NT Wind Resource Assessment and Wind Measurement Strategy

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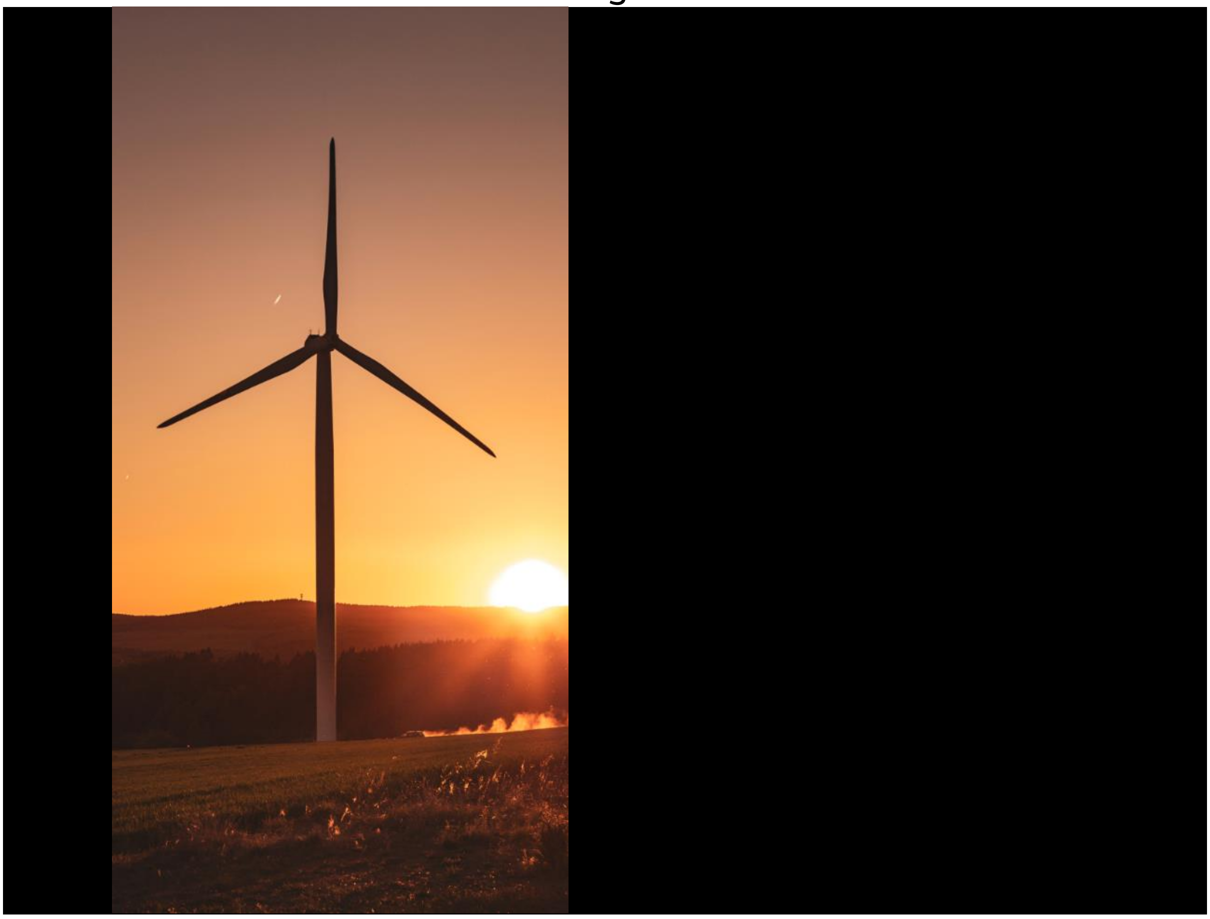
Department of Industry, Tourism and Trade
Q23-0019

Provision of Expert Advice on NT Wind Resource Measurement Strategy and Site Selection Assessment for Large Scale Wind Generation



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Contents

Appendices

Tables

Figures

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The NT Wind Resource Assessment and Wind Measurement Strategy was prepared to provide an overview and summary of information and data relating to the Territories wind resources and provides an evidence-based strategic approach to mapping the Territory's wind energy resources and identifying opportunities for wind generation.

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Additional work has been carried out for the Department of Industry, Tourism and Trade as part of this project delivery which does not form part of this report.

Acronyms and abbreviations

AAPA	Aboriginal Areas Protection Authority
APAC	Asia-Pacific
BoM	Bureau of Meteorology
DIPL	Department of Infrastructure, Planning and Logistics
DITT	Department of Industry, Tourism and Trade
ECMWF-ERA5	European Centre for Medium Range Weather Forecasting – Reanalysis version 5
ESCC	Earth Systems and Climate Change
GW	Gigawatts
HSE	Health, safety and environment
IEC61400-1	IEC 61400-12-1: Performance Measurements of Wind Turbines
ILUA	Indigenous Land Use Agreement
Kms	Kilometres
kW	Kilowatts
LiDAR	Light Detection and Ranging
MCA	Multi-criteria Analysis
MET MAST	Meteorological masts
M/s	Metres per second
MW	Megawatts
NESP	National Environmental Science Program
NLC	Northern Land Council
NT	Northern Territory
NTEPA	Northern Territory Environmental Protection Authority
SOCS	Sites of Conservation Significance
SODAR	Sonic Detection and Ranging
WaSP	Wind Atlas Analysis and Application Program
WRF	Weather Research Forecasting

1. Introduction

With its close proximity to Asia, the Northern Territory (the Territory) is positioned strategically to attract investment into renewable energy projects. The Territory's abundance of natural resources, sparsely populated land and planned integrated enabling infrastructure form an attractive proposition to potential developers.

The Northern Territory Government has set strategic goals focused on the growing global and Territory demand for clean, reliable and flexible energy sources. Investment attraction of developers interested in large-scale renewable energy generation will help the government achieve a number of these goals including:

- Supporting the 50% renewable energy target by 2030
- Advancing a $40 billion economy by 2030
- Enhancing a vision of a net zero emissions economy by 2050.[1]

Renewable projects also have the potential to co-locate with other infrastructure projects and generate economic and social benefits for the Territory. There are existing operators in the Territory that are already working towards their own net zero goals and wind resources have the potential to support this work.

The Territory has strong wind resource potential and whilst there is some data available, investment can be better encouraged by publishing industry standard wind resource information to assist prospective developers or investors.

This study demonstrates the wind resources are widespread over regions between Katherine in the north to highly potential southern areas of the Territory. The Northern Territory Government's focus on enabling infrastructure such as logistics hubs and an infrastructure corridor running adjacent to the Stuart Highway creates greater opportunity for developers considering investment in the Territory. The data generated through this study provides further certainty for potential developers that the Territory is well placed to host wind resources (as well as complementary solar). This study provides an evidence-based strategic approach to mapping the Territory's wind energy resources and identifying opportunities for wind generation.

The site selection study has identified viable locations to further investigate wind resource data for wind farm development in the Territory and recommends an approach to capturing data using industry standard technology.

This work will contribute to the Northern Territory Government's investment strategy by:

- providing baseline data and information for developers considering wind farm developments
- providing information on locations within the Territory, which have high wind resource potential.

[1] Northern Territory Climate Change Response: Towards 2050

2. Wind Resource Assessment and Site Selection Study

To assess the Territory wind resources, the suitability of prospective locations for wind power infrastructure and the sensitivities that may occur, an assessment has been carried out through the implementation of a definition-led spatial accumulation multi criteria analysis (MCA) approach.

2.1 Climate

Sitting between 11 and 26 degrees south of the equator, the Territory spans several climate zones (refer **Figure 2-1**). The north is tropical with a hot and humid 'wet' season and cooler 'dry' season. The dry season typically occurs from April to October with the wet season most apparent between December and February. The central parts of the Territory experience hot, dry summers and mild winters with the southern region experiencing hot and dry summers with cold winters.

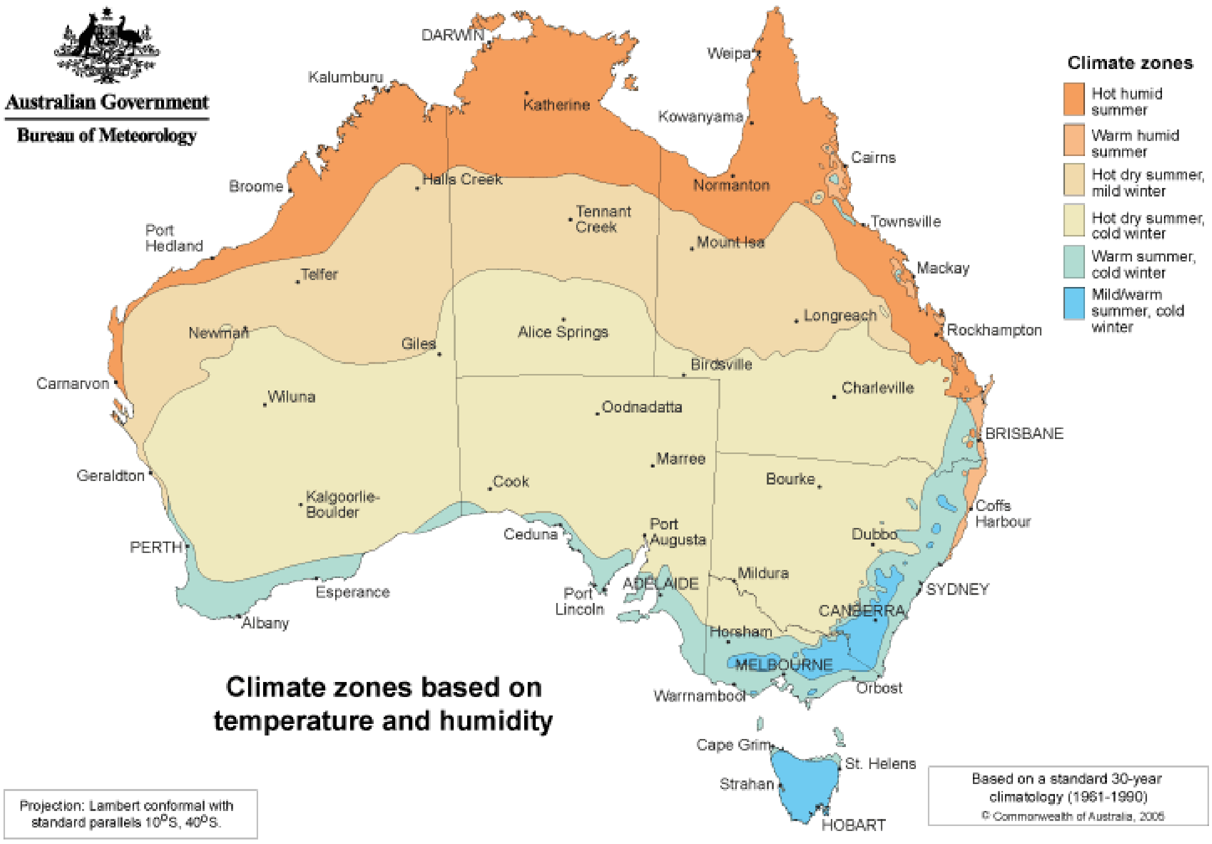


Figure 2-1. Climate zones based on temperature and humidity *(BoM, 2023)*

The northern region of the Territory is affected by tropical cyclones, which occur on average two to three times per year and affect the coastal regions and inland for around 50km (*BoM, 2023*). The cyclone season runs from November to April each year although cyclonic events can occur outside this period. Cyclones can bring destructive winds, high rainfall, and flooding. Severe tropical cyclones are associated with sustained winds exceeding100km/h (27.78m/s). Wind farms are susceptible to high intensity cyclones as the wind speeds exceed the design limits of the wind turbines causing failure, which can include loss of blades and buckling of the supportive tower.

2.2 Wind

The Territory has significant wind energy potential due to its vast land mass, with unique geography and climate patterns, predominantly generated by the monsoon and trade winds (refer **Figure 2-2**). Trade winds are dry, south-easterly winds that blow from the subtropics towards the equator. They are strongest during the dry season (May to October), when the subtropical ridge of high pressure is located over northern Australia. The trade winds pick up moisture as they cross the Pacific Ocean, but they lose this moisture as they descend over the continent. This results in clear skies and sunny days in the Territory's northern regions during the dry season. Monsoon winds are warm, moist winds that blow from the northwest towards the southeast during the wet season (November to April). The monsoon is caused by a low-pressure system that develops over the Indian Ocean which brings heavy rains, particularly in the coastal areas.

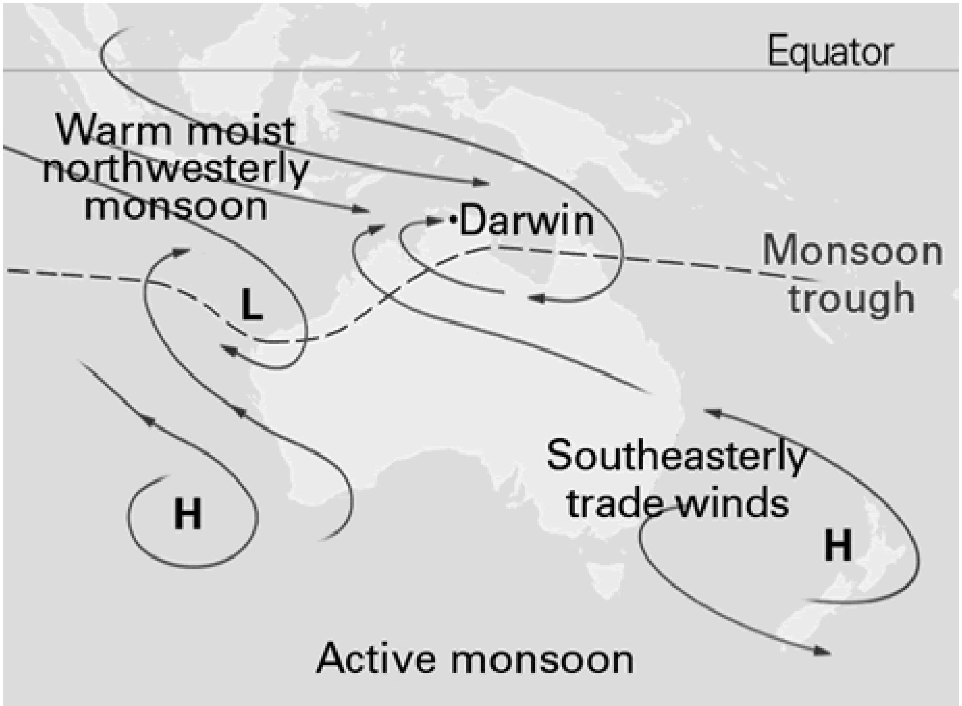


Figure 2-2. Trade wind and monsoon wind directions across Australia *(BoM, 2023)*

2.2.1 Summary of Territory wind resources

Generally speaking, there is great uncertainty in wind resources. In the Territory the highest wind speeds are found in elevated areas around the Davenport Ranges. The Territory is a vast area with few topographic features that will significantly affect wind resources.

In other states such as Tasmania and South Australia, wind resources are dominated by the circumpolar westerly flow, and in Western Australia winds are greatly influenced by the sea and land breezes. The Territory has neither of these atmospheric conditions, nor does it have high mountain ranges that might provide katabatic winds (wind caused by local downward motion of cool air) or provide acceleration to wind as it flows through passes or over escarpments.

The wind resource across the Territory has been assessed at a high-level using data from the Global Wind Atlas, WindLab and the Australian Bureau of Meteorology (BoM). All data sources indicate reasonable wind resources across the Territory with Global Wind Atlas distribution of mean wind speed presented in **Figure 2-3**.

