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Comprehensive Environmental Management of the Construction of the Marine Works of the Rabigh Coastal Power Plant Project on the Red Sea, Saudi Arabia

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Abstract

Construction of coastal power plants provides significant environmental benefits in comparison to conventional energy sources, thus contributing to the sustainable development of human activities. The construction of coastal power plants has considerable anticipated and unanticipated impacts on local hydrological and ecological conditions, soil and geology, marine water quality, air quality, hydrology, seabed sediment and hydrodynamics, human health and safety and environmental implications. To cope with these problems, this paper identifies broader environmental management issues that arise because of the marine construction works of coastal power plants and the incorporation of appropriate mitigation measures to achieve sustainable development. The case study is the Rabigh Coastal Power Plant No. 2 project, located on the Red Sea coast approximately 150 km to the north of the city of Jeddah in the Kingdom of Saudi Arabia. The environmental management study assures compliance with the regulatory requirements; identifies and analyzes sensitive components of the existing environment; determines the type, nature and importance of the probable environmental impacts during construction and operation; identifies and recommends practical, effective mitigation measures; recommends a framework for an environmental management and monitoring plan for the project; and ensures that all stakeholders deemed to be influenced by the projects or activities are fully considered.

Keywords

Environmental Management Plan, Construction, Marine Works, Power Plant Project, Safety, Mitigation Measures, Monitoring Plan

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1. Introduction

Energy from various sources is a necessity for our daily survival. Energy provides for essential services to humans, including lighting, cooking, manufacturing, power for transport, etc. Presently, energy to provide for these essential services comes from fuels: oil, gas, coal, nuclear, wood and other primary sources, such as solar, wind, or water power. The primary sources of energy are mainly nonrenewable: natural gas, oil, coal and conventional nuclear power. In real terms, energy is in such a high demand that any development surely depends on its availability in abundant quantities but from sources that are unsustainable! They are not dependable; some are environmentally unsound. The energy sources mentioned and those that are being experimented with today have environmental costs and risks.

In recent decades, the coastal zone has become an increasingly attractive location for industries, especially

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energy-related ones. In addition, the number of electric power plants in the coastal zone has been expanding rapidly because the seas provide easy access to the large volumes of water required for plant cooling. The main environmental threats resulting from power plants are thermal pollution, shoaling of the water intake basin, disruption of the stability of the coastline, and changes to the water quality of the surrounding ecosystem. During the construction of electric generating facilities, man can produce significant, although temporary, adverse environmental impacts by his interaction with natural sedimentation processes. The construction of power stations commonly involves dredging to make room for structures such as intake and effluent canals, docks, and berms. When fine bottom sediment is disturbed by this activity, the amount of suspended material in the water increases. Additional sources of environmental stress because of the construction of power plants are the creation of airborne dust, solid waste, noise, and chemical discharges released into nearby waters. The United Nations Joint Group of Experts on the Scientific Aspects of Marine Environment Protection defines pollution of the marine environment as “the introduction by man, directly or in directly, of substances or energy into the marine environment (including estuaries) which results in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities”, including the impacts of thermal discharges in the marine environment [1]. One of the most common sources of heat pollution in aquatic ecosystems is power generation.

Power-plant discharges in advanced nations of industry take place in 80 to 90% of whole thermal effluents. The amount is increasing with the expanded demands for energy consumption. The power plants are pumping up hundreds of thousands more tons of seawater every day while acting as a heat sink in a thermal power plant. Through the cycle, heat waste is emitted out to the environment of the river or sea. Although such thermal discharges have been made through various human living and industrial activities from ancient times, the amount was not as disruptive to aquatic ecological systems. Note that non-negligible effluent has been reported since the industrial revolution in the nineteenth century. The environmental impact of thermal discharge from many plants along the coasts, especially huge power plants, has been a big issue in the socioeconomic viewpoints of coastal eco-systems [2-8].

Some studies have been proposed for investigating the environmental impact assessment of power plants. Frihy et al. [9] undertook a monitoring program to evaluate the adverse impacts of the El Arish power plant on the northeastern Sinai coast of Egypt. They found that the cooling and wastewater discharging from the discharger to the sea are insignificantly warmer than the up-coast water and are not contaminated with chemical wastes. In addition, they found that the thermal and chemical plume has no significant effect on the quality of the coastal water in the study area. Kihwele and Kundy [10] studied the environmental effects associated with power generation from coal energy sources. They presented the characteristics of coal power sources and the environmental effects generated by coal power generation processes and corresponding mitigation measures. Zhang et al. [11] proposed a strategy for the management of thermal discharge by the Qingdao coastal power plant in China and gave some advice regarding these problems. Das and Bose [12] have clarified the different dimensions associated with corporate social as well as environmental responsibility and its significance with respect to the development of the Indian power sector.

Kulkarni et al. [13] noted that the establishment of thermal power plants on estuaries and tidal creeks exerts a tremendous stress on habitats. Das and Paul [14] make a study of the socioeconomic and environmental impact in the surrounding area of the Kolaghat thermal power station under the West Bengal Power Development Corporation in India.

