
Environmental Risk Assessment Methodology (ERAM) for Oil Pollution

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Abstract: Coastal areas have economical, archaeological, cultural, economic and environmental significance. During the last decades, a rapid development of recreation and other tourism activities has been noticed. However, these coastal areas are often visited by oil tankers for transportation purposes; this paper considers risk analysis by using index. Each index and methodology are presented in detail. This analysis provides a mathematical tool to determine oil pollution risks that lead to handle with marine environment and oil pollution prevention.

Keywords: Environmental Risk Assessment, ERA, Index Method, Coastal Safety, Oil Spill Risk Analysis

1. Introduction

Ecological risk assessment from the oil spill has become the most common practice on the areas where the ship transportation, oil terminals, pipelines drilling rigs and oil platform are active. Oil spill is a result of accidents in the above mentioned activities which pollutes the water and the surrounding environments which directly affects the ecological system of marine life and may have the adverse effects on human health.

In the past few decades many researches, risk reduction techniques, risk assessment methodology, models and reports have been developed and some of the recent researches are given below:

Trends in tanker/terminal are examined oil spills in the Greek Sea port and the main concern in this study was coastal zone. The paper uses a model for ship incidents to identify the sequence of events in a network and proposes a systematic approach for analysis of incidents which will help in taking preventive measures during operation and planning. It is discussed that human errors and operational failure can also be the cause of big incidents, [1] and [2].

The recent methodologies and advances are studied in the methodology using maritime transportation system (MTS) with incident/accident probability model and consequences model, and also presented improved graphical format to represent maritime transportation risk in geographic manner. All of these enhancements and improvement were made in

the context of two years oil transportation risk study conducted from 2006-2008 in the Puget Sound and surrounding waters, they also presented the comparison of risk relation analysis between a one way zone, an escorting and double hull requirement, [3], [4], [5] and [6].

The Statmap model for risk analysis is described in detail with example and explains all the input and output facilities of the model, [7].

The risk assessment of oil spill pollution in China waters from Chinese shipping industry is presented. In the paper, all the traffic data and the risk from the vessel traffic are presented; and also showed that with increase in oil import there is a greater risk than those who exports, but in China oil spill is relatively low, [8].

The assessments of environment risks created by increasing oil transportation in the Gulf of Finland for assessment are explained. The risk assessment tool was implemented as Perl Model and they concluded that the initial impression of the methodology and the tool are effective and useful, [9].

A dynamic risk assessment model for drift grounding is proposed, this model may function as a decision support tool. This model estimates the environmental risk of drift grounding accidents for oil tankers in real time and in forecast model, [10].

An oil spill risk assessment model developed for the US water is presented, [11]. The whole methodology was discussed in detail and risk was calculated as the product of spill probability and import indices, in this study they

presented the impact indices incorporated the total risk, The potential impact was characterized by the amount of oil spill, value, and type of oil, time of oil spill and place of spill.

The environmental risk assessment (ERA) is studies for soil pollution from the accident of oil spill at industrial site for drilling, [12]. Also, it is presented the methodology for qualitative and quantitative assessment of environmental risk and also the methodology for risk assessment of soil pollution based on modules and steps which require all the hazard analysis and all the technical data.

The most recent studies for risk analysis by using the available data for oil spill in the Crete over 1995-1999 are reviewed, [13], all the incident and accident of oil spill is thoroughly analyzed and presented, In the study, it is proposed a formula for combining the various risks It was found that all the Northern coast of the Heraklion and East Heraklion have high degree of risk whereas the Southern Crete have low risk.

The geographic information based risk assessment of oil spill in the coastal areas of AkwaIbom state of Nigeria is presented [14]. A combination of hazard and vulnerability data layers were used; and the resulting risk layer were formed and classified into risk zones of very high, high, moderate and marginal. From the study, it was found that the environs in the study are in the category of very high risk because of increasing investment in the oil section.

This concept paper is intended to present a background for development of a common approach (methodology) for ecological risk assessment Environmental Risk Assessment Methodology (ERAM) from oil pollution with application for all sea regions. The potential developer is expected to follow the main principles described here and to use the latest achievements in this field. The methodology/model should include risk assessment from both accidental and operational oil pollution from ships, oil terminals, pipelines, drilling rigs and oil platforms. It is expected that a software must be developed for practical implementations of the ERAM.

In the all factors for risk analysis are presented in detail and computational methodologies are explained and an example is given with coastal environmental sensitivity indexes.

2. Principles

The following main principles are expected to be followed during development of ERAM:

- Effectiveness; risk assessment should accurately measure the risks to the extent necessary to achieve an appropriate level of protection,
- Transparency, the reasons and evidences supporting the action recommended by risk assessment, and areas of uncertainty (and their possible consequences to those recommendations), are clearly documented and made available to decision-makers,
- Consistency, risk assessment should achieve a uniform high level of performance, using a common process and

methodology,

- Comprehensiveness, all aspects of influence of oil pollution should be considered when assessing risks and making recommendations - economic, environmental, social and cultural,
- Precautionary, risk assessment should include a level of precaution when making assumptions, and making recommendations, to account for uncertainty, unreliability, and inadequacy of information. The absence of, or uncertainty in, any information should therefore be considered as an indicator of potential risk.

3. Methodology

The following should be taken in mind during development of the ERAM for oil pollution:

1. The methodology should be standardized, Generally the ERAM is to be developed in respect to:
 - shipping traffic, oil terminals, pipelines, oil platforms and drilling rigs,
 - hydrological and meteorological conditions,
 - ecological sensitive/protected areas,
2. Assessment of response options available in case of oil spill for the region (effectiveness, logistics and limitations),
3. Estimation of the possible impact of the most probable and the worst case scenario of oil spills on resources and habitats in regard of the response techniques used,
4. Risk assessment should include procedures related to analyses, evaluation and acceptance of the risk,
5. The ERAM should be applicable for both, ports and coastal areas.

4. Software Application

All factors are effecting risk against oil pollution will be to be calculated and explained in the report. The respective section for description of the application should.

The ERAM should be made as a software application which will give the possibility risk consist of at least the following:

1. Diagram/flowchart for the logic of the programme,
2. Description of the list of variables and required input data/databases with data format,
3. Description of the output data – the output data should be presented both in a table format and in GIS format for visualisation,
4. User guide for work with the software.

5. Example: A Port with an Oil Terminal

A real case for application of the software is to be presented for one port (with an oil terminal).

5.1. Risk Factors

When considering the probabilities of accidents, the risk

factors caused by the facility are discussed, for this purpose; operation and constitution of the facility, particularities and the amount of the materials handled in the facility are used.

Other than this, when considering the environmental risks, geological, biological, ecological and socio-economical structures that might be damaged during or afterwards the accident, are carefully studied.

Headlines of the risk factors are as below:

1. Risks caused by the coastal facility, operation risks (staff, administration, organization etc,) and risks caused by the handled material (amount and particularities of the material etc,)
2. Environmental risks caused by the coastal facility (geological, biological, ecological and socio-economical structures in vicinity of the facility).

5.1.1. Risks Caused by the Coastal Facility

Risks caused by the coastal facility are studied under two headlines: risks concerning the operation of the facility and risks concerning the handled material.

- a. Risks caused by the operation deal with risks concerning the staff of the facility, the constitution of the organization and the operational administration,
- b. Risks caused by the material, furthermore include the risks caused by the type and the amount of the material.

Depending on the location of the facility, as the destroying made by the spills caused by both of the risks mentioned above will differ, the risk factors must be additionally depending on the location of the facility.

The risk factors and the weight coefficients dependent on location, are given in Table 1.

Table 1. Risk Factors Caused by Facility and Weight Coefficients Dependent on Location.