In summary:

- Average wind speeds below 6m/s at 100 meters at hub height[2] have been excluded from the figure as these are considered within the wind energy industry to be too low to achieve energy yield/capacity factors that would be economic for a development of wind resources at any scale.
- The assessment found that wind speeds across the northern part of the Territory are generally insufficient for wind power generation.
- There are substantial areas within the southern areas of the Territory that indicate good potential for wind resource development, at both small and large scale.
- There is opportunity to further consider the correlation of wind and solar in these southern regions of the Northern Territory which may provide efficiencies for developers.

[2] Hub height of a wind turbine is the distance from the ground to the centre of the rotor

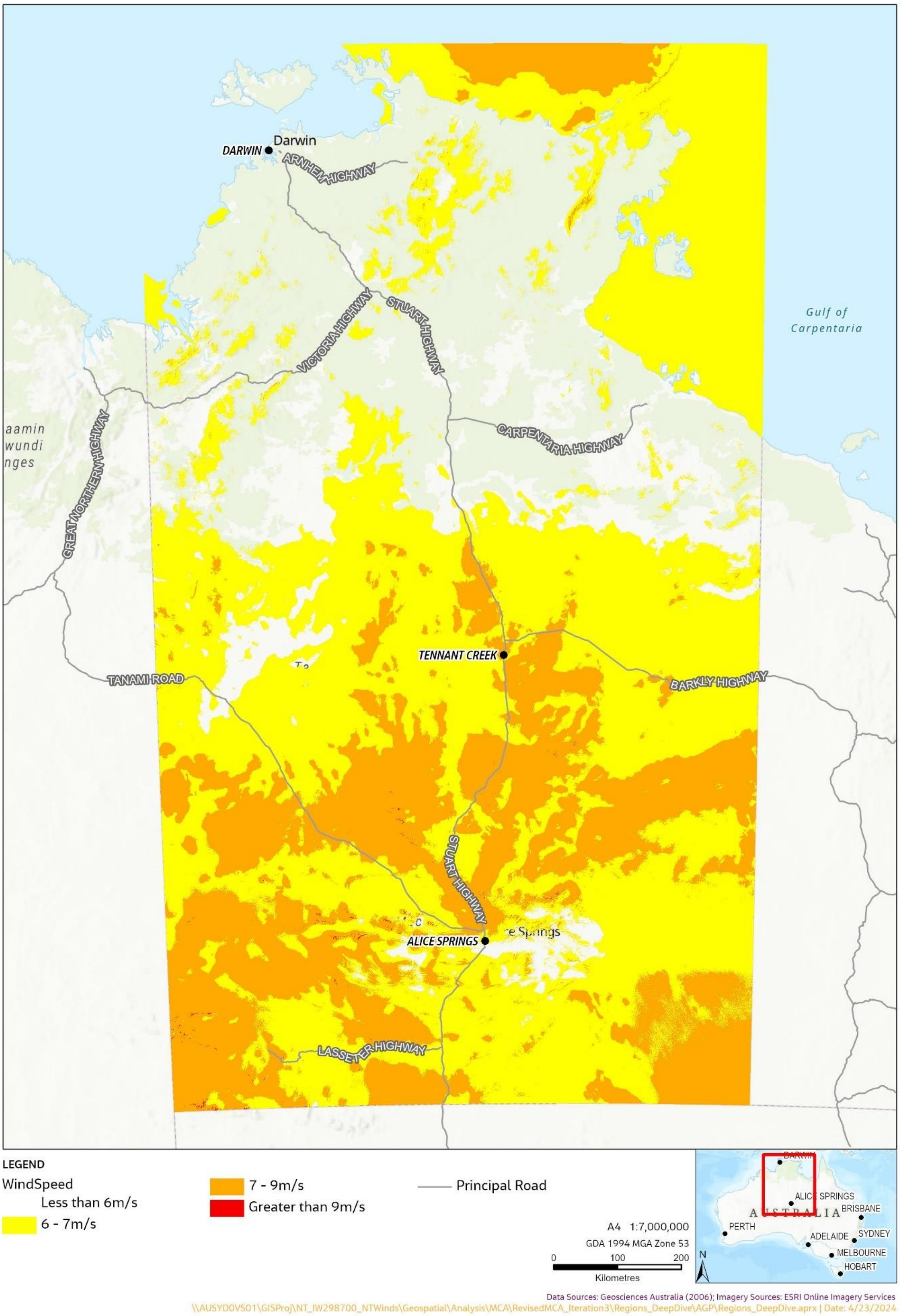


Figure 2-3. Wind resources in the Northern Territory

(Source: Global Wind Atlas)

2.3 Turbine technology

Wind turbine technology has evolved substantially in the past 25 years with sizes increasing markedly and it is likely technology will continue to advance and change. A selection of turbines available to the market in Australia as of 2024 is provided in **Table 2-1**. It can be expected that grid connected wind farms in the Territory will use turbines with rated capacities of between 4 MW and 8 MW, rotor diameters between 110 m 180 m, and hub heights between 90 m and 150 m. The turbine model selected for a wind farm will depend on the wind resource (mean wind speed, turbulence intensity, and wind shear profile), grid connection, planning requirements, logistical limitations, and availability.

Table 2-1. Current wind turbine specifications

Manufacturer	Model	Power Rating (MW)	Rotor Diameter (m)	Hub Height (m)
Vestas	V172-7.2	7.2	172	125
Vestas	V150-4.5	4.5	150	105
GE	GE6.3-164	6.3	165	112
GE	GE4.2-117	4.2	117	110
Siemens Gamesa	SG7.0-170	7.0	170	115
Siemens Gamesa	SG5.0-145	5.0	145	90
Goldwind	GW155	4.5	155	130
Goldwind	GE165	6.0	165	100

Turbine models are typically engineered to meet the wind resource classifications provided in Wind Standard Design Requirements, IEC61400-1. The classifications are defined by the mean wind speed and turbulence intensity, such that turbine models suited for high wind speed sites in complex terrain may have relatively smaller rotors and may have uprated yaw[3] and pitch[4] drives among other differences (**Table 2-2**). While most turbine models are engineered to meet specific environmental conditions, manufacturers may opt to classify machines as IEC-S whereby the machines are tailored to a site. Turbines may have specific engineering requirements such as backup power supplies or stronger towers and larger foundations to withstand extreme events such as cyclones where the extreme 50-year gust is 57 m/s.

Table 2-2. Wind Resource Classifications

Class	Maximum annual average wind speed [m/s]	Turbulence intensity [%]	Extreme 50-year gust [m/s]
Ia	10	16	50
Ib	10	14	50
IIa	8.5	16	42.5
Iib	8.5	14	42.5
Iic	8.5	12	42.5
IIIb	7.5	14	37.5

[3] Turns the turbines to directly face the wind

[4] Changes the angle of the blades

IIIc	7.5	12	37.5

The power output from a wind farm is dependent on the wind resource, wind turbine power curves, and site specifics of the wind farm. The wind resource is primarily defined using the mean wind speed, but also requires the shape of the wind speed frequency distribution, wind shear profile, air density, and turbulence intensity to be defined. The power curve describes the relationship between wind speed and power output.

Typically, wind turbines produce no power at wind speeds below 3 m/s. As wind speed increases above 3 m/s, the power output increases until rated power is reached at approximately 12 m/s. Above 12 m/s the turbine will regulate power to the rated power output unless higher wind speeds require power output to be reduced or the turbine shut down (typically for wind speeds above 25 m/s) to limit turbine loading. Wind turbines may reduce power output, or be curtailed, for many reasons such as grid congestion, compliance with noise regulations, or due to environmental conditions.

2.4 Influencing factors relating to wind farms in the Territory

2.4.1 Climate

Temperature variability

The Territory often experiences high temperatures which impact the performance of wind turbines. Typically wind turbines will limit maximum power output when outside temperatures are above 35°C. Dependent on the control strategy, power output will be reduced for temperatures between 35°C and 40°C, with turbines ceasing to operate when temperatures are greater than 40°C. Some turbine manufacturers produce wind turbines with a higher operational temperature range using hot climate kits. **Table 2-3** presents the mean maximum temperature ranges for each of the Territory's climatic regions.

Table 2-3. Northern Territory high temperature ranges

Temperature	Summer / Wet Season Mean Maximum Temperature (November to April)	Winter / Dry Season Mean Maximum Temperature (May to October)	Annual Mean number of days > 40°C
Northern Region	34.0– 38.0°C	29.9 – 37.7°C	9
Central Region	32.0 – 37.7°C	24.4 – 35.1°C	21.8 Airport (1969-2023) 28.2 (Post office1910-1970)
Southern Region	27.5 – 36.4°C	19.5 – 31.2°C	17.3 (Post office 1878 – 1953) 16.3 (Airport1941-2023)

(Source: BOM, August 2023)[5]

Climate Change

Climate change is a concept based around the global cycle of heat exchange and its influences on weather and where heat increases, greater extremes in weather patterns occur. A study conducted by the National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub in 2020 modelled climate scenarios to provide climate change projections in the Territory. Research and modelling undertaken

[5] BoM Stations: 014015 Darwin Airport, data 1941 to Aug 2023(Northern Region); 015135 Tennant Creek, data Feb 1969 to Aug 2023 (Central Region); 015590 Alice Springs, data 1941 to Aug 2023

indicates that the Territory will continue to get warmer with high temperature days to become more frequent and hotter (NESP, 2020).

Lightning

Lightning can irreparably damage wind turbines which, being tall metal structures are prone to strikes. It is unlikely that lightning strike risk will affect wind farm development, however turbines in regions with greater risk will require additional lightning protection, compared to locations in regions less prone to lightning strike.

Solar resources

The Territory has particularly good solar resources, and as such it is likely the number of Photo Voltaic (PV) power plants connected to the grid will continue to increase. If wind farms and PV power plants connect to the same electrical infrastructure, then it may be necessary to curtail power output from wind farms or solar PV when it is windy and sunny. The power loss due to curtailment will depend on how highly correlated the wind and solar resources are.

Wind and solar would be highly correlated if it was always windy whilst it was sunny. However, it is expected, and illustrated in the data, that in the Territory on average wind and solar resources are to an extent negatively correlated. This is because as the ground heats up during the day the atmospheric boundary layer becomes unstable. Conversely, during the night the ground radiates heat and cools down and the boundary layer becomes stable. The stability changes throughout the day and night, resulting in wind turbines experiencing higher wind speeds during the night and morning and lower in the afternoon and evening. As solar output is highest during the day this means that curtailment will be lower than expected if the two resources were uncorrelated. Hence wind and solar can be viewed as complementary technologies.

Even though wind and solar may be complementary technologies, there will remain some curtailment (if the grid is not able to absorb the power). In this case batteries may be used to store or absorb excess power and if correctly specified they may also provide grid balancing services.

A complementary profile between wind and solar irradiation in an area within the Barkly Region of the Territory is demonstrated in **Figure 2-4**.

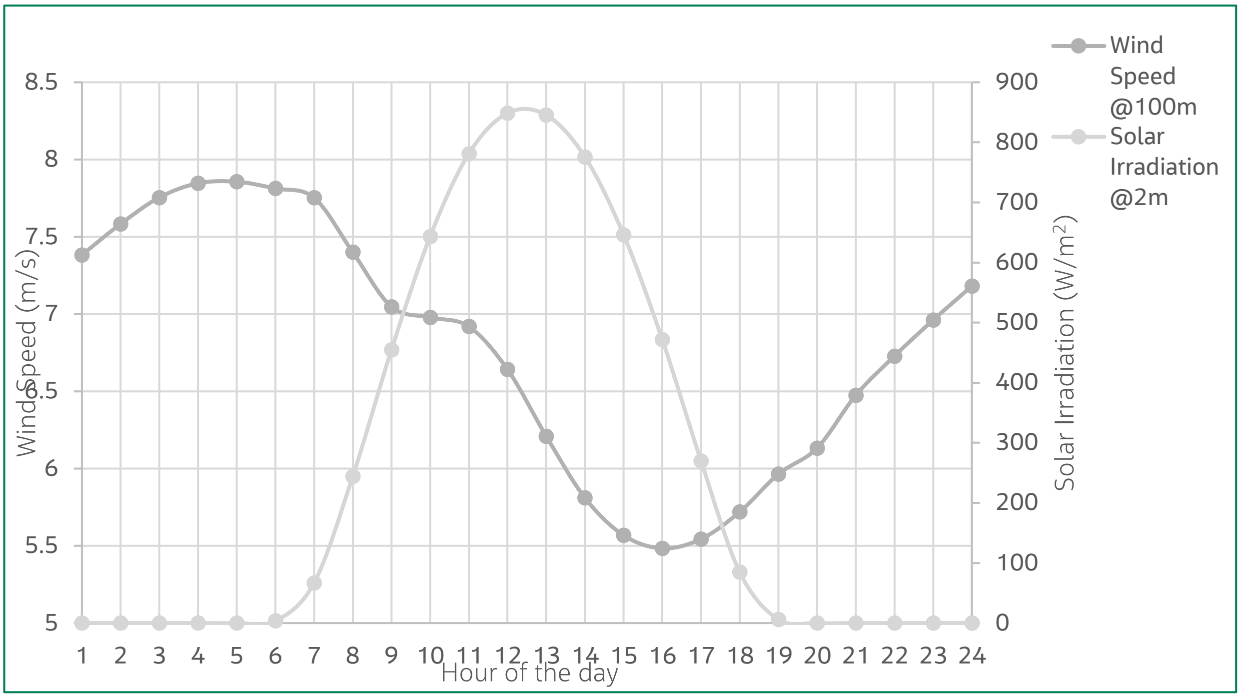


Figure 2-4. Wind/Solar Irradiation correlation (Jacobs, 2024)

2.4.2 Geology, Hydrogeology and Soils

When designing wind turbine foundations the geomorphology must be understood. The location of faults, the degree of weathering, layer slope and directions, karst regions/sinkholes (common in limestone and dolomite units), seismic activity, local water table, and clay content (important for swelling or expanding soils) all need careful consideration before specifying foundation designs.

Geology

Special caution is needed where limestone formations have the potential for karst development (sinkholes) to form. Other rock types such as mudstones and shale can be prone to instability and have poor ability to withstand compaction. Subsidence due to high groundwater withdrawal can be problematic in areas where there are high volumes of groundwater extraction. Consideration of these factors is required when choosing wind turbine sites, ensuring project integrity and stability.

Hydrogeology

Groundwater is the primary water source for the vast portion of the Territory featuring a range of aquifer types, predominantly influenced by geological factors. The flow systems within the aquifers vary in scale, ranging from local to intermediate and even regional. Some aquifers discharge through karstic springs, contributing to baseflows in rivers, often persisting throughout the dry season. In the arid zones of the Territory rainfall and recharge events occur only from time to time and can be separated by years or even decades and so management of stored water and groundwater dependant flows is therefore prioritised.

The Northern Territory Water Allocation Planning Framework sets out the water allocation rules for water resources in the Territory, where there is no resource specific scientific research on environmental and cultural water requirements. Under the *NT Water Act (1992)*, in the Top End zone (covering 34.5% of the Territory), 20% of an aquifer’s annual recharge from rainfall is allocated for consumption by various industries. In the arid zone (covering 65.5% of the Territory), up to 80% of an aquifer’s storage can be made available for extraction by industry over a span of 100 years.

Hydrogeological studies should be considered at the planning stage of a wind project in the Territory to understand the localised groundwater system and the potential impacts that infrastructure could have on the aquifers.

Soils

Wind turbines require large foundations placed on ground with suitable load bearing capacity. This means that soils must be removed or compacted so that a hard base is exposed. Some soil types, such as green sands and peat, can be unsuitable as they are difficult to compact or require deep excavations increasing costs. Further, during seismic events soils that are water-logged, as may occur during the wet season, may experience liquefaction and structures on these soils damaged. It is important that geotechnical studies are undertaken during investigations into wind farm development, however soil types do not present an overly high risk as to influence regional resource studies.