The application of an environmental impact assessment (EIA) reflects the economic and political system of each country that uses it. Within the framework of sustainable development and the increasing need to develop the country without causing any depletion or deterioration to limited natural resources, the Kingdom of Saudi Arabia’s General Environmental Regulations and Rules for Implementation (GERRI 2001) provides guidance on whether an EIA is required for a particular type and scale of project and the category of EIA required [15]. In addition to these guiding principles, Saudi Arabia contributes to many regional and international organizations that are concerned with the protection of the environment and conservation of natural resources, such as the United Nations Environment Program, the World Health Organization, the United Nations Food and Agriculture Organization, the World Meteorological Organization, UNESCO, the Regional Organization for Protection of Marine Environment, the relevant organizations working under the Arab League and the Gulf Cooperation Council, as well as the Gulf Area Oil Companies Mutual Aid Organization (GAOCMAO).

The main purpose of this study is to identify broader environmental issues that arise because of the Rabigh Power Plant (RPP) No. 2 project and the incorporation of appropriate mitigation measures to achieve sustainable development.

2. Environmental Impact Assessment Guidelines

2.1. Site Selection

Site selection is an important tool in ensuring that the facility operates in an environmentally acceptable manner. While operational considerations are an important factor in selecting a site, the environmental and social characteristics of the location should also be assigned high priority. In general, the supply of power to meet the progressive increase in demand for electricity for the KAEC industrial valley and other developmental projects cannot be obtained from other sources. In the case of this project, no sources/alternatives other than from Rabigh Power Plant (RPP) No. 2 in the proposed location are available to meet the requirements.

RPP No. 2 is located on the Red Sea coast approximately 150 km to the north of the city of Jeddah in the Kingdom of Saudi Arabia. The proposed site is situated on the shoreline of the Red Sea, approximately 4.5 - 5 km to the south of the Petro Rabigh Saudi Aramco refinery, 10 km to the north of the Rabigh cement factory, approximately 4 km away from the Rabigh airport and approximately 150 km to the north of the city of Jeddah. The proposed area of the site allocated for RPP No. 2 is located on the northernmost area of the Rabigh Power Station. The location of the RPP No. 2 is shown in Fig. 1.

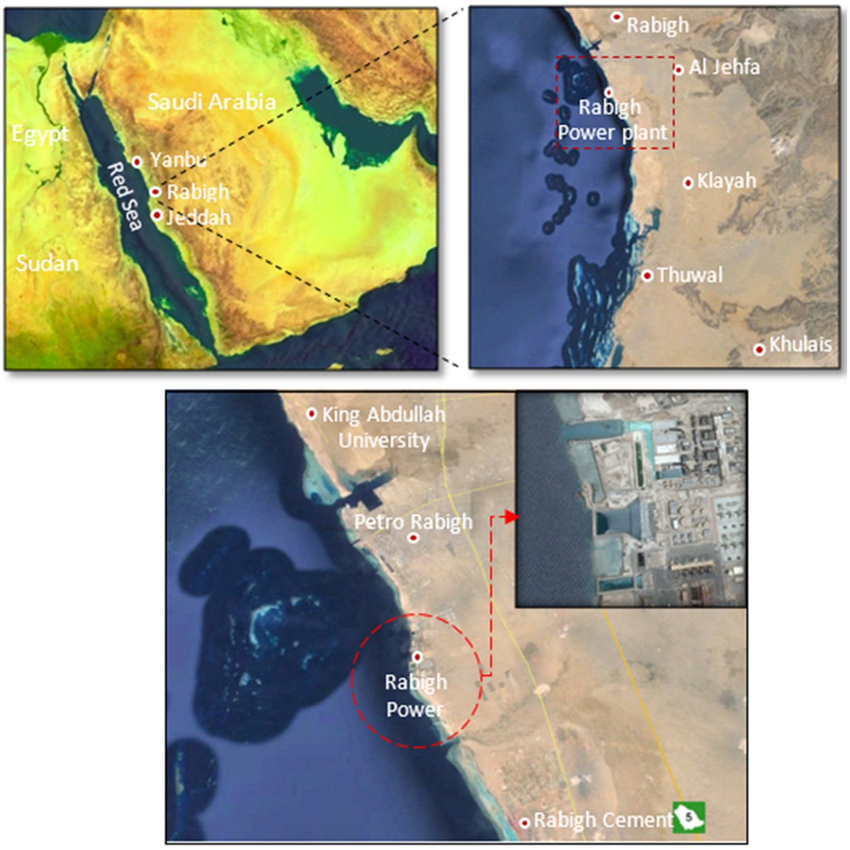

Fig. 1. Location of Rabigh Power Plant No 2.

2.2. Project Description

RPP No. 2 will have a gross output of 2800 MW and the size of each unit will be 700 MW (gross). The plant will be capable of firing on heavy fuel oil (HFO) and will include provision for future conversion to gas firing. HFO will be supplied from sea tankers at the existing unloading jetty through a new HFO booster pumping station to be installed at the most convenient location, preferably upstream of the existing metering station and onward to the new HFO storage tanks. Offshore works in this project include: temporary cofferdams and dewatering systems; dredging, excavation and backfill; circulating water intake concrete structure; jetty fish-holding pond; circulating water intake stilling basin; discharge channel; shore protection; cathodic protection systems; and navigational buoys.

2.3. Purpose and Need for This Study

The main purpose of this study is to identify broader environmental issues arising from the project and the incorporation of appropriate mitigation measures to achieve sustainable development. The GERRI classifies projects into three categories for the purpose of EIA. The three categories of projects are First Category: Projects with limited environmental impact; Second Category: Projects with significant environmental impact; Third Category: Projects with serious environmental impact. Third category projects require a comprehensive project environmental impact assessment.