Row	Risk Factor. F _i	Weight Coefficient Dependent on Location (WL _i)		
		Open Sea	Settlement Region	Sensitive Region
Factors Considering Operational Risk of the Facility				
1	Experience of crew at the port and of operators, A ₁	0	2	2
2	Crew sufficiency, A ₂	2	2	2
3	Condition of communication systems, A ₃	0	2	2
4	Condition of urgent intervention plans, A ₄	2	1	1
5	Condition of intervention tools to oil spill, A ₅	2	2	3
6	Accessibility to instalation, A ₆	1	2	3
7	Arriving frequency of ships, A ₇	1	1	1
8	Education condition of crew, A ₈	2	2	2
9	Ship traffic simulation, A ₉	2	1	3
10	Attitude of company at a dangerous situation, operational limits, A ₁₀	2	2	2
11	Maintenance period of the system, A ₁₁	2	2	2
12	Installation age, A ₁₂	1	1	1
13	Intervention beginning time, A ₁₃	2	2	2
Factors Considering Type and Amount of the Material				
14	Black oil transport, P ₁	2	2	3
15	White oil transport, P ₂	1	1	1
16	Metallic oil transport, P ₃	1	1	1
17	Number of oil tankers arriving to dock, P ₄	0	2	2
18	Maximum pumping capacity, P ₅	0	1	1
19	Tanker traffic in vicinity of the facility, P ₆	2	1	2
20	Oil generation plants in vicinity, P ₇	1	1	1
21	Length of oil pipe line belonging to facility, P ₈	1	1	1
22	Number of oil storage tanks in facility, P ₉	1	1	1
23	Automatic on off valves, P ₁₀	2	2	2
24	Accidents occurred in facility, P ₁₁	2	2	2

Values that risk factors caused by the facility will take are classed from 0 to 5 as below:

- 0: No risk for the corresponding factor,
- 1: Insignificant risk for the corresponding factor,
- 2: Poor risk for the corresponding factor,
- 3: Significant risk for the corresponding factor,

- 4: Heavy risk for the corresponding factor,
- 5: Maximum risk for the corresponding factor.

Explanation and values of risk factors are given in the tables below:

5.1.1.1. Experience of Crew and of Operators

Evaluation Criteria	Risk Factor Value, A ₁
Good and experienced	1
Good and inexperienced	2
Poor and experienced	3
Poor and inexperienced	4

5.1.1.2. Crew and Equipment Sufficiency

Evaluation Criteria	Risk Factor Value, A ₂
Sufficient	1
Insufficient	2
Unknown	3

5.1.1.3. Condition of Communication Systems

Evaluation Criteria	Risk Factor Value, A ₃
3 types of communication	1
2 types of communication	2
1 type of communication	3

Communication systems can be studied as wireless, mobile phone and telephone.

5.1.1.4. Condition of Urgent Intervention Plans

Evaluation Criteria	Risk Factor Value, A ₄
A+B+C+D	1
A+B+C, A+B+D	2
A+C, A+D	3
A	4
E	5

- A = Port has urgent intervention plan,
 B = It has regional urgent intervention plan,
 C = Usage probability of local opportunities,
 D = Usage probability of international opportunities,
 E = No urgent intervention plan.

5.1.1.5. Condition of Intervention to Oil Spill Tools

Evaluation Criteria	Risk Factor Value, A ₅
A+B, sufficient	1
A, sufficient	2
B, sufficient	3
A or B, insufficient	4
A + B, insufficient	5

A = Outfit for intervention to oil spill and sufficient staff member are available,

B = some outfit for intervention and staff as subcontractor are available.

5.1.1.6. Accessibility to Installation

Evaluation Criteria	Risk Factor Value, A ₆
Reachable from land by heavy vehicles	1
Reachable from land by light vehicles	2
Reachable only from sea	3
Reachable only from air	4

It is evaluated in terms of accessibility to the situation of the probable spill source.

5.1.1.7. Number of Arriving of Ships

AF = the number of arriving of ships.

Evaluation Criteria	Risk Factor Value, A ₇
AF ≤ 25	1
25 < AF ≤ 50	2
50 < AF ≤ 100	3
100 < AF ≤ 200	4
AF > 200	5

5.1.1.8. Education Condition of Staff

Evaluation Criteria	Risk Factor Value, A ₈
Good T1 + Good T2	1
Acceptable T2 + Good T1	2
Poor T2 + Good T1	2
Acceptable T1 + Acceptable T2	3
Poor T2 + Acceptable T1	4
Poor T1 + Poor T2	5

- T1 = Intervention education to first level spill,
 T2 = Intervention education to second level spill.

5.1.1.9. Ship Traffic Simulation

Evaluation Criteria	Risk Factor Value, A ₉
Iron/Windlass breakdown risk	1
Rope split risk	2
Dock/buoy damage	2
Grounding risk	3
Ramming risk	4
Collision risk	5

5.1.1.10. Attitude of the Company at Dangerous Situations, Operational Limits

Ev Evaluation Criteria	Risk Factor Value, A ₁₀
Company stops working at dangerous situations	0
Company continues working at dangerous situations	1

Dangerous situation is defined as the situation which might cause any spill;

- air conditions (strong wind and flow),
- busy sea traffic,
- terrorist threats.

5.1.1.11. Maintenance Period of the System

MP = the maintenance period of system.

Evaluation Criteria	Risk Factor Value, A ₁₁
MP ≤ 3 months	1
3 months < MP ≤ 6 months	2
6 months < MP ≤ 1 year	3
1 year < MP ≤ 2 years	4
MP > 2 years	5

5.1.1.12. Instillation Age

AI = the age of installation.

Evaluation Criteria	Risk Factor Value, A ₁₂
AI ≤ 5 years	0
5 years < AI ≤ 10 years	1
10 years < AI ≤ 15 years	2
15 years < AI ≤ 20 years	3
20 years < AI ≤ 25 years	4
AI > 25 years	5

5.1.1.13. Intervention Beginning Time

IT = beginning time of intervention.

Evaluation Criteria	Risk Factor Value, A ₁₃
IT ≤ ½ hour	0
½ hour < IT ≤ 1 hour	1
1 hour < IT ≤ 2 hours	2
2 hours < IT ≤ 3 hours	3
IT > 3 hours	5

5.1.1.14. Black Oil Transportation

AO = the amount of handling black oil.

Evaluation Criteria	Risk Factor Value, P ₁
AO = 0	0
AO ≤ 500 tones	1
500 tones < AO ≤ 1 000 tones	2
1 000 tones < AO ≤ 100 000 tones	3
100 000 tones < AO ≤ 500 000 tones	4
AO > 500 000 tones	5

5.1.1.15. White Oil Transportation

AW = the amount of handling white oil.

Evaluation Criteria	Risk Factor Value, P ₂
AW = 0	0
AW ≤ 500 tones	1
500 tones < AW ≤ 1 000 tones	2
1 000 tones < AW ≤ 100 000 tones	3
100 000 tones < AW ≤ 500 000 tones	4
AW > 500 000 tones	5

5.1.1.16. Metallic Oil Transport

MM = the amount of handling metallic oil.

Evaluation Criteria	Risk Factor Value, P ₃
MM = 0	0
MM ≤ 500 tones	1
500 tones < MM ≤ 1 000 tones	2
1 000 tones < MM ≤ 100 000 tones	3
100 000 tones < MM ≤ 500 000 tones	4
MM > 500 000 tones	5

5.1.1.17. Dock Traffic

TS = the number of oil tankers arriving to dock.

Evaluation Criteria	Risk Factor Value, P ₅
TS ≤ 10	1
10 < TS ≤ 100	2
100 < TS ≤ 500	3
500 < TS ≤ 1 000	4
TS > 1 000	5

5.1.1.18. Pumping Capacity

PK = the total pumping capacity in the facility.

Evaluation Criteria	Risk Factor Value, P ₅
PK ≤ 50 m ³ /hour	1
50 m ³ /hour < PK ≤ 250 m ³ /hour	2
250 m ³ /hour < PK ≤ 1 000 m ³ /hour	3
1000 m ³ /hour < PK ≤ 4 000 m ³ /hour	4
PK > 4 000 m ³ /hour	5

5.1.1.19. Tanker Traffic in Vicinity of The Facility

Evaluation Criteria	Risk Factor Value, P ₆
No tanker traffic in vicinity the facility	0
Tanker traffic in vicinity of the facility	1

5.1.1.20. Oil Generation Plants in Vicinity

OP = the number of oil generation plants in vicinity.

Evaluation Criteria	Risk Factor Value, P ₇
OP = 0	0
0 < OP ≤ 5	1
5 < OP ≤ 10	2
10 < OP ≤ 15	3
15 < OP ≤ 25	4
OP > 25	5

5.1.1.21. Length of Oil Pipe Line Belonging to Facility

PL_{Land} and PL_{Sea} = length of the oil pipe line at land and at open sea.