2.4.3 Topography

Wind turbines are best located in exposed sites that fetch the higher wind speeds with low turbulence. In mountainous terrain wind turbines will be located along ridges, whereas in flatter sites there is more flexibility in layout design.

Steep slopes (greater than 12 degrees) add complexity and cost to foundations and road access and can cause flow separation. Separation of the wind flow will result in turbulent eddies that increase loading on turbines leading to increased maintenance and reduced lifetimes. As such, wind turbines should not be built on slopes steeper than 12 degrees.

While it is preferable to locate wind turbines on locations that are not steeply sloping this does not transfer to a wholesale requirement that wind farms are not to be constructed in areas with complex terrain. However, there is a limit on the practicality and economics of construction of a wind farm in very complex terrain. Where turbine locations are inaccessible due to necessity of crossing very steep slopes or levelling sites for foundations and set down areas, they will not be economically viable due to the extensive earthworks and access road construction required. A limit on average slopes across the wind farm of 40 degrees has been applied to the assessment to exclude areas with extremely complex terrain.

2.4.4 Spacing of turbines

Wind turbines must be spaced well apart as they generate a wake downwind. The wake comprises turbulent eddies and these can impact downwind turbines resulting in increased loading that can increase maintenance costs and reduce turbine lifetimes.

Typical spacings that are applied between wind turbines are 6 to 10 rotor diameters in the prevailing wind direction and 3 to 5 rotor diameters perpendicular (refer **Figure 2-5**). The spacing used in a specific wind farm will depend on the wind rose. A wind rose is a tool used by meteorologists to give a view of how wind speed and direction is typically distributed at a specific location. Where there is a dominant wind direction, turbines may be spaced closer perpendicular to that direction, whereas if there is no dominant wind direction uniform spacing may be applied.

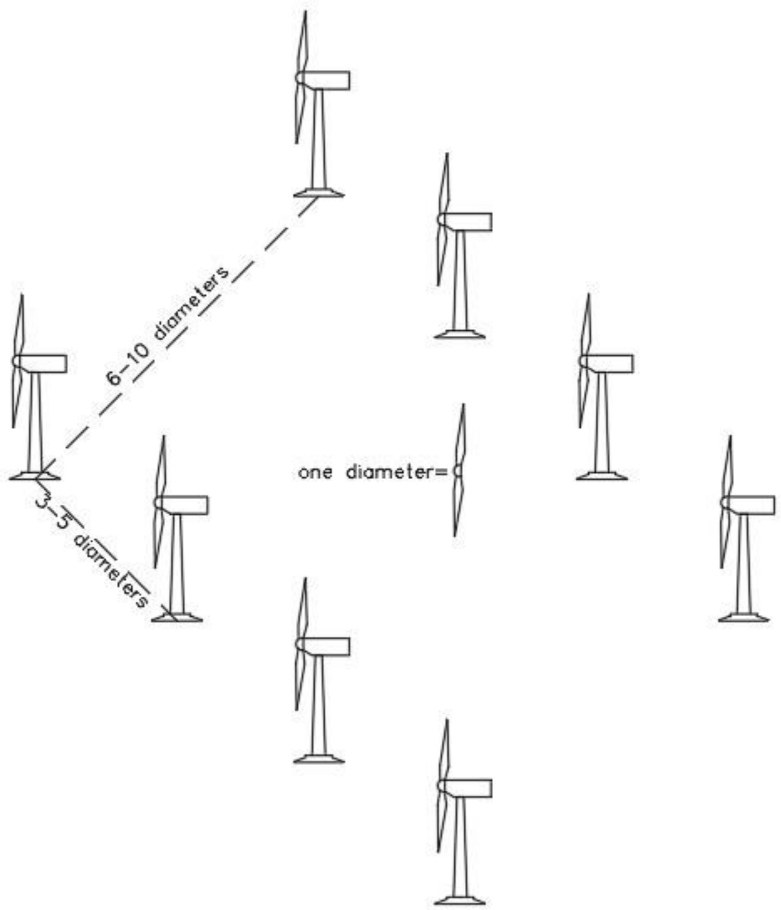


Figure 2-5. Wind Turbine Spacing (not to scale)

(Source: Jacobs, 2024)

2.4.5 Environmental values

2.4.5.1 Biodiversity

The Territory is rich in biodiversity. This is an important consideration when siting wind farms, as environmental factors and their complexity can constrain and prevent project approvals. Any proposed development will need to follow the NT EPA's environmental impact assessment and approval process under the under *NT Environment Protection Act 2019* and the Australian Government requirements under the *Environment Protection and Biodiversity Conservation Act 1999*. A high-level review of typical wind farm developments has been undertaken to allow identification of environmental values and sensitivities within the context of the NT EPA's objectives and environmental factors.

2.4.5.2 Sites of Conservation Significance

Sites of Conservation Significance (SOCS) have been established in the Territory to protect the Northern Territory's biodiversity. Significance ratings are given to five major conservation values: Threatened Species, Endemic Species, Wildlife Aggregations, Wetlands and Flora. Where a site is rated as being of international significance for one or more of the five criteria, it is given an overall International Significance rating: with a similar approach taken for attributing National Significance ratings. At present SOCS do not pose any regulatory or legislative protection above that of the existing threatened flora and fauna, although developers have an obligation to ensure further steps are taken to manage conservation values at each of the sites.

2.4.5.3 Bushfires

Whilst fire is considered a threat to biodiversity, conversely in northern tropical savannah regions bushfires are naturally a regular occurrence and deemed essential for some of the Territory's ecosystems. The Territory has five fire management zones, each with its own bushfire management plan which includes arrangements for mitigation, management and suppression of bushfires.

Aerial burning is a common practice used in the Territory for large scale fuel hazard reduction application using either rotary wing or fixed wing aircraft. Aircraft are also used for firefighting purposes. Wind turbines may restrict aircraft operation and consultation with affected parties needs to be undertaken in the planning stage of a wind farm development.

2.4.6 Social, Heritage and Cultural

Across all industries nationally, community expectations of developers earning their 'social licence' continue to rise. This includes the ability for Traditional Owners and Aboriginal organisations to gain economic participation in projects.

At business case stage, any wind resource proposals will consider specific sites identified as potentially suitable for wind resource development and consider key social factors such as:

- Culturally sensitive land – requiring AAPA certificates to identify any restricted work areas or culturally significant sites that must be protected throughout any investigation or construction work
- Native Title – providing permissions for any investigation and/or construction work on Aboriginal owned land (these will need to be negotiated well in advance of any planned investigations or work via the relevant Land Council)
- Sacred sites that may exist within the proposed area and protection measures required to protect them
- Feedback from relevant Land Councils highlighting Aboriginal land ownership, preferences and sensitivities

- Social impacts considering both positive and negative potential impacts of wind farm development and making commitments related to: potential employment and training, use of local supply chain, housing and social services, cumulative impacts based on other projects planned in the same area
- Heritage assessment identifying any areas of potential sensitivity regarding heritage and requiring heritage management plans or further consultation with stakeholders to ensure the protection/maintenance of items of heritage significance
- Community and co-investment opportunities.

Consideration of these social, heritage and culture factors may involve formal studies or consultation, as directed by the NT EPA or Federal environmental departments. For the NT Government, transparent communication and engagement about the long-term goals for renewable energy in the Territory and planned developments will be key. Developers will implement their own communication and engagement plans as well as assessments of social, economic and environmental impacts, based on their specific projects and to meet their Major Project Status or other regulatory requirements.

2.4.7 Land tenure, Use and Zoning

In the Territory, land use is regulated by the *NT Planning Act 1999*. It provides the framework for the establishment of the Northern Territory Planning Scheme (the Scheme) and provides for the prohibition of use or development that does not comply with the scheme (unless a permit has been issued) (s75). It also establishes the Development Consent Authority, division areas and the Minister for Infrastructure, Planning and Logistics as the consent authority outside of DCA Division areas, being responsible for determining planning applications where consent is required.

In accordance with the *NT Planning Act* and the NT Planning Scheme a development application is required to be lodged for any development requiring 'development consent' under the Planning Scheme. The consent authority grants a development permit when it consents to development of land in accordance with an application.

Developments that are planned in unzoned land are permitted, with planning controls and consent only required if the development triggers any of the following:

- Results in the subdivision or consolidation of land parcels/lots
- Involves the clearing of more than 1 ha of native vegetation
- Is located within a designated planning scheme overlay
- Is located within a designated Aboriginal community.

Within the assessment, land tenure has been considered, with Crown and Pastoral land promoted on the basis that there would be potential for a developer or government to either purchase or lease the land from a private landowner (pastoral land) or from government as the Crown landowner. There may be existing provisions within Crown Land governance that allow for the land to be used for renewable development, to help government reach broader net zero emissions targets. Aboriginal land may be leased and developed with agreement by Traditional Owners.

2.5 Site Selection Study

The site selection study sought to identify areas in the Territory suitable for investment in wind power infrastructure. Initially a high-level evaluation of the terrain and wind resources identified regions which have the potential to support wind power infrastructure. An assessment was then undertaken to evaluate the compatibility of the areas based on specific site requirements for the infrastructure along with economic drivers and land sensitivity constraints.

The study included the implementation of a MCA to assess different, relevant groups of spatial data, to consider where there is higher wind resource potential in the Territory. The site selection investigates measuring factors relating to compatibility, economics and any existing land sensitivity. Regions were then determined based on the values from these factors, and sites identified within the regions.

Sites were ranked, incorporating additional information, such as strategic objectives or additional constraints and/or opportunities, which due to data limitations, were not able to be included in the MCA. Using both the outputs of the assessments, along with considerations of any additional qualitative factors, enabled the prioritisation of sites relative to the project objectives. **Figure 2-6** demonstrates the high-level overall approach to the site selection assessment.

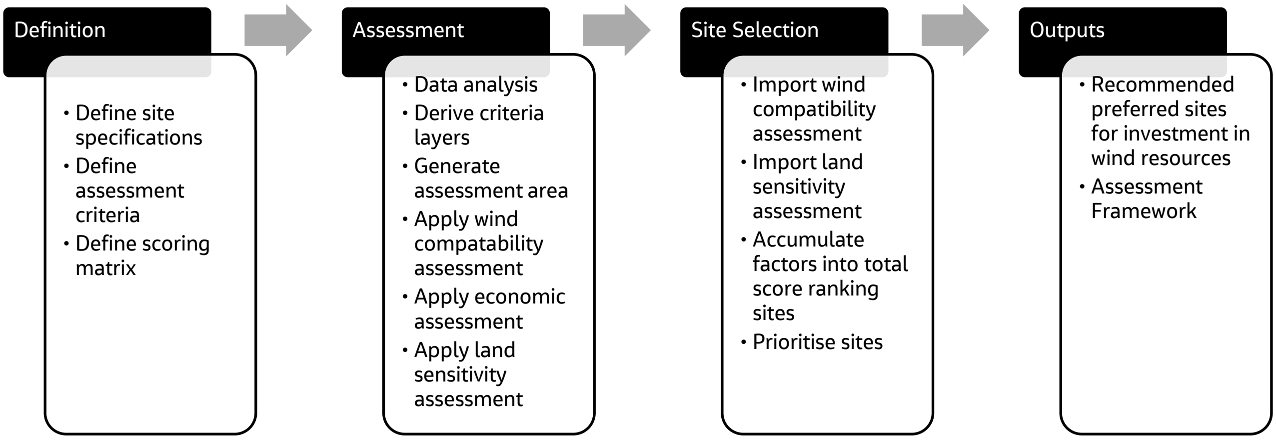


Figure 2-6. Site selection approach

2.5.1 Define site specifications, approach and scoring

The size of a potential wind farm site was a critical input into determining the resolution of the analysis. Large (Utility or Commercial) scale is normally defined for projects greater than 1 megawatt (MW). However, this trend has changed in the recent years with the increase in capacities that can be achieved with a single wind turbine. Consideration in this assessment has been made to accommodate a range of project sizes, from 100 MW to 1 GW. Applying typical spacing requirements between wind turbines (refer **Section 2.4.4**), a site size of 25 hectares (Ha) is required per MW installed capacity, this leads to a site size of 2,500 Ha for a 100 MW project to 25,000 Ha for a 1 GW project (refer **Figure 2-7**). A wind project of 100 MW would require approximately 20 wind turbines.

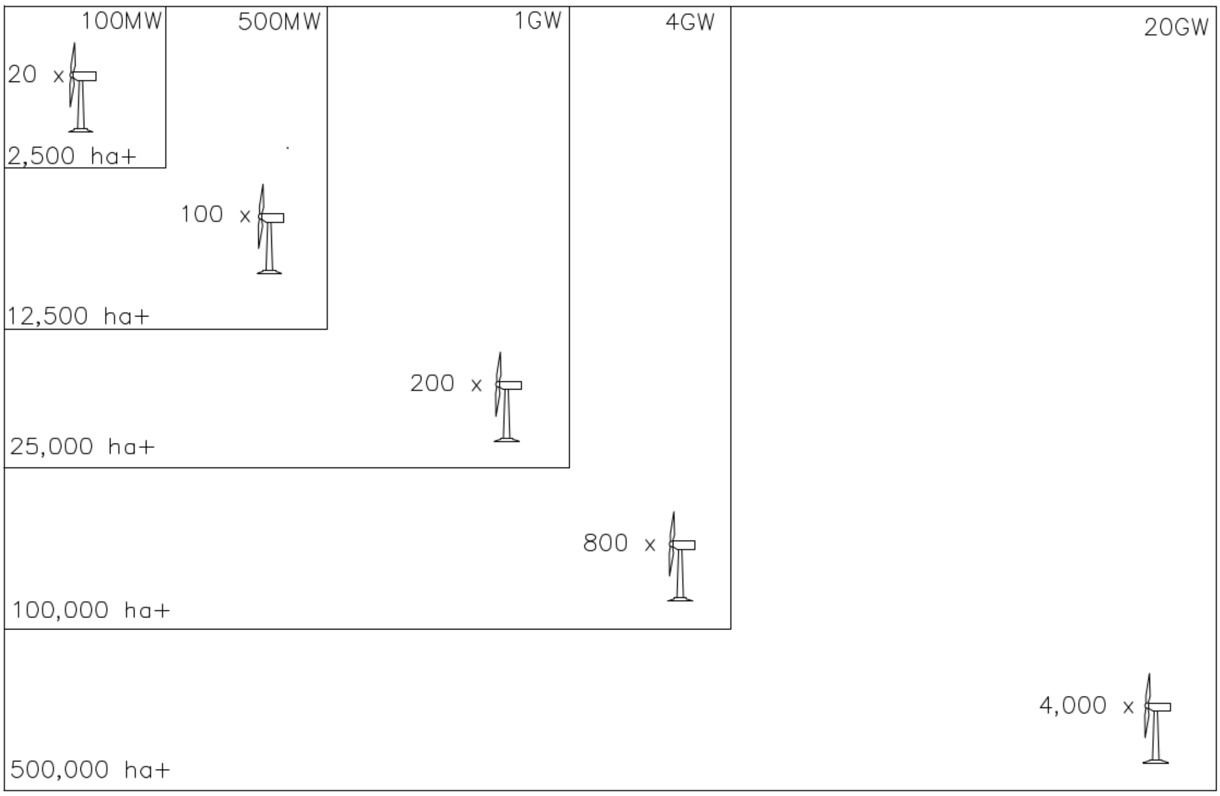


Figure 2-7. Indicative site sizes, installed capacity and number of turbines (not to scale)

(Jacobs, 2024)

With the minimum wind farm site and the resolution of the key spatial datasets (wind speed and terrain model) a 50-metre cell size was determined for the analysis. The analysis involved the accumulation of the criteria and extraction of statistics from the results within a raster environment. Datasets that had vector representation were converted to rasters, where line and point datasets buffered to create 'area polygons' which in turn are converted to raster cells.