Activities such as dredging, excavations, filling/reclamation and other marine construction works are categorized under the third category. It has been assumed that the proposed marine works of RPP No. 2 fall under 'third category' projects, and hence a comprehensive Environmental Impact Assessment study has to be carried out following the requirements of GERRI 2001.

2.4. Methodology

The environmental management study was carried using the relevant and appropriate methods for the Marine Works for RPP No. 2. The EIA was carried out in line with the requirements of the GERRI 2001. The guidelines of Presidency of Meteorology and Environmental (PME) for any Environmental Management Plan for any developmental projects in the KSA as per GERRI 2001 that were used for the present study are shown in Fig. 2.

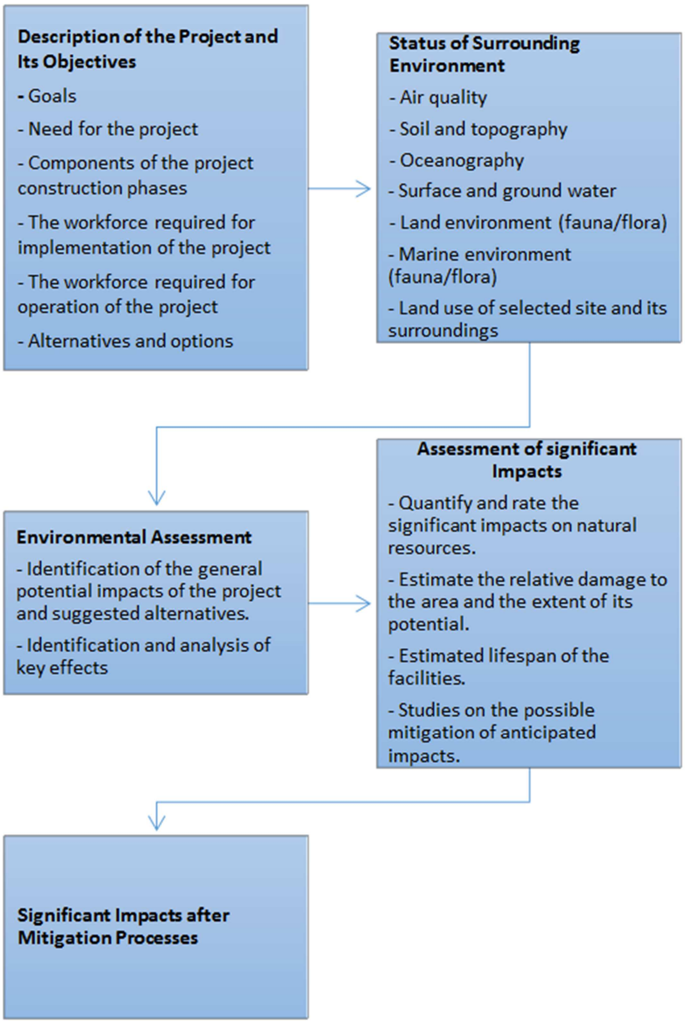

Fig. 2. Methodology of Environmental Management for developmental projects in Saudi Arabia.

2.5. Environmental Baseline

2.5.1. Marine Biological

Coral reefs are sensitive biological systems that are threatened by human activities and are therefore more threatened by high population density in coastal areas. Coral reefs can also be damaged by development activities such as dredging and fill operation for port development and construction and operation of tourist resorts. The Red Sea is one of the most important repositories of marine biodiversity in the world. Its relative isolation has given rise to an extraordinary range of ecosystems, biological diversity and endemism, particularly among reef fishes and reef-associated organisms [16].

The northern-central Red Sea (including Rabigh) has a much higher diversity of reef and coastal habitat types. It has large expanses of coastal marshes (sabkha), seagrasses, macroalgae, mangrove stands and reefs that fringe the mainland, islands, offshore patches and barrier reefs.

Overall, most reefs of the central-northern Red Sea of Saudi Arabia were in good to excellent condition in 1998-1999. There was little to no direct human impact on the great majority of the reefs. The exceptions were the reefs in urban areas, which were subject to reef fishing, land reclamation, urban run-off or littering. Coral communities on some reefs had also been adversely affected to a greater or lesser extent by coral bleaching or predation [17]. Based on the division of the coast and offshore islands into fourteen sectors [18], the coastline, of which the Rabigh development is part, based on the description of IUCN report (1984), is low-lying and dominated by coral sand and terrigenous beach sands. This coast also contains several large mersas and sharms, i.e., embayments. The overall reef pattern shows a rather narrow and steep wall-like formation, with sparse bommies growing on the lower portion of the slope. The bottom then slopes gradually to a sandy-silty bottom down to an indefinite depth (Fig. 3). The impact of anthropogenic construction activities, such as dredging and piling near the project site, increases the turbidity and siltiness of the water. The epibenthic and mesobenthic organisms, especially the sessile ones, are the most affected by this. Corals are the most impacted because they need sunlight for the symbiont zooxanthellae to manufacture energy by photosynthesis. The general view of the coastal area is shown in Fig. 4. Fig. 5 shows the coral reef at the study area at a 9 m depth.

Fig. 3. Bottom of the surveyed site (muddy sandy-silty).

Fig. 4. General view of the coastal area of the power plant.

