 14 days.

Trajectory

Most impact to neighbouring country

In the situation that resulted in the greatest impact to the waters of a neighbouring country, oil is steadily moved to the south west by winds and currents whilst spreading out over a wider area. Unlike other simulations, most of the oil remains on the sea surface and does not quickly disperse. Closer examination of the model suggests that this is caused by a period of unusually calm winds which do not generate sufficient mixing to disperse the oil.

Fastest impact to maritime boundary and sensitive area

The same simulation resulted in the fastest outcome to both the Bulgarian maritime boundary and also the nearby Canionul Viteaz sensitive area. This is unsurprising as they are both in the same direction from the release site. In this situation closer examination of the model shows this occurred during a period of strong northerly winds, which quickly pushed the oil southwards towards the sensitivity and maritime boundary. The mass balance graph shows the effect of the strong wind is to increase the rate of natural dispersion and within the first 12 hours the majority of the oil is in the water column. The mass balance graph shows oil resurfacing during day 1 and 3 when then wind speed reduces. After 4 days there is very little surface oil remaining.

Most impact to sensitivity (Canionul Viteaz)

The simulation that resulted in the greatest surface area impact to Canionul Viteaz shows oil moving initially south west and then curving round to the north west. Closer inspection of the model shows moderate northerly winds at the time of release combined with a strong current pushing the oil initially southwards towards the sensitivity. This combines to create a situation where the surface oil is moved quickly towards the sensitive area, but the winds are not strong enough to disperse the oil before it gets there. Natural dispersion continues to reduce the amount of oil on the sea surface and after 36 hours there is very little surface oil remaining. 75% of the surface area of Canionul Viteaz is impacted by surface oil at some point during this simulation.

Fate

The fate of the oil is dependant on the environmental conditions it is exposed to and there no ‘typical’ spill to comment on. The following in written in general terms.

The information gained from the trajectory models suggest that the rate of natural dispersion into the water column will play a large part in the fate of the spilt oil. Natural dispersion will happen faster during periods of stronger wind and, as illustrated by the ‘most impact to neighbouring country’ trajectory, much slower during periods of calm weather. The situations examined here are some of the extreme cases, most cases will lie somewhere in between. The stochastic model results suggest little surface oil persists beyond 7 days in most situations.

Evaporation and biodegradation also play a part, but generally the effect is smaller than natural dispersion. Sedimentation is negligible in the trajectories studied.

Scenario 2 – Accidental Spill from the Drilling Rig

Scenario 2 simulates a similar, but smaller, release of MGO from the drilling rig. The overall results from the stochastic models are very similar to that of scenario 1. The above discussion around the effects of a spill from scenario 1 are applicable to scenario 2 also.

APPENDIX A. METOCEAN DATA

Three-dimensional ocean current data is used to determine the movement of oil both on the sea surface and through the water column.

Table 15: Current Data – General Description

Dataset Name	Black Sea Physics Reanalysis		
OSRL Ref.	PRJ02947-Curr-01		
Description	The physical component of the Black Sea Forecasting System (BS-Currents) is a hydrodynamic model implemented over the whole Black Sea basin. The model horizontal grid resolution is 1/36° in zonal resolution, 1/27° in meridional resolution (ca. 3 km) and has 31 unevenly spaced vertical levels. The hydrodynamics are supplied by the Nucleus for European Modeling of the Ocean (NEMO, v3.4). The model solutions are corrected by the variational assimilation (based on a 3DVAR scheme), originally developed for the Mediterranean Sea and later extended for the global ocean. The observations assimilated in the BS-Currents includes in-situ profiles, along-track sea level anomalies (SLA) and gridded sea surface temperature (SST) provided by the U.K. MetOffice Hadley Center and the Copernicus TACs.		
Start Time	May 2015	**Spatial Resolution**	3 km
End Time	May 2020	**Temporal Resolution**	24 hour
Depth Levels	31 unevenly spaced vertical levels		

Two-dimensional wind data is used to enhance the prediction of movement of oil on the sea surface, estimate wave height, contribute to evaporation rates and capture mixing in the upper water column.

