City of Karratha

Land Supply Options Study for Commercial Scale Renewable Energy Development

Technical Report

August 2018

Executive Summary

Introduction - Scope

GHD were engaged by City of Karratha (the City) to conduct a high level analysis on land options for the development of commercial scale solar or wind energy systems within the City's Local Government Area (LGA) (the Study area).

The objective of this study was to evaluate development constraints and opportunities for these renewable energy options to produce a map of land suitability within the municipality, which may be used by the City and potential private sector developers to inform the selection of feasible development sites.

Methodology

In order to determine the suitability of land within the Study area, GHD's Infrastructure Development – Geospatial Information Systems (InDeGO) methodology was utilised. InDeGO combines Multi-Criteria Analysis (MCA) with desktop-based Geographic Information Systems (GIS) technology to assess and evaluate the complex physical, environmental, infrastructural and technical issues that are associated with determining potential development sites.

The results of this process produce a Site Suitability surface where it is possible to observe the cumulative effects of land constraints and opportunities in order to identify the optimum locations for development.

Solar Conclusions

The northern region of Western Australia has one of the best solar resources in the world. The results of the InDeGO process identified more than 119,000 ha as being highly suitable for commercial scale electricity generation through solar, constituting a significant component of the Study area.

The Site Suitability surfaces were utilised to guide a more detailed selection of the most feasible sites for the installation of different sized solar and wind energy generation systems considering the unique requirements for different size scales.

The siting assessment identified five feasible locations for solar, consisting of 2 small-scale solar sites (100 kW - 1 MW), 2 large-scale solar sites (1 MW – 100 MW) and 1 site large enough to produce export quantities of energy (>1 GW).

Wind Conclusions

The land area assigned as highly suitable for wind was significantly less, with 7,245 ha identified as being highly suitable for wind farm or turbine technologies.

Two feasible sites were also identified for wind, including 1 small-scale wind site (<5 MW) and 1 large-scale site capable of producing up to 30 MW.

General Conclusions

In general terms, development scenarios were better suited to land within close proximity to existing infrastructure (e.g. power grid and roads); with tenure or zoning which facilitates commercial development (e.g. Crown Land); and that is unconstrained by environmental or heritage matters (e.g. registered Aboriginal heritage sites). More specifically, land area (hectares) and topography (slope) influenced the increased suitable land for solar, whilst wind speed was a critical determinant for wind farm or turbine development.

Recommendations

The results of this study represents a high-level starting point for further analysis on the feasibility of commercial-scale renewable energy development. GHD recommend that the sites identified are used as starting points for any relevant feasibility study into a solar or wind energy generation system at a scale of 1 MW or larger within the Study area, noting that other suitable sites are a possibility.

GHD note that approvals have not been sought nor obtained for development of the sites identified. Results have considered Native Title, land tenure (including, mining tenements), natural constraints and State and City of Karratha Planning Framework (including the Local Planning Strategy and Local Planning Scheme). Further analysis / due diligence will be required of proponents to confirm further site suitability and project feasibility including, but not limited to;

- *Site conditions* such as: geotechnical, access, contamination, environmental and heritage
- *System costs*: wind regions, labour, operation and maintenance
- *Grid connection*: costs, access, curtailment, load
- *Power offtake*: power purchase agreements, export, large-scale generation Certificates

Generally, the Study area appeared more suitable for solar electricity generation than wind, although further steps of site suitability assessment should be undertaken.

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1. Introduction

1.1 Renewable Energy in the Pilbara region

The Pilbara region has long been considered a prime location for the development of large scale renewable energy industries. The northern region of Western Australia has one of the best solar resources in the word and has been increasingly looked at as a site for commercial-scale renewable energy development due to the high levels of solar radiation (refer Figure 1-1) and vast open space. Moderate wind speeds (refer Figure 1-2) may also support wind turbine energy production.

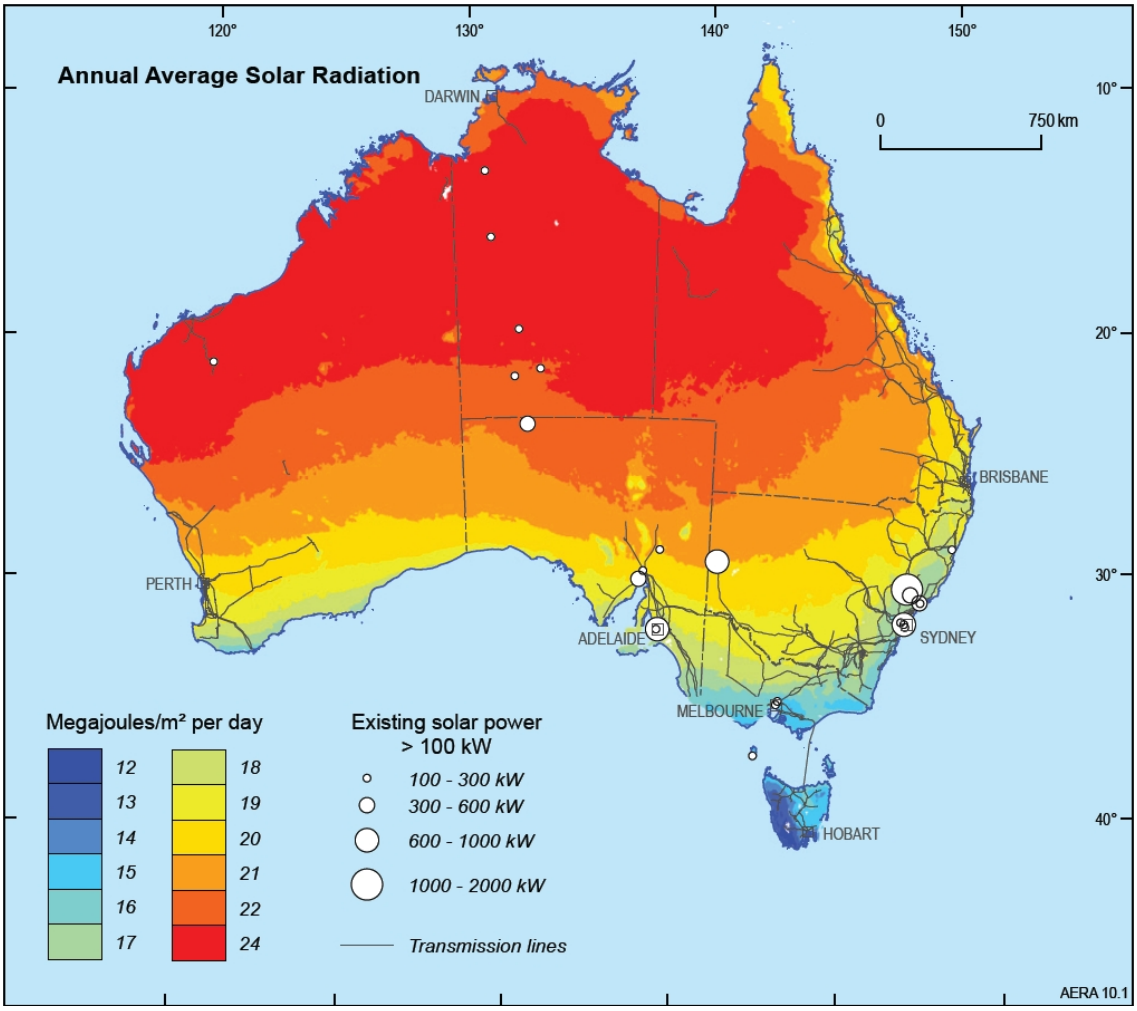


Figure 1-1 Annual average solar radiation (Mj/m²/day)

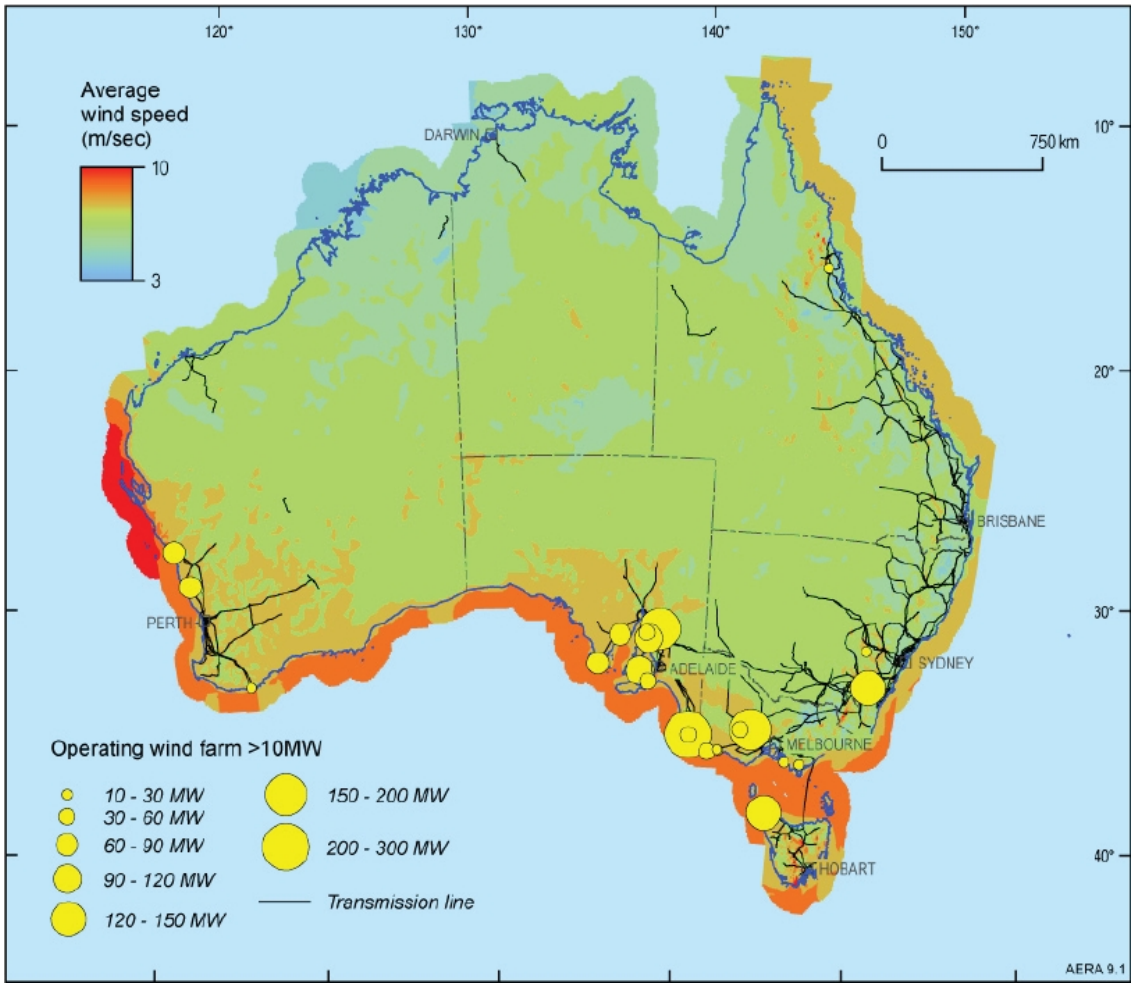


Figure 1-2 Australia wind resources

Source: Windlab systems Pty Ltd, DEWHA Renewable Energy Atlas (wind map data); Geoscience Australia

To date, the prohibitive costs associated with such technologies has largely precluded their development in the region, however renewable energy development in the Pilbara, particularly solar, is more topical than ever, with the current energy market seeing a shift towards large scale commercial solar photovoltaic (PV) systems largely due to the decreasing price of solar and the ever increasing demand for electricity. Solar PV is projected to be the lowest cost electricity generation technology by 2030 and is set to supply 15% of the world's electricity by 2040 (ABARE, 2010). Whilst for wind it is projected that by 2030, wind energy will provide approximately 12% of Australia's electricity (ABARE, 2010).

Investment in renewable energy industries within the Pilbara would provide a more environmentally sustainable and affordable source of electrical power to the increasing number of residents and businesses within the region, whilst improving sustainability practices and creating new employment opportunities. The potential renewable energy investment would also support economic development in regional Western Australia and economic development in the State more generally.

The major factor constraining development of renewable energy industries is access to suitable land. Constraints such as land tenure, environmental and heritage assets, and access to infrastructure all affect the availability of suitable land and must first be understood to attract investment and facilitate development.

All developments (except export scale systems) will be connected to the North West Interconnected System (NWIS). The NWIS network services the Pilbara Region and contains generation and transmission infrastructure owned by Horizon Power, ATCO Australia, Alinta

Energy, BHP Iron Ore, and Rio Tinto Iron Ore. The NWIS extends across an area measuring 400 km east to west and 350 km north to south and supports domestic customers as well as iron ore, gas, minerals and tourism developments. Connection to the NWIS will require careful consultation with the stakeholders listed above.

1.2 Background and Objective of this study

GHD were engaged by City of Karratha (herein the **City**) to conduct a high level analysis on land options for the development of renewable energy industries within the City's Local Government Area (LGA). The study was to consider the potential development of both commercial scale solar and wind turbine energy systems as options for long-term sustainable supply of power within the region. The objective of this study was to evaluate development constraints and opportunities for these renewable energy options to produce a map of land suitability within the municipality, which may be used by the City to inform the selection of feasible development sites.

This technical report documents the methodology used to assess the site suitability of the City's LGA (herein the **Study area**) and provides a summation of these results. It should be noted that the study did not require selection of an individual site(s) most suitable for solar and wind energy development; the focus was on understanding feasible sites for future development and what the constraints and opportunities in these locations may be.

1.3 Scope of Works

The scope of works included a desktop study to identify, assess and map land areas within the Study area that are suitable for commercial scale solar and wind electricity generation based on identified opportunities and constraints.

The map of land suitability was then utilised to guide a more detailed selection of feasible sites for the installation of different sized solar and wind systems considering the unique requirements for different size scales. The scope of this siting assessment was to identify:

- five feasible locations for solar consisting of:
    - 2 x small-scale solar sites (100 kilowatt [kW] - 1 megawatt [MW]);
    - 2 x large-scale solar sites (1 MW – 100 MW);
    - 1 x export-scale[1] site (>1 gigawatt [GW]); and
- two feasible sites for wind consisting of:
    - 1 x small-scale wind site (<5 MW); and
    - 1 x large-scale wind site (up to 30 MW).