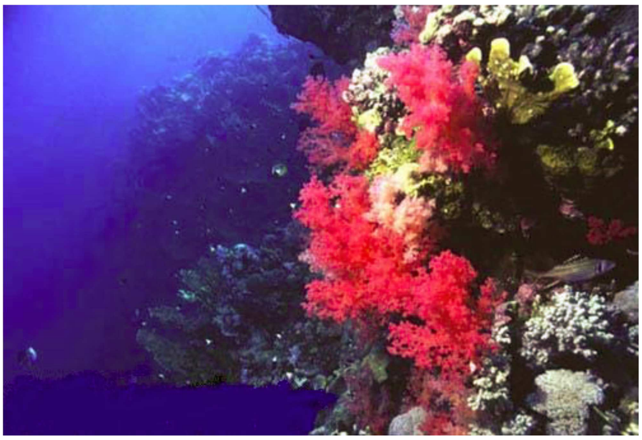

Fig. 5. Coral reef at the study area at a 9 m depth.

2.5.2. Soil and Geology

The coastal plain of the Rabigh area is characterized by Quaternary deposits such as gravel, sand, silt, clay and coral reef limestone. Coral reef limestone is the most characteristic feature of this area, especially on the sea shore, where it outcrops on the surface of the ground, but it is veiled by 30 to 70 cm of loose to slightly loose sediment.

The surficial marine sediments which covered the westwards portion of the coastal plain consist mainly of coral limestone, clay, silt, and sand, in addition to shell fragments.

In general, the geological survey of the site that was commissioned shows that the soil bearing (percentage sand, percentage silt, and percentage clay) in the different layers is similar. However, the difference in relative coarseness (> 2 mm) was apparent in the morphological representation. The soil bearing varies from a sandy bearing to an alluvial clay sandy bearing in the flood plain soils in the area that is formed by the sedimentation that surrounds the valley. In that location the proportion of clay soil varies from 5 to 23% in the different layers. The washed plain soils which prevail in the flat- and semi-flat plains have between 4.8 and 28.9% clay. The soil bearings in the floodplains, which are of greater clay content have a proportion of clay content from 7.3 to 25.3%.

2.5.3. Topography

The topography of the study area is generally fairly flat, slopping very gradually from the Jeddah - Madinah expressway in the east to the Red Sea to the west. However, breaking through the center of the site is a depression into which a number of valleys run, from the higher mountains to the east beyond the expressway. The valleys discharge into the lower land and may eventually reach the sea, but many appear to percolate into the ground, forming an extensive area of sabkha. A ridge of slightly higher land runs through the city along the seashore for much of its length.

2.5.4. Terrestrial Biological

Because of the absence of habitats in the area, such as open water areas that would enable a locally-based ecosystem to thrive, there is a low level of fauna in the area. This could be changed by introducing ponds and protected areas for vegetative areas that could support the development of a thriving local ecosystem for birds, small mammals, reptiles and amphibians, who would find a good habitat for growth which could populate the area.

2.5.5. Climate and Meteorology

The study area has typical coastal desert temperatures that are moderated by the proximity of the Red Sea. Temperatures rise above 38°C, but the relative humidity is usually more than 85 percent. The maximum temperature (often breaking 30°C) is reached in the months of June through September. The average temperature for the Rabigh area is shown in Fig. 6. Rainfall in the Red Sea region is extremely sparse and localized. There are no meteorological stations within the catchment of Rabigh; however, there are six nearby stations that have been used. Rainfall data shows that the rainy season is from October to May. The wettest months are in January (≈17 mm) and in April (≈14 mm) while the driest months are in June (≈0.5 mm) and in July (≈0.1 mm). The seasonal rainfall percentage values for the study area are 32% in spring, 1% in summer, 23% in autumn, and 44% in winter.

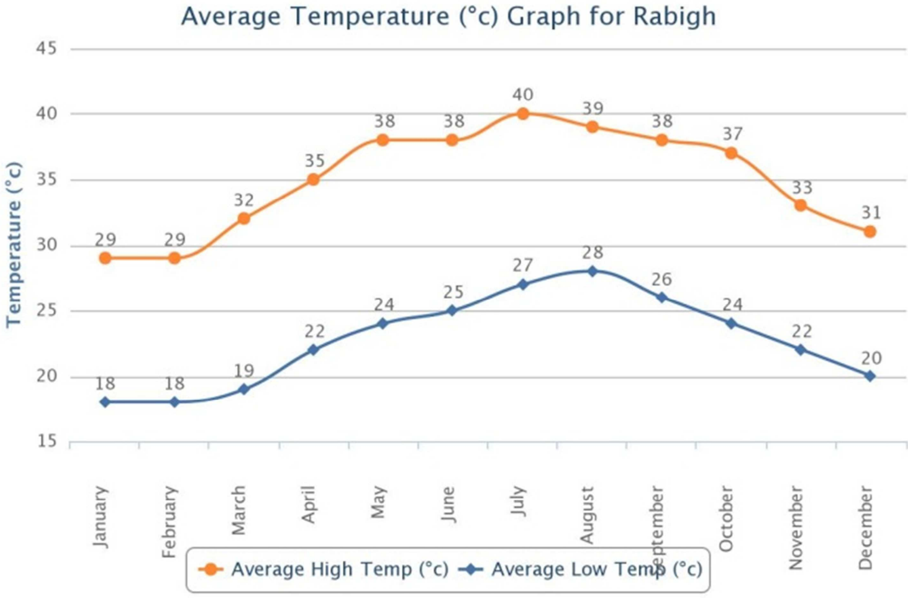

Fig. 6. Average temperature of the Rabigh area.