Evaluation Criteria	Risk Factor Value, P ₈
PL _{Land} = 0 m	0
PL _{Sea} = 0 m	0
PL _{Land} < 250 m	1
PL _{Sea} < 250 m	2
PL _{Land} < 250 m and PL _{Sea} < 250 m	2
PL _{Land} > 250 m	2
PL _{Land} > 250 m and PL _{Sea} < 250 m	3
PL _{Sea} > 250 m	4
PL _{Land} < 250 m and PL _{Sea} > 250 m	4
PL _{Land} > 250 m and PL _{Sea} > 250 m	5

5.1.1.22. Number of Oil Stocking Tanks in the Facility

OF = the number of oil tanks at shore.

Evaluation Criteria	Risk Factor Value, P ₉
OF = 0	0
OF = 1	1
OF = 2	2
OF = 3	3
OF = 4	4
OF ≥ 5	5

5.1.1.23. Presence of Automatic on-off Valves

Evaluation Criteria	Risk Factor Value, P ₁₀
A+B+C	1
A+B, A+C, B+C	2
A	3
B, C	4
None of them	5

A = Automatic on-off valve at loading point,
 B = Automatic on-off valve in the tank,
 C = Pipeline control on-off valve.

5.1.1.24. Accidents Occurred in Facility

Accident Intensity (AI) = Number of Accidents / Operation Time of Facility.

Evaluation Criteria	Risk Factor Value, P ₁₁
$0 \leq AI < 0.001$	1
$0.001 \leq AI < 0.01$	2
$0.01 < AI \leq 0.1$	3
$\leq AI$	4

5.1.2. Environmental Risks

In order to calculate the environmental risks, it is necessary to study the geological, ecological and socio-economical structure of the region. In this paper, it is assumed that shore facility is on the centre, each region of 20 kilometers of diameter is divided into circular strips of 1000 meters and risk assessments are carried out for coastlines and for sea areas in these circular strips. This distance is chosen by considering that oil spills move off during the day generally 15-20 kilometers. It is assumed that spills move by moving along the direction of the blowing wind with a velocity approximately at 3 % of the wind velocity and at 100 % of the surface flow. The distance of 20 kilometers is used. Maximum wind velocity in this area is assumed to be 10-15 knots.

The sum of the risk values in a strip cannot exceed maximum value of the corresponding risk factor, if it does; maximum value of the risk factor will be taken as the risk value.

Factors and their explanations belonging to environmental risks are given in Table 2 as below:

Table 2. Risk Factors and Comparative Weight Coefficients.

Row	Risk Factor, F _i	Weight Coefficient (W _{L_i})
Risk Factor of Coastline		
1	Coastal risk factors, RK ₁	1.00
Socio-Economical Risk Factors		
2	Settling, RED ₁	0.60
3	Tourism Areas, RED ₂	1.00
4	Archeological Areas, RED ₃	0.40
5	Industrial Plants, RED ₄	0.70
6	Fishing, RED ₅	1.00
7	Art Buildings, RED ₆	0.60
8	Accessibility to Coastline, RED ₇	1.00
Biological and Ecological Risk Factors		
9	Naval Biological Variety, RED ₈	1.00
10	Birds, RED ₉	1.00
11	Declared Areas of Private Status, RED ₁₀	1.00

5.1.2.1. Coastal Risk Factors

At indicating the risk factors of coastline, Environmental Sensitivity Index (ESI) [15] is taken as essential. Coastal risk factors are expressed with the values between 1 and 11 with respect to the structure of coastline; these values are given in Table 3 as below:

Table 3. Coastal Risk Factors.

Row	Shore Composition	Risk Factor Value RK _i
1	Cliff and steep rocks	1
2a	Rocks on surface	2
2b	Dock on a pile	3
3	Shore with sand of mid-fine thickness	4
4	Shore with sand of thick thickness	5
5	Art buildings	6
6	Shore with a mixture of sand and grit	7
7	Shore with a mixture of grit and stone	8
8	Shore with big stones	9
9	Tide area	10
10	Reed beds	11

5.1.2.2. Settlements

PS = the population of settlements;

Evaluation Criteria	Risk Factor Value, RED ₁
$0 < PS < 100$	0
$100 \leq PS < 500$	1
$500 \leq PS < 2\,000$	2
$2\,000 \leq PS < 5\,000$	3
$5\,000 \leq PS < 10\,000$	4
$PS \geq 10\,000$	5

5.1.2.3. Tourism Areas

Evaluation Criteria	Risk Factor Value, RED ₂
Not Available	0
A+C+E, G	1
A+C+F, B+C+E	2
A+D+E, B+C+F	3
A+D+F, B+D+E	4
B+D+F	5

A: The facility is in the Marmara or in the Black Sea region (less desired sea areas),

B: The facility is in the Aegean or in the Mediterranean region (more sea area),

C: Has 3 stars or less,

D: Has 3 stars or more,

E: Has 100 beds or less,

F: Has 100 beds or more,

G: Beaches, parks and recreation areas.

5.1.2.4. Archeological Areas

Evaluation Criteria	Risk Factor Value, RED ₃
None of them	0
A	1
A+C	2
B	3
B+C	4
A+B+C	5

A: Archeological areas are on the coast

B: Archeological areas are on the sea

C: Museum area

5.1.2.5. Industrial Plants

Evaluation Criteria	Risk Factor Value, RED ₄
Not Available	0
A	1
B	2
C, A+B	3
A+C, B+C	4
A+B+C	5

A: Industrial plants on the coast that do not use sea as direct or indirect source,

B: Industrial plants that use sea as indirect source: Factories that make transportation by their docks, depots, production and martial plants,

C: Industrial plants that use sea as direct source: Shipyards, electric generation plants etc.

5.1.2.6. Fishing

Evaluation Criteria	Risk Factor Value, RED ₅
Not Available	0
A	1
B	2
C	3
A+C, B+C	4
A+B+C	5

A: Small fishing activities (fishhook, sportive fishing, small boats),

B: Hunting ground, bigger fishing activities (trawl, larger grounds),

C: Fish farms.

5.1.2.7. Art Buildings

Evaluation Criteria	Risk Factor Value, RED ₆
Not Available	0
A	1
B	2
C	3
D	4
E	5

A: Slipway ground; coastal structure which allows fishing boats and small tonnage boats to be grounded for their maintenance and repair jobs, which has right equipment and which has a sandy or concreted inclined area for repair jobs,

B: Emergency port; coastal structure without any major substructure and superstructure where fishing boats at any length and at any waterline can take shelter in, in order to avoid bad weather conditions,

C: Fisher port; coastal structure protected by breakwaters to serve fishing boats at any length and at any waterline; which possesses a dry dock and a backyard for local fishers' needs; loading - unloading areas and tying docks; water, electricity, net drying field, market place, administration; fuel pumps, preliminary cooling system and a slipway for demands of the fishing boats,

D: Yacht dock; tourism certificated coastal structure protected from wind and sea effects, which provides a secure tying and a direct walking way onto the yachts; which also

offers technical and social substructure, administration, supporting, maintenance and repair services,

E: Dock; coastal structure naturally or artificially protected from wind and sea effects, and also convenient for the ships' boarding – disembarkation, loading – unloading, tying and waiting.

5.1.2.8. Accessibility to Coastline

Evaluation Criteria	Risk Factor Value, RED ₇
Reachable from land by heavy vehicles	0
Reachable from land by light vehicles	1
Reachable only from sea	2
Reachable only from air	3

5.1.2.9. Naval Biological Variation

Evaluation Criteria	Risk Factor Value, RED ₈
Not available	0
A, B, C, D, E, F, G, ID	1
Presence of any two classes	2
Presence of any three classes	3
Presence of any four classes	4
Presence of any five classes	5
Presence of any six classes	6
Presence of all classes together, H	7

A: Turtle, B: Dolphin,

C: Seal, D: Fish,

E: Mollusks, F: Shrimp,

G: Sponge, H: Endemic species,

ID=Insufficient data, it is assumed that only one class is present.