1.4 Assumptions and Limitations

This report has been prepared by GHD for City of Karratha and may only be used and relied on by City of Karratha for the purpose agreed between GHD and the City of Karratha as set out in this report.

GHD otherwise disclaims responsibility to any person other than City of Karratha arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

[1] For the purposes of this report, export-scale is defined as a system that is too be connected with the NWIS.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in Sections 2.2.1 and 2.4 of this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by City of Karratha and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Methodology

2.1 Potential Land Options

The determination of potential land options for the proposed renewable energy options was guided by the following features and principles:

- Solar and wind resource is sufficient to support competitive energy production;
- The preservation and protection of the environmental and cultural values of the area, including its waterways, native vegetation and Aboriginal heritage;
- Existing land use and infrastructure as the foundation for future renewable industries; and
- Land use options in the Study area will be used to attract investment from individuals and organisations to the region.

In order to determine the suitability of land within the Study area for large scale solar or wind energy industries, a systematic and transparent analysis using the GHD Infrastructure Development – Geospatial Information Systems (InDeGO) methodology was utilised.

This Chapter describes the InDeGO methodology applied in the determination of land options for these renewable energy options.

2.2 InDeGO

InDeGO combines Multi-Criteria Analysis (MCA) with desktop-based Geographic Information Systems (GIS) technology to assess and evaluate the complex physical, environmental, infrastructural and technical issues that are associated with determining potential development sites. The software has been designed such that it integrates the constraints and opportunities that have been identified in the natural and built environment alongside technical criteria relevant to the Study area and proposed development. The results of this process produce a Site Suitability surface where it is possible to observe the cumulative effects of these constraints and opportunities in order to identify the optimum locations for development. Importantly, InDeGO methodology enables the land suitability selection process to take a balanced, transparent and traceable approach where the environmental, land use and infrastructural data sets were assessed as per their 'constraint' for the two renewable energy options.

2.2.1 Multiple Criteria Analysis

Spatial datasets were accessed for the Study area and determined by the following factors:

- Representativeness of the area in terms and constraints and opportunities;
- A consistent level of coverage across the Study area;
- Availability of data from local, state and federal government sources; and
- Accuracy.

These datasets were considered by way of an MCA workshop process and involved assessment of both performance ratings and criteria weightings, held with the City representatives. The workshop provided a structured and transparent approach to determine overall preferences among alternatives, where participants identified, ranked and weighted the performance criteria guiding the alignment suitability modelling process.

The GHD facilitated workshop was held at the City's Offices on the 13th April 2018.

At the time of the workshop, only datasets relating to solar were considered. Those criteria agreed for solar were later applied for wind; although all criteria were re-evaluated giving

consideration to specifics associated with wind turbine technology and additional criteria were included. The datasets agreed upon and considered in the MCA process for solar and wind are provide in Appendix A.

The key issues collated and utilised in the constraints and opportunity mapping for solar and wind are shown in Table 2-1. The evaluated criteria were grouped into a four sets that relate to separate and distinguishable components - environmental, land use planning, infrastructure and technical criteria.

Assumptions and Limitations

Important consideration regarding the selected criteria:

- Solar radiation is constant across the study area (refer Figure 1-1) and hence was not used as a dataset in InDeGO (since it was not considered a potential constraint); and
- The study area is located in a moderate wind speed area, approximately 6.0 meters per second (m/s) at 100m height on average (refer Figure 1-2). The majority of wind turbines start producing energy at wind speeds of around 4.0 m/s and therefore the LGA is in an area that may prove sufficient for wind turbines to generate electricity based on wind speed alone.
- The dataset used is a spatial estimate of average wind speed was developed from the publicly available wind resource assessment tool *WindAtlas*. Average wind speed does not consider the distribution of wind speeds about the mean and should not be relied upon for estimating power output of a wind turbine or farm.

MCA is a powerful desktop tool for screening study areas and generating suitability surfaces, however, it does have a number of specific limitations to this approach, including:

- Inability to represent all of the aspects that determine suitability for a site suitability in a geographic format;
- Potential for rating and weighting, and distance buffering decisions to be made by non-subject matter experts;
- Dilution of results by trying to include too many criteria – sometimes the result of having too many contributors;
- Lack of data at a suitable scale relating to site specific considerations; and
- Accuracy and currency of the data.

This work is based on a high-level assessment and further detailed analysis for specific suitability is recommended. Subsequent field-based investigations and alternatives process are considered necessary to verify and validate the outputs of the MCA, in addition to the various considerations that cannot be represented through this approach. The MCA could be improved via the inclusion of more site-specific data collected during field investigations

Table 2-1 Relevant criteria used to develop the InDeGO site suitability for solar and wind energy options

Solar Constraints				Wind Constraints			
Environment	**Land use planning**	**Infrastructure**	**Technical**	**Environment**	**Land use planning**	**Infrastructure**	**Technical**
Department of Biodiversity, Conservation and Attractions (DBCA) legislated land	Agricultural land (pastoral lease)	Proximity to Restricted Access Vehicle 4 (RAV4) Network	Solar Radiation (megajoules/m^2)*	DBCA legislated land	Agricultural land (pastoral lease)*	Proximity to RAV4 Network	Wind speed (m/sec) at 100m height above ground level
Native vegetation – Environmentally Sensitive Areas (ESAs)	Land use Zoning	Proximity to power grid (e.g. high voltage distribution networks, transmission and sub-transmission networks)	Cyclone rating	Native vegetation – ESAs	Land use Zoning	Proximity to power grid (e.g. high voltage distribution networks, transmission and sub-transmission networks)	Cyclone rating
Proximity to receiving water bodies and waterways	Land Tenure		Lot size (ha)	Proximity to receiving water bodies and waterways	Land Tenure	Proximity to Airport	Lot size (ha)*
Slope	Native Title			Slope	Native Title		
Contaminated sites	Mining Tenure			Contaminated sites*	Mining Tenure		
Acid Sulphate Soil risk*	Aboriginal Heritage			Acid Sulphate Soil risk*	Aboriginal Heritage		
	Line Easement				Line Easement		

* *Denotes criteria considered but removed from the MCA due to having negligible impact on the Site Suitability surface result (i.e. uniform performance rating across Study area or low criteria weighting)*

2.2.2 Performance Rating

The performance rating reflects the importance of each criterion in siting the infrastructure. This is an important part of the process as incorrectly rated criteria have the potential to skew the model results. All attributes of a criterion within the study area are considered during the performance rating process. While past ratings can be used to inform the analysis team, each criterion requires a review in the context of solar and wind infrastructure. The agreed performance ratings for solar and wind criteria are recorded in Appendix A.

Attributes of each criterion were rated to determine the suitability for solar and wind energy infrastructure. Each criterion was given a rating in terms of its level of opportunity or constraints that it would exhibit for this project, as per the description shown in Table 2-2. The standard rating representation established for the InDeGO model is grouped into four categories (highly suitable, moderately constrained, highly constrained and highly unsuitable). These categories are described in this section, together with a summary of typical constraints.

Table 2-2 Performance rating and description

Performance rating	Description
1	Highly suitable
20	Moderately constrained
100	Highly constrained
999	Highly unsuitable

Highly suitable (Good)

“Highly suitable” performance rating is assigned to lands within the Study area that are highly suitable for the placement of commercial scale solar and wind energy industries.

In the current study, for solar and wind, this category was assigned to areas with the following characteristics:

- very close proximity to the power grid (<5 km) and usable road (<1 km);
- large in capacity (lot size >50 ha);
- unconstrained by land use planning, environmental (e.g. DBCA land or ESAs) or heritage matters (e.g. Registered Aboriginal Heritage Site); and
- for wind, sustain an average wind speed of >6 m/s.

Moderately constrained (Moderate)

The performance rating of “moderately constrained” represents areas of moderate suitability.

Areas “moderately constrained” for solar and wind were assigned to lands with the following characteristics:

- close proximity to the power grid (5-10 km) and usable road (1-5 km);
- moderate in capacity (lot size >10-50 ha);
- unconstrained by environmental (e.g. DBCA land or ESAs) or heritage matters (e.g. Registered Aboriginal Heritage Site); but
- potentially constrained by land use planning matters (e.g. inside a mining tenement, pastoral lease or determined Native Title); and
- in the case of wind, potentially constrained by lower wind speeds (4-6 m/s).

Highly constrained (Poor)

The performance rating of “highly constrained” represents areas of low to poor suitability. These lands generally represent habitats of moderate to high integrity and impacts are likely to generate less environmental consequences than communities identified as “highly unsuitable”.

Areas “highly constrained” for solar and wind were assigned to:

- environmentally sensitive areas;
- areas within 100 m of a contaminated or potentially contaminated site;
- land greater than 5 km from usable road, and areas greater than 10 km from the power grid; and
- for wind, areas with wind speeds of 3-4 m/s.

Highly unsuitable (Potential Fatal Flaw)

The “highly unsuitable” performance rating represents likely “no-go” areas: lands whose significance to conservation are such they should not be disturbed by the proposed project, or where engineering controls or planning conditions are too restrictive to be of any consideration. All areas identified as “Highly unsuitable” are rated numerically highly in the model.

In the current study area for solar this includes:

- registered Aboriginal heritage sites;
- slopes that exceed 5%; and
- all areas within DBCA land, within 50 m of waterways and waterbodies, or within a contaminated site.

Areas “Highly unsuitable” for wind were assigned to lands that:

- experience wind speeds of less than 3 m/s; and
- registered Aboriginal heritage sites, DBCA land, and all areas within 100 m of a waterbody or 3 km of an airport.

2.2.3 Criteria Weightings

In determining the performance ratings, the following were considered:

- Upon allocation of the ratings, each criterion was considered in relation to each other criterion in a pair-wise comparison. This enables the allocation of the relative importance of each criterion for use in the generation of the constraints and opportunities mapping outcome, in the form of percentage weights to moderate each ranking score.
- The value assigned to the criterion is independent of the criterion’s level of constraints; instead, the weight reflects a particular criterion’s importance or potential level of impact on the assessment process relative to another criterion. The criterion that was considered to be of more importance to the decision making process as compared to the other criterion was to be scored as a “1” and the relatively less important criterion in that instance was to be scored as a “0”.

The pair-wise comparison analysis and the weighting for each criterion used in the Site Suitability analyses are in Appendix B.

2.3 Site Suitability Surface

The results of the workshops were combined with the desktop GIS to generate two Site Suitability surfaces representing solar and wind.

The Site Suitability modelling utilises an overlay approach that requires all data to be converted into cell-based grids. The Site Suitability surfaces and criteria layers have been provided to the City for means of interrogation on a cell-by-cell basis in ArcReader.

The Site Suitability surfaces are described in Section 3 with reference to those key criteria driving land suitability or increasing constraint limiting development opportunity.

2.4 Siting Assessment

The Site Suitability surfaces were utilised to guide a more detailed selection of the most feasible sites for the installation of different sized solar and wind energy generation systems considering the unique requirements for different size scales.

The scope of the siting assessment was to identify:

- five feasible locations for solar consisting of:
    - 2 x small-scale solar sites (100 kW - 1 MW);
    - 2 x large-scale solar sites (1 MW – 100 MW);
    - 1 x export-scale site (>1 GW); and
- two feasible sites for wind consisting of:
    - 1 x small-scale wind site (<5 MW); and
    - 1 x large-scale wind site (up to 30 MW).

Sites were considered feasible if the MCA identified them as suitable ('Good' or 'Moderate' rating) based upon the assumptions and methodology detailed within this report. These feasible sites were further selected and evaluated considering the following information:

- Details on the nearby substation (voltage, size, potential to have spare capacity, ownership);
- Details on the transmission line (voltage, size, potential to have spare capacity, ownership);
- Details of any nearby competing generation; and
- Details of nearby loads.

GHD selected feasible sites based on the above information and confirmed this selection with the City.

Assumptions and Limitations

The following assumptions apply to the siting assessment for solar:

- A detailed network capacity study is outside the scope of this work. Reasonable assumptions have been made with regard to potential spare capacity available within the NWIS. Consultation with the network owner will be required to confirm available capacity;
- This analysis has only considered solar systems that are of a large commercial scale or larger; systems mounted on pre-existing structures have been excluded from the analysis as per the MCA criteria;
- Actual locations of solar farm sites shown are indicative and should be subject to a detailed land usage assessment;
- An assumption has been made that the network capacity exists to accommodate the recommended scale of each solar system for the identified sites; consultation with the network owner will be required to verify this; and

- Recent similar project experience indicates that solar systems require 1.5 hectare of land per MW of capacity.

The following assumptions apply to the siting assessment for wind:

- A detailed network capacity study is outside the scope of this work. Reasonable assumptions have been made with regard to potential spare capacity available within the NWIS, noting that consultation with the network owner will be required to confirm available capacity;
- It is assumed that the network capacity exists to accommodate the recommended scale of each wind generation system for the identified sites, noting that consultation with the network owner will be required to verify this; and
- Wind turbines within a wind farm must be at least 500m from each other for 1MW turbines.

While this study has endeavoured to identify the most suitable and feasible site for each of the selected scenarios and energy system types, it does not guarantee that the sites selected are the most feasible location within the Karratha LGA, nor does it guarantee that the data and assumptions used within this selection are correct.

Please note that approvals have not been sought nor obtained for development of the sites identified. This report has considered the following elements at a broad scale (Native Title, land tenure (including, mining tenements), natural constraints and State and City of Karratha Planning Framework (including the Local Planning Strategy and Local Planning Scheme), however proponents will need to consider these in greater detail when undertaking feasibility investigations for the potential each site may have for a particular development and to ensure that relevant/necessary approvals are obtainable.

3. Site Suitability Surfaces

3.1 Solar Energy Generation

The site suitability map for solar is presented in Figure 3-1 and the attributing criteria layers, scored according to the performance ratings listed in Appendix A, are presented in Appendix C, Figure C1.