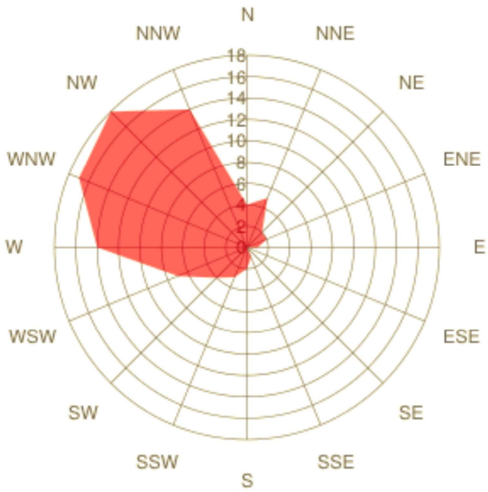

Fig. 7. Wind rose of the Rabigh area.

Prevailing winds are from the north and northwest, and when they are blowing, coastal areas become bearable in the summer and even pleasant in winter. The wind direction is mainly in the north-northwest from May to September. In October, the winds occasionally change to south-southwest and maintain this until April. The southerly wind is invariably accompanied by an increase in temperature and humidity and by a particular type of storm known in the gulf area as a "kauf". The average wind speed is 6.2 me/sec. The wind rose of the study area is shown in Fig. 7.

2.5.6. Surface Water Temperature

The surface water temperature ranges between 25.5°C and 27.0°C during the winter and between 32°C and 33°C in the summer.

2.5.7. Salinity

The surface salinity distribution reflects of the circulation patterns in the Red Sea resulting from evaporation and wind stress processes. During the winter, the surface water salinity ranges from 37.5% to 38.4% and is between 38% and 39% in summer.

2.5.8. Waves

General data for the study area suggest a significant wave height of approximately 1.2 m with a significant period of 6.7 sec, a root-mean-square wave height of 0.80 m, a mean height of 0.70 m and an average wave length of 128 m. The highest storm waves normally proposes from the south or west, although the most frequent wind direction is from the northwest and the north.

2.5.9. Tidal Currents

In the Rabigh region, tidal currents are typified by oscillatory and semidiurnal patterns, resulting in an average increase in sea level of 1.0 m during the winter period [20]. The tidal velocity generated through the reef and sand bars reaches 1-2 m/sec. Wind has limited impacts on the current speed.

2.5.10. Tides and Sea Level Variation

The tide in the Red Sea is semidiurnal and the mean range increases from an amphidrome located near Jeddah to 1.7 m in the Gulf of Aquaba to the north and 1 m at Perim in the south. The spring tidal range at Jeddah is 0.2 m. The mean sea level (MSL) in late summer is between 0.3 m and 0.5 m lower than in the winter because of the seasonal differential evaporation of the Red Sea and the prevailing regional atmospheric pressure and associated wind conditions. The maximum seasonal variations of MSL are + 0.23 m in December and -0.38 m in August.

2.5.11. Noise

An environmental noise survey was done continuously for 7 days to determine the existing noise levels at the study area. Analysis of the survey data indicates that current environmental noise levels are typically in the region of 35 – 60 dB. The results are under the PME limit, so there is no significant impact from this project.

2.5.12. Hydrology

The project is located in the vicinity of the outlet of a valley system originating from the high mountains on the east before the flow reaches the study area; floodwaters cross the new Taif highway via a set of culverts, then cross the old road via a bridge.

During 2007, water quality sampling and analysis was carried out on the groundwater. The following results are taken from a deep well that was sunk approximately 150 m inland from the beach on the site of the proposed area for a desalination plant. Table 1 indicates the results for groundwater quality. The results for the physico-chemical, organic and non-organic determinants are more or less as expected for groundwater where the main influence would be from the seawater. The exception is the results for the biological determinant, which shows that some biological contamination is present.

Table 1. Groundwater quality.

	pH	**7.40**
Physico-chemical	Total Suspended Solids (TSS)	2.10
	Temperature	27
	Turbidity, NTU	4.50
	Total Dissolved Solids (TDS)	42400
	Conductivity, EC uMhos	73500
	Total Organic Carbon (TOC)	4.50
Organic Pollutants	Alkalinity as CaCO3	120
Non Organic Pollutants	Sodium (Na)	12990
	Chloride (Cl)	23400
	Iron (Fe)	0.04
	Manganese (Mn)	0.02
	Ammonia (NH4)	0.12
	Silica (soluble)	1.50
	Boron (B)	< 1.00
	Barium (Ba)	0.03
	Sulfate (SO4)	3400
	Oil & Hydrocarbon	ND
Biological Pollutants	Fecal Coliform	None col/ml
	Total bacteria	3.0 col/ml
	Anaerobic Culture	3.0 col/ml growth of bacillus after 48 hrs.
	Aerobic Culture	2.0 col/ml growth of bacillus and 1.0 col/ml staphylococcus sp after 48 hrs.
	Fungus and algae growth	No growth after one week

3. Alternatives

3.1. Types of Mitigation

Suitable mitigation has to be worked out with the least anticipated impact. In the present case, there is no alternative to installing the power plant with seawater intake and cooling water outfall system at the project region. The main reasons are:

a) Saudi Arabia in general has a long history of an acute shortage of water;

b) There is no possibility of obtaining water from alternate sources like nearby dams east of the site in the mountainous areas, etc.