The assessment was completed using a definition-led spatial accumulation MCA approach. The MCA assessment lists criteria representing the benefits or constraints relating to the development of wind power infrastructure. Each of the criteria were grouped into categorised themes relating to their relevance and application. Criteria were subsequently transformed into spatial layers (where possible) assigned a score and passed through an accumulation MCA. An accumulation MCA adds the scored criteria together, where for example, in any location, the higher the score, the more compatible the location is for wind power infrastructure. The assessment workflow is presented in **Figure 2-8**, with the complete list of criteria considered presented in **Appendix A**.

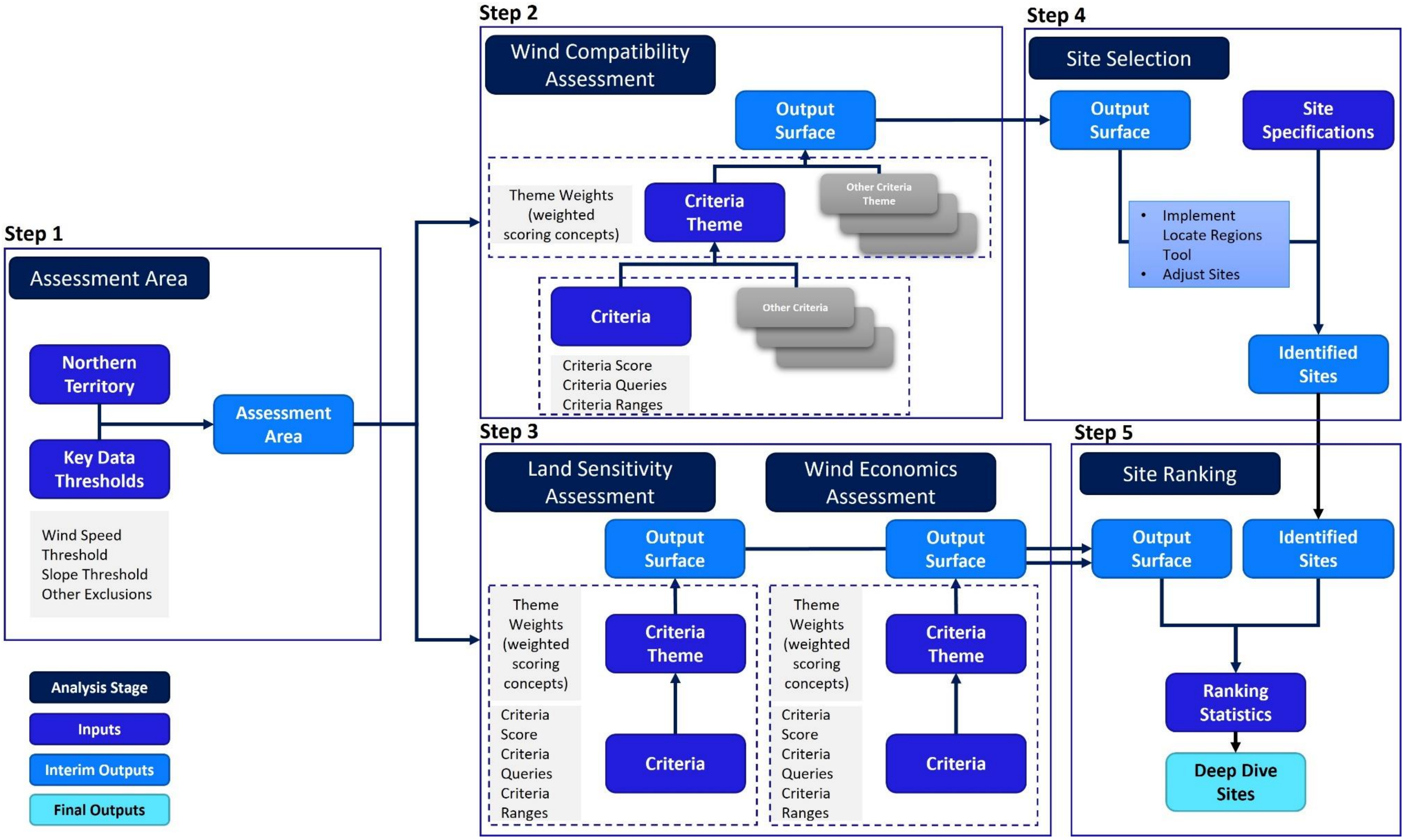


Figure 2-8. Assessment Workflow

A common scale approach was used as there was a logical scale that could be applied across the criteria, whilst maintaining a common relationship in the assessments where higher impacts (higher scores) are captured relative to lower impacts (lower scores).

Criteria were based on compatibility or sensitivity with the scoring matrix presented in **Table 2-4**.

Table 2-4. Scoring Matrix Concept

Category	Score	Scoring concept – Wind	Scoring concept – Land
Least	1	**Least Compatibility** Areas of lower compatibility, areas exhibiting lower benefits to construction (e.g. 1,000km from existing infrastructure)	**Least Sensitivity** Areas of least sensitivity, areas exhibiting least complexity to construction (e.g., publicly owned)
Lesser	2	**Lesser Compatibility** Areas of lower compatibility, areas exhibiting lower benefits to construction	**Lesser Sensitivity** Areas of lower sensitivity, areas exhibiting lower complexities to construction
Medium	3	**Moderate Compatibility** Areas of moderate compatibility, areas exhibiting moderate benefits to construction (e.g. moderate wind speeds)	**Moderate Sensitivity** Areas of moderate sensitivity, areas exhibiting moderate complexity to construction (e.g. Commonwealth Land)
High	4	**High Compatibility** Areas of high compatibility, areas exhibiting very high benefits to construction (e.g. closer proximity to roads and ports)	**High Sensitivity** Areas of high sensitivity, areas exhibiting high complexity to construction (e.g. Conservation Areas)
Very High	5	**Very High Compatibility** Areas of very high compatibility, areas exhibiting very high benefits to construction (e.g. high wind speed categories)	**Very High Sensitivity** Areas of very high compatibility, areas exhibiting very high complexity to construction (e.g. World Heritage sites)

Three iterations were run for this assessment, all with the same criteria data sources, representation and scoring applied:

- **Iteration 1**
  - Used only wind speed and topography to better understand the assessment area, identifying the wind speed driven exclusion areas and if there was a case for using weights in addition to the scoring scale. The results were seen to adequately reflect the inherent importance the common scale gave the criteria and subsequently no additional weightings were included.
- **Iteration 2**
  - Wind MCA combined criteria from both wind and economic themes into a single MCA (refer to results in **Figure 2-10**.
  - Land Sensitivity MCA (**Table 2-8**) used criteria representing sensitivity/complexity to the proposed infrastructure development.
- **Iteration 3**
  - Wind Compatibility MCA (**Table 2-6**) used criteria representing potential wind infrastructure compatibility only.

- Economic Development MCA (**Table 2-7**) used criteria representing potential economic compatibility only.
- Land Sensitivity MCA (**Table 2-8**) used criteria representing sensitivity/complexity to the proposed infrastructure development.

To support the development of sites to be investigated in a deep dive assessment (**Section 2.7**), regions were generated from the results of the Wind MCA as well as the Wind Compatibility combined with the Economic Development MCA. The output regions were compared, and sites identified representing areas where there is a strategic benefit in understanding the potential for wind resource development.

2.5.2 Assessment area

To assess only areas adequate to support wind power infrastructure, an area was defined by filtering out locations that are not suitable, nor have the adequate minimum wind speeds to support large scale wind power infrastructure. Two primary factors were considered in this stage: wind and slope. Other exclusion areas considered in the initial phase and their rationale are presented in **Table 2-5** and represented in grey in **Figure 2-9.**

Wind

Sufficient wind resources are required for wind turbines to generate power. Higher average wind speeds will improve the economic feasibility of wind projects. It is considered that areas with mean wind speeds less than 6 m/s would not be economically viable, hence these have been excluded. Weightings were then applied across the remaining area within the Wind Compatibility MCA, with areas of low, moderate and high average wind speeds being defined using data from the Global Wind Atlas.

Slope

Wind turbines are best constructed in areas without steep slopes. Wind turbines can have footings up to 9m deep and 25-30m in diameter and require relatively flat terrain for construction to be economic. Further areas with steep slopes will induce flow separation, resulting in the formation of turbulent eddies that can increase loads and reduce turbine lifetimes. For the initial assessment, an exclusion threshold of slopes > 40% has been applied as these slopes are too steep and not feasible to either construct wind turbines on or access locations, the remaining slope ranges are scored with higher scores preferencing flatter areas without restricting the assessment area. Further weightings were applied within the Wind Compatibility MCA to promote areas without steep slopes for development.

Table 2-5. Excluded Areas

Criteria	Description	Rationale
Airports	Land used or occupied by an airport or proposed to be used as an airfield.	Airports and airfields are exclusion zones due to technical feasibility and height restrictions, a 5km buffer has been applied.
Communities	Census Urban-Centres and Localities / Remote Community Boundaries	Townships and Communities – land-use incompatible for major wind farm infrastructure and sites already occupied.
Water inundation	Waterways, waterbodies, and areas affected by flood or inundation	Waterways, water bodies, flood prone and water inundation areas due to the technical feasibility. These areas also have potential environmental or cultural factors, having differing levels of significance to conservation values.

World Heritage and Ramsar Wetlands	Any item or place identified in World Heritage Convention (UNESCO)	Due to their significance, World Heritage and Ramsar Wetland sites are excluded. Rigorous development constraints and limitations apply.
National & Territory Parks	Land occupied by a National or State Park	Due to their significance, national parks are excluded as development constraints and limitations apply.
Wind Speed	Areas with wind speeds of less than 6m/s	Areas with mean wind speed less than 6m/s are not considered to produce sufficient power to be considered economic.
Slope	Steep slopes	Areas with slopes are not feasible to construct wind turbines on. Areas of slope greater than 40% excluded.
Defence Site	Commonwealth Defence Reserves	Activity or development within defence land will be severely limited.
Temperature	Average temperature above 39 °C	Areas with average temperature above 39 °C. High temperatures can impact the performance with wind turbines ceasing to operate in temperatures above 40 °C. Higher operational range can be achieved using hot climate kits, but this is subject to turbine manufacturer specifications.
Atmosphere	Cyclonic Winds	Areas of very high cyclone intensity. When wind speeds are greater than the maximum operating limit of 25m/s, turbines are shut down and blades feathered to 90°.

2.5.3 Wind compatibility assessment

The *Wind Compatibility Assessment* sought to identify locations in the assessment area that have the highest accumulated score. The wind compatibility assessment criteria and their rationale, listed below in **Table 2-6**, were put into an accumulation MCA. The resulting surface presented in **Figure 2-9** was used as an input into the site selection process.

The resulting surface presented in **Figure 2-9** was used as an input into the site selection process. A significant portion of the northern region of the Territory has not generated results due to a combination of exclusion criteria being present, particularly wind speed less than 6m/s. The higher scored areas are in the central and southern regions where there is the presence of the 'High' wind speed range listed in the table below.

Table 2-6. Wind compatibility assessment criteria

Assessment Theme	Criteria	Rationale	Score
Wind	**Wind Speed** **refer Section 2.2.1**	Promote areas with higher wind speeds having greater energy generation potential. Ranges applied: ▪ Moderate Compatibility: wind speeds 6-7m/s ▪ High Compatibility: wind speeds 7-9m/s ▪ Very High Compatibility: wind speeds 9+ m/s	 1 4 5
Topography	**Slope**	Wind turbines require construction on relatively flat terrain.	

	refer Section 2.4.3	Ranges applied: ▪ Low Compatibility: slope 20<25° ▪ Moderate Compatibility: slope 10<20° ▪ Very High Compatibility: slope <10°	 1 4 5
	Geology refer Section 2.4.2	Certain geologies, such as granite, basalt, gabbro, schist, gneiss, limestone, and sandstone, are particularly suitable for construction projects due to their strength, stability, and load-bearing capacity. Special caution is needed in carbonate formations due to the potential for karst development (sinkholes) caused by the rock's reactivity with water. Subsidence due to high groundwater withdrawal is also of concern, especially in areas with high-volume groundwater extraction.	3
	Soils refer Section 2.4.2	Some soil types do not have sufficient load bearing capacity, or do not allow compaction, requiring deep excavations to ensure ground surfaces are suitable for foundations.	NA
Land-use	**Tenure Refer Section 2.4.7**	Land tenure may impact or inhibit the development of wind power infrastructure. Pastoral land – areas of existing agriculture land use, Crown Land – government owned/managed.	3
Environment	**Bushfire refer Section 2.4.5.3**	Bushfire management zones cover the entire Northern Territory with bushfires a regular occurrence within the Northern Australian Tropical Savanna landscapes. Bushfire management and mitigation works in the Territory are undertaken by aerial methods, consideration is required in the planning and development of wind power infrastructure. Range applied: ▪ Lesser Compatibility: Bushfire management zones ▪ Least Compatible: Tropical Savanna landscapes	NA
Climate	**Solar irradiance Refer Section 2.4.1**	Areas which have the potential of generating greater energy (wind and solar combined). Solar irradiance is the key factor in identifying land compatibility with solar farms. Range applied: ▪ Moderate Compatibility: Annual solar irradiance less than 1750 W/m2 ▪ High Compatibility: Solar irradiance from 1750 to 1850 ▪ Very High Compatibility: Solar irradiance above 1850	NA
	Lightning days Refer Section 2.4.1	Lightning can impact the performance of major components of a wind turbine mainly the blades. The less lightning days, the less probability of having major component failures. Range applied: ▪ Moderate Compatibility: lightning days < 7 moderate ▪ Lesser Compatibility: 14 >= lightning days > 7 ▪ Least Compatible: lightning days > 14	NA

Scores of NA indicate criteria where the spatial data available was not available or not suitable for inclusion due to data accuracy, data coverage or criteria coverage.

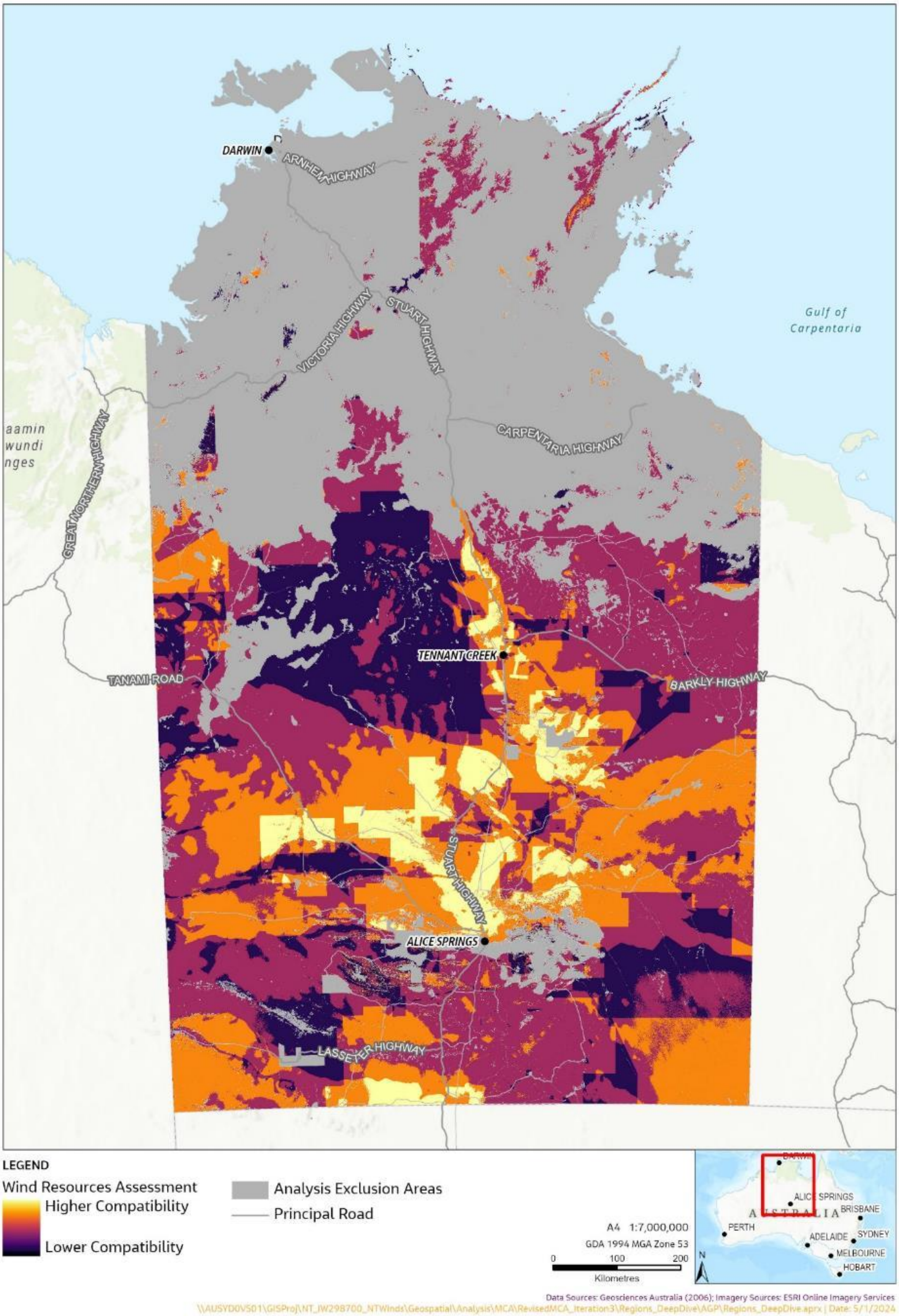


Figure 2-9. Wind compatibility assessment surface

Figure 2-9 Shows the Wind Compatibility assessment alone while **Figure 2-10** shows the Wind Compatibility assessment with the addition of the economic development criteria, combining the scores from both sets of criteria. This result has significantly high scoring where there is existing infrastructure, particularly along the Stuart Highway.

