MANAGEMENT STRATEGIES TO PROTECT COASTAL AREAS FROM OIL-POLLUTED SEAWATER (A CASE STUDY OF COASTAL AREAS IN BEKASI REGENCY)

Disusun dan diajukan oleh

PRAMADANIA AGUSTINE
P022191017

PROGRAM STUDI PERENCANAAN DAN PENGEMBANGAN WILAYAH
SEKOLAH PASCASARJANA
UNIVERSITAS HASANUDDIN
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MANAGEMENT STRATEGIES TO PROTECT COASTAL AREAS FROM OIL-POLLUTED SEAWATER (A CASE STUDY OF COASTAL AREAS IN BEKASI REGENCY)

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PRAMADANIA AGUSTINE
P022191017

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LEMBAR PENGESAHAN TESIS

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Telah di pertahankan di hadapan Panitia Ujian yang dibentuk dalam rangka Penyelesaian Studi Program Studi Perencanaan dan Pengembangan Wilayah Sekolah Pascasarjana Universitas Hasanuddin

Pada tanggal 9 September 2021
dan dinyatakan telah memenuhi Syarat kelulusan

Menyetujui,

Pembimbing Utama	Pembimbing Pendamping
Prof. Dr. -Ing. Herman Parung, M.Eng	Emer. Prof. Patricia Dale
Nip.196207291987031001	

Ketua Program Studi. Perencanaan dan Pengembangan Wilayah	Dekan Sekolah Pascasarjana Universitas Hasanuddin
Prof. Dr. Ir. Ahmad Munir, M.Eng	Prof. Dr. Ir. Jamaluddin Jompa, M.Sc
Nip.196207271989031003	Nip.19670308 1990031001

PERNYATAAN KEASLIAN TESIS

Yang bertanda tangan di bawah ini:

Nama	: Pramadania Agustine
Nomor Mahasiswa	: P022191017
Program Studi	: Perencanaan dan Pengembangan Wilayah

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Makassar, 9 September 2021

Yang Menyatakan

Pramadania Agustine

FOREWORD

Bismillaahirrahmaanirraahim

Alhamdulillaahi rabbil ‘aalamin

First of all, I would like to thank my supervisors, Prof. Herman Parung, Prof Patricia Dale, Prof Chris Frid and Dr Peter Davey, for their guidance and constructive feedbacks during the process of writing this thesis.

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PRAMADANIA AGUSTINE

ABSTRAK

Pramadania Agustine. Strategi Pengelolaan untuk Melindungi Wilayah Pesisir dari Air Laut yang Tercemar Minyak: Studi Kasus Wilayah Pesisir di Kabupaten Bekasi (Dibimbing oleh Herman Parung, Patricia Dale, Chris Frid dan Peter Davey).

Penelitian ini bertujuan untuk memberikan rekomendasi rumusan kebijakan yang dapat diambil oleh pemerintah daerah setempat untuk melindungi wilayah pesisir dari air laut yang terkontaminasi minyak, terutama yang bersumber dari insiden tumpahan minyak.

Dalam merumuskan rekomendasi tersebut, beberapa tahapan dilakukan dalam penelitian ini. Analisis geografis dilakukan dengan mengoptimalkan aplikasi GIS untuk memetakan kondisi lahan termasuk penilaian perubahan penggunaan lahan selama beberapa tahun dan menyajikan deteksi sebaran tumpahan minyak yang terjadi. Selain analisis geografis, penelitian ini juga menggunakan analisis Statistik, analisis Strength Weakness-Opportunity-Threat (SWOT) dan Analytical Hierarchy Process (AHP).

Hasil penelitian ini menunjukan perubahan lahan di Muara Gembong selama 20 tahun terakhir (2000-2020), dari 14.475,46 ha pada tahun 2000 menjadi 12.869,70 ha pada tahun 2020. Adanya abrasi dan akresi mempengaruhi perbedaan luas total. Hasil ini menggambarkan permasalahan yang dihadapi kawasan Muara Gembong sebelum kejadian tumpahan minyak. Setelah melakukan penilaian terhadap kondisi geografis, dilakukan penelitian mengenai sejauh mana dampak yang ditimbulkan oleh tumpahan minyak dan persepsi masyarakat terhadap kejadian tersebut. Analisis statistik menunjukkan bahwa terlepas dari dampak signifikan yang ditimbulkan oleh kejadian tumpahan minyak, masyarakat pesisir Muara Gembong tidak menganggap kejadian tersebut sebagai bencana yang memerlukan kesiapan, seperti jika terjadi gempa bumi atau tsunami. Temuan ini semakin menekankan pentingnya pengelolaan wilayah pesisir yang lebih baik. Berdasarkan serangkaian analisis yang dilakukan, mulai dari analisis SWOT hingga AHP dirumuskan bahwa sinergi dan koordinasi antar instansi terkait merupakan strategi terpenting dalam perancangan strategi pengelolaan strategis kawasan pesisir Muara Gembong dari pencemaran minyak.

Kata Kunci: dampak lingkungan; polusi minyak; pengembangan pesisir.