Table 16: Wind Data – General Description

Dataset Name	CFSR Winds		
Reference	Saha, S., et al. 2010. NCEP Climate Forecast System Reanalysis (CFSR) Selected Hourly Time-Series Products, January 1979 to December 2010. Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory. https://doi.org/10.5065/D6513W89. Accessed Oct 2019.		
OSRL Ref.	PRJ02947wind-01		
Description	The CFSR is a third-generation reanalysis product. It is a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system designed to provide the best estimate of the state of these coupled domains over this period. The CFSR includes (1) coupling of atmosphere and ocean during the generation of the 6-hour guess field. (2) an interactive sea-ice model, and (3) assimilation of satellite radiances. The CFSR global atmosphere resolution is ~38 km with 64 levels although the wind data we extract is at 1 level, 10 m above sea level.		
Start Time	May 2015	**Spatial Resolution**	20 km
End Time	May 2020	**Temporal Resolution**	1 hour
Further Information	"The Climate Data Guide: Climate Forecast System Reanalysis (CFSR)." Retrieved from https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr		

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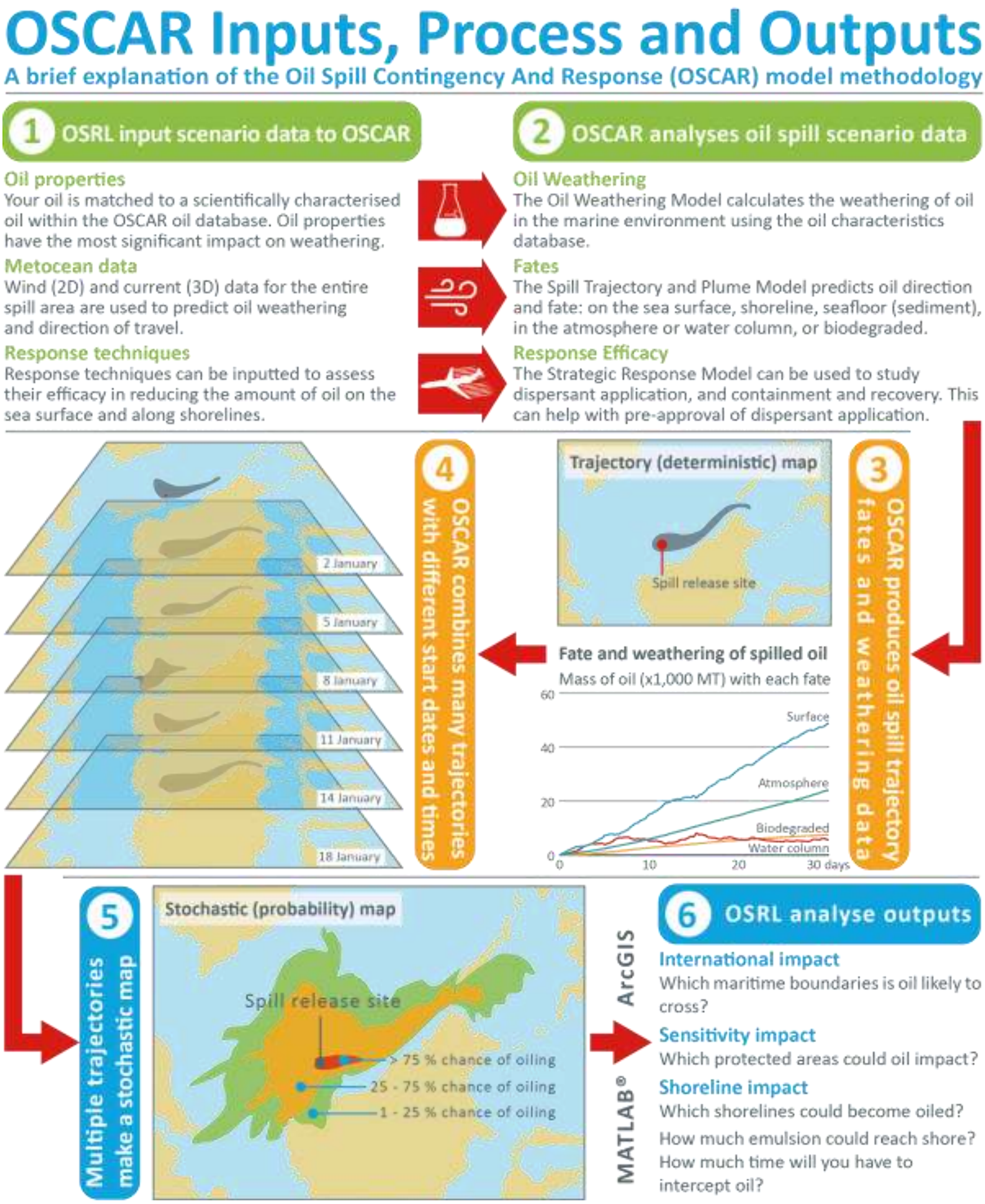
APPENDIX B. OIL SPILL MODELLING SOFTWARE AND METHODOLOGY

This project was completed using the version of OSCAR contained within the Marine Environmental Modelling Workbench (MEMW) 13.1.0., a model that has been fully validated and calibrated using various field observations from a number of experimental oil spills.

