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Assessment Parameters for Coal-Fired Generation Plant Site Selection

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ABSTRACT

In order to meet future demand for electricity, Tenaga Nasional Berhad (TNB) is committed to the long-term strategic planning in locating suitable sites for future development of power stations. Site selection is an important process in the early planning stage of any power plant development as it will have significant implications on the capital investment, operational as well as the environment and socio-economic costs of the power plant.

The aim of this presentation is to briefly describe the ten (10) main assessment parameters having the most profound effects on the selection of potential coal-fired generation plant sites. These assessment parameters were derived based on a survey of approximately 40 experts, comprising from various specialists such as engineers from TNB, senior officers from Department Of Environment Malaysia (DOE), scientist from University Malaya (UM) and a number of other independent consultants.

1. INTRODUCTION

The aim of this paper is to describe the ten (10) main assessment parameters identified as having the most profound effects on the selection of potential coal-fired generation plant sites.

These ten (10) parameters are:

- Air Quality,
- Water Quality,
- Geology and Construction Costs,
- Geomorphology and Bathymetry,
- Landuse,
- Flora and Fauna,
- Coastal Resources,
- Population,
- Housing and Infrastructural Facilities; and
- Engineering Costs.

These assessment parameters were derived based on a survey of approximately 40 experts, comprising from various specialists such as engineers from TNB, senior officers from Department Of Environment Malaysia ("DOE"), scientist from University Malaya ("UM") and a number of other independent consultants.

Whilst the parameters can be derived based on expert opinions from consultants in the relevant fields, the relative weights (importance) between the different parameters cannot be readily derived. This was due to the vast multitude of differing opinions on the relative importance of each of the ten criteria.

1.1 Air Quality

A coal-fired power plant is a large emitter source of various air pollutants, including dust particulates and oxides of sulfur and nitrogen. This will affect directly the quality of air in the immediate vicinity of the power station. There is thus the concern on the potential adverse impact to air quality arising from the development of large scale coal-fired power stations. Assessment is thus based on three (3) sub-parameters as follows:

1.1.1 Existing Air Quality

Existing air quality of the surrounding areas is assessed based on the presence of other industries with significant emission of air pollutants in the vicinity of the proposed site. Thus, the presence of other power generating plants, petrolchemical plants, steel mills, cement plants, fertilizer factories etc., which are all significant emission sources of the oxides of nitrogen and or oxides of sulphur and dust particulates are taken into consideration for assessing existing air quality. If there are already such industries in the area, any additional source to be located there will only aggravate further the air quality.

1.1.2 Projected Impact to Air Quality

The behavior of the dispersion of stack emission depends on the prevailing meteorological conditions as well as the surrounding topographic conditions. Much modification will occur over a high hill area than on a plain because protruding surfaces serve as barriers to plume propagation. Such elevated surfaces are closer to the centreline of the plume and thus will receive higher concentrations of the pollutants. If the hills are too high, then the plume will not be able to cross the hill crests and this will result in prolonged fumigation over the receptor slopes of the hills. For assessment of the ground level concentration of pollutants in the dispersion of the plume, the Gaussian plume model is used. It is one of the most widely used air pollution models and is the backbone of almost all models developed by the United States Environmental Protection Agency (U.S. EPA) for regulatory purposes.

1.1.3 Potential Impact of Air Quality to Population

One potential impact of a power station to public health and safety arises from the large volume of atmospheric pollutants emitted from the stack. Such an impact to public health and public safety is directly propor-tional to the population density in the vicinity of the potential power station site. For the purpose of assessing such an impact, the population density of the district where the site is located is used.

1.2 Marine Water Quality

Marine water is used as cooling water in the operation of the steam generators. Cooling water intake structure and location will exert impacts on the surrounding ecosystem. The cooling water intake system will impinge and entrain aquatic organisms such as phytoplankton, alga, larvae, fish and pawns. The discharges of cooling water could affect the water quality and the marine ecosystem. Larvae of fish and prawn, which drift with the tidal current, may be killed by the combined effect of simultaneous chlorinated and elevated temperature conditions caused by the cooling water discharge.