ABSTRACT

Pramadania Agustine. Management Strategies to Protect Coastal Areas from Oil-Polluted Seawater: A Case Study of Coastal Areas in Bekasi Regency (Supervised by Herman Parung, Patricia Dale, Chris Frid and Peter Davey).

This study aims to provide recommendations for policy formulations that can be taken by local governments to protect coastal areas from seawater contaminated with oil, especially those originating from oil spill incidents.

In formulating these recommendations, a number of assessment stages were carried out. Geographic analysis is carried out by optimizing GIS applications to map land conditions including assessment of land use changes over several years and presenting detection of the distribution of oil spills that occur. In addition to geographic analysis, this study also uses Statistical analysis, Strength-Weakness-Opportunity-Threat (SWOT) analysis and Analytical Hierarchy Process (AHP).

This study showed the land changes in Muara Gembong during the last 20 years (2000-2020) from 14,475.46 ha in 2000 to 12,869.70 ha in 2020. The existence of abrasion and accretion influences the differences in the total area. This result illustrates the problems faced by the Muara Gembong area prior to the oil spill incident. After that, study was carried out on the extent of the impact caused by the oil spill and the community's perception of the incident. The statistical analysis shows that regardless of the significant impact caused by the oil spill incident, the Muara Gembong coastal community does not consider the incident a disaster that requires readiness, such as in the case of an earthquake or tsunami. These findings further emphasize the importance of better coastal area management. Based on a series of analyses carried out, starting from the SWOT analysis to AHP, it was formulated that synergy and coordination between related agencies is the most important strategy to protect Muara Gembong coastal area from oil pollution.

Keywords: environmental impacts; oil pollution; coastal development.

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
API	American Petroleum Institute
DEM	Digital Elevation model
ESI	Environmental Sensitivity Index
ETM+	Enhanced Thematic Mapper Plus
FWS	US Fish and Wildlife Service
GIS	Geographic Information System
GNOME	General NOAA Operational Modelling Environment
HAZMAT	Hazardous Materials Response Division
IPB	Institut Pertanian Bogor (Bogor Agricultural Institute)
ITOPF	International Tanker Owners Pollution Federation
LAPAN	Lembaga Penerbangan dan Antariksa Nasional (National Institute of Aeronautics and Space of the Republic of Indonesia)
LULCC	Land Use and Land Cover Change
OLI	Operational Land Imager
NDVI	Normalised Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
PHE ONWJ	Pertamina Hulu Energi Offshore North West Java
SAR	Synthetic Aperture Radar
SWOT	Strength-Weakness-Opportunity-Threat

SPSS	Statistical Package for the Social Sciences
TRIS	Thermal Infrared Sensor
USGS	United States Geological Survey

CHAPTER I

INTRODUCTION

A. Background

The oil spill incident that occurred in the Java Sea in July 2019, further emphasized the importance of long-term spatial planning for coastal protection. Research conducted by Maitieg (2017) revealed that understanding the oil risk and vulnerability is key for this type of planning. Douvere et al. (2007) argued that such planning is needed to quickly respond to events/problems that occur to minimize negative impacts, resulting in a decrease in the quality of aquatic and terrestrial ecosystems.

According to Laffon et al. (2016), oil pollution negatively impacts aquatic ecosystems and terrestrial ecosystems, such as creating health problems for coastal residents (people and biota). Given the significant potential impact that may arise from oil pollution, Laffon et al. (2016) considered oil pollution, especially an oil spill, as an ecological disaster. This is in line with Stikova et al. (2008) who considered that an event could be considered a disaster when it has a severe impact on society and causes social, economic, or environmental loss. Therefore, it is increasingly clear that the threat of oil pollution in the future needs to be taken seriously (Ivshina et al., 2015).

The discussion about terrestrial ecosystems that are affected by oil pollution in the sea cannot be separated from the matter of coastal area

planning. Coastal management planning is an important instrument to determine the dynamics of coastal communities related to utilization patterns and appreciation of coastal and marine resources (Zefri et al., 2009). However, in its utilization, the Muara Gembong Coastal Area (the study area), is still considered to be unsustainable due to the irregular use of space (Setra & Asyiawati, 2019). Land use that has been carried out has not considered environmental capability and carrying capacity. For this reason, it is necessary to monitor land changes so that the negative impacts due to land change can be overcome and coastal management in the future can be sustainable. The first objective of this study is to assess land changes in Muara Gembong and the impact on coastal residents, especially when an oil spill occurs.

Coastal planning in the context of controlling pollution in coastal and marine areas is one form of efforts to conserve the coastal environment and the natural resources it contains (Putra, 2018). One approach that can be taken in overcoming the impact of disasters or incidents in the region is to involve the aspect of preparedness (Stikova et al., 2008). Carter (1991) defines preparedness as actions that enable stakeholders to be able to respond to a disaster situation effectively. Since the perception of disaster risk can shape a person's intention to perform preparedness behaviour, the second objective of this study is to determine the extent of community perceptions of risk to oil spills, and how this perception affects their preparedness in the face of such event.