OSCAR predicts the movement of oil at the water's surface and throughout the water column. OSCAR consists of a number of interlocking modules that are activated as required. The following infographic illustrates the OSCAR modelling process.



APPENDIX C. GLOSSARY OF TERMS, ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius (1.0°C = 33.8° Fahrenheit)
µm	Micrometre (1.0 µm = 10^{-6} m)
API	American Petroleum Institute
API Gravity	API Gravity, like specific gravity, is a ratio between the densities of oil and water. Unlike specific gravity, API gravity is only used to describe oil, which it characterises as: • Light - API > 31.1 • Medium - API between 22.3 and 31.1 • Heavy - API < 22.3 • Extra Heavy - API < 10.0 API Gravity is converted to Specific Gravity using the following formula: *API gravity = (141.5/Specific Gravity) – 131.5* An API of 10 is equivalent to water, so oils with an API above 10 will float on water while oils with an API below 10 will sink. See also: *Specific Gravity, API*
Asphaltenes	The asphaltenes present the crude oil components that are (1) insoluble in n-heptane at a dilution ratio of 40 parts alkane to 1 part crude oil and (2) re-dissolves in toluene. The asphaltenes include the crude oil material highest in molecular weight, polarity and aromaticity.
bbls	Barrels of oil (a unit of volume). (1.0 bbls = 0.15899 m^3 and 1.0 m^3 = 6.2898 bbls) The conversion between mass and volume requires knowledge of the oil density. See also: *MT, API Gravity, Specific Gravity*
bbls/day	Barrels of oil per day (rate).
BONN Agreement	The BONN Agreement is an international standard and agreement on how to characterise and respond to pollution. Although aimed at pollution in the North Sea (Europe) many of the characterisation standards are internationally recognised.
GOR	Gas to Oil Ratio - the ratio of volumetric flow of produced gas to the volumetric flow of oil. Although GOR is a ratio, the volume units must be known since gas and oil volumes are measured differently. GOR changes with temperature and pressure so the condition under which GOR is measured must be known.
ITOPF	The International Tanker Owners Pollution Federation Limited
km	Kilometres (1.0 km = 1,000 m) See also: *m*
m	Metres (1.0 km = 1,000 m) See also: *µm, km*
m^3	Metres cubed See also: *m*
MEMW	Marine Environmental Modelling Workbench - the modelling software package developed by SINTEF. The MEMW consists of three models: • **DREAM (Dose, Risk and Effects Assessment Model)** • **OSCAR (Oil Spill Contingency and Response Model)** • **ParTrack Model**

	When combined, these three models quantify the environmental effect of most chemical pollution activities. See also: *OSCAR, SINTEF*
MT	Metric Tonnes - this is a unit of oil mass. (1.0 MT = 1,000 kg) The conversion between mass and volume requires knowledge of the oil's API or Specific Gravity as follows: *Barrels per metric ton = 1/[(141.5/(API + 131.5) x 0.159]* See also: *bbls, API Gravity, Specific Gravity*
NOAA	National Oceanic and Atmospheric Administration – an American scientific agency focussed on metocean conditions
OSCAR	Oil Spill Contingency And Response A state of the art 3D oil spill model and simulation tool for predicting the fates and effects of oil released into the marine environment. Developed by SINTEF, it sits within the larger MEMW application. See also: *SINTEF, MEMW*
OSRL	Oil Spill Response Limited
Pour Point	The pour point of a liquid is the lowest temperature at which it shows flow characteristics. If ambient temperature is less than the liquid's pour point it will begin to solidify.
SINTEF	SINTEF is an independent research organisation in Norway which develops the OSCAR model used in this study.
Specific Gravity	Specific gravity is a ratio of the density of one substance to the density of a reference substance, usually water. Specific gravity of oil is a ratio of the density of oil to the density of water. See also: *API Gravity, bbls, MT*
Stochastic	Stochastic (or probabilistic) results show the probability or likelihood of an event occurring. They provide statistical data that can be used to assess risk and identify worst-case scenarios. Stochastic results are achieved by combining many different trajectory simulations. See also: *Trajectory*
Trajectory	Trajectory or deterministic results show the impact of a single spill event over time. Can be used to assess different response options such as booms, skimmers and dispersant. See also: *Stochastic*
UTC	Coordinated Universal Time
Wax Content	Represents the crude oil components that are soluble in higher molecular weight normal alkanes (n-heptane) but are insoluble in lower molecular weight alkanes (n-pentane).