For marine biota with higher mobility, if they are able to sense the perturbation and recognize it as aversive, the organisms might respond appropriately and move away. Thus, it will create an externality in which the local population, especially those depending on the coastal resources will suffer adverse consequences. It is thus important to assess the ambient water quality which when correlated with the diversity and the vulnerability of coastal resources can be used for the ranking of the potential power plant sites. Water quality criterion for the ranking of sites is based on two main considerations:

- Assessment of existing sea water quality
- Projected impacts on the water quality in the vicinity

Because of the intake and discharge of cooling water and wastewater from a power plant, it will undoubtedly have an impact on the surrounding waters.

The parameters used for assessing existing water quality are total suspended solids, coliform counts, and oil and grease. The assessment of projected impacts is based upon the possible impacts of various types of wastewater discharges emanating from the power plant and the effect of cooling water intake and discharge structure. In this evaluation, the impacts are grouped and assessed under two main categories; the impacts due to the cooling water intake and discharge, and the impacts due to other types of wastewater discharges combined. A more detailed assessment is given to the cooling water discharge compared to other types of wastewater discharges combined. This is based on the fact that it has been generally recognized that the former is expected to have a more significant impact.

1.3 Geology and Construction Costs

Topographic base maps at a scale of 1:25,000 were first prepared for the general area in which potential sites were located. The surface and sub-surface earth materials present in the area were then determined from published and unpublished literature and maps and from interpretation of aerial photographs and site visits.

The topography and geology at each proposed site was then evaluated to identify approximately the layout of the three major components of a coal-fired power plant, i.e. Power Plant and Switchyard covering 38 ha, Coal Yard covering 57 ha and Ash Pond covering 189 ha for 25 years use. This layout was carried out to locate the Power Plant and Switchyard over parts of the site where firm or strong sub-surface earth materials were present.

Foundation costs for each of the three major components of the power plant were then calculated. In the case of hilly terrain, there is firstly the need for excavations to create the platforms (or level ground surface) on which the power plant, coal yard and ash pond can be located. In the case of low-lying and swampy terrain, there is the need to create embankments (or raised flat ground surface) on which the power plant, coal yard and ash pond can be located. The heights of the embankments, however, will vary not only with the structural loads to be imposed, but also the sub-surface earth materials present at, and the environmental setting of, the site. Earth materials furthermore, need to be transported to the site to serve as fill material for construction of the embankments.

At sites where sub-surface soft and/or loose sediments are present, there can be expected problems with compaction and consolidation as a result of the structural loads to be imposed. Soil improvement works involving surcharge and subsoil drains were therefore, considered necessary in order to reduce these problems which are important only in the case of the power plant and coal yard. The amount of surcharge and length of subsoil drains will, however, vary with the thickness and type of sub-surface earth materials as well as the structural loads to be imposed.

The bearing capacity of the sub-surface earth materials present at the selected sites also needs to be evaluated as the various structures associated with the power plant as the boiler house, turbine house, switchyard, etc will impose heavy structural loads. Such structural loads can be supported by high strength surface or sub-surface earth materials as granite bedrock, though where unconsolidated sediments are present, pile foundations are perhaps the easiest means of transmitting deeper the imposed loads.

1.4 Geomorphology and Bathymetry

The component of geomorphology and bathymetry identifies those physical parameters that are considered important in influencing the siting of a power plant. The geomorphic parameters considered are those that describe landform configuration. These include inland relief (and also its tendencies to floods), morphology of the nearshore zone and site stability. Assessment is based on three (3) sub-parameters as follows:

1.4.1 Inland Geomorphology

Inland relief parameters are relief, height, and flood tendencies of the sites. Relief distinguished by its shapes, height and slope angle and their mass transport processes which in turn affect engineering works including the transmission lines layout. An area that is flood prone (in terms of magnitudes and frequencies) could also influence the siting of a power plant. The problem of wear and tear associated with water fluctuations and siltation could determine the threshold limits of major structures associated with the power plant.