Considering that oil pollution is a major threat to environmental sustainability, government policies are needed to minimize the possible future impacts (Albert et al., 2018). The third objective of this study is to formulate initial recommendations for coastal development policies using a SWOT analysis. This stage analyses the strengths, weaknesses, opportunities, and threats of the management of the Muara Gembong coastal area, in relation to alternative development of the area in the future. From the SWOT analysis, several recommendations for coastal management strategies were developed. To ensure that each recommendation is feasible, further analysis of the recommendations using tools such as geographical analysis will be performed.

As the fourth objective of this study, an Analytical Hierarchy Process (AHP) will be carried out to ensure that this research will produce better final decisions justified by the analysis. The SWOT analysis will then be carried out as a priority analysis, covering aspects such as the actors, resource utilization and management strategies. The application of a combination of SWOT and AHP analysis in this study is expected to improve the quantitative aspects of strategic planning, allowing the results obtained to be used for the formulation of appropriate alternative strategies (Görener et al., 2012).

B. Research Questions

One form of pollution that may occur in the western Java Sea that may threaten the coastal area of Muara Gembong are oil spills caused by offshore oil mining activities. To address this potential threat, it is necessary to formulate policy recommendations that can be implemented by the local government to protect the Muara Gembong coastal area in the event of an oil spill. Therefore, in this study, problems that need to be resolved consider the following research questions, including:

1. To what extent has land change occurred in Muara Gembong over the last few decades, and how was the impact on coastal residents, especially during an oil spill?
2. To what extent do community perceptions of risk from oil spills affect their preparedness in the face of such events?
3. What kind of policies can be implemented to protect coastal areas?
4. What are the appropriate management strategies to protect coastal areas from oil-polluted seawater?

C. Aim and Objectives

This study aims to provide scientific-based management directions for coastal area management while still considering its geographical conditions. Thus, in the future, the coastal area of Muara Gembong can be protected from seawater contaminated with oil.

To achieve this, several objectives were set, including:

1. To identify land changes that have occurred in Muara Gembong and the impact on coastal residents, especially when an oil spill occurs.
2. To analyse the extent to which community perceptions of risk to oil spills affect their preparedness in the face of such events.
3. To determine the most applicable strategy to protect the coastal areas in Muara Gembong District from oil pollution.

D. Significance of the Study

This research is expected to provide an overview of the management strategies to protect the coastal areas from oil pollution. More specifically, this research is expected to be beneficial for several parties, including:

- For the private sector
  This research is expected to be used as input to be more aware of the impact of oil pollution on coastal resources. Also, this research is expected to provide input in developing strategies for implementing community development programs or Corporate Social Responsibilities (CSR).
- For academics and researchers
  This research is expected to provide additional literature on the ecological and social impacts of oil pollution on coastal areas and future management strategies.
- For the government
  This research is expected to provide input for policymakers (decision-makers) in managing and utilizing sustainable coastal resources. Also, it is expected that the government can develop appropriate coastal pollution prone management strategies to minimize the impacts that may arise in the future.
- For the community

This research is expected to be able to broaden people's insights about the impact of oil pollution on coastal areas, the things that cause it to occur, and management strategies to protect the coastal areas from oil pollution.

E. Scope and Limitations of the Study

The scope of this research focuses on the following crucial issues:

1. Among several sources of oil pollution in the sea, this research focuses on oil pollution from oil spills due to offshore oil mining activities;
2. Discussion on the efforts needed to control and minimize the impact of oil pollution that may occur is carried out from the local government's perspective.

The limitations of this research is that this study aims to promote the use of technical tools as a part of formulating management decisions, by giving some simulation techniques, but will not formulate the model itself.

F. Study Outline

In order to make easy the understanding of this thesis, an early brief is needed to illustrate the content of each chapter. Therefore, structure of the thesis below gives the description of the content shortly, as follows:

Chapter 1 is an introduction chapter. It will talk about background of the research which explains the research object, research questions,

research objectives, significance of the study, the scope of the study and structure of thesis.

Chapter 2 is a literature review. This chapter presents some theories related to the research. The theories used in this research are the condition of coastal areas in Muara Gembong (land-use and land cover change), overview of preparedness, management of coastal area, oil spill impacts, and oil spill control.

Chapter 3 is a research methodology. It will explain the data that has been collected and the data processing.

Chapter 4 is results of analysis. This chapter discusses the results gained from the research analysis.

Chapter 5 is discussion. This chapter discusses more about findings and implications that need to be considered. It also discussed the obstacles and limitation of the research.

Chapter 6 is conclusion. This chapter consist of summary and recommendations. The summary based on the analysis on Chapter 4 and 5. Meanwhile, the recommendation can be used as an input for the government to make a policy that related.

CHAPTER II

LITERATURE REVIEW

A. Land Use and Land Cover Change Analysis

Humans and various kinds of development that occur change the global landscape (Paul, 2013). For example, population growth will be followed by an increase in the need for land for settlement. This then leads to land conversion from vegetated land to settlements and buildings due to urbanisation (Wiggers et al., 2020). As human population and activity rapidly increases, undeveloped land is quickly becoming a scarce natural resource. Land use and land cover change (LULCC) or land change is unavoidable due to the increasing demand for land use by population growth requirements (Wahyuni et al., 2014).