Economic development assessment

Economic development factors were considered, given they will largely influence whether a developer proceeds with project development in the Territory or not. Distance to key infrastructure such as major highways, railway lines and ports are key factors in the planning phase of a project and impact significantly on cost.

Additionally, wind farm components are large and require sufficient space and capacity to be transported, whether via road, rail or ship. For government, these factors are important as they may require substantial infrastructure planning and investment.

In this assessment, only the Darwin Port was considered, as it is currently the only port with capacity to import wind turbine components to the Territory (based on the size of components and logistical support needed to transport to site). Should sites reside closer to other ports and be considered in the future, such as Gove, further development of the current infrastructure would be required to facilitate the logistics of components.

Other areas of strategic importance were also considered as there may be benefits of co-location of wind with other infrastructure. For example, investment in roads, rail, ports may be rationalised if serving multiple projects. Work is underway to service large scale projects including road upgrades, logistics hubs and the infrastructure corridor to service projects in the Beetaloo Basin. **Table 2-7** below lists the economic development assessment criteria and their rationale. Results of the combined wind compatibility and economic development assessment MCA is presented in **Figure 2-10**, with each of the criteria results presented in **Table 2-7**.

Table 2-7. Economic development assessment criteria

Assessment Theme	Criteria	Rationale	Score
Economic	**Port Distance**	Wind farm infrastructure requires transportation of large/heavy wind turbine components from international suppliers / manufacturers. Promote proximity to Ports, closer attracts a higher ranking. Ranges applied: ▪ Moderate Compatibility: 750<1,000km ▪ High Compatibility: 500<750km ▪ Very High Compatibility: <500km	3 4 5
	Logistics – Road/Rail	Wind farm infrastructure requires transportation of large/heavy wind turbine components from international suppliers / manufacturers. Proximity to Roads (major arterials)/Rail – closer attracts a higher ranking. Ranges applied: ▪ Moderate Compatibility: 100<200km ▪ High Compatibility: 50<100km ▪ Very High Compatibility: <50km	3 4 5
	Transmission Distance	Promote proximity to existing electrical transmission easements / corridors.	NA

Assessment Theme	Criteria	Rationale	Score
		Noting the absence of electrical transmission lines in all regions but the top end of the Territory.	
	Strategic Importance	Areas of strategic importance for future development – gas/hydrogen/minerals Promote proximity areas of strategic importance, including existing major projects.	Scores range from 1-5
	Strategic Infrastructure	Areas of strategic importance for future development – infrastructure/transmission. Including the proposed NT Infrastructure Corridor. Promote proximity areas of strategic importance, for power transmission and supporting infrastructure.	Scores range from 1-5
	Resources / Mining Tenements and other industrial land uses	Land occupied by an operating mine or quarry; industry may benefit using renewable power source (decarbonisation). Opportunity to co-locate wind/solar and minimise operational costs of mine. Promote proximity to supply industry with power generation.	3

Scores of NA indicate criteria where the spatial data available was not available or not suitable for inclusion due to data accuracy, data coverage or criteria coverage.

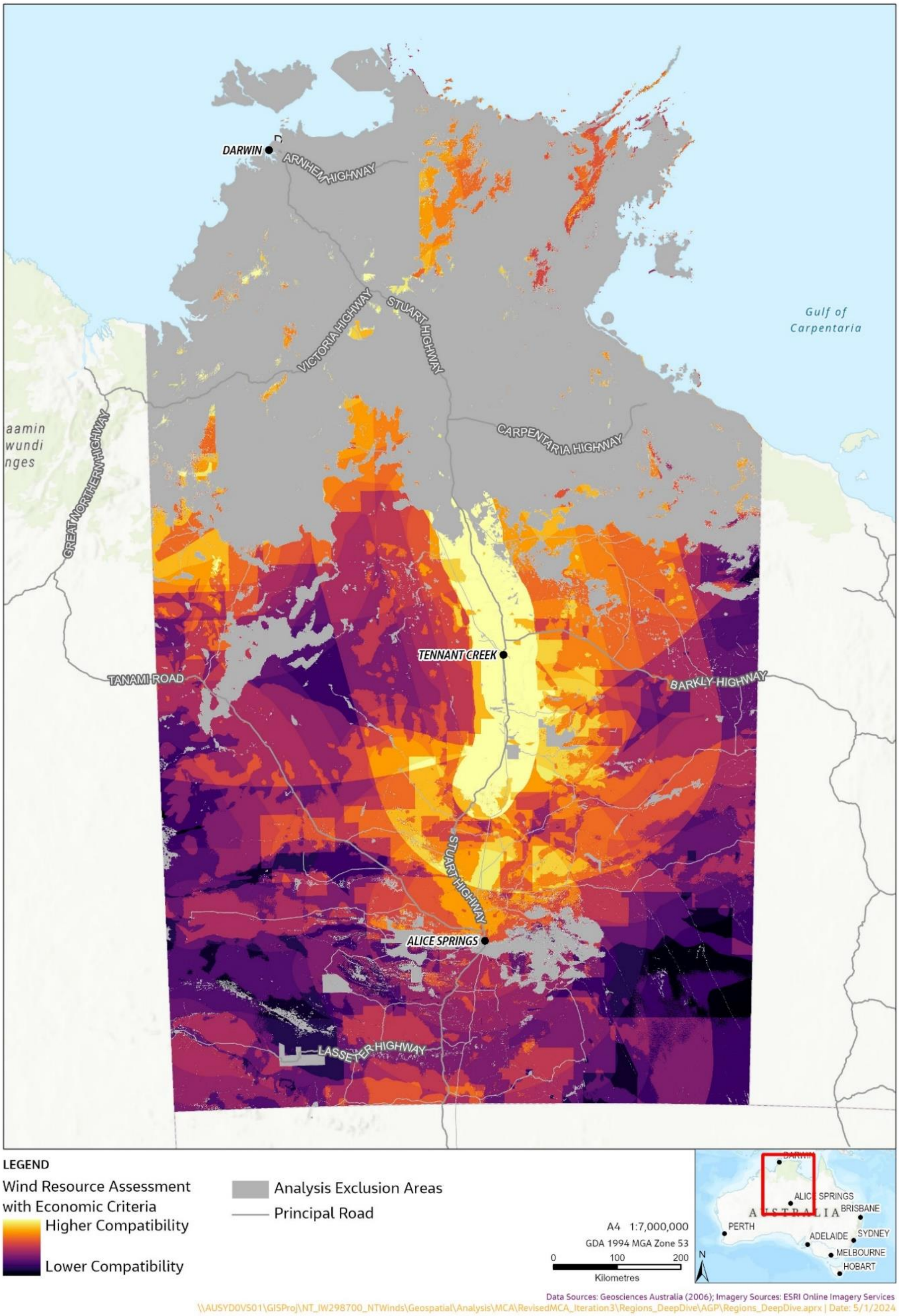


Figure 2-10. Wind compatibility and economic development assessments surface

2.5.4 Land sensitivity assessment

A land sensitivity assessment has been undertaken, noting the importance of identifying any areas that may need to be reconsidered in the presence of high wind compatibility or economic results. The criteria that represent sensitivity have been assessed separately as the unit of measurement “sensitivity” conflicts with the other MCAs. This method allows us to understand the risk of sensitivity independently from an area’s potential, where the absence of values can indicate low sensitivity.

The land sensitivity assessment was carried out across the assessment area surface using the same MCA approach. This MCA considered land-use and planning, community, heritage and environmental factors which may constrain or impact the planning and approvals process.

Environmental criteria reflect the importance and complexity of environmental factors and potential difficulty of obtaining approvals for wind farms. The criteria considered the *NT Environment Protection Act 2019* and the *Environment Protection and Biodiversity Conservation Act 1999*. This allowed for identification of environmental values and sensitivities within the context of the NT EPA’s objectives and environmental factors. The criteria also focus on areas which provide protection to Australian native landscapes, including native flora and fauna along with community concerns about construction in, or adjacent to, a national park could also adversely impact on the time taken to engage with the community and to secure approvals for any future development.

Risks to cultural heritage values are also integral to the approvals process and siting of wind infrastructure, noting the regulatory requirements and community expectations.

The other consideration focuses on land uses which may present constraints to future development. Consent may be required, or the land may not be available in the future for occupation by wind farms.

Land sensitivity assessment criteria and their rationale are listed below in **Table 2-8,** with the output surface presented in **Figure 2-11**.

Table 2-8. Land sensitivity assessment criteria

Assessment Theme	Criteria	Rationale	Score
Environment	**Conservation Areas/ Public Reserves and Parklands**	Land occupied by a conservation area or public reserves. Areas to protect Australian native landscapes, including native flora and fauna. Community concerns about construction in or adjacent to a national park could adversely impact on the time taken to engage with the community and to secure approvals.	5
	Native Vegetation	Impacts to native vegetation that provides habitat for threatened species or threatened ecological communities. Where possible to be avoided or impacts minimised or managed through Territory and/or Commonwealth approvals with conditions, possibly involving offsetting payments/efforts.	NA
	Significant Biodiversity Areas	Land and the associated landscapes identified as being significantly important for conserving biological diversity. No regulatory or legislative protection above that of the existing threatened flora and fauna, however there is an obligation to ensure further steps are taken to manage conservation values.	3
	Nationally Important Wetland surrounds	Ramsar wetlands are those that are representative, rare, or unique wetlands, or are important for conserving biological diversity (migratory species). Australia’s commitments under the	4

Assessment Theme	Criteria	Rationale	Score
		Ramsar Convention (international treaties) and responsibilities under the EPBC Act. Wind turbines pose some threat to migratory birds, areas surrounding these wetlands should be considered sensitive also. Buffer of 100km to be applied to Ramsar wetlands.	
	Groundwater	Groundwater is the primary water source for the majority of the NT. Within the arid zones, rainfall and recharge events occur sporadically and there can be years or decades between events; management of stored water and groundwater dependant flows is prioritised. The NT Water Allocation Planning Act sets out the water allocation rules for water resources in the NT, where there is no resource specific scientific research on environmental and cultural water requirements.	NA
Heritage	**Historical Heritage – Commonwealth**	Any item or place identified on Commonwealth Land. Areas listed in the Commonwealth Heritage List. Protected under The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), Commonwealth Heritage List and UNESCO.	5
	Historical Heritage – Territory	Any item or place listed in the Territory Heritage List. Declared heritage places and objects as well as those which have been nominated to the register. Heritage places are protected by the *NT Heritage Act 2011*.	NA
	Indigenous Heritage – Territory	Sacred Sites and Restricted Work Areas. Aboriginal sacred sites are recognised and protected under the *Aboriginal Land Rights (Northern Territory) Act 1976* (Land Rights Act) and the *Northern Territory Aboriginal Sacred Sites Act (Sacred Sites Act) 1989*.	NA
	Indigenous Land Use Agreement (ILUA)	Any item or place listed as having ILUA, consent required to impact on the land. Land may not be available in the future for occupation by wind farms.	NA
Land Use & Planning	**Resources and Mining Tenements**	Land occupied by an operating or historic mine or quarry may have tailings or excavations that may place barriers to wind farm construction. Conversely an operating mine may require power and thus a wind farm constructed nearby will be advantageous.	3
	Residential Areas/Township adjacent	Community concerns of construction near residential areas could delay planning approvals. Buffer zones of 1km are applied around residential urban centres and localities based on planning zones and cadastral parcels.	3
	Contamination Areas	Avoid disturbing large areas of contamination. Legislation ensures there is adequate protection of human health and the environment, where site contamination is found to exist. *National Environment Protection Council Act 1994* (Cwlth).	NA

Assessment Theme	Criteria	Rationale	Score
	Commonwealth Land	Actions on or affecting Commonwealth land have the potential to require an EPBC Act Referral.	3
	Tourist Roads	Roads that are consistently travelled by tourists.	2-4

Scores of NA indicate criteria where the spatial data available was not available or not suitable for inclusion due to data accuracy, data coverage or criteria coverage.