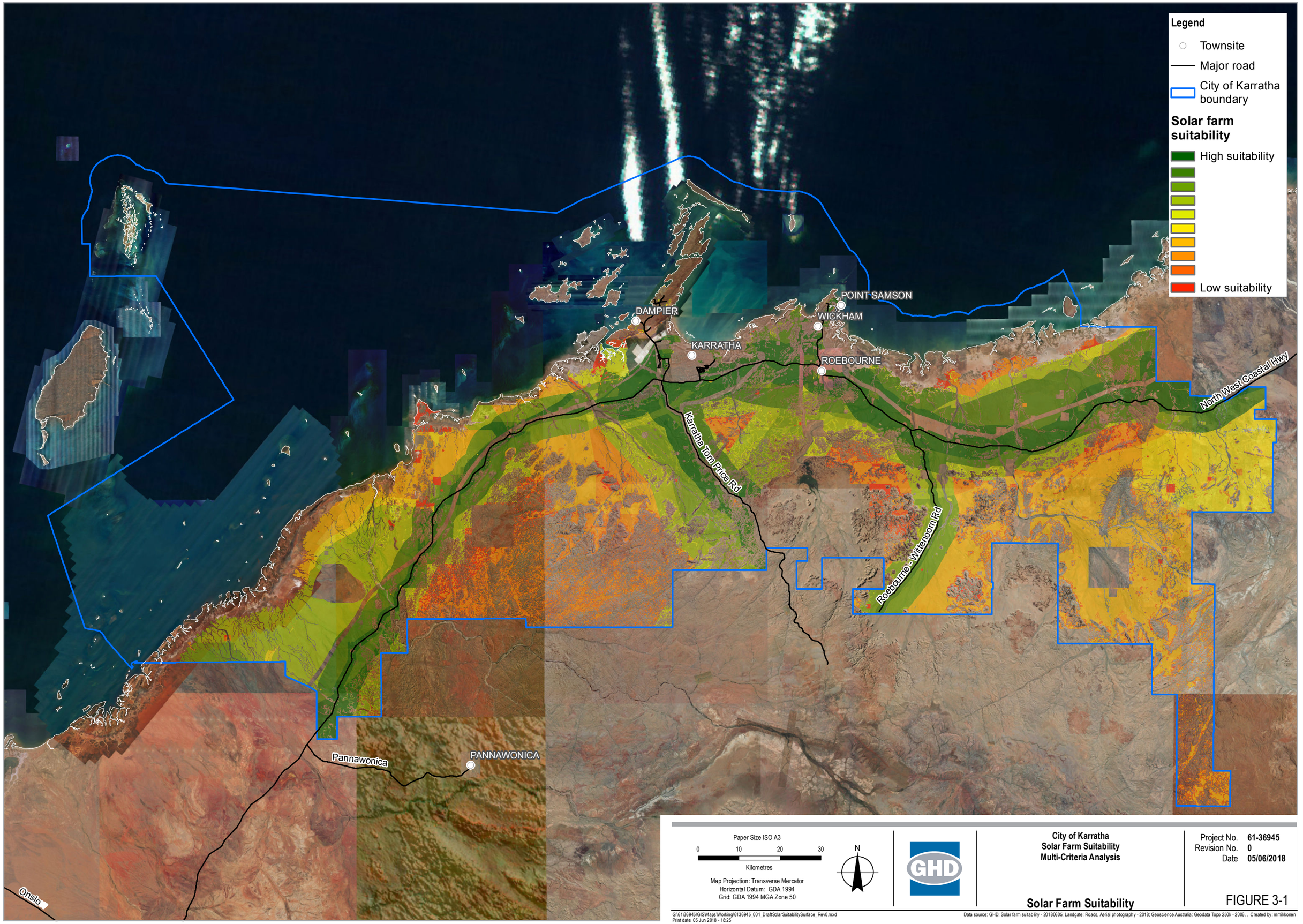
The site suitability map highlights large areas as being highly suitable ('Good' rating) for large scale solar electricity generation. In general terms, solar development scenarios are better suited to land within 5 km of the power grid and RAV4 vehicle network, with both of these criteria showing suitability trends similar to those presented for the solar suitability surface (refer Figure C1). This includes lands in proximity to the North West Coastal Highway, and up to 30 km inland along Karratha-Tom Price Road. Site suitability tends to reduce exponentially from these roadways, largely reflecting increasing distance from established infrastructure.

Other key criteria that have influenced the increased suitable land area are the reduced risk of impact to environmental assets (e.g. DBCA land, waterways or ESAs) or Aboriginal heritage sites, and increased land capacity, reflected by appropriate land use zoning and tenure.

'No Go' areas correspond to lands where development would likely result in unacceptable impacts to environmental or cultural assets (including registered Aboriginal heritage sites); zoning precludes commercial development; or topography is unsuitable for development of large scale solar arrays (e.g. hillsides).

Note that for this study, one existing land use – the Dampier Salt operations near the Karratha – was not captured in isolation in any of the criteria datasets. Therefore, and due to its very visible nature, it was decided that it should be manually excised from the resultant suitability surface. This was the only occurrence of such a scenario in the MCA process.

In order to further highlight the solar options determined by this study, a select number of sites have been interrogated further in Section 4.



Paper Size ISO A3

0 10 20 30

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

City of Karratha
Solar Farm Suitability
Multi-Criteria Analysis

Project No. 61-36945
Revision No. 0
Date 05/06/2018

Solar Farm Suitability

FIGURE 3-1

G:\61\36945\GIS\Maps\Working\61\36945_001_DraftSolarSuitabilitySurface_Rev0.mxd
Print date: 05 Jun 2018 - 18:25

Data source: GHD: Solar farm suitability - 20180605; Landgate: Roads, Aerial photography - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mmikkonen

3.2 Wind Electricity Generation

The site suitability map for wind is presented in Figure 3-2 and the attributing criteria layers, scored according to Appendix A, are presented in Appendix C, Figure C2.

The site suitability map highlights only small areas as being highly suitable ('Good' rating) for wind electricity generation and it is these areas that offer the most appropriate starting point for any investigation into the feasibility of this renewable energy option. These areas are typically in close proximity to infrastructure (power grid and RAV4 network) as well as at an increased elevation to access a higher wind resource compared to the surrounding areas. The larger areas of higher suitability in the east of the study area are a reflection of a higher wind resource in this area and the proximity to the Cape Lambert to Port Hedland transmission line.

Large areas of moderate suitability ('Moderate' rating) based upon the assessment method used typically coincide with proximity to roads and infrastructure. This includes lands east of Karratha in proximity to the North West Coastal Highway, inland along Karratha-Tom Price Road and, to a lesser extent, Roebourne-Wittenoom Road. Site suitability tends to reduce exponentially from these roadways, largely reflecting increasing distance from established infrastructure.

Large areas of low suitability ('Poor' rating) reflect increasing distance from established infrastructure and a less suitable wind resource.

'No Go' areas correspond to lands where development would likely result in unacceptable impacts to environmental or cultural assets (including registered Aboriginal heritage sites); zoning precludes commercial development; or areas within 3 km of an airport.

In order to further highlight the wind options determined by this study, a select number of sites have been interrogated further in Section 5.

Legend

Townsite

Major road

City of Karratha boundary

Wind Farm Suitability

High suitability

Low suitability

DAMPIER

POINT SAMSON

WICKHAM

KARRATHA

ROEBOURNE

North West Coastal Hwy

Karratha Tom Price Rd

Roebourne - Wittenoom Rd

Pannawonica

PANNAWONICA

Onslow

Paper Size ISO A3

0 10 20 30

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

City of Karratha
Wind Farm Suitability
Multi-Criteria Analysis

Wind Farm Suitability

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Date **21**/**08**/2018

FIGURE **3-2**

G:\61\36945\GIS\Maps\Working\6136945_007_WindSuitabilitySurface_Rev0.mxd
Print date: 21 Aug 2018 - 00:37

Data source: GHD: Wind Farm Suitability - 20180622; Landgate: Major Roads, Aerial photography - 2018, City of Karratha Boundary - 201803; Geoscience Australia: Geodata Topo 250k - 2006 . Created by: mczekaj

3.3 Constraints and Opportunities

In general terms, access to infrastructure was the influencing determinant for sites within the Study area most suited to the development of large scale renewable energy; since site development would likely be reliant on proximity to the established power grid and access to suitable roads for construction and operation. Appropriate zoning, such as strategic industrial or rural zones, which are less constrained by zoning restrictions, were considered opportunities for future development.

Pastoral leases or mining tenements were considered 'moderately constrained' and offer opportunity for development if tenure can be negotiated. Similarly, Crown Land would be favoured over Private tenure due to a higher likelihood of land acquisition.

Most Aboriginal sites were listed as 'highly unsuitable' areas and therefore sites not suitable for renewable energy industries.

The environmental features of the Study area (e.g. DBCA land, waterways and ESAs) are widely regarded as valuable assets that are to be protected and enhanced. Most of these environmental assets were listed as 'highly unsuitable' areas and therefore sites not suitable for development.

Lot size and topography were important determinants of the sites most suitable for solar, since PV arrays would typically require large areas of flat land (depending on selected production capacity). Whereas for wind, turbine technology might be positioned at elevation on smaller land parcels across the Study area, and hence are less constrained by these criteria.

Wind speed is the critical determinant in the selection of suitable sites for wind electricity generation. The majority of wind turbines start producing energy at wind speeds of around 4.0 m/s, but wind speeds of less than 6.0 m/s at 100 m height are typically not considered a suitable resource for efficient operation of current turbine technologies. Wind speeds across the Study area average <6.0 m/s and therefore are in the minimum accepted range. 'Highly suitable' areas for wind electricity generation represent locations with the most favourable wind speeds (amongst other criteria), but might still be considered constrained by low winds speeds across the Study area generally.

A summary of the dominant themes (highly desirable criteria) for each of the renewable energy options is shown in Table 3-1 and Table 3-2.

Table 3-1 Solar power development opportunities in the Karratha LGA (Preferred Criteria)

Criteria	Preferred Criteria by Suitability Rating		
	High Suitability	Low Suitability	No-Go
DBCA Legislated Land	Outside DBCA land	Outside DBCA land	Within DBCA land
Terrestrial Vegetation / ESAs	Outside ESAs	Outside ESAs	Within an ESA
Water Bodies and Waterways	No impact of waterway or water bodies (>50m separation distance)	No impact of waterway or water bodies (>50m separation distance)	Potential impact of waterway or water bodies (<50m separation distance)
Slope	Appropriate topography (slope <2%)	Less suitable topography (slope 2-5%)	Slope exceeds 5%
Contaminated Sites	Outside contaminated or potentially contaminated sites	Within 100m of a contaminated or potentially contaminated site	N/A
Agricultural Land (Pastoral Leases)	Not within a pastoral lease	Within a pastoral lease	N/A
Land Use (by LPS zoning)	Appropriate zoning (i.e. 'No zone', 'Rural', 'Strategic Industry')	N/A	Zoning not appropriate (e.g. 'City centre' , 'Commercial' , 'Conservation landscapes', 'Ocean' etc)
Native Title	Outside determined NT area	Inside determined NT area	N/A
Mining Tenure	Outside all tenements	Inside mining tenements	N/A
Heritage (Cultural)	Outside Aboriginal Heritage Sites	Impacts on Lodged Aboriginal Heritage Sites	Impacts on Registered Aboriginal Heritage Sites
Line Easement	On a cadastral lot adjacent to easement	On a cadastral lot not adjacent to easement	N/A
Acid Sulphate Soil Risk	Outside any known ASS risk area	Inside known ASS risk area	N/A
Site Road Access	Proximal to Heavy Vehicle Network (1 - 5km)	More than 5km from usable road	N/A
Grid Proximity	Less than 5 km from high voltage distribution networks, transmission and sub-transmission networks	More than 10 km from high voltage distribution networks, transmission and sub-transmission networks	N/A
Cyclone rating	>60km from coast	<30km from coast	N/A
Lot size	50+ ha	<10 ha	N/A
Ownership (Freehold vs Crown)	Crown land	Freehold	N/A

Table 3-2 Wind power development opportunities in the Karratha LGA (Preferred Criteria)

Criteria	Preferred Criteria by Suitability Rating		
	High Suitability	Low Suitability	No-Go
DBCA Legislated Land	Outside DBCA land	Outside DBCA land	Within DBCA land
Terrestrial Vegetation / ESAs	Outside ESAs	Within an ESA	N/A
Water Bodies and Waterways	No impact of waterway or water bodies (>50m separation distance)	No impact of waterway or water bodies (>50m separation distance)	Potential impact of waterway or water bodies (<50m separation distance)
Slope	Appropriate topography (slope <15 degrees)	Less suitable topography (slope > 15 degrees)	N/A
Wind	Average windspeed >6m/s at 100m height above GL	Average windspeed <6m/s at 100m height above GL	Average windspeed <3m/s at 100m height above GL
Land Use (by LPS zoning)	Appropriate zoning (i.e. 'No zone', 'Rural', 'Strategic Industry')	N/A	Zoning not appropriate (e.g. 'City centre' , 'Commercial' , 'Conservation landscapes', 'Ocean' etc)
Native Title	Outside determined NT area	Inside determined NT area	N/A
Mining Tenure	Outside mining tenement	Inside mining tenements	N/A
Heritage (Cultural)	Outside Aboriginal Heritage Sites	Impacts on Lodged Aboriginal Heritage Sites	Impacts on Registered Aboriginal Heritage Sites
Airports	Outside of a 3km radius from any airport	Outside of a 3km radius from any airport	Inside of a 3km radius from any airport
Line Easement	On a cadastral lot adjacent to easement	On a cadastral lot not adjacent to easement	N/A
Site Road Access	Proximal to Heavy Vehicle Network (1 - 5km)	More than 5km from usable road	N/A
Grid Proximity	Less than 5 km from high voltage distribution networks, transmission and sub-transmission networks	More than 10 km from high voltage distribution networks, transmission and sub-transmission networks	N/A
Cyclone rating	>50km from coast	<50km from coast	N/A
Ownership (Freehold vs Crown)	Crown land	Freehold	N/A

A cell-by-cell interrogation of criteria driving land suitability (or constraint) was outside this scope of works. However to facilitate future feasibility studies and site selection processes, the Site Suitability surfaces and criteria layers have been provided to the City for means of interrogation on a cell-by-cell basis in *ArcReader*. Individual areas or cells of interested can be zoomed upon, and each criteria layer turned on/off, to identify those criteria driving land suitability or development constraint. An example of these views are provide in Figure 3-3.