Land cover change and land use change have different meanings. According to Liping et al. (2018), land cover change is defined as the physical and biological changes in land cover by vegetation, including water. Whereas land-use change has a more complex meaning as it involves natural and socio-economic perspectives on changes in land use for human activities. The human activities impact changes in processes that occur on the earth's surface, including biogeochemistry, hydrology and biodiversity. The dynamics of land-use change often lead to changes in land quality due to the mismatch between land capability and its use (Wahyuni et al., 2014).

Although they are two different terms, land use and land cover are often used together to describe the type of human activities and the land used (Ryngnga & Ryntathiang, 2013). In some instances, the two terms are difficult to separate. For example, in forest vegetation land cover, there is land use for ecotourism, watersheds or timber production. Therefore, in general, especially in the use of remote sensing data on a semi-detailed scale, the two terms are combined with the designation of land use/land cover (Baja, 2012).

B. Coastal Community Preparedness Against Oil Spill Disaster

Disaster preparedness is a series of acts that enables governments, organizations, communities, and individuals to respond to a disaster situation quickly and efficiently (Carter, 1991). Disaster preparedness is a part of the disaster management process. Increased disaster preparedness is one of the important elements of pro-active disaster risk reduction activities, before a disaster occurs (LIPI, 2006).

LIPI (2006) states that the parameters for measuring community preparedness in anticipating disasters are:

- Knowledge and Attitude Towards Disaster Risk
  The knowledge they have can usually influence the attitude and concern of the community to be ready and alert in anticipating disasters, especially for those who live in coastal areas that are prone to oil spills.
- Policy Guidelines
  Oil spill disaster preparedness is very important and is a concrete effort to carry out disaster preparedness activities.
- Resource Mobilization

Resource mobilization is a crucial factor because the available resources, such as human, financial and important infrastructure for emergencies constitute a potential that can support or otherwise become an obstacle in disaster preparedness.

Further, the perception of disaster risk has become an important topic for policy makers who are concerned with safety issues (Sjöberg et al., 2004). Although there are differences in the models used to explain the perception of disaster risk, researchers and practitioners generally reach an agreement that the perception of disaster risk is important (Yong et al., 2017).

Perceived Risk is a subjective assessment of the likelihood that certain types of events may occur and the extent consequences are prioritised (Sjöberg et al., 2004). Yong et al. (2017) suggests that risk perception of disasters is a multidimensional structure consisting of beliefs about the risks and problems of natural disasters. The research investigates risk perception and disaster preparedness for natural disasters. Yong et al. (2017) reveals three psychological dimensions that underlie risk perception, such as:

- External Responsibility for Disaster Management
  External responsibility for disaster management reflects that individuals believe that the government, organizations and people have a role and are responsible for disaster preparedness and management. Individuals are willing to follow directions or calls from governments, organizations, communities and society for disaster management to reduce the risk disaster impact (Yong et al., 2017).
- Self-preparedness Responsibility

Self-preparedness responsibility represents the belief that individuals are in control and responsible for the risk of natural disasters through disaster preparedness. The likelihood of risk that individuals will receive as a result of a disaster depends on the efforts made to minimize this risk by implementing preparedness (Yong et al., 2017).

- Illusiveness of Preparedness

  The Illusiveness of Preparedness shows the individual's attitude in responding to disaster risk with a fatalistic attitude (surrender to fate), through rejection and wishful thinking. This attitude can increase the sense of uncertainty about disasters and a lack of control over risks as well as the view that disaster preparedness is a waste of time and efforts (Yong et al., 2017).

C. Management of Coastal Areas

The coastal area has to be carefully managed, especially in planning and allocating natural resources (Lamin-Wadda, 1999; Vallejo, 1993). To ensure this, effective coordination and cooperation between the relevant sectors, such as the government and the local community is required. This is in line with the Regulation of Minister of Maritime Affairs and Fisheries Republic of Indonesia number 14/MEN/2009 relating to Maritime Partners; which regulates that management of coastal areas and small islands is a process of planning, utilization, supervision, and control of coastal resources and small islands with several sectors.

Coastal development may have implications for existing ecosystems (Sevilla et al., 2019). There are two kinds of implications, direct impacts such as dredging and indirect impacts such as pollutants (Reefresilience, 2016). Given the differing nature of these impacts, it is necessary to consider

management using a sustainable framework that can be applied to reduce a range of negative impacts. According to Jamil (2007), to develop a coastal area with sustainable framework, five management issues in ecological dimension need to be carried out:

- The existence of spatial harmony, between the preservation zone and the conservation zone;
- The rate of utilization of renewable resources. This should not exceed the renewable capacity of the resources within a certain period of time;
- Implementation of methods that do not damage the environment when exploiting mining materials and minerals;
- The rate of disposal of biodegradable waste which does not exceed the assimilative capacity of the coastal and marine environment; and
- Consideration of the characteristics and natural dynamics of the coastal and oceanic environment when modifying them.