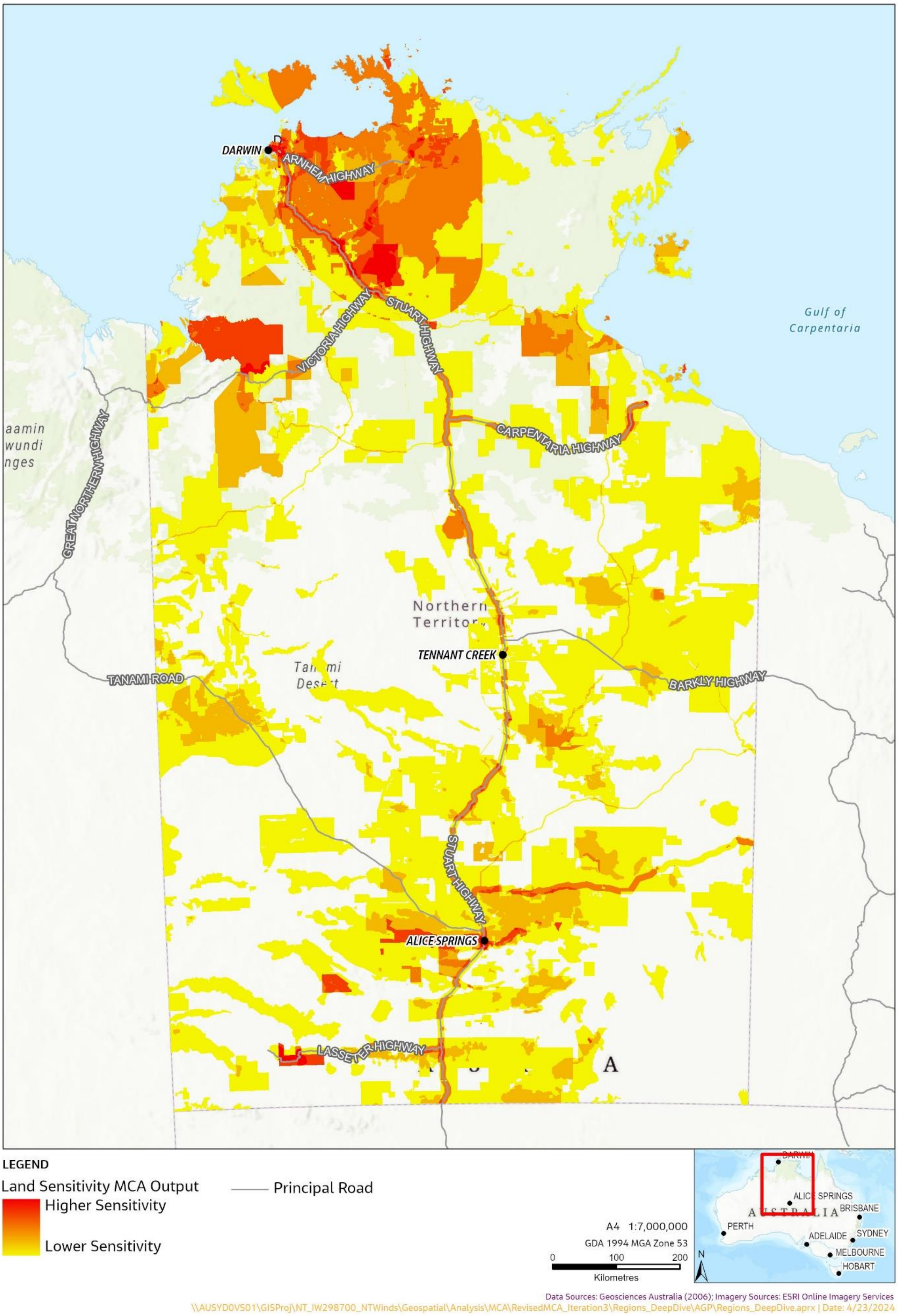
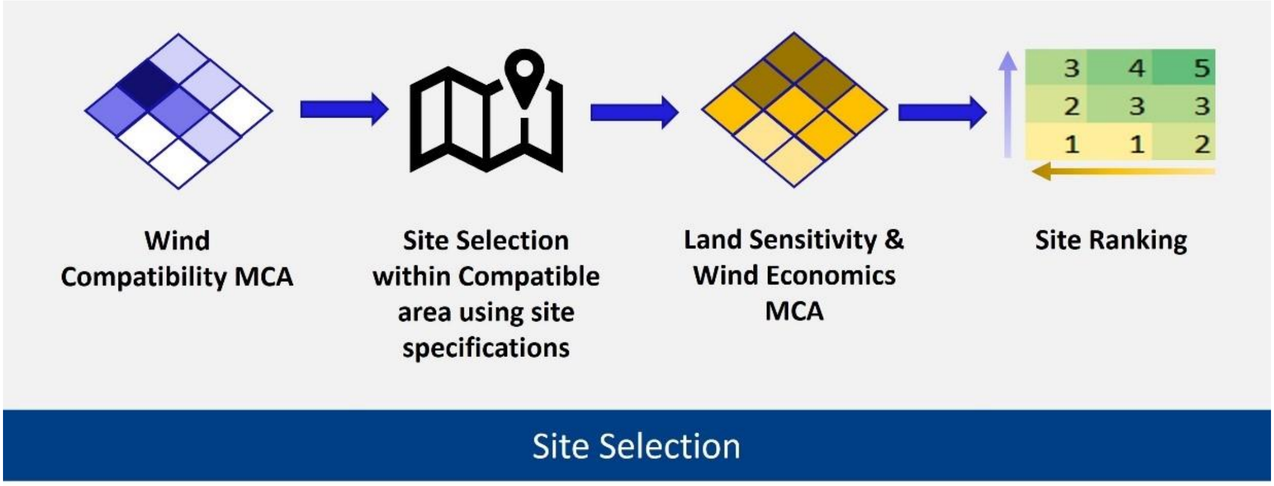


Figure 2-11. Land sensitivity assessment surface

2.6 Site Ranking



Sites were identified by the *Wind Compatibility Assessment* MCA surface fed into a 'Locate Regions' geoprocessing tool which identifies optimal regions (groups of contiguous cells).

Parameters were defined:

- Minimum site size: 25,000 hectares
- Maximum site size: No Limit
- Evaluation method: Highest Average value
- Shape: Square (trade off of 50%).

The tool generated regions at locations on the MCA surface aligning with the set parameters, whilst looking for consistent higher values from the input MCA surface (**Figure 2-12**). Regions with large area parameters were generated to ensure spread across the assessment area. Regions with higher average MCA values were located in close proximity to Stuart Highway. The regions ranged between 750,000 – 800,000 hectares, with each having the potential to generate over 30GW. This allows for vast portions of land to be considered and refined against the economic and land sensitivity MCA results.

An initial ranking generated regions ranked based on a statistical metric of choice (in this case the highest average value) where higher values indicate the presence of multiple compatibility criteria. Sites were assessed in further detail and prioritised considering the economic benefits and land sensitivities that may impact on the feasibility or planning of building wind power infrastructure to rank the best sites. This was achieved by applying the *Economic Assessment* and *Land Sensitivity Assessment* MCA surfaces across the identified sites, using statistical metrics such as mean, minimum and maximum values, as well as proportional area coverage to determine less sensitive regions.

This site prioritisation stage also provided an opportunity to incorporate additional information, such as overarching strategic objectives or additional constraints/opportunities.

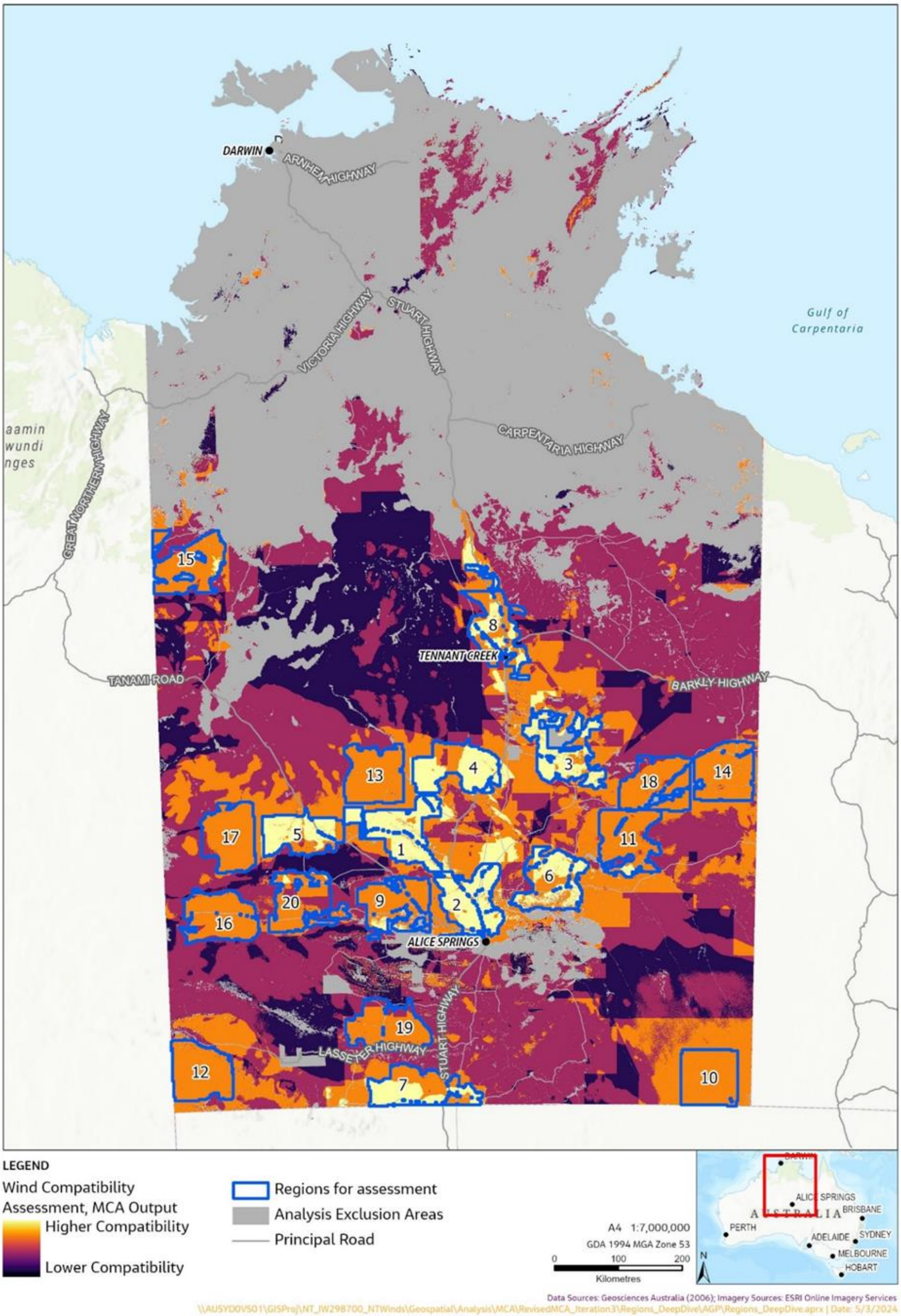


Figure 2-12. Site Ranking

In determining the locations for deep dive sites, the mean MCA score from the Wind Compatibility MCA was used in combination with qualitative factors and strategic priorities to explore candidate, assumed and unexpected sites. The mean MCA scores from the Economic and Land Sensitivity MCAs were then added to this. Land Sensitivity scores were uniformly low throughout the Territory, hence the site ranking was dependent on the wind resource and economic factors. The sites selected for the deep dive primarily focus on areas with good MCA scores, however, consider a holistic approach to the assessment so that various regional areas of the Territory have been considered.

The generated mean scores for each of the MCA surfaces are presented in **Table 2-9**. This number is calculated using the MCA values contained within the generated regions, it is an indication of the overall presence of criteria within the region. Cells highlighted blue in the 'Sites' column indicate a site that was considered for a deep dive assessment.

Red, yellow and green cell colours have been applied in the economic and land sensitivity surface columns to classify the regions based on low, moderate, high mean scores. For the wind compatibility and economic MCA result, higher scores are presented as most viable. Lower scores for the land sensitivity MCA represent sites with less impacts that are potentially more viable. An example of the mean MCA average MCA score for Site 8 (Deep Dive Site 2) is 14.77 in the table below, this aligned with a consistent high score of 15 in the Wind Compatibility Surface Map.

A site (Deep Dive Site 1) was manually generated so that a location in the northern region of the Territory was also considered. This was not generated by the analysis tool and is significantly smaller than the other deep dive sites.

Table 2-9. MCA Site Ranking

Site	Wind Compatibility Surface	Economic Surface	Land Sensitivity Surface
1 (Deep Dive Site 4)	14.77	7.92	3.04
2 (Deep Dive Site 5)	14.72	8.65	4.12
3 (Deep Dive Site 3)	14.49	10.91	4.15
4	14.16	12.62	3.33
5	14.07	5.07	3
6	13.75	9	4.6
7	13.6	5.44	3.65
8 (Deep Dive Site 2)	13.15	18.02	3.76
9	12.17	7.27	4.22
10	12	1.67	No Sensitivity Present
11	12	7.97	3.52
12	11.99	4.53	3
13	11.99	8.01	3.13
14	11.99	5.72	2.5
15	11.96	11.49	3.08
16	11.78	5	3.02

17	11.76	3.55	No Sensitivity Present
18	11.71	8.16	2.8
19	11.47	6.02	3.36
20	11.35	5.4	3

2.7 Deep Dive Sites

As a result of the assessment process, five sites were selected for a more detailed assessment into the criteria present (deep dive). This was achieved by undertaking a comparison of the Wind Compatibility MCA and the Wind Compatibility combined with the Economic Development assessment MCA, refer **Figure 2-13.** The sites were selected to represent areas where there is a strategic benefit in understanding the potential for wind resource development.

The geometric boundaries of the regions were adjusted to create simpler shapes and, in some cases, the size increased. Small areas with low MCA scores were not considered as they may present material barriers for larger projects.

The sections below provide detail on each of the five sites, noting the constraints, compatibilities or sensitivities that impact the assessment results.