3.2. No Action Alternative

The "no action" alternative –not constructing the project- is considered to demonstrate environmental conditions without it. The project has a number of positive socioeconomic impacts in the region. The project will have gross output of 2800 MW and the size of each unit will be 700 MW (gross). Therefore, the no action alternative to the proposed project would result in the demand for electricity exceeding supply, with an increasing deficit as demand increases in the future. Hence, the lack of a secure and reliable electricity generation and supply system would have significant social and economic implications, including constraining existing and future economic development and restricting socioeconomic development.

3.3. Location Alternative

Elements, such as geotechnical, infrastructure, water availability, waste disposal, environmental and social impact, etc., were considered as assessment criteria during the site selection process. The alternative will not result in any development. The consequences of not proceeding with the power plant development would include the loss of the economic and social benefits and the avoidance of the potential environmental and social impacts. Therefore, the project location is of a significant advantage in minimizing cost and environmental implications. In addressing the environmental impacts of the project, one must study the adverse impacts of the project on all elements of the surrounding environment, such as the biological environment, the natural environment, socioeconomic factors, and human health and safety.

4. Assessment Impacts

The significance of any impact depends largely on the nature, scale and magnitude of that impact and the sensitivity of particular aspects of the environment.

4.1. Marine Water Quality

During the construction phase, dredging will increase suspended sediment loads and turbidity in the water near the dredger and at the disposal site. The extent to which this will occur depends on the dredging practices adopted. Additionally, the marine construction work of the power plant project could potentially impact marine water quality because of the waste from construction materials, spills of pollutants during construction (fuels, lubricants, chemicals), and installation of different marine works. Construction activities in particular could impact marine water quality because of:

a) Direct loss of marine habitat;

b) Increased turbidity from rock placement for breakwater, channel dredging, pile driving and excavations;

c) Nutrient and hydrocarbon re-suspension; and

d) Potential spills and leaks from dredges and other marine vessels involved in the dredging.

Marine water quality impacts are considered to be major locally and moderate on a regional scale. However, impacts to water quality because of dredging and disposal of dredge spoil are expected to be temporary and can be mitigated by utilizing appropriate technology and implementing appropriate management measures, including monitoring before, during and after dredging and disposal operations. The potential for impacts from spills or leaks contaminating the marine waters during construction is considered minor and temporary; however, mitigation measures are proposed to protect water quality. During operation, cooling water discharges from the power plant to the sea increase the temperature and cause alterations in salinity. This impact is considered moderate. A summary of the impacts' significance for marine water quality are presented in Table 2.

Table 2. Environmental impact assessment for marine water quality.

Activity	Impact	Receptor	Significance
During Construction			
Dredging works Effluent discharge Contamination from spills or leaks	Suspended sediment and turbidity in the water.	Marine life (moderate sensitivity) Marine life (moderate sensitivity)	Minor Minor
During Operation			
Cooling water discharges from the power plant to the sea.	Increase in temperature and alteration in salinity.	Marine life (moderate sensitivity)	Moderate

4.2. Marine Biology

From the baseline studies it was found that the fauna and flora in the study area are generally of low species diversity and abundance. There is also very low floral and faunal species diversity compared with other non-developed or nonoperational areas further offshore. The relative difference in species diversity can be attributed to infill, sedimentation, sewage and eutrophication. There are no resident bird species, but very rarely some sea birds and migrating birds may be temporarily seen in the area.

Disturbance of seabed sediments during dredging and filling impact the marine biology. The noise that will be generated during construction activities impacts on wildlife species inhabiting the project area. The noise impact is, however, considered short-term and therefore no long-term impacts on wildlife species are expected. Therefore, the impact from noise on marine biology is considered to be minor. The source of the impact is the chemical waste from the maintenance and servicing of construction activities. Chemical waste arising during the dredging phase could pose environmental, health and safety hazards if not stored and disposed of in an appropriate manner. It is difficult to quantify the amount of chemical waste that will arise from the construction activities.

With regard to the impact of the discharge of pollutants into the sea, this is not considered significant. The main sources of impact on marine biology occur during the operation phase, mainly through the risk of pollution from the cooling water discharge. This impact is considered moderate.

4.3. Seabed Sediment and Hydrodynamics

During construction, the dredging of the intake and outfall channels, construction of the marine works, installation of the marine pipeline, the placing of scour protection, and trenching associated with the installation of the marine pipeline have an effect on the sediment transport and currents, depending on the size and shape of the structure.

Changes to bathymetry are expected to be long term in dredged areas; however, the potential impacts of dredging are expected to be medium term (approximately 1 – 2 years) and reversible with appropriate management. The impacts to coastal processes are considered to be short term and of a low magnitude because of the placement of the structures in the marine environment. However, these impacts can be minimized and compensated for if appropriately managed.

4.4. Air Quality

The potential impacts on air quality from marine construction works are dust generated from construction activities; exhaust emissions from construction vehicles, machinery and vessels; and volatile emissions that can impact workers health. These impacts are relatively of minor significance given the nature of the works because these are typically localized and on site.

4.5. Noise

The main source of noise and vibration will come from marine dredging equipment, dump trucks, barges and other onshore equipment. The workers may be exposed to increased levels of noise. However, because of the distance to the nearest sensitive receptor (approximately 5 km), the impacts are likely to be minimal, and it is predicted that PME standards, ADB and World Bank noise guidelines of 70 dBA can be met for construction noise.

4.6. Terrestrial Biological

Potential impacts on terrestrial flora and fauna may result from:

a) Destruction of the habitat of birds and terrestrial fauna during construction activities;

b) Loss of beach and rock roosting/nesting sites;

c) Impact on ecology because of dust and exhaust emissions from the construction vehicles and machinery;

d) Soil disturbance through the use of heavy trucks; and

e) Introduction of weeds through construction activity and landscaping.