D. Oil Pollution

Oil pollution refers to pollution caused by the spillage of oil creating negative ecological impacts on marine and terrestrial ecosystems (Macías-Zamora, 2011). There is widespread agreement in the literature that the magnitude of the impact caused by an oil spill depends on several factors: the number of spills, the condition of the spill location, the type of oil, and responsiveness in handling the oil spill (Adamu et al., 2016; Chang et al., 2014; Ramseur, 2010).

Generally, oil pollution in the sea can occur in various ways, such as water transportation (Sunar et al., 2007; B. Zhang et al., 2019), offshore exploration (Mukhtasor, 2007; B. Zhang et al., 2019), and originating from the mainland (P. Nwilo & Badejo, 2005). When oil enters the marine environment as a pollutant, oil immediately undergoes physical and chemical changes which can reduce the quality of seawater (Mukhtasor, 2007). This becomes a threat to biodiversity (Bassem, 2020) even though the oil may not be visible on the sea surface (Adzigbli & Yuewen, 2018).

1. Crude Oil Characteristics

To minimize the impact of future oil spills, it is vital to understand the types of oil that have polluted the sea. By understanding the types and characteristics of oil, it is expected that it will facilitate handling incidents. Thus, the impact on coastal residents and the environment can be minimized.

Crude oil is mainly made from a combination of hydrocarbons and 10% of molecules, including Oxygen, Sulphur, and Nitrogen (Adzigbli & Yuewen, 2018). Crude oil that has just come out of the exploration contains various types of chemicals in gas, liquid, or solid. Based on statement by PHE ONWJ, the type of oil spilled in the Java Sea is crude oil with a waxy clumping characteristic (Fikri, 2019). Table 2.1 details the characteristics of crude oil.

Table 2.1 Crude Oil Characteristic (Fingas, 2012)

Property	Units	Gasoline	Diesel	Light Crude	Heavy Crude	Intermediate Fuel-Oil	Bunker C	Crude Oil Emulsion
Viscosity	mPa.s at 15°C	0.5	2	5-50	50 to 50,000	1,000 to 15,000	10,000 to 50,000	20,000 to 100,000
Density	g/ml at 15°C	0.72	0.84	0.78 to 0.88	0.88 to 1.00	0.94 to 0.99	0.96 to 1.04	0.95 to 1.00
Flash Point	°C	-35	45	30	60	80 to 100	>100	>80
Solubility in Water	ppm	200	40	10 to 50	5 to 30	10 to 30	1 to 5	-
Pour Point	°C	-	-35 to 1	-40 to 30	-40 to 30	-10 to 10	5 to 20	>50
API Gravity		65	35		10 to 30	10 to 20	5 to 15	10 to 50

As shown in Table 2.1, Fingas (2012) formulated an outline of crude oil characteristics by describing each oil property. The first characteristic is viscosity, which determines the fluid's internal resistance to flow (Saeed et al., 2016). It shows the tendency for crude oil to float or sink. Clark et al. (1989) stated that the lower the oil viscosity value, the faster oil will spread. The other property is density; where the oil will float on the water if the density of the oil is less than water. The flash point is an essential indicator of the safety of an oil spill clean-up operation (Wang et al., 1964). According to Wang et al. (1964), immediately after an oil spill, most crude oils have a low flash point so that the lighter components evaporate or disperse. Crude oil will be considered dangerous if the flash point is less than 60°C. The solubility in water indicates how much oil will dissolve in water at a known temperature and pressure (Wang et al., 1964). Solubility is important to understand, considering that dissolved oil components are often very toxic to aquatic life. A Pour Point is a procedure used to assess wax deposition.

Pour Point above ambient temperature indicates the amount of wax content (Oliveira et al., 2018). API gravity indicates the quality of crude oil (Dickson & Udoessien, 2012). The higher the API gravity, the lower the crude oil liquid's density, so that light oil has a high API gravity (Geary, 2017).

2. Behaviour of Oil at Sea

The distribution of oil into the water depends on the amount, characteristics and type of oil, weather conditions, waves, currents, and shoreline type (FWS, 2010). Pollutants originating from petroleum (petroleum hydrocarbons) have received enormous international, political, and scientific attention when polluting waters. This is due to the effect of oil on aquatic ecosystems, which can reduce the quality of seawater (Mukhtasor, 2007).