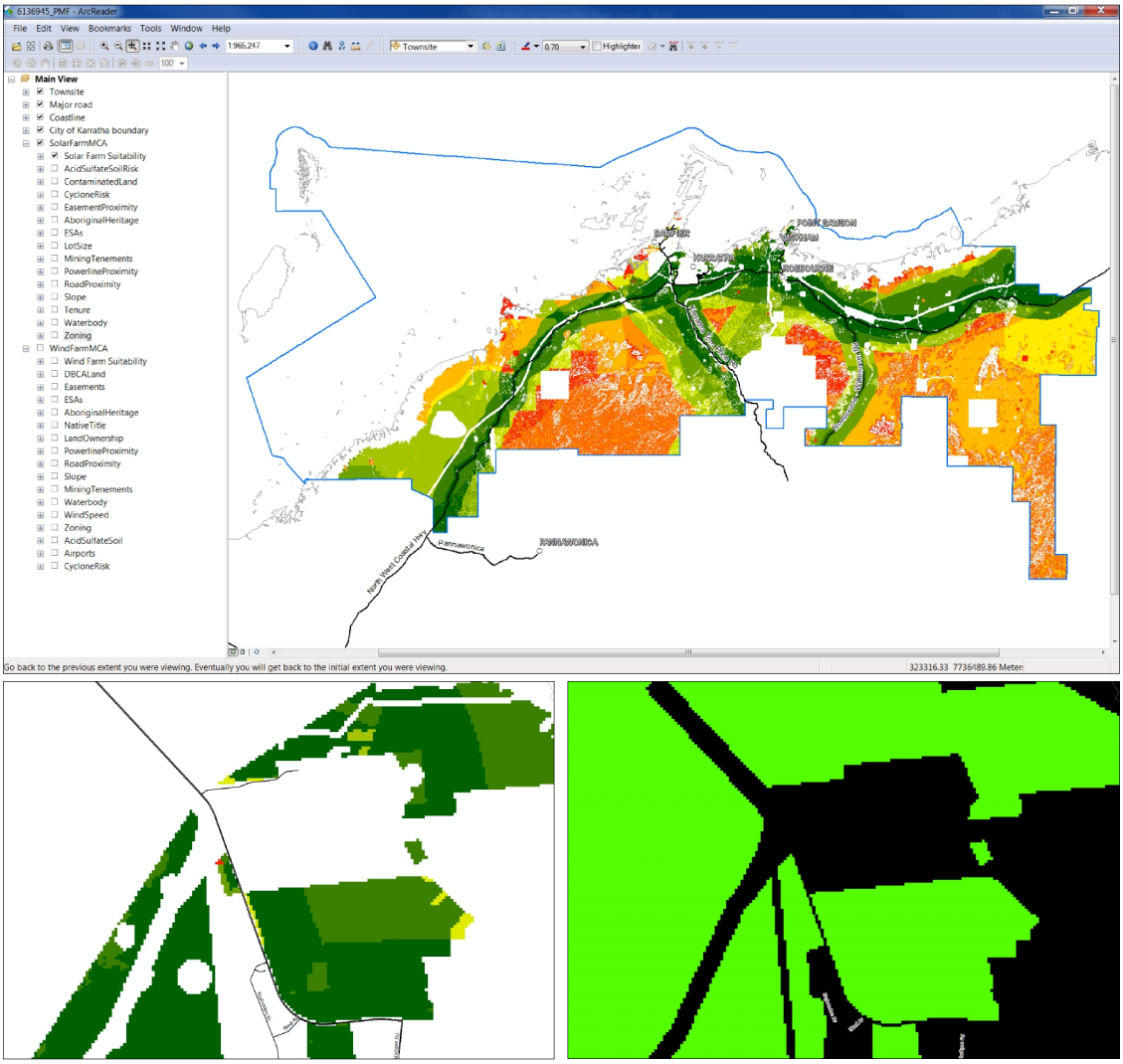


Figure 3-3 Screenshot of data interrogation tool for evaluating site suitability surfaces, with focus on Gap Ridge / Karratha Airport region.

3.4 Land Area

Table 3-3 provides a breakdown of the estimated land area (hectares) against the mapping scale applied to the InDeGO classification for solar and wind. The InDeGO process has indicated more than 119,000 ha as being highly suitable for commercial scale electricity generation through solar, constituting a significant component of the Study area. The land area assigned as highly suitable for wind was significantly less, with 7,245 ha indicated to be highly suitable for wind farm or turbine technologies.

Table 3-3 InDeGO site suitability mapping scale and estimate of land area (ha) for solar and wind energy

Suitability	Solar Hectares	Wind Hectares
High	119,472	7,245
	139,112	10,598
	66,140	529
	127,820	57,625
	27,033	105,913
	59,646	142,205
	162,813	160,992
	66,504	198,884
	57,177	191,000
Low	24,293	302,553

Note: Hectares were estimated based on the number of cells per suitability class. The resolution of the wind MCA was constrained by the spatial resolution of the WindAtlas data and estimate of average wind speed.

4. Solar Siting Assessment

The MCA developed in this study has been utilised to guide a more detailed selection of five feasible sites for the installation of different sized solar systems considering the unique requirements for different size scales.

The definition and site selection requirements are detailed within this section of the report. The initial locations will consist of suitable sites ('Good' and 'Moderate' rating) produced by the MCA mapping, refer Figure 3-1.

As mentioned previously, the corridors of high suitability (green) indicate close proximity to road and transmission infrastructure. These regions are found to be most suitable for a solar system for the following key reasons:

- Reduce the length of the transmission line required to connect the solar farm to existing infrastructure; and
- Reduce the construction costs associated with delivering components and construction personnel to a site with limited road access.

Consideration has been made regarding the location and available information on electrical infrastructure within the North West Interconnected System (NWIS) network to further refine the feasibility of Solar PV by choosing sites with optimal proximity to suitable infrastructure and geographic suitability.

4.1 Small Scale Systems

Small-scale solar systems provide an entry point for investment into renewable energy within the City of Karratha. These systems can typically be connected to the existing network with limited augmentation works required and will have the lowest impact on the power system in terms of power flow and back-feeding of the network.

Small-scale solar systems are most suitable for connection to the distribution network close to existing load, of a similar or greater size, where they are less likely to compete with the other generators for distribution line capacity.

Small-scale solar sites have been selected based on the following criteria:

- Total solar farm size between 100 kW − 1 MW;
- Close proximity to medium voltage substation or transmission line (i.e. 11 or 33 kV) for Point of Connection (POC);
- Close to a load, next to either Karratha, Dampier, Roebourne, Wickham or Point Samson; or an industrial load near a substation within the boundaries of the City; and
- Only sites within the area considered suitable ('Good' or 'Moderate' rating) by the MCA analysis have been considered.

4.1.1 Small-Scale Solar System #1 – Bayview Road

Located off Bayview Road, on unallocated crown land east of Karratha, this site is considered to be a prime location for future solar development (Figure 4-1). Horizon Power own and operate the Karratha 22kV distribution network and the Pegs Creek substation that is approximately 2.5km from the site. Relevant details related to this site are as per Table 4-1.

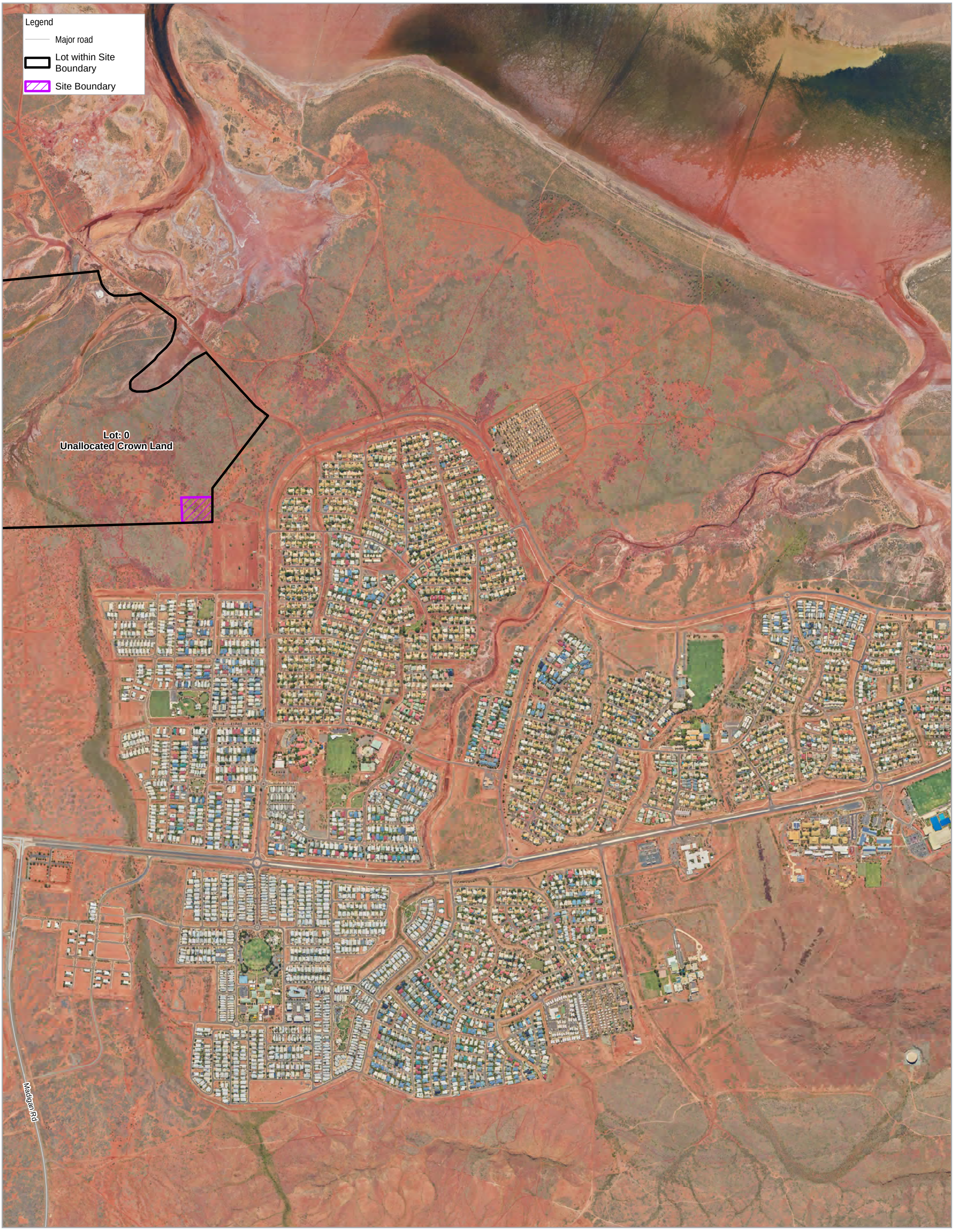
Table 4-1 Small Scale Solar #1 Key Factors

Bayview Road – Small Scale Solar System #1	
Footprint (ha)	1.5
Coordinates	-20.7326194°, 116.7959229°
Potential Size (MW)	1
Recommended POC	22kV Distribution line
Distance to POC	400m
Distance to nearest substation (m)	2500
Substation details	132/22 kV
POC owner	Horizon Power
Substation owner	Horizon Power
LPS Zoning	Rural
Tenure	Lot: 0 - Unallocated Crown Land

It is imperative that consultation with Horizon Power is undertaken to assess the available capacity within the 22kV distribution network as the first step in any potential development.

Key risks for such a project include:

- Obtaining a connection agreement with Horizon Power;
- The network impact assessment for proposed size; and
- Proximity of the solar system to the residential area.



Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometres

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

City of Karratha
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FIGURE **4-1**

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Print date: 21 Aug 2018 - 12:25

Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mczekaj

4.1.2 Small-Scale Solar System #2 – Point Samson

Located to the west of the Point Samson township, this site has been identified by the MCA as suitably zoned land for a solar system (Figure 4-2). The load at the townsite and adjacent sand mine are supplied from the NWIS by a radial 11kV distribution line which indicates that capacity for the connection of a small-scale system is highly likely. Horizon Power own and operate the 11kV radial feeder to the townsite and sand mine and the Cape Lambert Terminal that is approximately 7.5km from the potential site. Relevant details of the site are as per Table 4-2.

Table 4-2 Small Scale Solar #2 Key Factors

Point Sampson – Small Scale Solar System #2	
Footprint (ha)	1.5
Coordinates	-20.6209862°, 117.1836521°
Potential Size (MW)	1
Recommended POC	11kV Distribution line
Distance to POC	100m
Distance to nearest substation (m)	7500m
Substation details	132/11 kV
POC owner	Horizon Power
Substation owner	Horizon Power
LPS Zoning	Strategic Industry
Tenure	Lot: 317 - Propriet: State of Western Australia; Lot: 0 Reserve: R 35813

It is imperative that that early consultation with Horizon Power is undertaken to confirm the details and available capacity at the end of the Point Samson radial 11 kV feeder. The current capacity of the Cape Lambert Substation is 1.5 MVA, and the summer demand at Point Samson is growing, currently at 1.2 MVA.

Key risks for such a project include:

- Obtaining a connection agreement with Horizon Power;
- The network impact assessment for proposed size;
- Proximity of the solar system to the residential area; and
- The impact of dust on energy output from nearby operations, resulting in increased maintenance costs.