5.1.2.10. Bird Species

Evaluation Criteria	Risk Factor Value, RED ₉
Not Available	0
A	1
B	2
C, A+B	3
B+C, A+C	4
A+B+C, D	5

A: Local species

B: Migrant species

C: Extinct species

D: Endemic species

5.1.2.11. Declared Areas of Private Status

Evaluation Criteria	Risk Factor Value, RED ₁₀
Not available	0
A, B, C, D, E	1
Presence of any two classes	2
Presence of any three classes	3
Presence of any four classes	4
Presence of any five classes	5

A = RAMSAR [15] / Wet Lands,

B = Private Environmental Protective Areas,

C = National Parks,

D = Hunting, Wild Life Fields,

E = Other Areas of Private Status.

5.2. Method of Calculating Risk Value

5.2.1. Calculation of Risk Caused by Coastal Facility

Coastal facility risk caused by materials ($R_{material}$) is worked out by the product of the risk factor value and the weight coefficients depending on location of the facility,

A_i = Risk factor value caused by material
 WL_i = Weight coefficient depending on location

$$R_{material} = \sum_{i=1}^{13} A_i \cdot WL_i \quad (5.1)$$

Coastal facility risk caused by enterprise ($R_{enterprise}$), is worked out by the product of the risk factor value and the weight coefficients depending on location of the facility,

P_j = Risk factor value caused by enterprise
 WL_j = Weight coefficient depending on location

$$R_{enterprise} = \sum_{j=1}^9 P_j \cdot WL_j \quad (5.2)$$

Maximum risk constant value (N_F), is worked out by the sum of the products of the weight coefficients depending on maximum location and maximum value of each risk factor;

$A_{i\ max}$ = Maximum value of the risk factor caused by material,

$P_{j\ max}$ = Maximum value of the risk factor caused by enterprise,

N_F = Maximum risk constant;

$$N_F = \sum_{i=1}^{13} A_{i\ max} \cdot WL_i + \sum_{j=1}^9 P_{j\ max} \cdot WL_j = 167 \quad (5.3)$$

On the other hand, total risk or probability caused by coastal facility ($R_{facility}$) is equivalent to the normalization of the sum of material risks ($R_{material}$) and maximum risk constant (N_F),

$$R_{facility} = (R_{enterprise} + R_{material}) / N_F \quad (5.4)$$

5.2.2. Calculation of Environmental Risk

Assuming that shore facility is on the centre, each region with 20 kilometers of diameter is divided into circular strips of 1 000 meters and risk assessments are carried out for coastlines and for sea areas in these circular strips.

When working out environmental risk values, each strip is firstly evaluated on itself and then one risk value that represents the entire coastline is calculated.

Environmental risk factors are differed in every strip in terms of length as well as classification of coast. For this

$$R_{environmental} = \left(\sum_{i=1}^p RV_{total, i} \cdot LD_{total, i} \cdot A_{strip\ influence, i} \right) / \left(\sum_{i=1}^p LD_{total, i} \cdot A_{strip\ influence, i} \right) \quad (5.8)$$

5.2.3. Influence of Total Coastline Length of Facility Effect Area on Risk

Coastline length between circular strips is different for

reason when studying the coastal risk factors, the risk value is worked out by considering the weight averages of the coast class distances in the strip,

$RK_{k, i}$ = value of k^{th} coastal risk factor of i^{th} strip
 LK_k = coastline length of k^{th} coastal risk factor in the strip
 $LD_{total, i}$ = total length of coastline on i^{th} strip
 M = total number of coastal risk value on i^{th} strip
 $RKV_{i,}$ = coastal risk factor value of the corresponding strip;

$$RKV_i = \left(\sum_{k=1}^m RK_{k, i} \cdot LK_k \right) / LD_{total, i} \quad (5.5)$$

At this point, environmental risk values except coastal risk value (REV_i) have to be picked from corresponding tables.

According to the importance rate of each environmental risk factor, a weight coefficient (EA_i) is determined,

Maximum environmental and coastal risk factor at any i^{th} strip, $EA_{total, i}$ is worked out as below;

$$EA_{total, i} = EA_{coastal} \cdot RKV_{maximum} + \sum_{i=1}^n EA_i \cdot REV_{maximum, i} \quad (5.6)$$

n = total number of environmental risk factors at i^{th} strip,

Total risk value at i^{th} strip $RV_{total, i}$ is worked out as below;

$$RV_{total, i} = (RKV_i \cdot EA_i + \sum_{i=1}^n REV_i \cdot EA_i) / EA_{total, i} \quad (5.7)$$

Total coastline length of each strip ($LD_{total, i}$) will be different from another, Strips with longer coastlines are riskier than the ones with short coastlines. For this reason, total coastline length of i^{th} strip ($LD_{total, i}$) must be included into risk evaluation.

Because probable source of contamination is assumed to be the center, more distant from this point more risk value would reduce. Therefore, to continue the evaluation, strip influence weight coefficient ($A_{strip\ influence, i}$) must be used. Strip influence weight coefficients are indicated according to Table 4.

Table 4. Strip Numbers and Strip Influences.

Strip Number	±10	±9	±8	±7	±6	±5	±4	±3	±2	±1
$A_{strip\ influence}$	0.3	0.3	0.3	0.5	0.5	0.5	0.7	0.7	1	1

Environmental risk ($R_{environmental}$) value or probability is worked out as below,

each facility with respect to geographic factors. While coastline length and distance inside strip are approximately equivalent for rough coastlines, coastline length increases for

the opposing situations, If the corresponding facility is situated on a geography which has less than 5 kilometers between its two coasts, total coastline length to evaluate may increase up to 100 kilometers as there is the risk that spill might reach the opposite coast.

Therefore, influence of total coastline length of the facility on risk is fairly high. Larger effect area of a facility, more the risk value will increase.

Minimum value of total coastline length (LD_{minimum}), is 20 kilometers which is the total length of a smooth coastline. This situation has no effect on risk.

Maximum value of total coastline length (LD_{maximum}) is assumed to be 100 kilometers. Thus, total risk is predicted to increase of 30% and this value is at the same time equal to 130% of maximum value of total coastline influence coefficient ($A_{LK_{\text{maximum}}}$).

Even if total coastline length is upper than maximum value, increase of the risk value will be equivalent to maximum increase.

Increase of coastline influence coefficient (A_{LK}) is predicted to be linear at the time when coastline lengths are between minimum and maximum values, Provided that total coastline length of facility effect area (LD_{total}) is in kilometers, coastline influence coefficient (A_{LK}) is worked out as below;

$$A_{LK} = 0.00375 \cdot LD_{\text{total}} + 0.925 \quad (5.9)$$

5.2.4. Calculation of Spill Risk

Risk factors caused by facility and environmental risk factors are the values which would not vary in short periods, However, spill risk is rather more variable because of tanker traffic of the facility, Maximum waste amount that would spill is proportional to transferring load, Under these circumstances, high capacity tankers have higher spill risk. If total product arriving to the facility between intervals of time is studied, a curve of oscillation would be observed, then, spill risk varies as well, and spill risk can be determined as three values: maximum, average and minimum,

L_i = transferring load by i_{th} ship (tones)

N = total tanker number;

Average transferring load (L_{average}) is worked out as below:

$$L_{\text{average}} = \sum_{i=1}^N L_i / N \quad (5.10)$$

From the column of ‘‘Transferring Load’’ in Table 5 which gives probable waste spill and risk factor value, amount which comes as against calculated L_{average} is picked, From hence, value in the column of ‘‘Risk Factor Value (RV)’’ is determined. Average spill risk value ($R_{\text{spill, average}}$) is equivalent to the risk factor value (RV),

$$R_{\text{spill, average}} = RV \quad (5.11)$$

Table 5. Probable Waste Spills and Risk Factor Values.