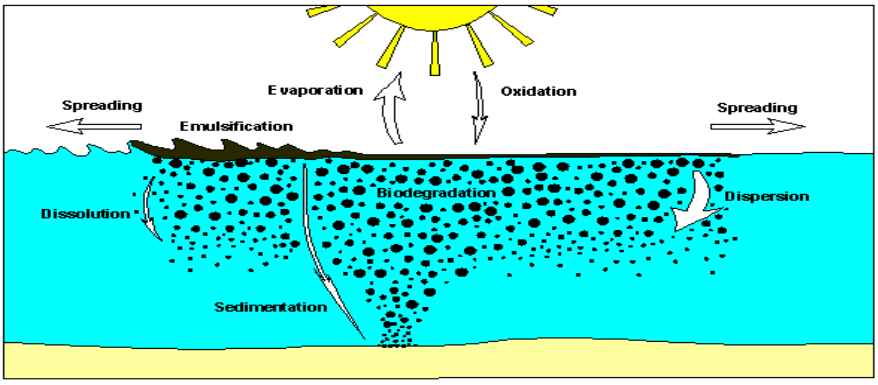

Figure 2.1: The Behaviour of Oil at the Sea

When oil enters the marine environment as a pollutant, oil immediately undergoes physical and chemical changes through various processes. According to ITOPF (2019), eight main processes as shown in Figure 2.1 are:

- Spreading

  The speed of the dispersion process depends on the ambient temperature and the composition of the oil.

- Evaporation

  The rate of evaporation depends on oil volatility, sea conditions, ambient temperature and wind speed.

- Dispersion

  The degree of oil dispersion is determined by sea conditions, oil properties and oil viscosity.

- Emulsification

  The process of oil emulsification is characterized by physical mixing which is promoted by sea level turbulence. This stage is a source of mortality for organisms, especially in eggs, larvae, and embryonic development because at this stage it is very susceptible to polluted environments.

- Dissolution

  Dissolution is determined by the condition and composition of the oil. This stage is accelerated when the oil is spread well in the water column.

- Oxidation

  The oxidation process takes place if there is contact between oxygen with oil or fat. This stage is promoted by the type of oil, sunlight, and form in which it is exposed to sunlight.

- Sedimentation

  This process occurs when oil in the sandy coastline is mixed with sand and then swept from the beach back into the sea and submerged.

- Biological degradation (Biodegradation)

Biodegradation is largely determined by the level of nutrients (phosphorus and nitrogen) in water, temperature and oxygen levels available.

3. Impact of Oil Pollution

Oil pollution as a result of oil spills or accidents is the biggest threat to the sea and its supporting ecosystems (Sayol et al., 2014). To assess the impact caused by oil spills, it is essential to have knowledge about the effects of oil physically, chemically and biologically (De Araújo et al., 2014). Physically, oil pollution can be seen in marine environments such as when beaches become dirty due to the sea surface being covered by a layer of oil on the surface of sea water. Chemically, petroleum contains aromatic hydrocarbon compounds which are toxic and can kill marine organisms. Biologically, the presence of oil pollution can disrupt the lives of organisms including fish. Therefore an intensive effort must be made to minimize oil pollution at sea.

a. Impact on Coastal Area

Coastal areas may have a significant impact from oil pollution (Bejarano & Michel, 2016). Extensive research has been conducted to see the degree of the impact of oil on coastal areas and its ecosystems, such as mangroves (Sodré et al., 2013) and rocky shorelines (Castège et al., 2014). A semi-quantitative sensitivity index which was earlier known as Environmental Sensitivity Index (ESI) as introduced by E. Gundlach and Hayes (1978) can be used to determine the sensitivity of coastal areas to oil pollution.

b. Impact on Natural Resources

In general, there are three main ecosystems on the coast that interact with one another, including mangroves, coral reefs and seagrass beds.

Since coral reefs and seagrass beds do not exist in the Java Sea, this section will focus on the impact on mangroves as the most vulnerable coastal habitat when exposed to oil pollution (Duke, 2016; Hoff, 2002).

c. Impact on Marine Biota

In general, oil pollution can cause damage to the food chain, which is described by the relationship between fish and plankton. According to Jiang et al. (2010), the hydrocarbon component of petroleum influences reproduction, the development, growth, and behaviour of marine life, especially in plankton. As a consequence, fish are killed and fish reproduction decreases due to a lack of plankton.

d. Impact on Animals

Oil pollution has a serious effect on ecosystems and organisms such as seabirds, particularly in their regenerative periods (Al-Majed et al., 2012). According to Michel and Fingas (2016), seabirds are exposed to oil through the food chain, physical exposure, absorption and consumption. Seabirds come in to contact with crude oil floating on the water's surface causing them to become smothered with oil and this can cause immediate mortality via suffocation. Crude oil disrupts feather integrity displacing insulating air between feathers leading to loss of water-proofing, thermal insulation and buoyancy. They become unable to dive or fly so they cannot forage to feed. Relatively quickly fat reserves are depleted and ultimately birds become severely hypothermic and emaciated causing significant mortality (Troisi et al., 2016).

E. Formulation of Management Recommendations

To formulate recommendations for the management of oil pollution, the combination of Strength-Weakness-Opportunity-Threat (SWOT) and Analytical Hierarchy Process (AHP) analysis will be used for this research.

This technique has been used in several environmental studies (Eslamipoor & Sepehriar, 2014; Masozera et al., 2006), but so far, there has been no use of this technique to prioritize planning policies for coastal areas prone to oil spills.