Paper Size ISO A3

0 0.07 0.14 0.21 0.28

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

City of Karratha
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FIGURE **4-2**

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Print date: 21 Aug 2018 - 12:26

Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mczekaj

4.2 Large Scale System

Large-scale solar systems are the key opportunities for investment into renewable energy within the City of Karratha. These systems should be connected into transmission infrastructure (66kV or greater) as the energy they produce is significantly larger than typical localised loads. It may be necessary to compliment the system with a synchronous power station or large-scale energy storage, of a similar or greater size to manage the intermittency of the system without impacting network stability

Large-scale solar sites were selected based on the following criteria:

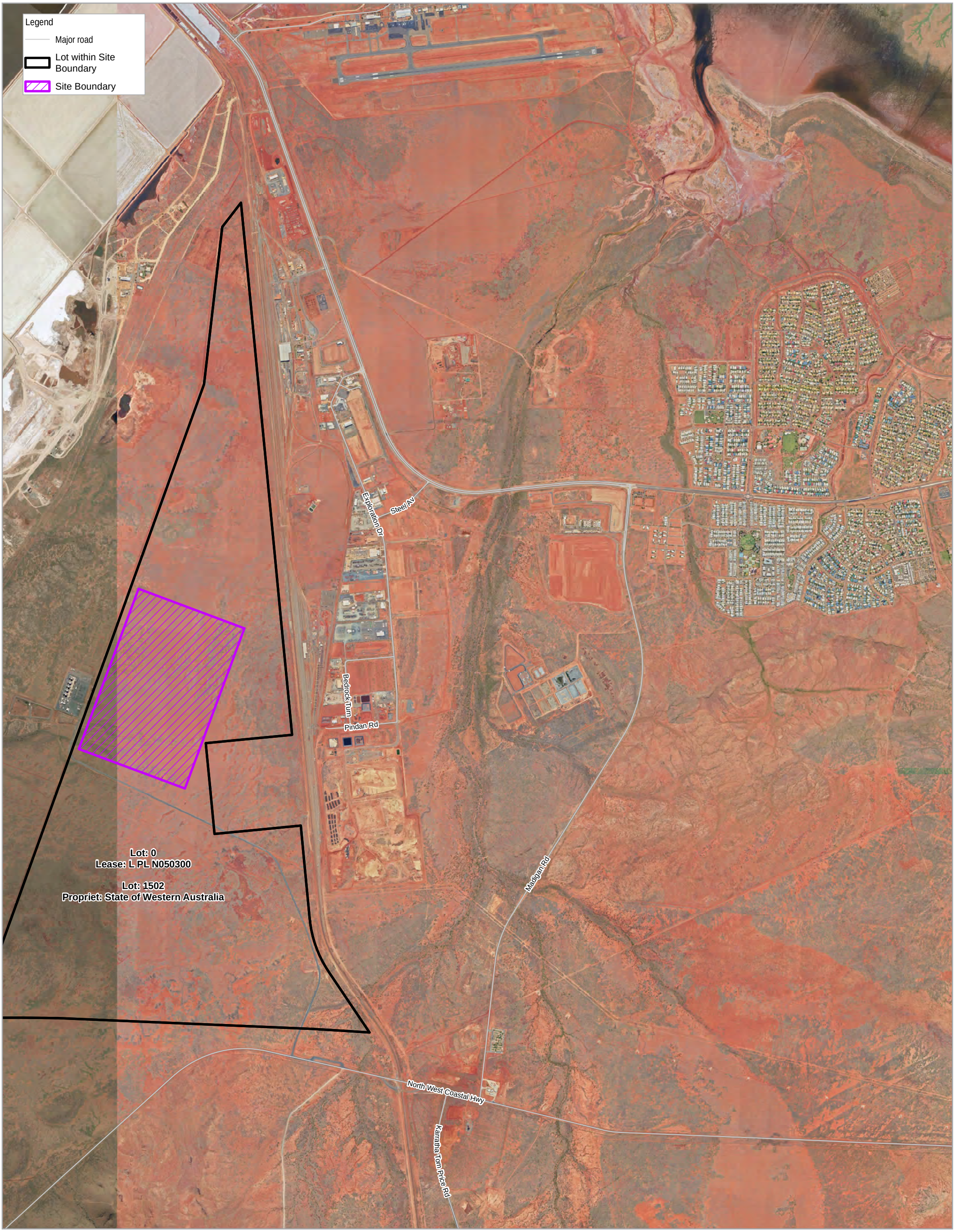
- Total solar system size between 1 MW – 100 MW;
- Close proximity to medium to high voltage substation or transmission line; and
- Close to a load and generation source, next to either Karratha, Dampier, Roebourne, Wickham or Point Samson; or an industrial load near a substation within the boundaries of the City.

4.2.1 Large Scale Solar System #1 – Gap Ridge

This site is located adjacent to the 240 MW Yurralyi Maya Power Station, to the west of Karratha and Gap Ridge, in an area currently owned and operated by RTIO, refer Figure 4-3. Aerial imagery from May 2017 suggests that there are two free line bays which could be utilised by a solar farm development. The solar farm will require step up transformers to 220 kV to connect to the POC. This option presents a key opportunity for investment in such a system to streamline the connection and approval process, noting that agreement from RTIO would be required. The relevant details of the site are as per Table 4-3.

Table 4-3 Large Scale Solar #1 Key Factors

Yurralyi Maya – Large Scale System #2	
Footprint (ha)	150
Coordinates	-20.7663618°, 116.7511824°
Potential Size (MW)	100
Recommended POC	220 kV Yurralyi Maya Power Station
Distance to POC	100m
Distance to nearest substation (m)	100m
Substation details	220 kV
POC owner	RTIO
Substation owner	RTIO
LPS Zoning	Rural
Tenure	Lot: 1502 - Propriet: State of Western Australia; Lot: 0 Lease: L PL N050300



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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

City of Karratha
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FIGURE **4-3**

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Print date: 21 Aug 2018 - 12:27

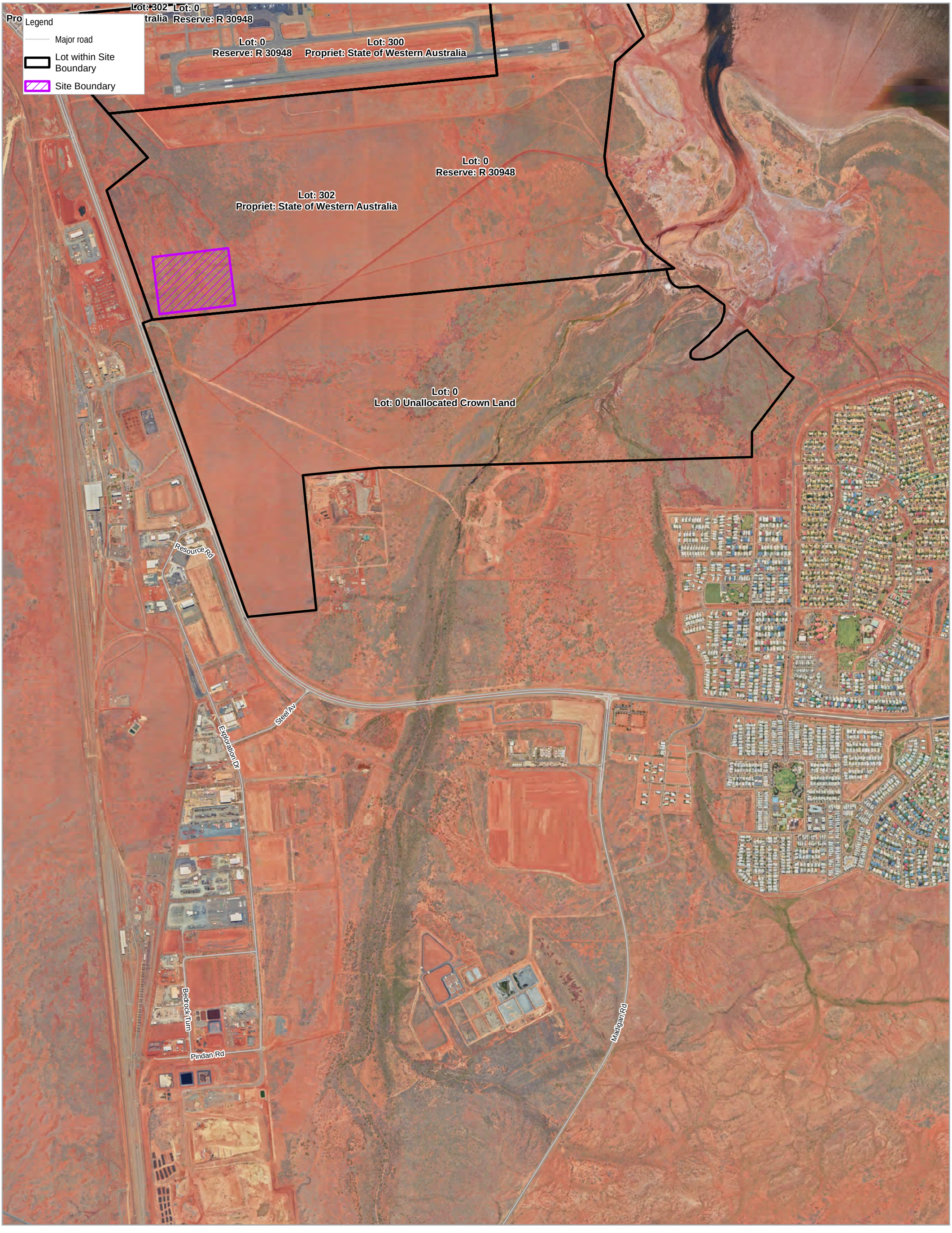
Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mczekaj

4.2.2 Large-Scale Solar System #2 – Karratha Airport Reserve

Located to the south of Karratha Airport, this site is located upon the Karratha Airport Reserve, which is considered to be a prime area for future solar development (Figure 4-4). The facility would require step up transformers to connect to the 132 kV transmission line that is owned and operated by Horizon Power. As with the small scale options presented, consultation with Horizon Power should be undertaken to assess the available capacity within the 132 kV transmission network. Relevant details of the site are as per Table 4-4.

Table 4-4 Large Scale Solar #2 Key Factors

Karratha Airport Reserve – Large Scale Solar System #2	
Footprint (ha)	15
Coordinates	-20.724623°, 116.765345°
Potential Size (MW)	10 (possible to scale up or down)
Recommended POC	132kV Transmission line
Distance to POC	350m
Distance to nearest substation (m)	3000m
Substation details	220 kV
POC owner	Horizon Power
Substation owner	RTIO
LPS Zoning	Public Purposes
Tenure	Lot: 302 - Propriet: State of Western Australia; Lot: 0 Reserve: R 30948



Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

City of Karratha
Solar Farm Suitability
Multi-Criteria Analysis

Large Scale Solar System #2

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FIGURE **4-4**

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Print date: 21 Aug 2018 - 12:28

Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mczekaj

4.3 Export Scale Solar System

The northern region of Western Australia has one of the best solar resources in the world and has been increasingly looked at as a site for export-scale renewable energy. While the export of energy is still in the concept phase, current research efforts have focussed on two forms of energy export:

1. Liquid Ammonia – energy would be used to produce hydrogen and then liquid ammonia and would be shipped internationally as a clean liquid fuel; and
2. Direct subsea transmission – high voltage, typically DC, cable would be installed between the energy generation source and an international user.

The Pilbara and particular the City of Karratha, is well positioned for both of these forms of energy export with proximity to Southeast Asia and current shipping facilities.

An export-scale solar system is expected to be required to be much larger than 1 GW, noting that this is subject to the feasibility of energy export. Due to the size of the electrical infrastructure required to transmit this export quantity of energy, this option is not required to be near to existing transmission infrastructure, but would require considerable land capacity.

A potential region for a solar farm large enough to produce export quantities of energy has been identified east of the LGA, north of Sherlock and close to Whim Creek, refer Figure 4-5. The key details related to this site have been summarised in Table 4-5. The MCA has been used to guide the selection of this site, however due to the scale and specific nature of such a system, reasonable assumptions have been made in interpreting some areas deemed of lesser suitability by the MCA.

Table 4-5 Export Scale System Key Factors

North Sherlock – Export Scale Solar System	
Footprint (ha)	11,696
Coordinates	-20.8377089°, 117.5334584°
Potential Size (MW)	7800
Recommended POC	New transmission line and substation
Distance to POC	N/A
Distance to nearest substation (m)	N/A
Substation details	N/A
POC owner	N/A
Substation owner	N/A
LPS Zoning	Rural and Local Road
Tenure	Lot: 0 Reserve: R 9701; Lot: 0 Road; Lot: 50 Propriet: State of Western Australia; Lot: 0 Lease: L PL N050345; Lot: 91 Propriet: State of Western Australia; Lot: 49 Propriet: State of Western Australia; Lot: 0 Lease: L PL N049883

Legend

- Townsite
- Major road
- Lot within Site Boundary
- Site Boundary

DAMPIER
Burrup Peninsula
Cinders Rd
KARRATHA
Coolawanyah Rd
WICKHAM
POINT SAMSON
Point Samson Roebourne
ROEBOURNE
North West Coastal Hwy
Karratha Tom Price Rd
Roebourne - Wittenoom Rd

Lot: 0
Lease: L PL N050345
Lot: 49
Propriet: State of Western Australia
Lot: 50
Propriet: State of Western Australia
Lot: 91
Lot: 0
Propriet: State of Western Australia
Lease: L PL N049883
Lot: 91
Propriet: State of Western Australia
Lot: 0
Reserve: R 9701
Lot: 0
Lease: L PL N050345
Lot: 49
Propriet: State of Western Australia
Lot: 50
Propriet: State of Western Australia
Lot: 0
Lease: L PL N049883

Paper Size ISO A3

0 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

City of Karratha
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Export Scale Solar System #1

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FIGURE **4-5**

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Print date: 21 Aug 2018 - 12:29

Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mczekaj

4.4 Alternative Solar Developments

This report has not considered the feasibility of solar PV mounted on pre-existing structures such as buildings or industrial surfaces as the intended purpose of the MCA is to assess feasibility for large commercial sized (and greater), ground mounted solar PV only.

The City of Karratha has an excellent solar resource and the feasibility of this scale of solar (pre-mounting on existing structures) is only limited by the Horizon Power Technical Requirements for the connection of behind the meter (to the LV network) solar PV.

5. Wind Siting Assessment

The MCA developed in this study has been utilised to guide a more detailed selection of two feasible sites for the installation of different sized wind generation systems considering the unique requirements for different size scales. These selected solar sites should serve as a starting point for any feasibility study into wind generation within the City of Karratha.