Transferring Amount, M_{tonnage} (tonnes)	Designation of Spill	Risk Factor Value, RV
$M_{\text{tonnage}} > 100\,000$	Very severe catastrophe	12
$70\,000 < M_{\text{tonnage}} \leq 100\,000$	Severe catastrophe	11
$50\,000 < M_{\text{tonnage}} \leq 70\,000$	Serious catastrophe	10
$30\,000 < M_{\text{tonnage}} \leq 50\,000$	Catastrophe	9
$20\,000 < M_{\text{tonnage}} \leq 30\,000$	Very severe disaster	8
$10\,000 < M_{\text{tonnage}} \leq 20\,000$	Severe disaster	7
$5\,000 < M_{\text{tonnage}} \leq 10\,000$	Serious disaster	6
$3\,000 < M_{\text{tonnage}} \leq 5\,000$	Disaster	5
$2\,000 < M_{\text{tonnage}} \leq 3\,000$	Very severe spill	4
$1\,000 < M_{\text{tonnage}} \leq 2\,000$	Severe spill	3
$500 < M_{\text{tonnage}} \leq 1\,000$	Serious spill	2
$0 < M_{\text{tonnage}} \leq 500$	Minor spill	1
0	Insignificant spill	0

Values above being valid for open sea, risk is increased one level up at settling areas and at sensitive zones.

After having determined average value of the transferring load, standard deviation of the transferring load (σ) would be defined in terms of transferring load (L_i), average transferring load (L_{average}) and tanker number (N) as:

$$\sigma = \sqrt{\left[\sum_{i=1}^N (L_i - L_{\text{average}})^2 \right] / N} \quad (5.12)$$

If standard deviation of transferring load (σ) and average transferring load (L_{average}) are summed up, maximum transferring load (L_{maximum}); if these two are subtracted, minimum transferring load (L_{minimum}) would be obtained,

$$M_{\text{maximum}} = M_{\text{average}} + \sigma. \quad (5.13)$$

$$M_{\text{minimum}} = M_{\text{average}} - \sigma. \quad (5.14)$$

Afterwards, risk factor values which come up against M_{maximum} and M_{minimum} are picked from Table 5. In this way, maximum and minimum spill risks ($R_{\text{spill, maximum}}$ and $R_{\text{spill, minimum}}$) are worked out;

$$R_{\text{spill, maximum}} = RL_{\text{maximum}} \quad (5.15)$$

$$R_{\text{spill, minimum}} = RL_{\text{minimum}} \quad (5.16)$$

Under the case that RL_{maximum} and RL_{minimum} are equivalent, average value (RL) is used in calculations.

5.2.5. Final Risk Calculation

Final risk value concerning a facility (Risk) is obtained by the multiplication of risk value caused by shore facility (R_{facility}), environmental risk value ($R_{\text{environmental}}$) and total coastline influence coefficient (A_{LK}). This risk value determines risk or probability which comes up against unit spill risk.

At this condition, probability or risk value coming up against unit spill force becomes in the table with 12 steps;

$$\text{Risk} = (0.9 \cdot R_{\text{facility}} + 0.1 \cdot R_{\text{environmental}}) \cdot 12 \quad (5.17)$$

Under the condition that Risk exceeds maximum possible value which is 12, risk will be assumed to be equivalent to

the maximum value. Designation and probabilities of these values are given in Table 6.

Since spill risk value possesses maximum, average and minimum value, final risk value concerning the shore facility will be between an interval depending on spill risk value. As spill risk value approaches to maximum, final risk value will proportionally increase. Minimum spill risk will similarly decrease the final risk value.

At this condition, final risk value ($Risk_{final}$) is worked out in the table with 144 steps as below;

$$Risk_{final, maximum} = Risk R_{spill, maximum} \quad (5.18)$$

$$Risk_{final, average} = Risk R_{spill, average} \quad (5.19)$$

$$Risk_{final, minimum} = Risk R_{spill, minimum} \quad (5.20)$$

Final risk value for the facility is indicated in the interval of;

$$Risk_{final, minimum} < Risk_{final, average} < Risk_{final, maximum} \quad (5.21)$$

Table 6. Designation of Risk and Probability Relation.

Risk Level or Probability Level (Risk)	Designations	Probability Range, Pr
1	Extremely remote	$Pr \leq 10^{-6}/\text{years}$
2	Remote	$10^{-6}/\text{years} < Pr \leq 10^{-5}/\text{years}$
3	Very rare	$10^{-5}/\text{years} < Pr \leq 10^{-4}/\text{years}$
4	Rare	$10^{-4}/\text{years} < Pr \leq 10^{-3}/\text{years}$
5	Low	$10^{-3}/\text{years} < Pr \leq 10^{-2}/\text{years}$
6	Possible	$10^{-2}/\text{years} < Pr \leq 0.02/\text{years}$
7	Moderate	$0.02/\text{years} < Pr \leq 10^{-1}/\text{years}$
8	Reasonably probable	$10^{-1}/\text{years} < Pr \leq 0.2/\text{years}$
9	Quite frequent	$0.2/\text{years} < Pr \leq 1/\text{years}$
10	Frequent	$1/\text{years} < Pr \leq 2/\text{years}$
11	Regular	$2/\text{years} < Pr \leq 10/\text{years}$
12	Very frequent	$Pr > 10/\text{years}$

For this calculation; the risk becomes,

$$0 \leq Risk_{final} \leq 144. \quad (5.22)$$

If 20% of this value is evaluated; it becomes,

$$0 \leq Risk_{final} < 24. \quad (5.23)$$

Its probability can be worked out from Table 8.

Another situation is either between 20% and 35% or

$$24 \leq Risk_{final} < 42. \quad (5.24)$$

In this situation, it is necessary to be ready for an unwanted incident; to revise the intervention equipment, to follow the incoming ships and to arrange the staff education.

Unacceptable risk situation is;

$$42 \leq Risk_{final} \quad (5.25)$$

In this situation, handling material and equipment condition need to be studied in detail.

5.3. Risk Analysis for an Oil Company Terminal Terminal for Sea Spills

An oil company is located close to shore in the borders of a coast line. Since oil products are handled in the facility, there is a high risk of oil contamination. As indicated in the previous sections of this supplemental, environmental risks are studied such as operational risks of the facility, type of the transferring material, risks caused by its amount and risks which appear after having studied the geological, ecological and socio-economical situation of the region. Risk values caused by the facility and by the material are as given in Table 7. The values about environmental risk values pointed are summarized in Table 8.

All risk values belonging to an oil company terminal given in Table 9. According to this table, total risk caused by the coast facility is calculated as $R_{facility} = 0.39$.

Table 7. Risk Value Caused by Operation and Material.

Row	Risk Factor, F_i	Designations	Risk Value
Factors Considering Operational Risk of the Facility			
1	Experience of crew at the port and of operators, A_1	Good and experienced	2
2	Crew sufficiency, A_2	Sufficient	2
3	Condition of communication systems, A_3	3 kinds of communication	2
4	Condition of urgent intervention plans, A_4	A+C, A+D	3
5	Condition of intervention tools to oil spill, A_5	A or B, insufficient	8
6	Accessibility to installation, A_6	Accessible from land by heavy vehicles	2
7	Arriving frequency of ships, A_7	$2 < AF \leq 4$	3
8	Education condition of crew, A_8	Acceptable T2 + Good T1	4

Row	Risk Factor, F_i	Designations	Risk Value
9	Ship traffic simulation, A_9	Grounding risk	6
10	Attitude of the company at dangerous situations, operational limits, A_{10}	The company stops working at dangerous situations	0
11	Maintenance period of the system, A_{11}	6 months < MP ≤ 1 year	6
12	Instalation age, A_{12}	10 years < AI ≤ 20 years	2
13	Intervention beginning time, A_{13}	1 hour < IT ≤ 2 hours	4
Factors Considering Type and Amount of the Material			
14	Black oil transport, P_1	AO = 0	0
15	White oil transport, P_2	100000 tones < AO ≤ 500000 tones	4
16	Metallic oil transport, P_3	MM = 0	0
17	Number of oil tankers arriving to dock, P_4	10 < TS ≤ 100	4
18	Maximum pumping capacity, P_5	250 m ³ /hour < PK ≤ 1000 m ³ /hour	3
19	Tanker traffic in vicinity of the facility, P_6	Tanker traffic in the vicinity of the facility	2
20	Oil generation plants in vicinity, P_7	0 < OP ≤ 5	1
21	Length of oil pipe line belonging to facility, P_8	PL _{Land} < 250 m and PL _{Sea} > 250 m	4
22	Number of oil storage tanks in the facility, P_9	5 ≤ TS	5
23	Automatic on off valves, P_{10}	A + B, A + C, B + C	4
24	Accidents occurred in the facility, P_{11}	0,001 ≤ KY < 0,01	4

Table 8. Environmental Risk Values.