1. Strength-Weakness-Opportunity-Threat (SWOT) analysis

The SWOT analysis may be an organized arranging strategy to assess a project's strengths, weaknesses, opportunities, and threats (Rim-Rukeh, 2015). It is ordinarily utilized to identify strategic directions (Chambers, 2014). A SWOT analysis produces valuable information about the Muara Gembong coastal area's sustainability to stem the negative impacts that oil-producing companies may generate from their activities, such as oil spills.

A SWOT analysis scans the relevant information from the environment. The SWOT analysis will serve as part of program building, evaluation, and action planning (Olaniyi & Viirmäe, 2017). Piercy and Giles (1989) stated that a SWOT analysis uses knowledge about threats to calculate the risk so that actions are taken to mitigate, exploit, and avoid losses.

The two main components of a SWOT analysis are the internal situation indicators described by strengths and weaknesses and the indicators of the external environment described by opportunities and threats. Many European countries have used a SWOT analysis to select policy priorities and ensure horizontal policy coherence in their national strategies for sustainable development (Markovska et al., 2009). Further,

the steps taken in determining the direction of pollution management strategies in the SWOT analysis in this study consisted of identifying and scoring internal and external factors and making the SWOT Matrix.

1. Internal and External Factors

   Identification of internal factors is carried out to determine the factors that become strengths and weaknesses as well as the identification of external factors that become opportunities and threats (H. Zhang & Chen, 2013). Then determine the weights of each parameter with the sum of all weights of 1.0 (with a value category of 1 = very important, 0.75 = important, 0.50 = standard, 0.25 = not important, 0.10 = unimportant). Determination of the weight of each factor uses a scale of 1, 2, 3, and 4, such as:

   - If the horizontal indicator is less important than the vertical indicator.
   - If the horizontal indicator is as important as the vertical indicator.
   - If the horizontal indicator is more important than the vertical indicator.
   - If the horizontal indicator is significant compared to the vertical indicator.

2. The SWOT Matrix

   The SWOT matrix can clearly illustrate how external opportunities and threats faced in managing coastal areas prone to oil pollution can be adjusted according to their strengths and weaknesses. Table 2.2 shows a SWOT matrix that generates four possible sets of strategic alternatives so that strengths and opportunities can be increased and weaknesses and threats can be overcome. (Aslan et al., 2012).

   Table 2.2: The SWOT Matrix (Hunger & Wheelen, 2003)

internal / external	Strength (S)	Weakness (W)
Opportunities (O)	**S/O Based Strategies** Generate strategies here that use strengths to take advantage of opportunities	**W/O Based Strategies** Generate strategies here that take advantage of opportunities by overcoming weaknesses
Threats (T)	**S/T Based Strategies** Generate strategies here that use strengths to avoid threats	**W/T Based Strategies** Generate strategies here that minimize weaknesses and avoid threats

2. Analytical Hierarchy Process (AHP)

An AHP is a decision support model developed by Thomas L. Saaty in 1994. This decision support model describes complex multi-factor or multi-criteria problems into a hierarchy/level. According to Saaty (1994), hierarchy is defined as a representation of a complex problem in a multi-level structure. The first level is the goal/focus, followed by the next level, namely criteria, sub-criteria, and so on to the last level, namely alternatives.

Expert Choice is software that can solve problems based on the AHP method by comparing many alternatives with specific criteria. In this study, Expert Choice was useful in determining important priorities that were aligned with strategic objectives through stakeholder participation and support.

A vital tool needed to carry out the AHP method is the pairwise comparison table created for each criterion. According to Simon et al. (2019), for the AHP process, each alternative is compared to other

alternatives according to the given criteria. Another matrix, as shown in Table 2.3, was then constructed to give relative weight to each criterion concerning the objective.

Table 2.3: The Pairwise Comparison Scale (Prasetyo & Handajani, 2019)

Intensity of Interest	Explanation
1	The two elements contribute equally
3	Moderate the importance of one element compared to other elements
5	Stronger importance of one element compared to other elements
7	One element is clearly essential and has domination in practice compared to the other element
9	One element is absolutely more important than other element, based on strong facts and evidences.
2,4,6 and 8	The value between the two elements approximates the value of consideration

F. Controlling Oil Pollution in Coastal Areas

Marine pollution by oil will cause a decrease in the quality of resources and damage ecosystems. Therefore it is necessary to control efforts. According to Nedi (2010), attempts to control oil pollution at sea must be carried out holistically through two aspects as a foundation, such as policy and technology utilization aspects.

1. Policy Aspect

Through its specialized agencies, the government plays a role in fostering, supervising, and controlling the occurrence of oil pollution. The oil pollution is caused by various oil and gas industry activities and transportation activities of ships and ports around the Java Sea. This policy

instrument's existence is a control to prevent oil pollution that aims to minimize community losses and damage to the marine environment in the future.

One of the policies discussed in this study is a policy related to the utilization of land or land use conflict issues. Often in the land use process, aspects of land capability or suitability are ignored. This can lead to the harm of living organisms. Therefore, in this study, the level of suitability of land use in the Muara Gembong area will be assessed as a policy recommendation for local governments. Land suitability itself is a description of the level of suitability of a piece of land for a particular use. Land suitability evaluation has a strong emphasis on locations that have positive traits concerning the success of its production or use (Sitorus, 1985). The result of land suitability analysis is the land suitability map.