1.4.2 Coastal Geomorphology

The form and stability of the shoreline must also influence siting of a power plant. In general, a retreating coastal site would require lower expenditure than an advancing site. The main reason being that it only requires maintenance of coastal erosion controlling structures (mainly sea walls, revetments, sea mazes and groins). An advancing site needs to overcome sedimentation as well as to maintain deeper and better quality waters offshore (dredging becomes a very important process here). It is for these reasons that sites should not be selected in areas that are susceptible to sedimentation.

Thus, sites should not be located at river mouths and associated estuarine formations, bays, sand spits and sand bars and also areas with extensive formations of intertidal flats (the length of the intertidal flats could also determine the set up of the water cooling and fuel lines). Here, the offshore waters are generally shallow where mixing of the waters is low (less turbulence). Data were derived from the temporal interpretation of aerial photos and topographic maps with reference to each site.

1.4.3 Bathymetry

Bathymetry refers to the topographic configurations of the oceans. Of importance are the isobaths characteristics (transect or spatial), that shows offshore gradients and curvatures. Isobaths characteristics were determined from the British Admiralty Charts. Bathymetric characteristics are considered one of the more important parameters in the study because of their influence on water cooling availability and ship docking facilities (fuel lines).

1.5 Landuse

The choice of sites for a coal-fired power station depends very much on the future impact that it will have on existing landuse. Coal-fired power stations have very specific land and landuse requirements. Among the requirements are extra lands for coal yard and ash pond, clean water for cooling, very deep sea for berthing of ships and open air space for effective dispersal of emissions and other pollutants. Assessment is based on three (3) sub-parameters as follows:

1.5.1 Land Usage

All districts in Peninsular Malaysia have its own structure plans for physical demarcations of different types of landuse within their respective districts. Land usage under the structure plans is determined by land zoning, a process which takes into considerations future economic development master plan by the state government and also various inputs provided by the general public and by the various government agencies.

1.5.2 Land Ownership

There are two main components for this sub-parameter:

- *Status Of Land Owners*: There are two types of land owners, i.e. private and state government. Ideally, the best sites to acquire are sites with a single ownership, either private or state-owned. Although it is easier and quicker to buy private lands in the open market, it is currently almost impossible to acquire private lands, under a single ownership, large enough for a coal-fired power station.
- *Number of Land Owners*: TNB will acquire land through the state government, using the Land Acquisition Act, 1960. Normally, this process will take between 6 to 18 months. The process to acquire private-owned land with a large number of owners will be costlier and takes longer time as it will involve negotiation with various parties representing each individual land owners such as family members, land valuers, solicitors, real estate agents etc.

1.5.3 Land Cost

Source of reference to determine the average estimated market price for lands within each site are taken from 2002 Property Market Report (published by Valuation and Property Services Department, Ministry of Finance) and verbal indications from independent real estate agents/existing land owners.

1.6 Flora and Fauna

The aquatic and terrestrial flora and fauna are considered in terms of their conser-vation values and vulnerability to changes in the environment. Their impacts may be direct or indirect. A species list of the flora and fauna will be prepared from a survey of all available literature including published papers, fishery department statistics and other reports. Data on components like fish and prawns, mangroves, turtles and shorebirds were updated from more recent publications and on-site field observations.

Together with the species list will be a list of estimated abundance of the flora and fauna. If quantitative data is available, it will be provided. If not, a subjective estimation of the abundance may be provided for species which may be observed during the site visits.

Of the species of flora and fauna identified, those which are of commercial or potentially commercial importance (e.g. fish and prawns) and those which are known to be endangered, will be identified.

Information on the effects (thermal and chemical) of the discharge from the power station on the flora and fauna will be obtained through literature search. Fieldwork was conducted for the identified sites were based on the other parameters like geology, bathymetry, currents and landuse.