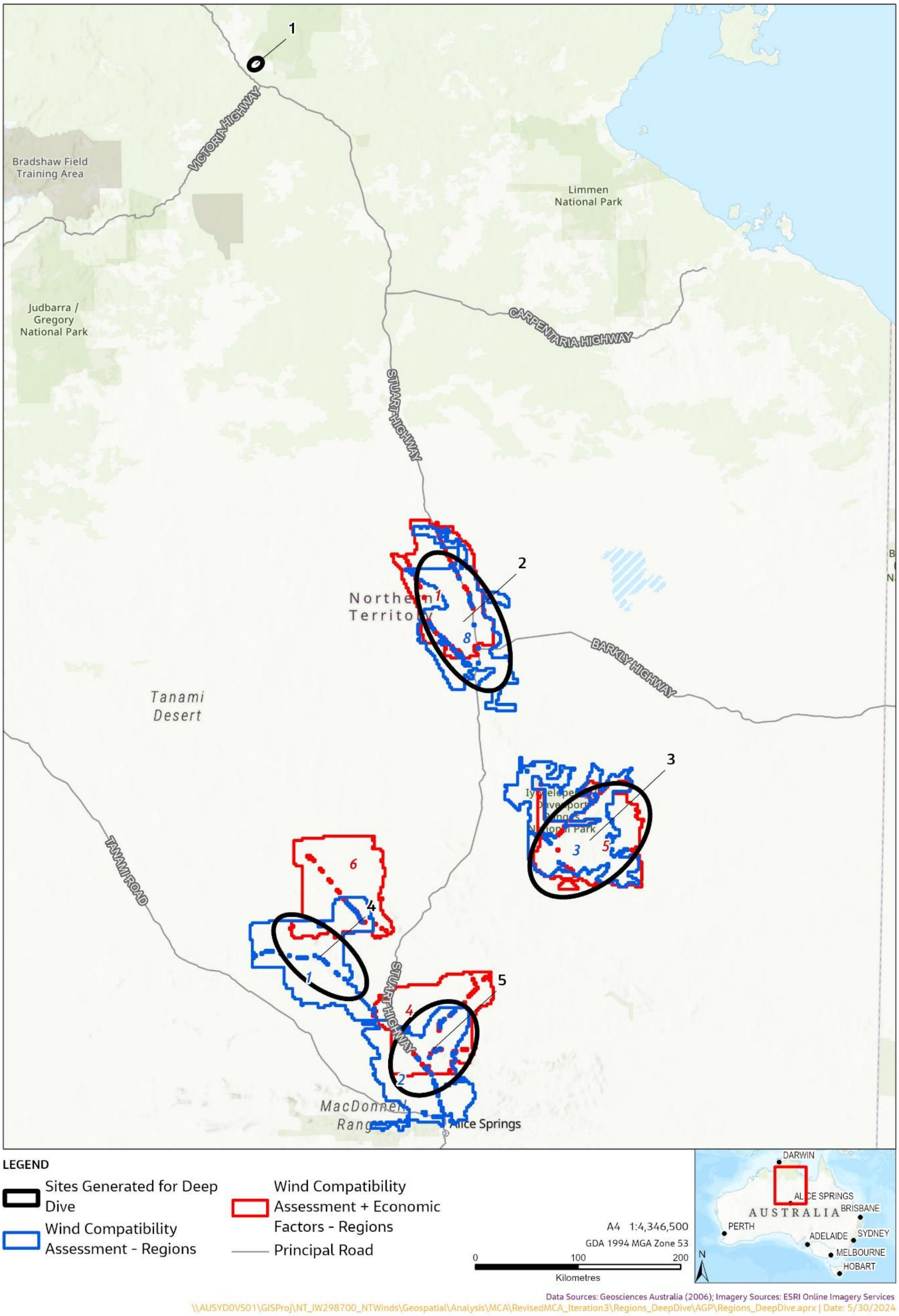
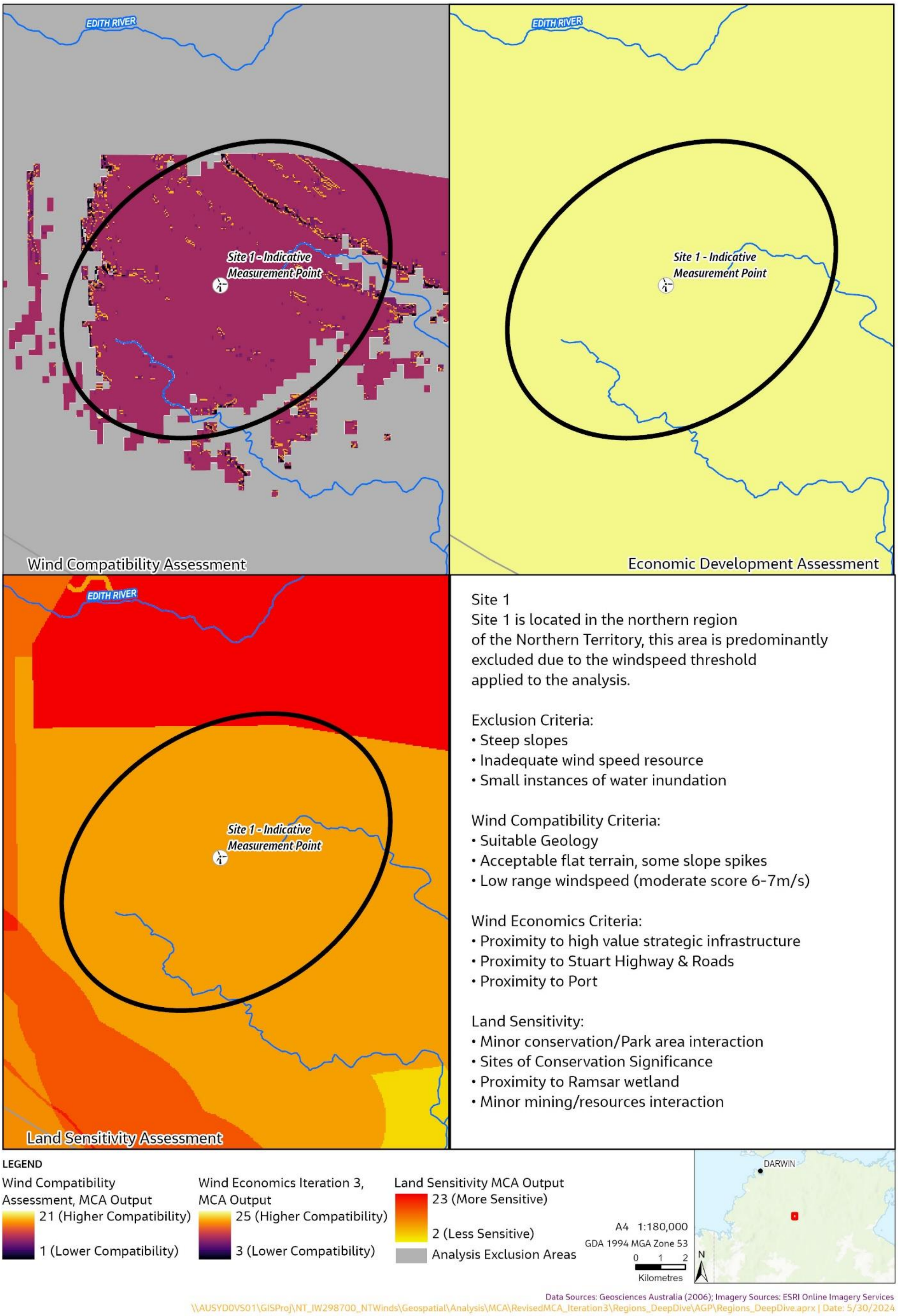


Figure 2-13. Deep dive sites

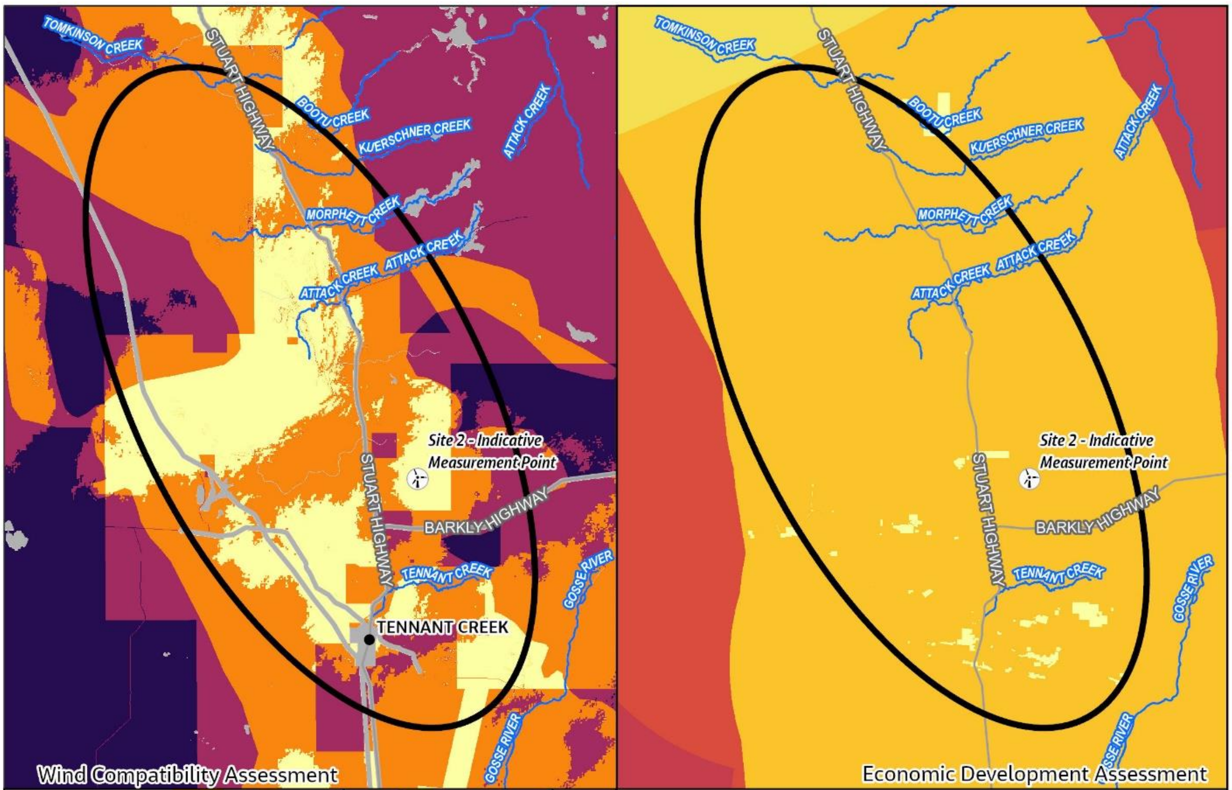
2.7.1 Deep Dive Site 1 – Northern Region of the Territory

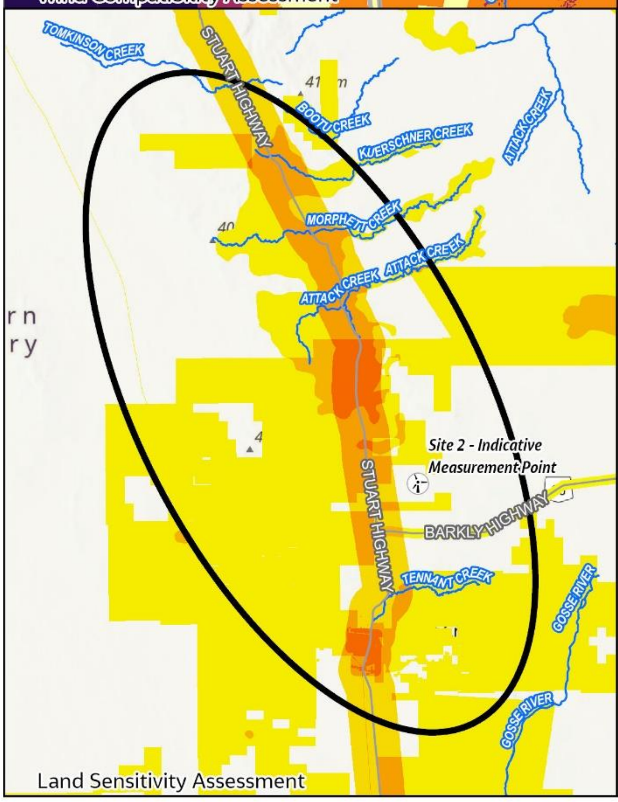
Deep dive site 1 is located in the northern region of the Territory and surrounded by many exclusion factors, primarily the lack of an adequate wind resource. There is also the presence of multiple land sensitivity criteria, in particular proximity to conservation areas. This region is significantly smaller and isolated, however, is in closer proximity to existing built up areas and infrastructure as presented by the economic criteria summary below. There would most likely be a trade-off between the potential capacity of the site and the cost to construct and connect to existing infrastructure.


EDITH RIVER
Site 1 - Indicative Measurement Point
Wind Compatibility Assessment
EDITH RIVER
Site 1 - Indicative Measurement Point
Economic Development Assessment
EDITH RIVER
Site 1 - Indicative Measurement Point
Land Sensitivity Assessment
Site 1
Site 1 is located in the northern region of the Northern Territory, this area is predominantly excluded due to the windspeed threshold applied to the analysis.
Exclusion Criteria:
• Steep slopes
• Inadequate wind speed resource
• Small instances of water inundation
Wind Compatibility Criteria:
• Suitable Geology
• Acceptable flat terrain, some slope spikes
• Low range windspeed (moderate score 6-7m/s)
Wind Economics Criteria:
• Proximity to high value strategic infrastructure
• Proximity to Stuart Highway & Roads
• Proximity to Port
Land Sensitivity:
• Minor conservation/Park area interaction
• Sites of Conservation Significance
• Proximity to Ramsar wetland
• Minor mining/resources interaction
LEGEND
Wind Compatibility Assessment, MCA Output
21 (Higher Compatibility)
1 (Lower Compatibility)
Wind Economics Iteration 3, MCA Output
25 (Higher Compatibility)
3 (Lower Compatibility)
Land Sensitivity MCA Output
23 (More Sensitive)
2 (Less Sensitive)
Analysis Exclusion Areas
A4 1:180,000
GDA 1994 MGA Zone 53
0 1 2
Kilometres
N
DARWIN
Data Sources: Geosciences Australia (2006); Imagery Sources: ESRI Online Imagery Services
\\AUSYD0VS01\GISProj\NT_IW298700_NTWinds\Geospatial\Analysis\MCA\RevisedMCA_Iteration3\Regions_DeepDive\AGP\Regions_DeepDive.aprx | Date: 5/30/2024

2.7.2 Deep Dive Site 2 – Near Tennant Creek

Deep dive site 2 is in close proximity to Tennant Creek and is a simplified geometrical representation of Site 8 from the MCA results. This region has one of the highest mean scores for the economics result due to the occurrence and stacking of multiple high scoring criteria. This indicates that the economic potential in the region is high. There is also the presence of high wind speeds and other compatible wind resource criteria. This region does have some sensitivities due to its proximity to a built-up areas like Tennant Creek. Consequently, though it has reasonable capacity potential, development approvals may be hindered.





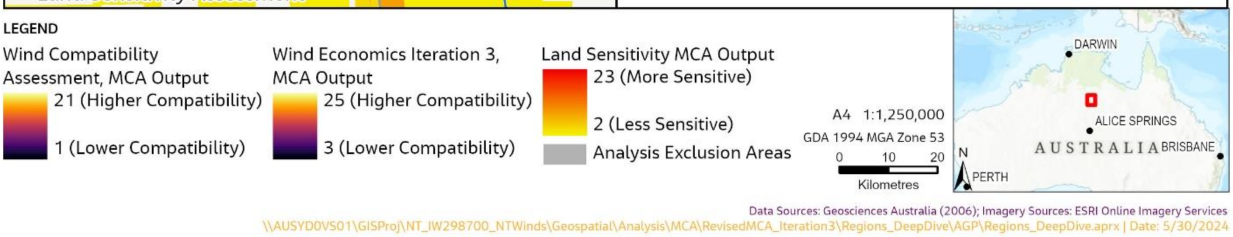
Site 2
Site 2 is located in close proximity to Tennant Creek.

Exclusion Criteria:
- Communities
- Small instances of water inundation

Wind Compatibility Criteria:
- Suitable Geology
- Compatible Land tenure
- Acceptable flat terrain
- High - Moderate range windspeed (7-9m/s, 6-7m/s)

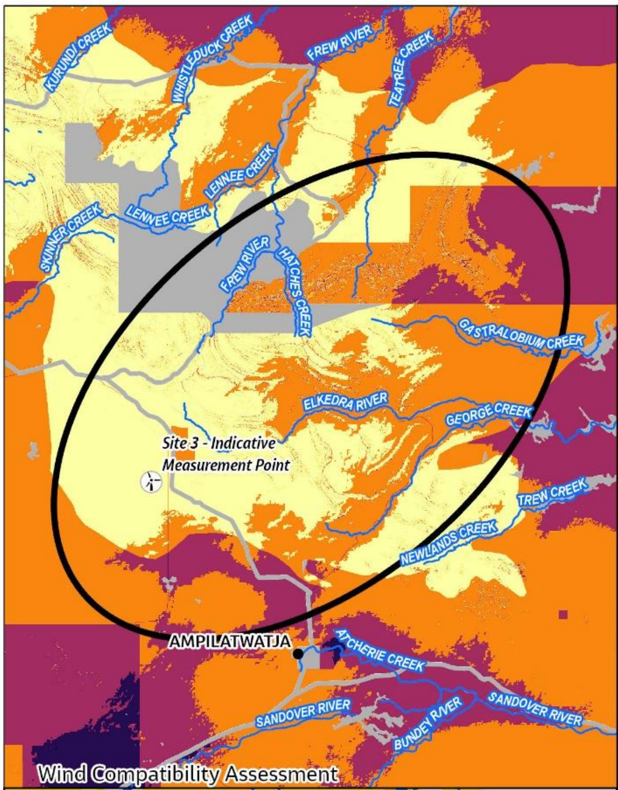
Wind Economics Criteria:
- Proximity to high value strategic infrastructure
- Proximity to Stuart Highway & Roads
- Mining/Resources areas

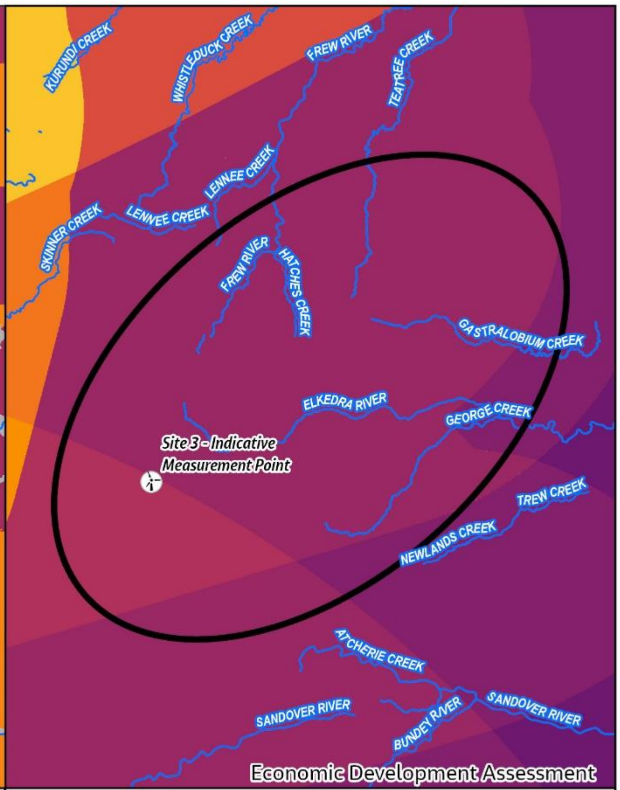
Land Sensitivity:
- Tourist Roads
- Communities – Tennant Creek
- Sites of Conservation Significance
- Mining/resources interaction