The definition and site selection requirements are detailed within this section of the report. The sites chosen are within the most suitable sites ('Good' or 'Moderate' rating) identified by the MCA mapping, refer Figure 3-2.

As discussed in pervious sections, the corridors of limited suitability indicate close proximity to road and transmission infrastructure. The scattered regions that are light green (refer Figure 3-2) within these corridors are found to be most suitable for wind generation due to favourable factors as per the MCA criteria, primarily a higher wind resource due to increased elevation.

Consideration has been made regarding the optimal locations and available information on electrical infrastructure within the NWIS network to determine the most feasible options by choosing sites with optimal proximity to suitable infrastructure, geographic suitability and the highest wind resource.

5.1 Small-Scale Wind System

Small-scale wind generation represents a potential for entry point investment into wind energy within the City of Karratha. These systems should be connected into transmission infrastructure (66 kV or greater) or near to large loads.

The site for a small-scale wind generation system has been selected based upon the MCA and may be potentially suitable for a total capacity of 5 MW. The location is sufficiently far from a generation source that it is expected that spare capacity is available within the system at the POC, however, a detailed network assessment study will be required to confirm available capacity.

The selected site is at Point Samson/Cape Lambert (Figure 5-1) and is in close proximity to RTIO's Cape Lambert operations, including the camp to the west, which will increase the complexity of the approval process. The facility would be located upon RTIO's tenement, hence agreement from RTIO would need to progress this option. It is likely the facility would require connection into the RTIO network which would require additional negotiations.

The site represents a location with the highest feasibility within the City of Karratha, disregarding any impact on local operations. It should be noted that this site is within a Wind Region C (cyclonic), which will impact on the types of turbines that are suitable. It is recommended that this site be a starting point for future feasibility studies into small-scale wind generation within the City. The relevant details of the site are as per Table 5-1.

Table 5-1 Small Scale Wind System Key Factors

Point Samson/Cape Lambert – Small Scale Wind System	
Footprint (ha)	70
Coordinates	-20.635670°, 117.150178°
Potential Size (MW)	5 MW
Recommended POC #1	220kV/132kV Cape Lambert substation
Recommended POC #2	132kV/11kV Cape Lambert Terminal
Distance to POC #1	500m
Distance to POC #2	1000m
Substation details	220 kV
POC #1 owner	RTIO
POC #2 owner	Horizon Power
LPS Zoning	Strategic Industry
Tenure	Lot: 317 - Propriet: State of Western Australia; Lot: 0 - Reserve: R 35813

Note: there are two potential connections locations for this site, one being RTIO owned infrastructure and the other being Horizon Power owned.

Paper Size ISO A3

0 0.15 0.3 0.45 0.6

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

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Wind Farm Suitability
Multi-Criteria Analysis

Small Scale Wind System #1

Project No. **61-36945**
Revision No. **0**
Date **21/08/2018**

FIGURE 5-1

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Print date: 21 Aug 2018 - 15:24

Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mmikkonen

5.2 Large-Scale Wind System

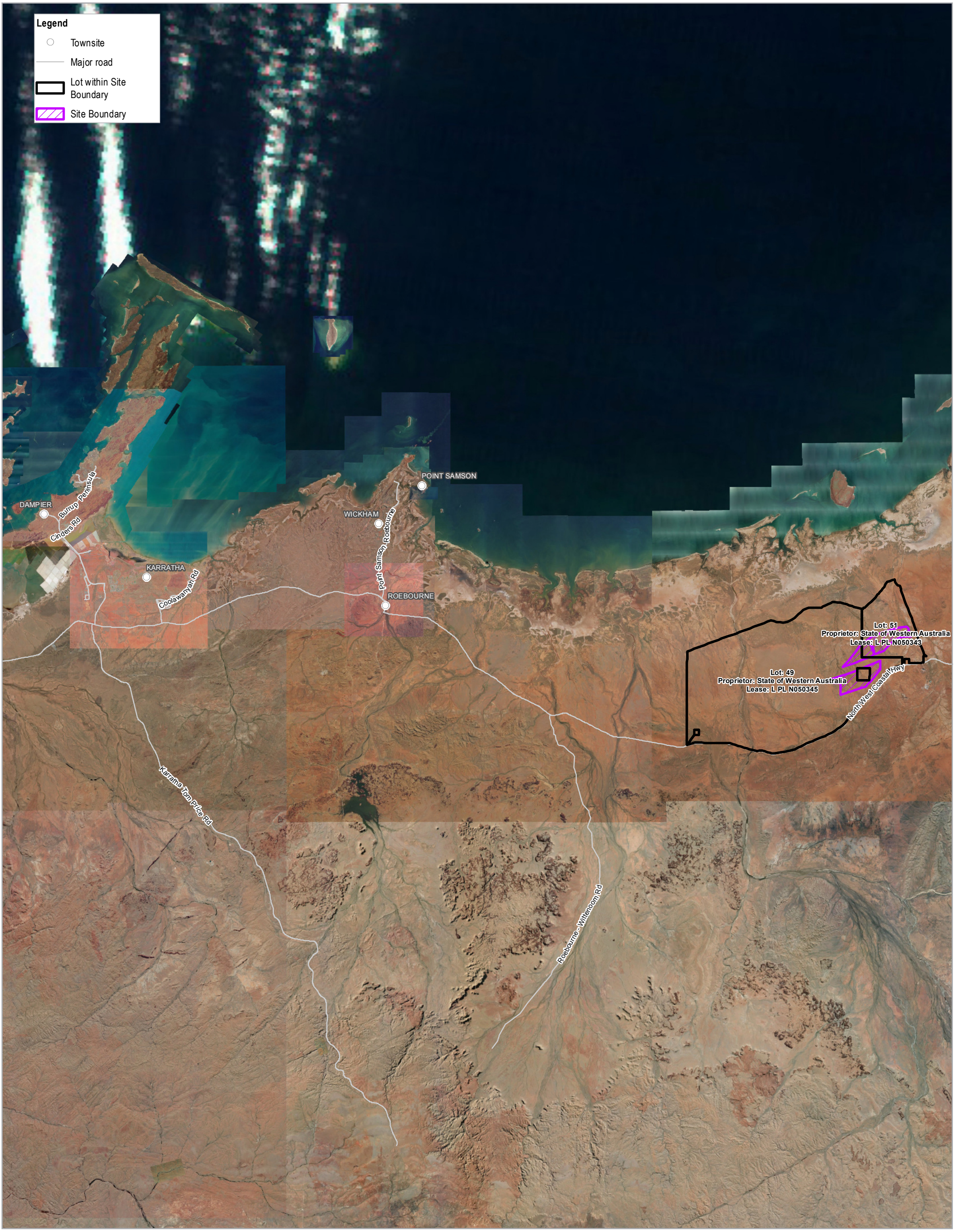
Large-scale wind generation within the City of Karratha may be suitable for interconnection into the transmission network to supply energy to the greater NWIS.

It should be noted that it is anticipated that the cost of developing, constructing and the interconnection of a large-scale wind generation system will outweigh the benefit that can be realised by current wind generation technologies.

Potential sites(s) have been identified near Whim Creek, refer Figure 5-2, in a similar location to the export scale solar site, discussed in section 4.3. This site selection was guided by the MCA aswell as further details on nearby infrastructure, terrain & the direction of prevailing wind and should serve as a starting point for determining the feasibility of large-scale wind within the City of Karratha region; the relevant details of the site are as per Table 5-2.

Table 5-2 Large Scale Wind System Key Factors

Whim Creek – Large Scale Wind System	
Footprint (ha)	2,500
Coordinates	-20.806093°, 117.783757° & -20.856394°, 117.741984°
Potential Size (MW)	30 MW
Recommended POC	220kV transmission line
Distance to POC	<3000m
POC owner	Horizon Power
LPS Zoning	Rural
Tenure	Lot: 0 - Lease: L PL N050345; Lot: 49 - Propriet: State of Western Australia Lot: 0 Lease: L PL N050343; Lot: 51 Propriet: State of Western Australia; Lot: 0 Lease: L PL N050345; Lot: 49 Propriet: State of Western Australia



Paper Size ISO A3

0 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

City of Karratha
Wind Farm Suitability
Multi-Criteria Analysis

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Revision No. **0**
Date **21/08/2018**

Large Scale Wind System #2

FIGURE 5-2

G:\61\36945\GIS\Maps\Working\6136945_010_Rev0_SiteLocation.mxd
Print date: 21 Aug 2018 - 15:24

Data source: GHD: Wind farm suitability - 20180622; Landgate: Roads, Aerial photography, Lot size, Easements, Tenure - 2018; DPIRD: Pastoral leases - 2016; DWER: ESAs - 2018, ASS risk - 2014; DPLH: Zonings - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mmikkonen

6. Conclusions and Recommendations

The InDeGO process has indicated areas with elevated suitability for commercial scale solar and wind energy production. This represents a high-level starting point for further analysis on the feasibility of these renewable energy options considering the specific technologies and systems available.

GHD recommend that the sites identified are used as starting points for any relevant feasibility study into a solar or wind energy generation system at a scale of 1 MW or larger within the Study area, noting that other suitable sites are a possibility.

GHD note that approvals have not been sought nor obtained for development of the sites identified. Results have considered Native Title, land tenure (including, mining tenements), natural constraints and State and City of Karratha Planning Framework (including the Local Planning Strategy and Local Planning Scheme). Further analysis / due diligence will be required of proponents to confirm further site suitability and project feasibility including, but not limited to;

- *Site conditions* such as: geotechnical, access, contamination, environmental and heritage
- *System costs*: wind regions, labour, operation and maintenance
- *Grid connection*: costs, access, curtailment, load
- *Power offtake*: power purchase agreements, export, large-scale generation Certificates

Generally, the Study area appeared more suitable for solar electricity generation than wind, although further steps of site suitability assessment should be undertaken.

Solar radiation is in infinite supply and suitable to support commercial scale electricity generation for the region. Average wind speeds are typically less suitable for large scale electricity generation, and are poorly defined, constraining development of this option. Potential investors looking to establish wind energy systems should implement an appropriate wind monitoring strategy to investigate the wind resource available prior to any estimates of energy generation.

This study has not considered the feasibility of areas of ocean as it was considered outside the scope of this study. There may be potentially feasible sites with access to a higher resource and limited constraints within these regions, which could be investigated separately.

In future, opportunities may arise from interventions in the landscape, which alter land capability such as mining operations. These interventions may reduce the impact of constraints associated with infrastructure or tenure. The site suitability presented should be considered in relation to any current or future proposals which may alter land capability.

7. References

ABARE (Australian Bureau of Agricultural and Resource Economics), 2010, Australian energy projections to 2029-30, ABARE research report 10.02

Geoscience Australia and ABARE, 2010, Australian Energy Resource Assessment, Canberra.

Mella, S., James, G. & Chalmers, K. 2017. Evaluation the potential to export Pilbara solar resources to the proposed ASEAN grid via a subsea high voltage direct current interconnector, Pilbara Development Commission.

Appendices

Appendix A – Site suitability selection criteria and performance ratings

Solar study MCA criteria and performance rating

Solar Siting Study MCA Criteria						
Issue	**Objectives**	**Dataset**	**Good = 1**	**Moderate = 20**	**Poor = 100**	**Fatal Flaw = 999**
Environmental Considerations						
DBCA Legislated Land	Impacts on sites with legal conservation status are avoided or minimised	LegislatedLandsandWaters_WGS84_DBCA_20170730	Outside DBCA land	None	None	All DBCA Land
Terrestrial Vegetation	Clearing of conservation significant vegetation is minimised.	ClearingRegulations_EnvironmentallySensitiveAreas_WGS84_DWER_2015101	Outside ESAs	None	Environmentally Sensitive Area	None
Water Bodies and Waterways	Impacts on water bodies and waterways are minimised.	MediumScaleTopoWaterLine_GDA94_LGATE018 and MediumScaleTopoWaterPolygonLGATE_016	Greater than 50m from waterway	None	None	Within 50m of stream order 4-9, or waterway area or waterbody
Slope	Minimise development cost and	Generated from contour data	Slope less than 2%	Slope is between 2 - 5%	N/A	Slope exceeds 5% based on 10m DEM
Contaminated Sites	Avoid areas that listed as contaminated.	Contaminated_ReportedSitesDER_015.shp (20171219)	Outside 100m of a contaminated or potentially contaminated site	None	Within 100m of a contaminated or potentially contaminated site	Within a contaminated site as listed on the Department of Water and Environmental Regulation (DWER) Contaminated Sites
Land Use Planning Considerations						
Agricultural Land	Good Quality Agricultural Land is conserved	Pastoral_Boundaries_GDA94_DAFWA_20160916	Not within a pastoral lease	Within a pastoral lease	None	None
Land Use	Cannot build on current intensive/urban land uses, conservation or road zonings.	LPS Zoning	No zone', 'Rural', 'Strategic Industry'	None	None	'City centre' , 'Commercial' , 'Commercial and civic' , 'Conservation recreation and natural landscapes' ' etc
Native Title	Delays due to Native Title issues are minimised, rights of Native Title claimants are respected.	NativeTitleDeterminationLGATE_066	Outside determined NT area	Inside determined NT area	None	None
Mining Tenure	Mining and exploration activities are not impacted on.	MiningTenements_WGS84_DMIRS_20180115	Outside all tenements	Inside tenements	None	None
Heritage (Cultural)	Items of cultural heritage are not impacted	AboriginalHeritagePlaceRegister_GDA94_DAA_20180121	Outside all Aboriginal Heritage Sites	None	Contact DAA, Lodged status	Within registered site on the Department of Aboriginal Affairs (DAA) Heritage Inquiry System, EPBC Act Protected Matters Search Tool or
Line Easement	Existence of easements for the line connection	EasementsPolygonsLGATE_090	on a cadastral lot adjacent to easement	None	on a cadastral lot not adjacent to easement	None
Acid Sulphate Soil Risk	Avoid risky areas	PotentialAcidSulfateSoil_AcidSulfateSoilRiskMap_PilbaraCoastline_WG84_DWER_20140922	Outside any known ASS risk	Moderate to low risk	High to moderate risk	None
Land Tenure	Prefer state-owned land	Cadastre_Ownership_LGATE082_MGA50.shp	org_type = S (State)	Outside of dataset (ownership unknown)	org_type = APTY, APUB or P	None
Infrastructure Considerations						
Site Road Access	Access to site is possible via designated heavy vehicle routes.	Roads_Merged_GDA94	<1km from usable road	1-5 km from usable road	More than 5km from usable road	None
Grid Proximity	Focus on sites with reasonable proximity to high voltage distribution networks, transmission and sub-transmission networks	NationalElectricityTransmissionLines	<5 km from high voltage distribution networks, transmission and sub-transmission networks	5-10 km from high voltage distribution networks, transmission and sub-transmission networks	More than 10 km from high voltage distribution networks, transmission and sub-transmission networks	None
Technical Considerations						
Cyclone rating	Cyclone rating is given based broadly on the Australian Standards method for assigning cyclone ratings for building design in Australia.	Islands_Mainland_Merge	>60km from coast	30-60km from coast	<30km from coast	None
Lot size	Scores for lot size are allocated as detailed below. Larger sites are given a better score based on ease of dealing with fewer landowners etc.	Cadastre	50+ ha	10-50 ha	<10 ha	None