Risk Factors	Maximum Risk Factor Value	Weight Coefficients, WLi	Strip Number																				
			10	9	8	7	6	5	4	3	2	1	-1	-2	-3	-4	-5	-5	-7	-8	-9	-10	
Risk Factor of the Coastline																							
Coastal Risk Factors. RK1	11.00	1.00	5.39	8.9	6.4	5.9	4.1	7.5	8.0	4.4	4.3	7.2	7.4	7.8	7.5	8.6	7.7	7.5	6.2	7.2	7.3	6.2	
Socio-Economical Risk Factors																							
Settling. RED1	5.00	0.60	0	0	0	3	3	5	5	0	0	0	0	0	5	5	5	5	5	0	0	0	
Touristic Areas. RED2	5.00	1.00	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	1	
Archeological Areas, RED3	5.00	4.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Industrial Plants, RED4	5.00	0.70	0	2	2	2	2	0	0	0	2	2	2	2	2	0	0	0	0	0	0	0	
Fishing, RED5	5.00	1.00	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Art Buildings, RED6	5.00	0.60	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	
Accessibility to the Coastline, RED7	3.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Biological and Ecological Risk Factors																							
Naval Biological Variety. RED8	8.00	1.00	3	3	3	3	2	2	2	1	1	1	1	1	1	2	2	4	3	3	3	3	
Bird, RED9	5.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	
Declared Areas of Private Status RFD10	5.00	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Risk Value in the Strip. RVtotal.i			0.22	0.2	0.2	0.2	3.2	0.2	0.2	0.1	0.1	0.1	3.1	0.1	0.2	0.3	0.2	3.2	0.2	0.1	0.2	0.2	
Strip Influence Weight Coefficient (Astrip influence,i)			0.3	0.3	0.3	0.5	0.5	0.5	0.7	0.7	1	1	1	1	0.7	0.7	0.5	0.5	0.5	0.3	0.3	0.3	
Strip Coastline Length (LK _i)			1.13	2.6	2.7	2.5	2.7	1.0	1.1	1.3	1.4	1.5	1.0	3.5	5.8	1.8	1.3	1.3	1.4	1.3	1.6	1.2	
Environmental Risk (R _{environmental})			0.23	7	6	8	5	7	2	2	3	9	8	5	5	7	2	3	3				

Finally, $R_{\text{environmental}} = 0.23$ and $A_{LK} = 1.07$ are obtained.

Table 9. Risk Values.

Row	Risk	Risk Value
1	Total risk caused by coast facility (R_{facility})	0.40
2	Environmental risk ($R_{\text{environmental}}$)	0.23
3	Coastline influence coefficient (A_{LK})	1.07
4a	Maximum spill risk ($R_{\text{spill, maximum}}$)	5.00
4b	Average spill risk ($R_{\text{spill, average}}$)	5.00
4c	Minimum spill risk ($R_{\text{spill, minimum}}$)	4.00
5	$(0.9 R_{\text{facility}} + 0.1 R_{\text{environmental}}) A_{LK}$	4.87
6a	Maximum final risk ($R_{\text{risk final, maximum}}$)	24.37
6b	Average final risk ($R_{\text{risk final, average}}$)	24.37
6c	Minimum final risk ($R_{\text{risk final, minimum}}$)	19.50

Using the above values;

Probability which comes up against unit spill force or risk value (Risk) is worked out in the table with 12 steps as

Risk = 4.79 .

This is the probability of a spill, Table 8.

Final risk varies from 19.59 to 24.37. This is an acceptable risk value. However;

- It is necessary to take particular cautions for big tankers,
- It is necessary to develop the staff education,
- It is necessary to keep the intervention equipments in good condition and sufficient,
- It is necessary to take essential cautions and to make the appropriate agreements for Tier 2.

5.4. Coast Classification Under the Influence Area of an Oil Terminal

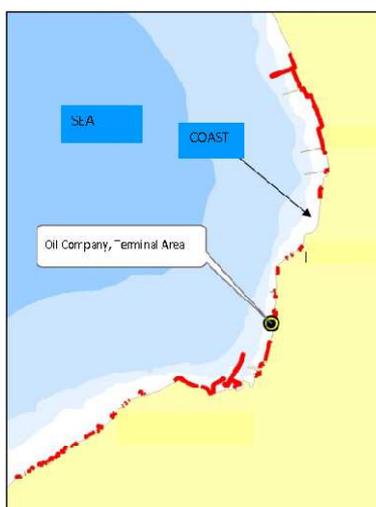
As shore areas vary between themselves, they are all influenced in several different ways in the contaminations caused by oil and oil products. For this reason, shore areas are classified according to their influence from contamination. This classification is called “Coastline Sensitivity Determination”. While making this determination; geomorphologic composition of the coast, coast ecology, settling, industry and location of tourism facilities are taken into consideration.

In order to determine the coastline sensitivity, defined risk factors are listed in Table 10 as below:

Table 10. Risk Factors in Coastline Sensitivity.

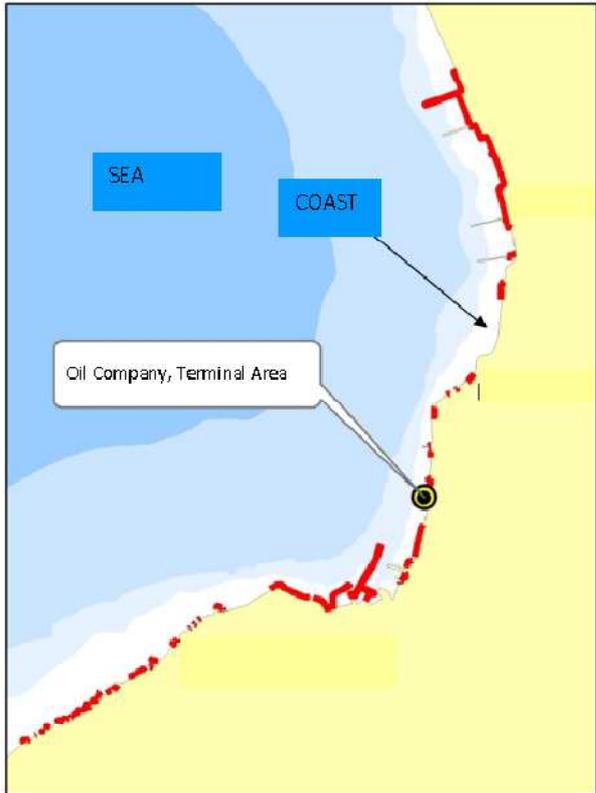
Coastal Risk Factors		Socio – Economical Risk Factors	Biological and Ecological Risk Factors
Shore Index	Shore Type		
1	Cliff and steep rocks	Settling	Fish
2a	Rocks on the surface	Tourism Areas	
2b	Dock on a pile	Archeological Areas	Birds
3	Shore with sand of mid-fine thickness	Industrial Plants	
4	Shore with sand of thick thickness		
5	Art buildings	Fishing	Other Biological Living (turtle, seal, dolphin)
6	Shore with a mixture of sand and grit		
7	Shore with a mixture of grit and stone	Art Buildings	Declared Areas of Private Status (RAMSAR area, private environmental protective area, national parks, hunting-wild life protective areas, other areas of private status)
8	Shore with big stones		

The maps according to the shore classification studies as well as the details about the studies which remain inside the influence area of an oil terminal installation and which are obtained according to the Environmental Sensitivity Index (ESI) [16] are given in the tables below:



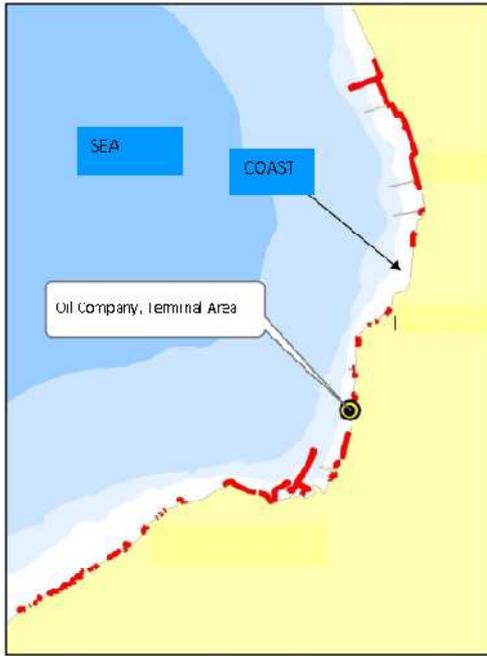
ESI 1. Cliff and Steep Rocks.