The potential impact is least significant but the construction of the marine infrastructure and breakwaters will create new habitat, including roosting and nesting sites, and therefore the long-term impacts are considered minimal.

4.7. Soils and Geology

Potential impacts on soils and geology may result from:

a) Compaction of soil during construction of site roads;

b) Disturbance and dispersion of soil because of movement of construction traffic;

c) Contamination of soil because of spills or leaks of fuels, lubricants and/or chemicals stored and used onsite; and

d) Contamination of soils because of solid and liquid wastes deposited or stored prior to disposal on land during construction, dredging and excavation works.

Modifications to the soil environment are expected in localized areas within the proposed power plant project site; however, given the poor quality of the soils and the limited potential land uses, impacts on a local and regional scale are considered to be minimal. The potential for soil contamination because of construction activities or use of dredge spoil as fill can be minimized by implementing appropriate management measures.

4.8. Topography

During construction, earthworks, alteration of the existing drainage regime, reclamation, filling, and creation of laydown areas for construction equipment will have an effect on the on-site topography. Dredging and reclamation impacts to the topography are expected to be short term. However, considering that elevations at the proposed power plant project site are expected to remain within the ranges of existing local elevations, it is expected that these impacts would be minimal. Potential impacts to drainage at the proposed power plant project site can be avoided or minimized by developing and implementing an appropriate drainage management plan.

4.9. Groundwater Quality

The main source of impacts is the routine effluent discharges (leaks of fuels and lubricants) from construction vehicles and the plant and spills or leaks of fuels, lubricants and chemicals from storage or maintenance areas. A second source of impact is the effluent from construction workers' temporary amenities leaching into the groundwater, carrying with it nutrients and microorganisms

Because of the relatively shallow groundwater depth at the proposed RPP No. 2 site, shallow excavation has the potential to intercept groundwater, and it is likely that dewatering will be required for infrastructure. If construction activities are appropriately managed, the potential for impacts to groundwater are considered minimal.

4.10. Human Health and Safety

The storage and use of hazardous substances at the site during dredging and filling works have the potential to contribute negatively to health and safety. Construction staff are very likely to be affected by health and safety issues, but as this is a typical workplace hazard, they should have access to personal protection equipment. The sensitivity is therefore moderate.

4.11. Socioeconomic

There is potential for interference with fishing activities because of the presence of vessels during towing, dredging, trenching, and pipeline-laying activities, and from the long-term operation of the marine works. Damage to fishing equipment is also a concern from a safety perspective. It is considered that there may be limited conflicts between marine works and pipeline construction and operations and local fishermen. However, these can be maintained within acceptable levels via mitigation.

4.12. Impacts from the Waste Generation

The likely waste sources during the marine construction works of the power plant are as follows:

a) Excess construction and excavation materials,

b) Food wastes;

c) Site office wastes; and

d) Human waste.

Implementation of appropriate mitigation should reduce the potential for waste generation and impacts from its disposal during construction. Impacts from waste are therefore considered minimal.

5. Mitigation Measures

Mitigation measures during construction and operation will be adopted to minimize potential negative environmental impacts from the different project stages. Detailed mitigation measures are presented in Table 3.

Table 3. Mitigation measures.

Mitigation measures
Marine water quality
Management practices developed and enforced through the environmental management plan ensure adequate systems for reception and treatment (on or off site);
Develop and implement a sediment sampling and analysis program to determine the existence and extent of sediment contamination in the intake and outfall channels and other marine related constructions;
Daily inspection of the water surface in the surrounding sea for any visual signs of recent pollution;
Equipment and vessels should be in good working order and not leaking fuel or volatile missions;
Selecting a dredging and reclamation methodology that minimizes the resuspension of sediments and provides a higher degree of precision in dredging.
Suspension of dredging activities during unfavorable weather conditions.
Appropriate storage and handling of fuels and chemicals on vessels.
Marine biology
Design and implement a sediment sampling and analysis program.
Investigate locations for an appropriate spoil disposal ground.
Develop and implement a marine ecology and water quality monitoring program for the construction phase of the power plant project.
Seabed sediment and hydrodynamics
Use the type of dredging machine that reduces the volume of suspended sediments produced.
Use hoses for the disposal of dredged spoils close to the seabed to reduce the generation of suspended sediments.
Use scour protection around infrastructure to reduce scouring.
Air quality
Proper and efficient use and operation of construction vehicles, plant and machinery by qualified and skilled personnel.
Undertake regular checks throughout the day by Site Managers;
Implementation of a construction phase dust monitoring program on site to monitor respirable dust and nuisance dust.
Minimize unnecessary idling and operation of earthwork and construction machinery.
The number of fuel and chemical storage areas should be minimized and properly managed.
Ensure proper on site storage of volatile fuels and chemicals in appropriately sealed containers.
Noise
Adherence to national noise guidelines of Kingdom of Saudi Arabia.
Ensure all plant, machinery and vehicles are fitted with appropriate mufflers, and that all mufflers and acoustic treatments are in good working order.
Ensure all plant, machinery and vehicles are regularly maintained and broken parts are replaced immediately.
Ensure all plant, machinery and vehicles are operated efficiently and according to the manufacturers' specifications, by trained and qualified operators.
Development and implementation of appropriate safety measures for site personnel, including the provision of suitable hearing protection.
Timing restrictions on certain activities may be required in occupied areas.
Using equipment and procedures that minimize noise.
Terrestrial biological
All earthworks vehicles will be washed down or driven over shakers to remove any seeds of weed species prior to coming onto the site.
Minimize the disturbance of land surface.