Wind study MCA criteria and performance rating

Wind Siting Study MCA Criteria						
Issue	**Objectives**	**Dataset**	**Good = 1**	**Moderate = 20**	**Poor = 100**	**Fatal Flaw = 999**
Environmental Considerations						
DBCA Legislated Land	Impacts on sites with legal conservation status are avoided or minimised	LegislatedLandsandWaters_WGS84_DBCA_20170730	Outside DBCA land	None	None	All DBCA Land
Terrestrial Vegetation	Clearing of conservation significant vegetation is minimised.	ClearingRegulations_EnvironmentallySensitiveAreas_WGS84_DWER_20151012	Outside ESAs	None	Environmentally Sensitive Area	None
Water Bodies	Impacts on water bodies and waterways are minimised.	MediumScaleTopoWaterLine_GDA94_LGATE018 and MediumScaleTopoWaterPolygonLGATE_016	Greater than 50m from waterbody	None	None	Within 50m of waterbody
Slope	Minimise development cost and	Generated from contour data	Slope less than 15Deg		>15Deg	
Land Use Planning Considerations						
Land Use	Cannot build on current intensive/urban land uses, conservation or road zonings.	LPS Zoning	No zone', 'Rural', 'Strategic Industry'	None	None	'City centre' , 'Commercial' , 'Commercial and civic' , 'Conservation recreation and natural landscapes' etc
Native Title	Delays due to Native Title issues are minimised, rights of Native Title claimants are respected.	NativeTitleDeterminationLGATE_066	Outside determined NT area	Inside determined NT area	None	None
Mining Tenure	Mining and exploration activities are not impacted on.	MiningTenements_WGS84_DMIRS_20180115	Outside all tenements	Inside tenements	None	None
Heritage (Cultural)	Items of cultural heritage are not impacted	AboriginalHeritagePlaceRegister_GDA94_DAA_20180121	Outside all Aboriginal Heritage Sites	None	Contact DAA, Lodged status	Within registered site on the Department of Aboriginal Affairs (DAA) Heritage Inquiry System, EPBC Act Protected Matters Search Tool or Heritage Council InHerit database
Line Easement	Existence of easements for the line connection	EasementsPolygonsLGATE_090	on a cadastral lot adjacent to easement	None	on a cadastral lot not adjacent to easement	None
Acid Sulphate Soil Risk	Avoid risky areas	PotentialAcidSulfateSoil_AcidSulfateSoilRiskMap_PilbaraCoastline_WG84_DWER_20140922	Outside any known ASS risk	Moderate to low risk	High to moderate risk	None
Land Tenure	Prefer state-owned land	Cadastre_Ownership_LGATE082_MGA50.shp	org_type = S (State)	Outside of dataset (ownership unknown)	org_type = APTY, APUB or P	None
Infrastructure Considerations						
Site Road Access	Access to site is possible via designated heavy vehicle routes.	Roads_Merged_GDA94	<1km from usable road	1-5 km from usable road	More than 5km from usable road	None
Airport	Polygon of Airstrip buffer 1.5km on longer distance and 3km on shorter distance	Based on GA and verified by GHD - the polygon was drawn based on aerial image	Outside airstrip buffer	None	None	Insite airstrip buffer
Grid Proximity	Focus on sites with reasonable proximity to high voltage distribution networks, transmission and sub-transmission networks	NationalElectricityTransmissionLines	<5 km from high voltage distribution networks, transmission and sub-transmission networks	5-10 km from high voltage distribution networks, transmission and sub-transmission networks	More than 10 km from high voltage distribution networks, transmission and sub-transmission networks	None
Technical Considerations						
Wind	Speed of wind raster	Based on informaton show: https://globalwindatlas.info/	>6m/s	4-6m/s	3-4m/s	< 3m/s
Cyclone rating	Cyclone rating is given based broadly on the Australian Standards method for assigning cyclone ratings for building design in Australia.	Islands_Mainland_Merge	>100km from coast	50-100 km	<50	None

Appendix B – Criteria weightings

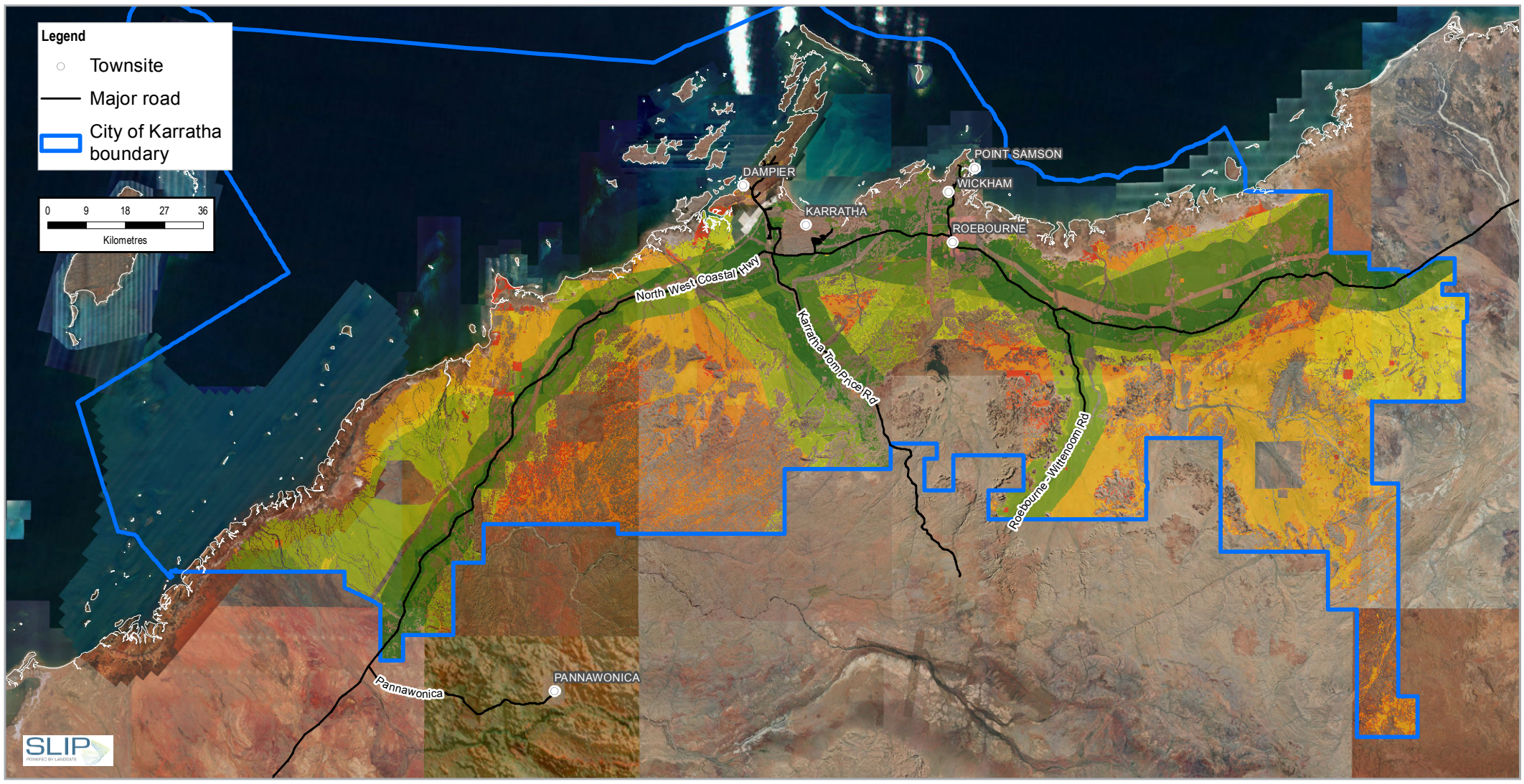
Solar Criteria Weighting

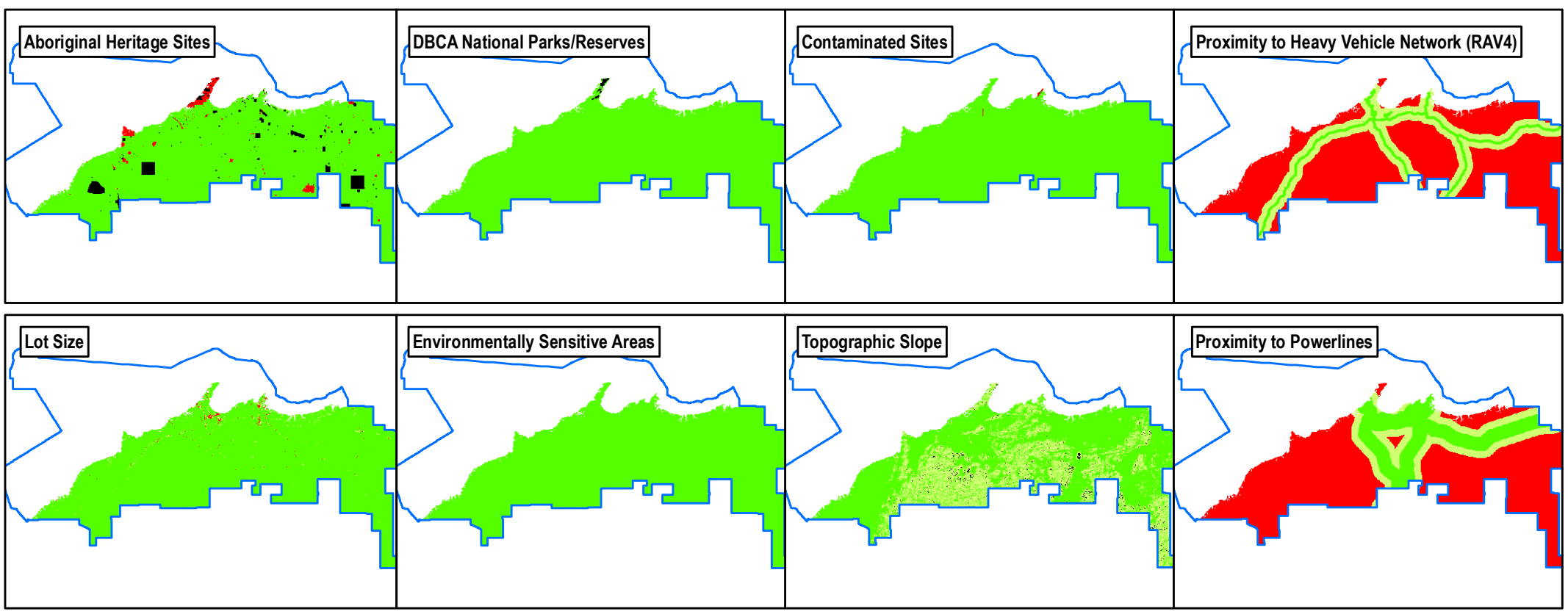
Criteria	DBCA Legislated Land	Terrestrial Vegetation (ESAs)	Water Bodies and Waterways	Slope	Contaminated Sites	Agricultural Land (Pastoral Leases)	Land Use (by LPS zoning)	Native Title	Mining Tenure	Heritage (Cultural)	Line Easement	Acid Sulphate Soil Risk	Site Road Access	Grid Proximity	Cyclone rating	Lot size	Ownership (Freehold vs Crown)	Count	Weighting (%)
DBCA Legislated Land		1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	15	11.03%
Terrestrial Vegetation (ESAs)	0		1	0	0	1	1	1	1	0	0	1	0	1	1	1	0	9	6.62%
Water Bodies and Waterways	0	0		0	0	1	0	0	0	0	0	1	0	1	1	0	0	4	2.94%
Slope	0	1	1		0	1	1	1	1	0	1	1	0	0	1	0	0	9	6.62%
Contaminated Sites	0	1	1	1		1	1	1	1	0	1	1	1	1	1	1	0	13	9.56%
Agricultural Land	0	0	0	0	0		1	1	0	0	0	0	0	0	1	0	0	3	2.21%
Land Use (by LPS zoning)	0	0	1	0	0	0		0	1	0	0	1	0	0	1	0	0	4	2.94%
Native Title	0	0	1	0	0	0	1		1	0	1	1	0	1	1	0	0	7	5.15%
Mining Tenure	0	0	1	0	0	1	0	0		0	1	1	0	0	1	0	0	5	3.68%
Heritage (Cultural)	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	16	11.76%
Line Easement	0	1	1	0	0	1	1	0	0	0		1	0	1	1	0	0	7	5.15%
Acid Sulphate Soil Risk	0	0	0	0	0	1	0	0	0	0	0		0	0	0	0	0	1	0.74%
Site Road Access	0	1	1	1	0	1	1	1	1	0	1	1		0	1	0	1	11	8.09%
Grid Proximity	0	0	0	1	0	1	1	0	1	0	0	1	1		1	1	1	9	6.62%
Cyclone rating	0	0	0	0	0	0	0	0	0	0	0	1	0	0		0	0	1	0.74%
Lot size	0	0	1	1	0	1	1	1	1	0	1	1	1	0	1		0	10	7.35%
Ownership (Freehold vs Crown)	0	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1		12	8.82%
																		136	100.00%