The sites will then be further assessed based on the following criteria:

- Species richness - the total number of species (if quantitative data is avail-able; if not then an estimated value will be provided);
- Abundance or an index of abundance, if available;
- Presence of commercially important species;
- Presence of endangered species;
- Existence or possible existence of nursery or feeding grounds for fish, prawns and shorebirds especially the migratory species (only if information is available);
- Effect of the power station discharge on the flora and fauna to assess the environmental impact of siting a power station in the area.

The flora and fauna, and in particular the economically important species, in the 13 mukims will be described from available data. The information will be used for the classi-fication, mapping and ranking of potential sites. Information on rare and endangered species existing in the areas, including information on possible migratory pathways will also be considered in the identification of site. Sites of great importance for nature conservation will be identified. Major potential impacts from power station devel-opment on wetlands and wildlife will be identified.

1.7 Coastal Resources

The coastal areas of Malaysia are blessed with abundant resources which support a wide range of economic activities. Assessment criteria for potential sites under this parameter were based on three (3) sub-parameters as follows:

1.7.1 Fishing

Notable among these coastal activities is fishing, a traditional source of livelihood to the majority of the coastal inhabitants. The fisheries sector is indeed an important source of employment to the coastal population.

1.7.2 Tourism

Another significant economic activity which utilizes the coastal resources is tourism. For Malaysia, tourism has been recognized as an increasingly important industry not only as a source of foreign exchange earnings but also as a means of diversifying the country's economic base. Beside the sandy golden beaches and clear blue waters, tourists are also attracted to water sports like sailing, water skiing, snorkeling and scuba-diving. It is the presence of these attractions that have made marine-based tourism one of the most important users of marine and coastal resources with tremendous economic potentials.

1.7.3 Aquaculture

Coastal aquaculture has become one of the most significant commercial activities over the last five years. Depleting natural stock from capture fisheries combined with strong demand for prawns in the international market and proven commercial viabili-ty of the culture enterprise have attracted tremendous foreign and local investors alike to venture into aquaculture activities.

The prevalence of the above economic activities, all of which are dependent upon the coastal resources, and their socioeconomic importance to the coastal population would certainly have to be taken into considerations when choosing suitable sites for coal-fired power stations. It is without doubt that the construction of a power station is bound to have conflicting uses and interest with existing and potential coastal resources-based activities. This in turn would invariably have adverse effects on the coastal population, especially fishermen, whose traditional sources of income and employment have always come from the seas. Lastly, coastal aquaculture, especially prawn culture in brackishwater ponds in coastal areas, competes directly for the same resources as the power station, and thus merits serious consideration when selection of sites for power stations has to be made.

1.8 Population and Settlement

Population exerts a significant demand on energy resources. For the population and settlement parameter, three (3) sub-parameters were identified of which one was related to settlements within the site while the other two are related to district population density. The three (3) sub-parameters are as follows:

1.8.1 Number of houses within the site

An ideal site is one without any human settlement. On the other extreme, a very unfavorable site is the one with a dense permanent human settlement. Therefore, potential sites with least permanent human settlement will be more favorable as compared to densely populated sites.

1.8.2 Population density of the district

Sites with a low population density (<50 persons per sq. km) in a particular district shall be more favorable than sites with mukim (sub-district) population density more than 200 persons per sq. km. This parameter assumes that a site with a lower population density is a better choice than a site with a higher density.

1.8.3 Projected mukim population density for 2020

An assumption is made here that in the year 2020, the site with a high mukim population density is not a good choice as compared to a site with a low mukim population density. Mukim population for 2020 shall be projected by linear interpolation based on the population of 1990 and 2000.

A site with a projected district population density of more than 200 persons per sq. km for 2020 shall be least favorable as compared to potential sites with a projected mukim population density of less than 50 person per sq. km.

Sites with the least permanent human settlement is considered to be the best sites while sites with the highest permanent human settlement is considered the worst site as far as the population component is concerned.