Mitigation measures
Appropriate waste storage to limit the potential proliferation of non-desirable fauna.
Implement the air quality and noise impact mitigation measures identified under air quality and noise.
Soils and Geology
Implement the spill response mitigation measures identified under Groundwater Quality.
Undertake vehicle maintenance and refueling on covered, impermeable surfaces.
Compact the ground to minimize the erosion of unconsolidated and unvegetated material.
Topography
Reduce earthworks and the extent of filling to the minimum required for the proposed facilities.
Reuse any excess excavation material generated by the construction of facilities within the proposed project site.
Groundwater quality
Develop and implement a Spill Response Plan, as part of an overall construction phase Emergency Response Plan.
Maintain spill response and cleanup equipment close to construction and storage areas.
Provide programs for routine checking of machinery.
Store fuels, oils and chemicals in concrete lined and bonded areas.
Human health and safety
Ensure the facility has safe working systems.
Use equipment and procedures that minimize noise.
Waste generation
Develop and implement a waste management plan.

6. Monitoring Plan

Environmental monitoring is essential and should be undertaken during the construction and operation phases of the project. Given the current (international and national) environmental regulations, the application of environmental monitoring tools is required to avoid, minimize and mitigate the potential impacts arising from exploration and production of oil and gas [21]. The proposed monitoring program is composed of three separate monitoring categories: Environmental monitoring; socioeconomic monitoring; and operational and management performance monitoring.

6.1. Environmental Monitoring

During the construction and operation phases, an environmental monitoring program shall be implemented that will include:

a) Visual Inspection;

b) Water resources;

c) Coastal processes (sediment transport, currents, waves, …)

d) Air emissions and noise levels;

e) Solid and hazardous waste;

f) Incoming and outgoing chemicals;

g) Trucking and machinery use; and

h) Workspace monitoring.

In the early phases (construction and operation start-up), the environmental monitoring program shall include all regulated parameters. Subsequently the list of parameters can be re-examined according to their significance to the power plant and to the specific site conditions.

6.2. Socioeconomic Monitoring

A survey shall be undertaken annually starting the first year of construction and continuing for the first two years of operation, then undertaken every 2-4 years thereafter. Key elements to be monitored may include numbers of temporary and long-term jobs created during the project construction and operation, change of income, job availability, internal transportation costs, etc.

6.3. Operational and Management Performance Monitoring

Operational and management performance monitoring shall involve checking that all data are documented and interpreted and that corrective actions are followed up and implemented.

7. Environmental Management Plan (EMP)

The required Environmental Management Plan (EMP) will be composed of four elements:

7.1. Construction Environmental Management Guidelines

The EMP shall include a set of Construction Environmental Management Guidelines (CEMG) for implementation of this project. The guidelines shall detail contractor responsibility with respect to compliance with national and international environmental laws and standards as they apply within the Kingdom of Saudi Arabia, and will stipulate specific environmental management requirements.

7.2. Environmental Mitigation Plan

This covers potential environmental impacts, impact assessment, mitigation measures, and monitoring.

7.3. EMP Implementation Framework

This will be composed of an implementation structure for the EMP including:

a) Reporting arrangements that may be required to ensure that project managers, financiers, and institutions are informed of environmental developments; i.e., compliance and any infringements;

b) Schedules for completion of the EMP work in line with the project milestones; and

c) A monitoring plan designed to assess the effectiveness of the EMP.

7.4. Operational Impact Management Plans

This covers a water quality management plan (Turbidity Monitoring Plan and monitoring of water temperature); a marine environmental management plan; and a waste management plan.

8. Conclusions

Energy, a key ingredient of industrialization and one of the determinants of the economic strength of a country, is generated by the power station. Construction of coastal power plants have the potential for a variety of impacts on the environment, depending upon the stage of the process, the nature and sensitivity of the surrounding environment, and pollution prevention, mitigation and control techniques. With regards to the aquatic environment, the principal problems are linked to the presence of the temporary cofferdams and dewatering systems; dredging, excavation and backfill; circulating water intake concrete structure; jetty fish-holding pond; circulating water intake stilling basin; discharge channel; shore protection; cathodic protection systems; and navigational buoys.

The case study is Rabigh Coastal Power Plant No. 2, which will have a gross output of 2800 MW; the size of each unit will be 700 MW (gross). The environmental management study has been presented in compliance with the General Environmental Regulations and Rules for Implementation (GERRI, 2001) of the Kingdom of Saudi Arabia. The environmental management study assures compliance with the regulatory requirements; identifies and analyzes sensitive components of the existing environment; determines the type, nature and importance of the probable environmental impacts during construction and operation; identifies and recommends practical effective mitigation measures; recommends a framework for an environmental management and monitoring plan for the project; and ensures that all stakeholders deemed to be influenced by the projects or activities are fully considered.

From the comprehensive environmental impact assessment, it is concluded that the marine works of the Rabigh Power Plant No. 2 project will not lead to significant impacts on various environmental components and marine life after the recommended mitigation. The most significant impacts will occur during dredging and filling works. These are anticipated to be short-term and, providing full mitigation is applied, the baseline condition will have largely returned to the predevelopment conditions after a very short period.

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