2. Technology Utilization Aspect

For effective management, local governments need to have administrative methods to appropriately deal with oil pollution and an indispensable tool for risk assessment, safety, and contingency planning as part of the decision support framework. To preserve the marine environment, the local government should have the ability to predict the evolution of an oil spill and have data to analyse extreme events and scenarios. Many current oil tracking models are used by various oceanographic centres. General NOAA Oil Modelling Environment (GNOME) is an oil spill distribution model that simulates the movement of oil affected by wind, currents, tides, and oil spills distribution. GNOME was

developed by the Hazardous Materials Response Division (HAZMAT) of the National Oceanic and Atmospheric Administration Office of Response and Restoration (G. NOAA, 2002). HAZMAT uses this model during an oil spill to estimate the “best guess” of the oil spill distribution associated with the uncertainty of the oil spill distribution. The broad function of GNOME is to predict the effect of wind, currents, and other processes of movement in the ocean on oil spills in the sea. GNOME is also used to predict the uncertainty of oil spills' distribution and the condition of oil affected by the weather around oil spills (G. NOAA, 2002).

In predicting the distribution of oil spills, GNOME uses visual aids of splots consisting of black and red splots. Black splots represent GNOME's best guess for an oil spill, estimated to be 1-2 miles accurate in 48 hours. To make a best guess, GNOME assumes that; (1) the wind continues to blow rapidly at the speed and direction entered into the model, (2) the data in the Location File accurately represents the current pattern over the lifetime of the spill. Red splots represent GNOME's larger minimum regret trajectory estimates for the same spill. GNOME assumes a level of uncertainty based on the input data, so that the estimated prediction error of the oil spill trajectory will not be outside the area covered by the red splots with probability 90% (G. NOAA, 2002).

GNOME has two main modes, standard mode and diagnostic mode. In standard mode, location files are used in the form of polygon map information, currents, winds, oil characteristics, sea depths and other data. In this mode, the user only varies various additional parameters to see their

impact on changes in the oil trajectory. Although using standard mode is very easy, the available location maps are very limited. If the desired location is not available, you can use the diagnostic mode (Salim & Sutanto, 2013).

The measurement of oil pollution control must be able to run effectively and efficiently. This can only be achieved if a good system of oil pollution control information is available. One example of the information needed is information related to the level of vulnerability or sensitivity of the coast to oil spills. The results of the analysis of the environmental sensitivity index (ESI) for oil pollution will be ESI maps. ESI maps provide a concise summary of coastal resources that are at risk if an oil spill occurs nearby (NOAA, 2000). This information is valuable to determine oil pollution control strategies and to save the surrounding ecosystem.

Furthermore, to ensure that both analyses can be carried out, there needs to be a supply of geographic data presented through the Geographic Information System. Weng (2010), states that Geographical Information Systems (GIS) is an integrated software package created specifically for processing geographic data with various purposes. GIS is able to do the processing, starting from data entry, storage, displaying information back to the user, and analysing the data.

G. Previous Research and Links to the Present Research

In the last few decades, research in the environmental field has increasingly been directed to understand whether there is a relationship

between the phenomenon of changing environmental conditions and its impact on human-nature (Seymour, 2016). One of which is the research on the impact of oil pollution on the environment and surrounding communities. Research conducted by various authors focused on the impact of oil pollution on the environment (Albers et al., 1985); (Olita et al., 2012); (Partelow et al., 2015); (Seymour, 2016) and (Ventikos & Psaraftis, 2004). On the other hand, Albert et al. (2018) focused on the social impacts that emerged. This paper covers both aspects, however with a few differences and adjustments. For the environmental impact, this research will discuss the impacts not only for one specific species, as discussed in previous studies, but also discuss the environmental impacts experienced by various species, such as coastal areas, marine biota, animals, and natural research. For the social impact, the direction of the discussion will be slightly different as this study will focus on handling impacts with long-term strategies. This includes recommendations for optimizing the use of technological tools to minimize future impacts. In contrast, previous studies Albert et al. (2018) focused on short-term strategies for handling impacts by talking about compensation policies.

Furthermore, another distinguishing factor about this research compared to previous research conducted by Nedi (2010) and Samuels et al. (2013) is it aims to formulate a model of the distribution of oil pollution. The distribution simulation is not intended to formulate a model but only to promote the use of technological tools as a support for decision making. This is important to discuss in this study, because based on the results of

interviews, the Bekasi Regency Government has not implemented an oil spill simulation system when an oil spill incident occurred. It is expected that the simulation results in this study can provide an overview of the importance of running oil spill simulations for coastal areas that are prone to oil spills.

The other difference in this research is related to the alternative selection method to be implemented to deal with oil pollution. The method used in the research conducted by Zafirakou et al. (2018), was PROMETEE analysis, in which a multi-criteria analysis method is to rank the options or treatment approaches to be carried out. Although this research and this study both aim to rank, the methods used are quite different. For this research, the AHP method will be used.