1.9 Housing and Infrastructure

The siting and operation of a power station at a particular site would not only generate other activities surrounding the site but also snowballed to further developments and interactions in the district and state. Thus, both the availability and the need for infrastructure and housing facilities were assessed. Under this assessment parameter, the component was categorized into three (3) sub-parameters as follows:

1.9.1 Accessibility

Accessibility refers to both the general accessibility of the mukim, which is measured in terms of the overall road network in the mukim and the accessibility of a particular site from the main road, including the distance as well as the types of road leading to the site. The potential of a particular site would be greater if the level of accessibility is high.

1.9.2 Infrastructure

Infrastructural facilities include those basic facilities and services available in the area. These include electricity and water supply, health and education together with other religious and recreational facilities. The availability of these facilities in the vicinity of the site is an important consideration because, the siting of a power station initially and its operations subsequently would enhance economic activities and also population growth.

1.9.3 Housing

Finally, the housing component refers specifically to the availability of housing to accommodate laborers as well as staffs of Tenaga Nasional Berhad (TNB) in the initial stage and to accommodate further population influx in the subsequent stage. In order to provide living quarters for its staff, the potential of housing development in the area, i.e. the availability of land for housing development is considered an important parameter of this sub-component.

Among the three (3) sub-components, accessibility is considered to be the most important criterion, followed by infrastructure and housing. As mentioned earlier the significance of examining this component in the present study is to assess the availability and adequacy of the infrastructural and housing facilities in the area. This is because the siting of a power station in that area would have certain impact and implications on the above component.

1.10 Engineering Aspects

Power engineering criteria are also important factors in the identification and ranking of sites for coal-fired power stations. This section takes into account of the engineering cost factors of raw material supply and accessibility to the market. The relative advantages of one site over the others will be identified in terms of accessibility of coal supply and the transmission of electricity generated to the load centers. Thus, three (3) important sub-parameters considered in this assessment are:

1.10.1 Fuel Supply

As coal will be delivered by ocean long haul shipping, a coal port of substantial handling capacity and sufficient berthing draft is the prerequisite. A draft of 15 m is used as the minimum requirement for coal delivery to a 2,100 MW power plant. By using British Admiralty Charts, the bathymetry depth of the sites was determined. The seaward distance from the mean sea level shoreline to the specified depth was determined for each site.

1.10.2 Power Transmission

If the site is located at a deserted area, where it is very far away from the existing transmission line, the cost of constructing new transmission line to connect to the grid will be very expensive. A site will more favorable if it is nearer to the transmission line with appropriate capacity. In view of the size of the power station in this assessment, the distance to the 500 kV transmission line is taking into account for the ranking.

1.10.3 Load Centre

Higher power losses are incurred in longer transmission distance. These losses can be reduced if power stations are sited near load centers. Thus, the load size in the vicinity of the site is one of the aspects of load distribution to be considered. Therefore, the load from the nearest 132 kV substation would form the basis for the assessment of local load demand. When evaluated to 30 km and 60 km radii, it was found that the loads were proportional to the nearest 132 kV substation. Hence it was sufficient to derive the load using the demand from only the nearest 132 kV substation.

2. CONCLUSIONS

As described above, for each of the criteria or parameters, there are various sub-parameters which bear relevance to the site potential / suitability. Assessment of each of the sub-parameters were based on various expert opinions and also taking into considerations comments of TNB engineers and a few other independent consultants expressed at a power station site selection and ranking workshop held in 1990.

Whilst the assessment parameters of the main and sub-components can be derived based on expert opinions from consultants in the relevant fields, the relative weights between the different criteria cannot be readily derived. There is a vast multitude of differing opinions on the relative importance of each of the ten criteria in the process of determining the relative suitability of the sites.

However, provisions were made in the Site Information System software developed recently by the project consultants to enable reassessment of the sites to be based on a different set of weights or for ranking sensitivity studies.

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