Wind Criteria Weighting

Criteria	DBCA Legislated Land	Terrestrial Vegetation (ESAs)	Water Bodies and Waterways	Slope	Wind	Land Use (by LPS zoning)	Native Title	Mining Tenure	Heritage (Cultural)	Line Easement	Acid Sulphate Soil Risk	Land Tenure	Site Road Access	Grid Proximity	Cyclone rating	Airport	Count	Weighting (%)
DBCA Legislated Land		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	12.50%
Terrestrial Vegetation (ESAs)	0		1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	11.67%
Water Bodies and Waterways	0	0		0	0	1	1	1	1	0	0	1	0	0	0	0	5	4.16%
Slope	0	0	1		1	1	1	0	0	1	0	1	0	0	1	0	7	5.83%
Wind	0	0	1	0		1	1	1	0	1	1	1	0	0	1	0	8	6.67%
Land Use (by LPS zoning)	0	0	0	0	0		1	0	0	0	1	0	0	0	0	0	2	1.67%
Native Title	0	0	0	0	0	0		0	0	0	1	0	0	0	0	0	1	0.83%
Mining Tenure	0	0	0	1	0	1	1		0	1	1	1	0	0	1	0	7	5.83%
Heritage (Cultural)	0	0	0	1	1	1	1	1		1	1	1	1	1	1	0	11	9.16%
Line Easement	0	0	1	0	0	1	1	0	0		0	1	0	0	1	0	5	4.16%
Acid Sulphate Soil Risk	0	0	1	1	0	0	0	0	0	1		1	0	0	0	0	4	3.33%
Land Tenure	0	0	0	0	0	1	1	0	0	0	0		0	0	1	0	3	2.50%
Site Road Access	0	0	1	1	1	1	1	1	0	1	1	1		1	1	0	11	9.16%
Grid Proximity	0	0	1	1	1	1	1	1	0	1	1	1	0		1	0	10	8.33%
Cyclone rating	0	0	1	0	0	1	1	0	0	0	1	0	0	0		0	4	3.33%
Airport	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1		13	10.83%
																	120	100.00%

Appendix C – Criteria layers and performance rating solar and wind





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- Moderate (some constraints)
- Poor (high constraints)

Paper Size ISO A3

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Kilometres

Map Projection: Mercator Auxiliary Sphere
Horizontal Datum: WGS 1984
Grid: WGS 1984 Web Mercator Auxiliary Sphere

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City of Karratha
Solar Farm Suitability
Multi-Criteria Analysis

Project No. **61-36945**
Revision No. **0**
Date **05/06/2018**

Solar Farm Suitability Criteria

FIGURE C1

G:\61\36945\GIS\Maps\Working\6136945_002_SolarSuitabilityCriteria_Rev0.mxd
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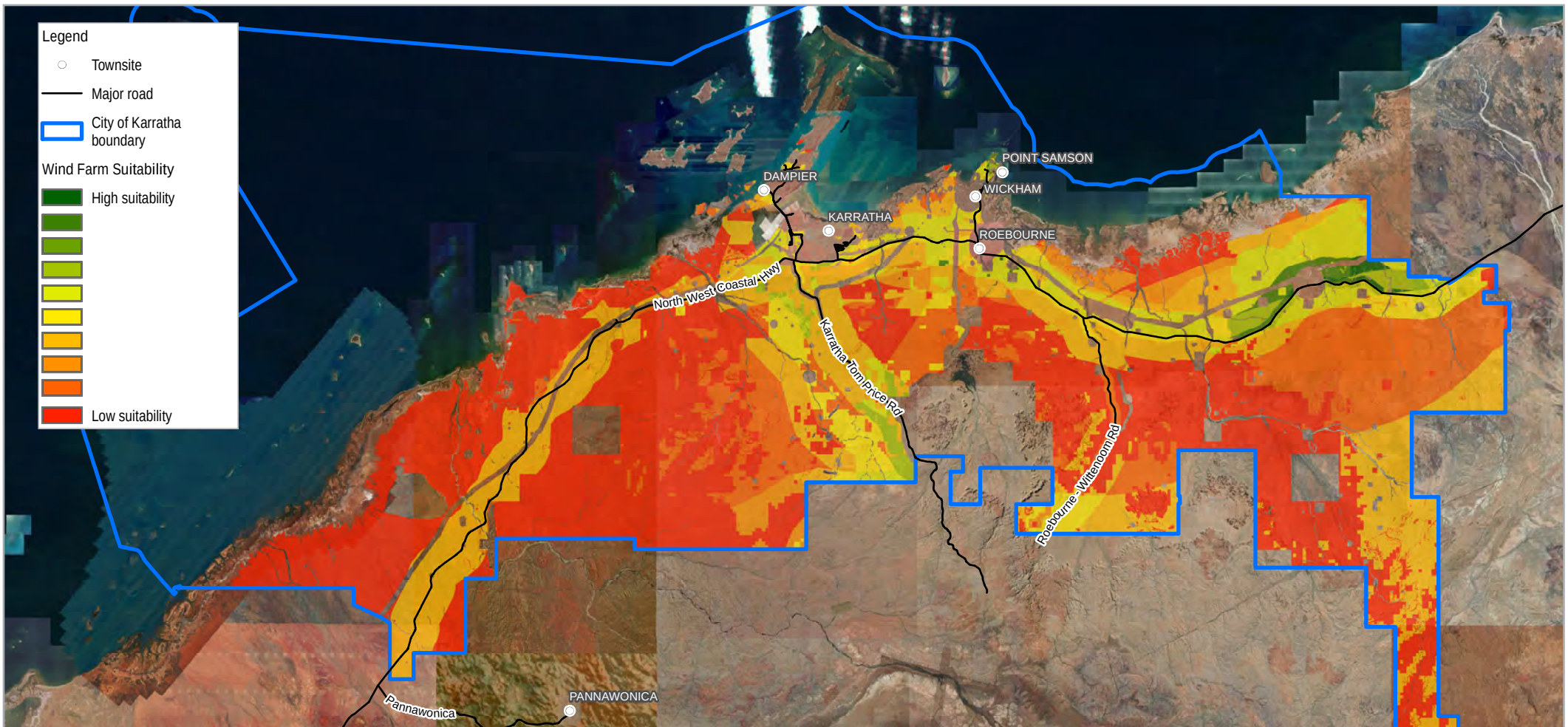

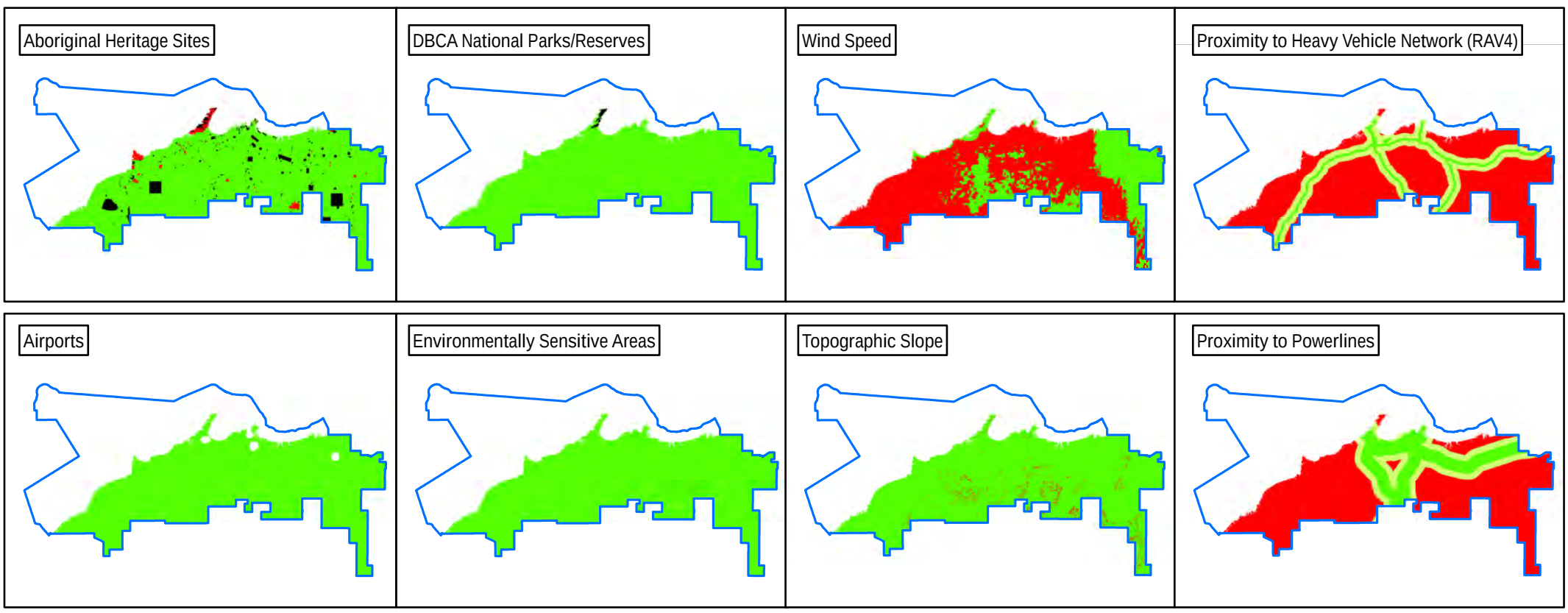

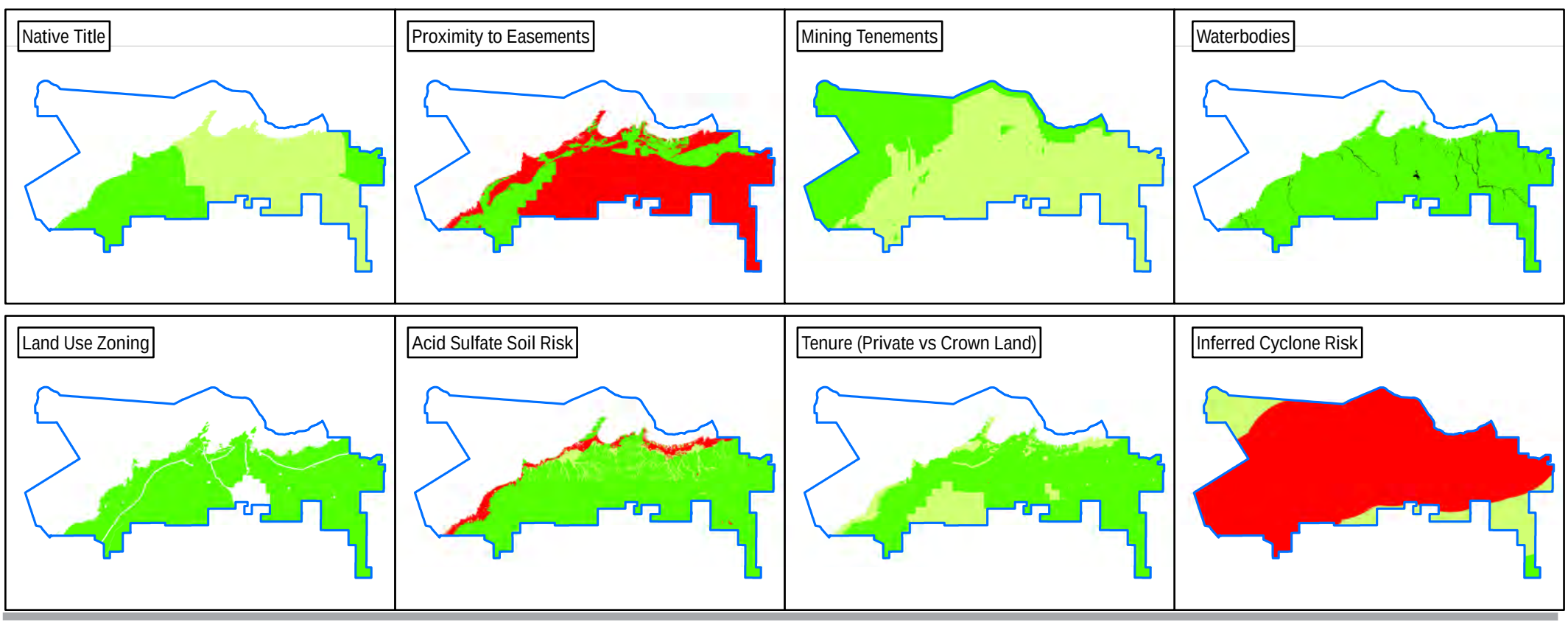

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- Moderate (some constraints)
- Poor (high constraints)

Paper Size ISO A3

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Kilometres

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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City of Karratha
Wind Farm Suitability
Multi-Criteria Analysis

Project No. 61-36945
Revision No. 0
Date 21/08/2018

Wind Farm Suitability Criteria

FIGURE **C2**

G:\61\36945\GIS\Maps\Working\6136945_008_WindSuitabilityCriteria_Rev0.mxd
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Data source: GHD: Wind Farm Suitability - 201808197, Unsuitable, Good (no constraints), Moderate (some constraints), Poor (high constraints) - 20180817; Landgate: Roads Name, Aerial photography, City of Karratha boundary - 2018; Geoscience Australia: Geodata Topo 250k - 2006. . Created by: mczekaj

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6136945-31883/https://projects.ghd.com/oc/WesternAustralia/karrathacouncillands/Delivery/Documents/6136945-REP-Rev4_CofK Renewables Study Report.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	K Potts M Mikkonen	H O'Keeffe	**H O'Keeffe*	H O'Keeffe	**H O'Keeffe*	07/06/2018
1	T Hibberd	H O'Keeffe	**H O'Keeffe*	H O'Keeffe	**H O'Keeffe*	02/06/2018
2	A Burton J Mazza	H O'Keeffe	**H O'Keeffe*	H O'Keeffe	**H O'Keeffe*	02/08/2018
3	T Hibberd	H O'Keeffe	**H O'Keeffe*	H O'Keeffe	**H O'Keeffe*	21/08/2018
4	T Hibberd	H O'Keeffe	**H O'Keeffe*	H O'Keeffe	**H O'Keeffe*	24/08/2018

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