In general, there is not any possibility of access to the coastline from cliff and steep rocks. Beneath the steep rocks, in general there lie mixed sediment and a shore of grit and stone. There is a large variety and density of genres, although typical organisms such as mussels, whelks, sea algae and lichens live on the rocky shores; the number of genres on the shore is less. As rock surfaces are not smooth, small puddles resulting from tides can be seen. Typical organisms such as crustaceans, whelks, lichens and even sea algae live.



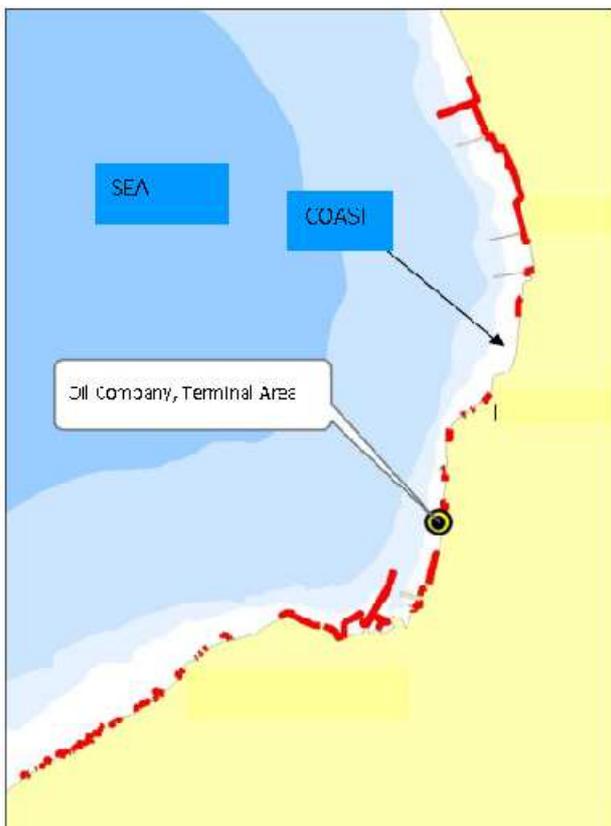
ESI 2a. Rocks on the Surface.

Most of the coastlines of this kind are only accessible from land. In the tide area, local rocks on the surface are dominant. This type of coastline also includes volcanic blackstones and big stone pieces are seen on the shore. At high from the coastline, sandy coasts or of sand and grit can be observed. As rock surfaces are not smooth, small puddles resulting from tides can be seen. Typical organisms such as crustaceans, whelks, lichens and even sea algae live.



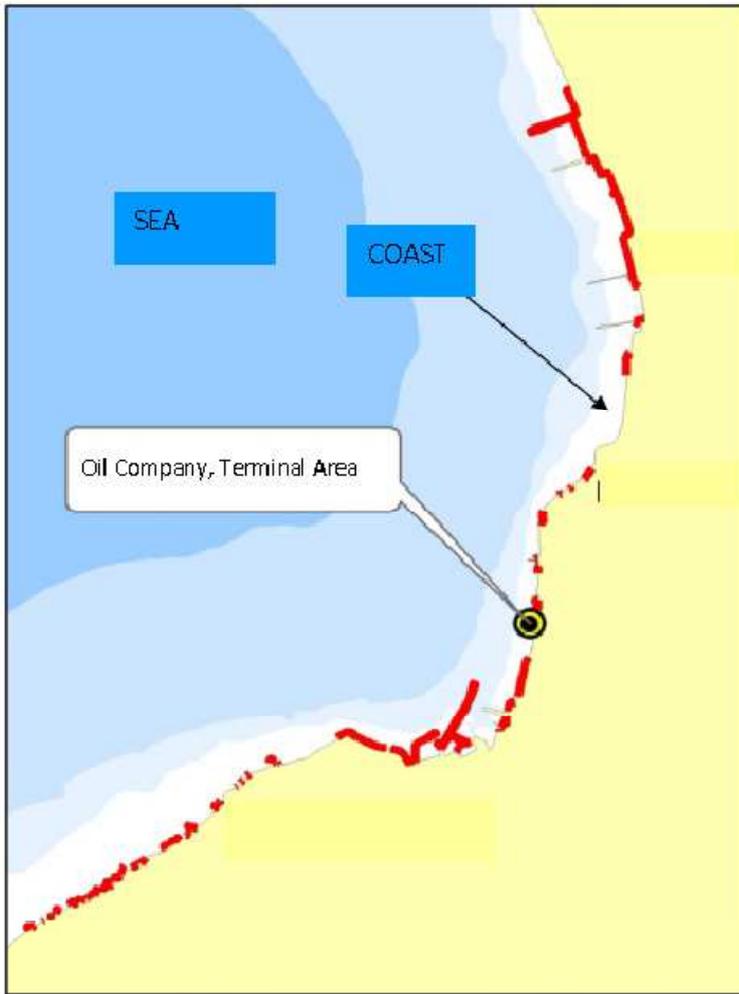
ESI 2b. Dock on a Pile.

These are the staging structures built on concrete or steel piles. Piles largely exposed to oil are placed perpendicularly or close to perpendicular. Organisms such as algae which hold on piles are observed, however these plants and organisms are rare where the sea is wavier. Docks are rather located in the industrial areas.



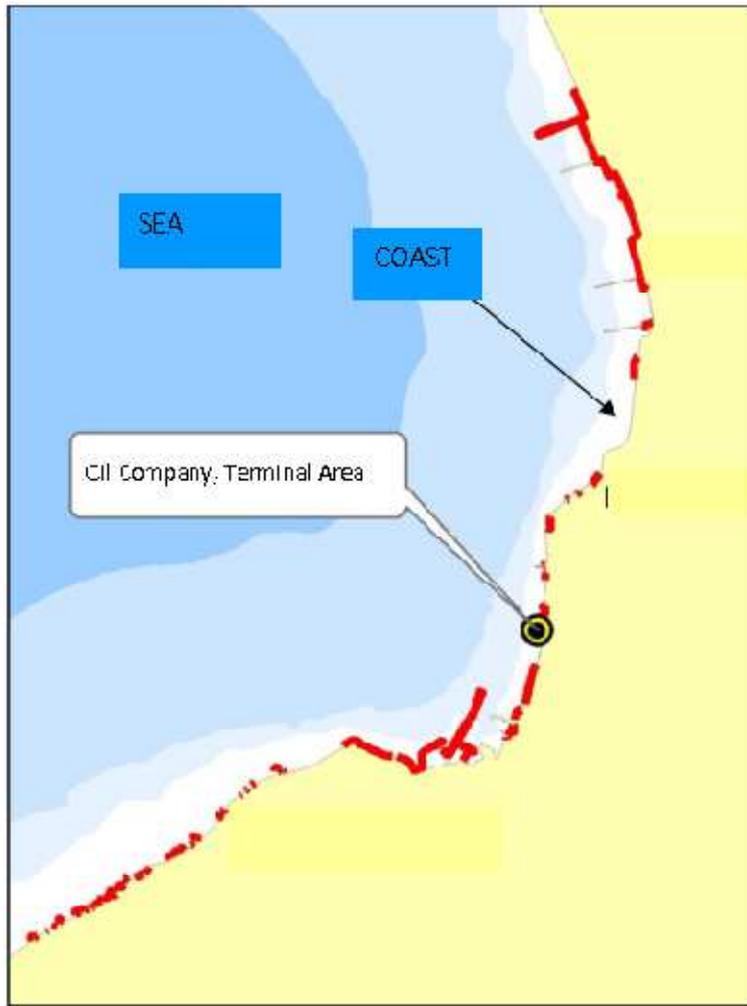
ESI 3. Shore with sand of mid-fine thickness.

A few amount of grit or sea shell might have been mixed with sand. Stranded sea algae and plastic sediments can be seen. In certain zones, ovulation and nutrition areas of birds and of turtles are present. Shore fauna being rare, crabs are observed on some of the shores. Generally, plant cover is common on sand hills, since the shore is densely sandy, vehicles except ones with 4 tires should not be used.



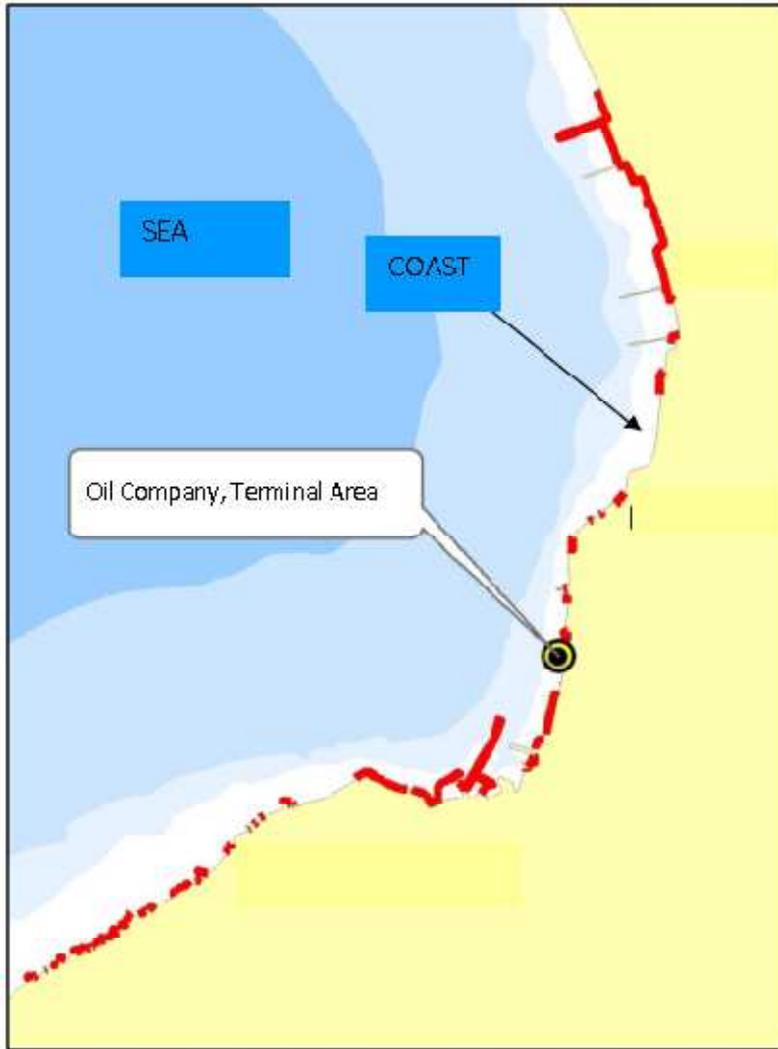
ESI 4. Shore with sand of thick thickness.

These shores are lightly inclined, having soft layers and they do not enable the vehicles to operate. It also includes uncommon organisms such as crabs and scallops.



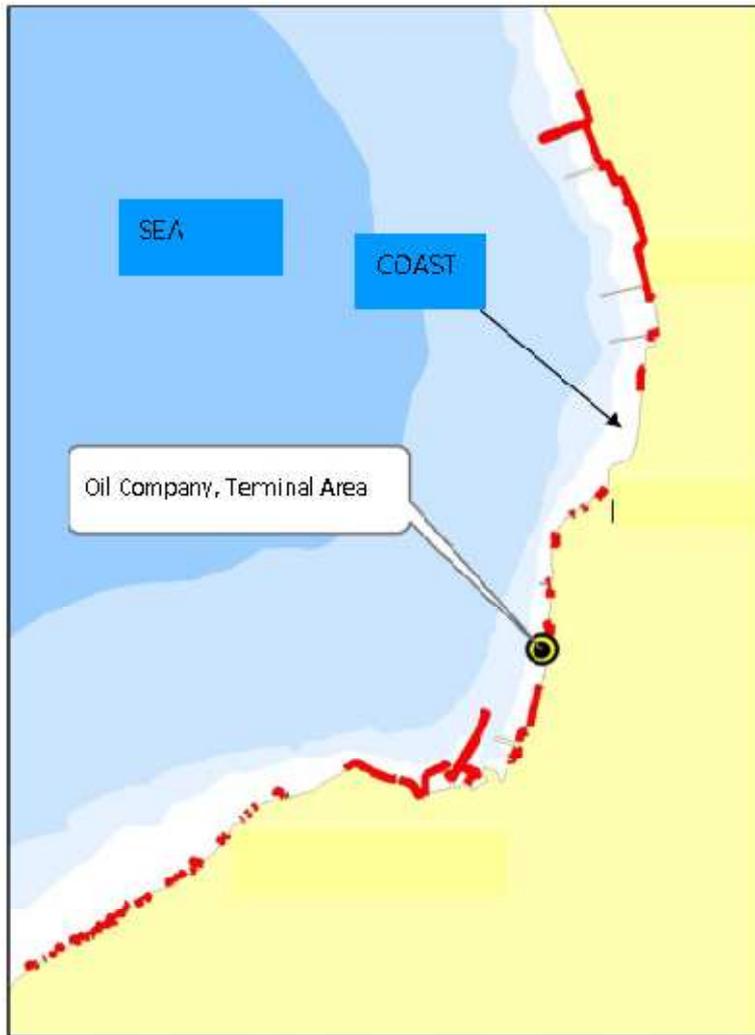
ESI 5. Art buildings.

Constitutions such as breakwater and sheathing are generally built of stone and concrete to protect the dock and shoreline. On the sides of the breakwater facing the sea; sand, sand with grit and grit are observed. Crustaceans, whelks, lichens and sea algae can be seen on the breakwaters in tide areas, In case of an oil spill, it is necessary to take cautions as these areas are socio-economically important.



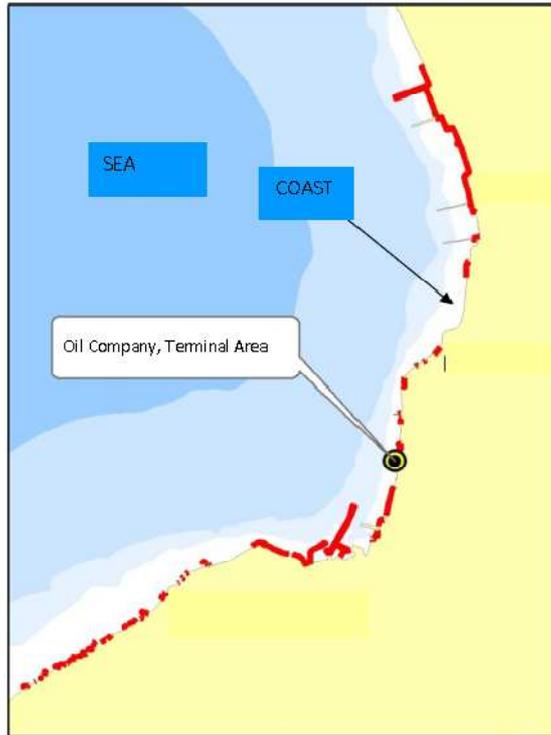
ESI 6. Shore with a mixture of sand and grit.

Shores of this type are partly inclined. Tide zone is formed of the mixture of sand and grit. Depending on sediment growth sand, grit or curbstones are present especially in upper tide zone. Small numbers of vegetables and of animals are encountered.



ESI 7. Shore with a mixture of grit and stone.

These are the sediments formed of a mixture of grit, stone and unattached. They could be found as a range of mountains close together. Organisms such as snails and mussels as well as algae, which are held at lower areas of the shore where the sediment is decisive, are encountered.



ESI 8. Shore with big stones.

Shores with big stones are formed of massive blocks made of concrete or limestone and in general, are used for shore, dock protection and to consolidate the docks. As these areas are important from a socio-economical view, it is necessary to take good care of its cleaning in case of an oil spill. As a consequence of pulling back of the sea after tide, sea algae, mussels and other crustaceans are observed.

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