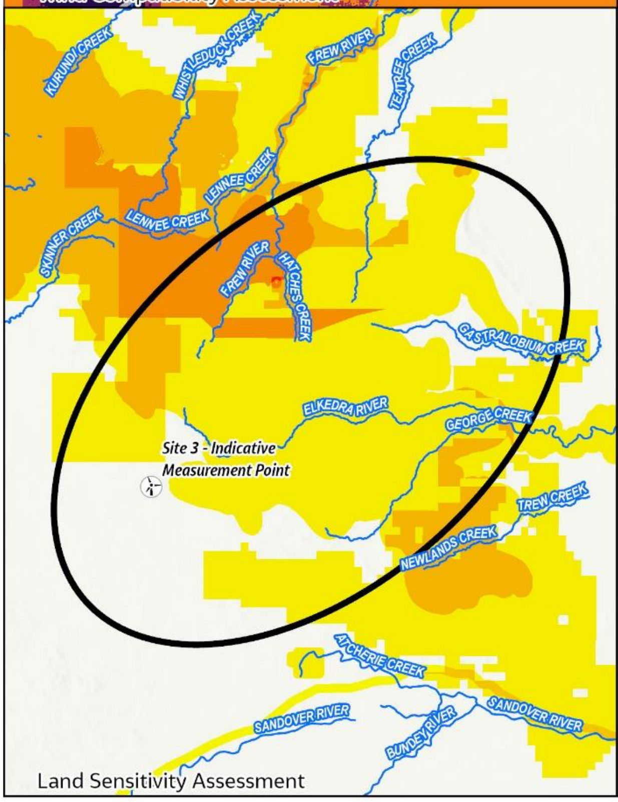


2.7.3 Deep Dive Site 3 – Davenport Ranges

Deep dive Site 3 is located close to the Davenport Ranges National Park in the southern area of the Territory. It is a simplified geometrical representation of Site 3 from the MCA results. This region has one of the higher average scores for the Wind Compatibility MCA assessment, as well as a high score from the economic assessment. The proximity of a National Park does cause some sensitivity spikes as well as a larger exclusion area. The site is close to the Stuart Highway in addition to other existing infrastructure. There will likely be a trade-off between the potential capacity due to the size, the presence of the wind and economic resources and constraints due to the presence of a National Park, communities and other park or conservation areas. There is also the presence of mining or resources, existing or potential. Whether this is a positive or negative to the overall potential would require further investigation.







Site 3
Site 3 is located in close proximity to Davenport Ranges National Park / Iytwelepenty.

Exclusion Criteria:
- Communities
- Small instances of water inundation
- National Park

Wind Compatibility Criteria:
- Suitable Geology
- Compatible Land tenure
- Acceptable flat terrain (some steep slope spikes)
- High - Moderate range windspeed (7-9m/s, 6-7m/s)

Wind Economics Criteria:
- Proximity to high value strategic infrastructure
- Proximity to Stuart Highway & Roads

Land Sensitivity:
- Conservation/Park Areas
- Communities
- Sites of Conservation Significance
- Mining/resources interaction

LEGEND

Wind Compatibility Assessment, MCA Output
21 (Higher Compatibility)
1 (Lower Compatibility)

Wind Economics Iteration 3, MCA Output
25 (Higher Compatibility)
3 (Lower Compatibility)

Land Sensitivity MCA Output
23 (More Sensitive)
2 (Less Sensitive)
Analysis Exclusion Areas

A4 1:1,400,000
GDA 1994 MGA Zone 53
0 10 20
Kilometres

Data Sources: Geosciences Australia (2006); Imagery Sources: ESRI Online Imagery Services
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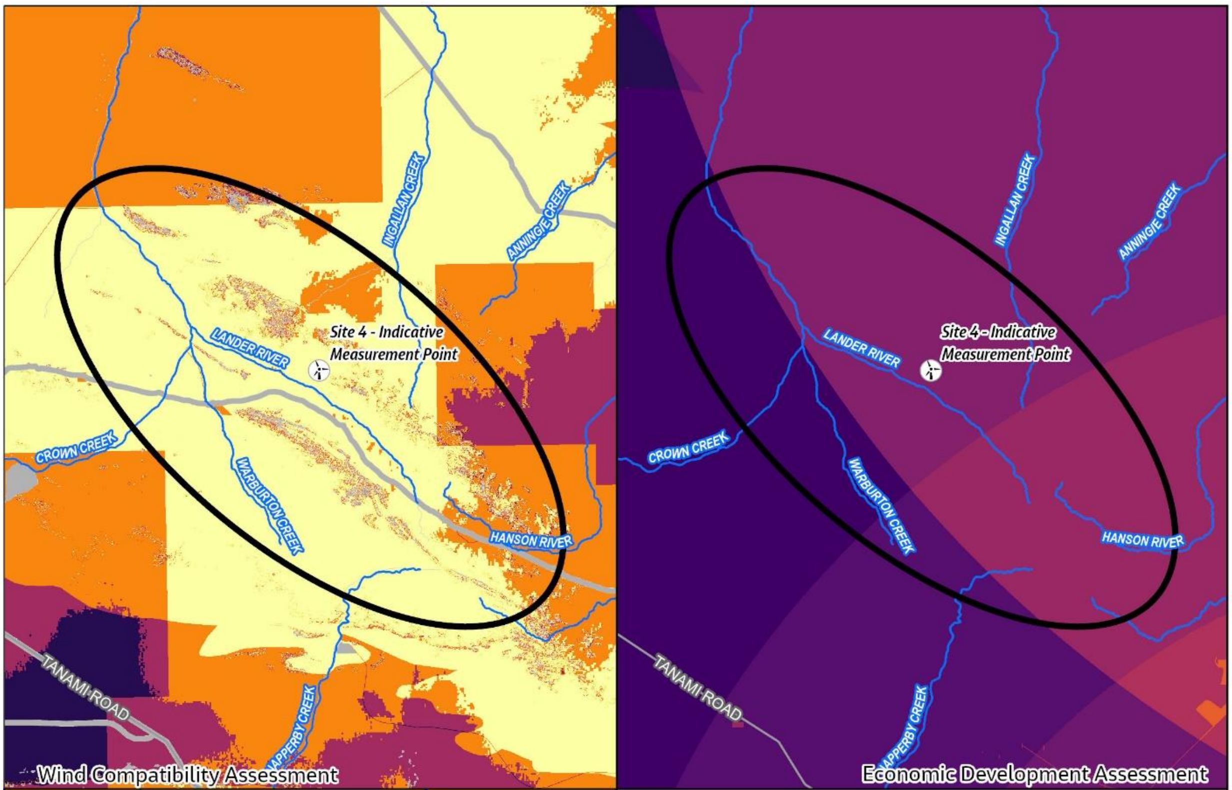
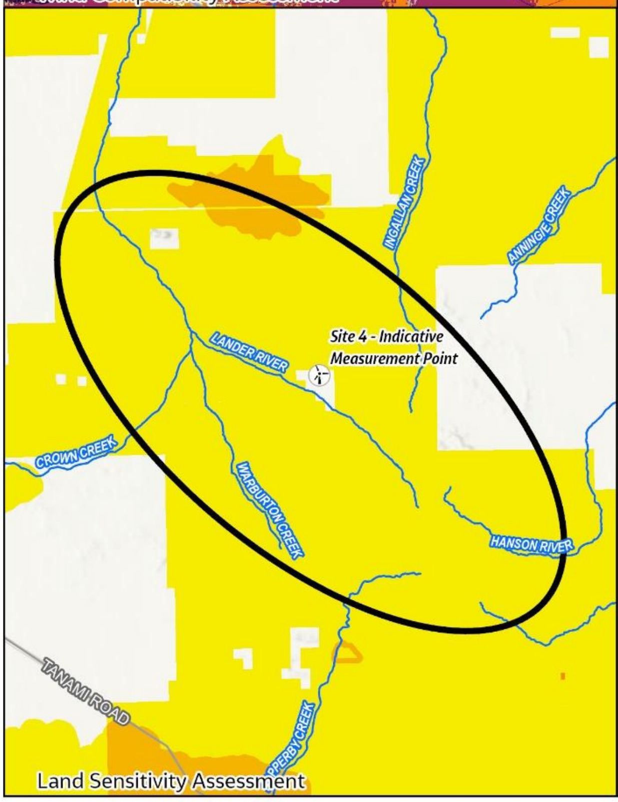
2.7.4 Deep Dive Site 4 – Northwest of Alice Springs

Deep dive site 4 is located northwest of Alice Springs. It is a simplified geometrical representation of Site 1 from the MCA results. This region has the highest mean score for the wind compatibility MCA result due to the occurrence and stacking of multiple high scoring criteria, in particular a large area of high wind speeds. This indicates that the wind resource potential in the region is higher. The site has less sensitivities and a lower mean score for the economics result, due to its regional and more isolated location. This indicates there would likely be a trade-off for this region, between its capacity potential and the cost of construction in a more remote area.





Site 4

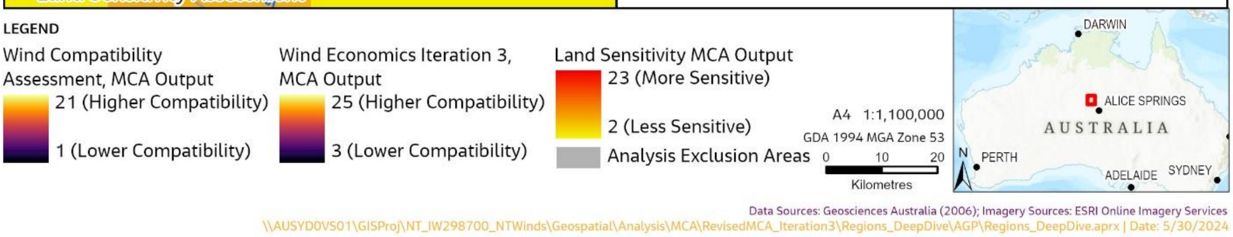
Site 4 is located north west of Alice Springs. The locations appears to be remote.

Exclusion Criteria:
- Small areas of incompatible slope
- Small instances of water inundation
- Road

Wind Compatibility Criteria:
- Suitable Geology
- Compatible Land tenure
- Acceptable flat terrain (some steep slope spikes)
- High - Moderate range windspeed (7-9m/s, 6-7m/s)

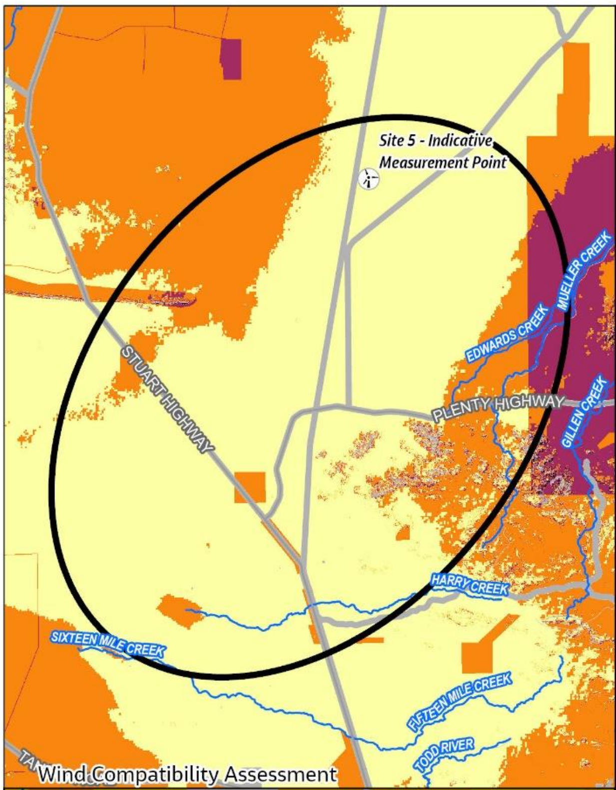
Wind Economics Criteria:
- Proximity to moderate value strategic infrastructure
- Proximity to Roads

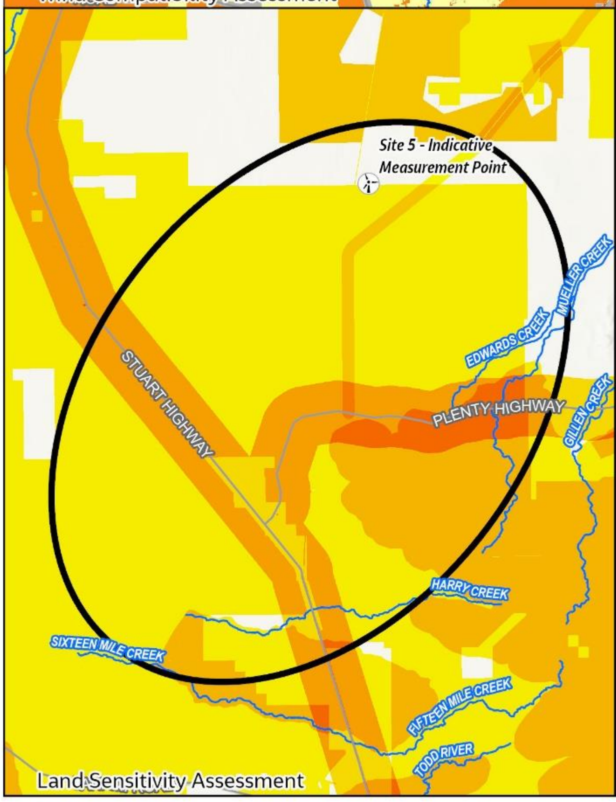
Land Sensitivity:
- Sites of Conservation Significance
- Mining/resources interaction



2.7.5 Deep Dive Site 5 – North of Alice Springs

Deep dive site 5 is located north of Alice Springs. It is a simplified geometrical representation of Site 2 from the MCA results. This region has the second highest mean score for wind compatibility due to the occurrence and stacking of multiple high scoring criteria, in particular high wind speeds. This indicates that the wind resource potential in the region is higher. This region has a similar profile to deep dive site 4 however, has a stronger sensitivity presence due to its proximity to the Stuart Highway. This region would have a similar capacity potential to deep dive site 4, but likely lower construction costs due to its proximity to the major highway.





Site 5

Site 5 is located north of Alice Springs, along the Stuart Highway.

Exclusion Criteria:
- Small instances of water inundation
- Small areas of incompatible slope

Wind Compatibility Criteria:
- Suitable Geology
- Compatible Land tenure
- Acceptable flat terrain
- High - Moderate range windspeed (7-9m/s, 6-7m/s)

Wind Economics Criteria:
- Proximity to moderate value strategic infrastructure
- Proximity to Stuart Highway & Roads

Land Sensitivity:
- Conservation/Park Areas
- Roads
- Sites of Conservation Significance
- Mining/resources interaction

LEGEND

Wind Compatibility Assessment, MCA Output
21 (Higher Compatibility)
1 (Lower Compatibility)

Wind Economics Iteration 3, MCA Output
25 (Higher Compatibility)
3 (Lower Compatibility)

Land Sensitivity MCA Output
23 (More Sensitive)
2 (Less Sensitive)
Analysis Exclusion Areas

A4 1:1,000,000
GDA 1994 MGA Zone 53
0 10 20
Kilometres

Data Sources: Geosciences Australia (2006); Imagery Sources: ESRI Online Imagery Services
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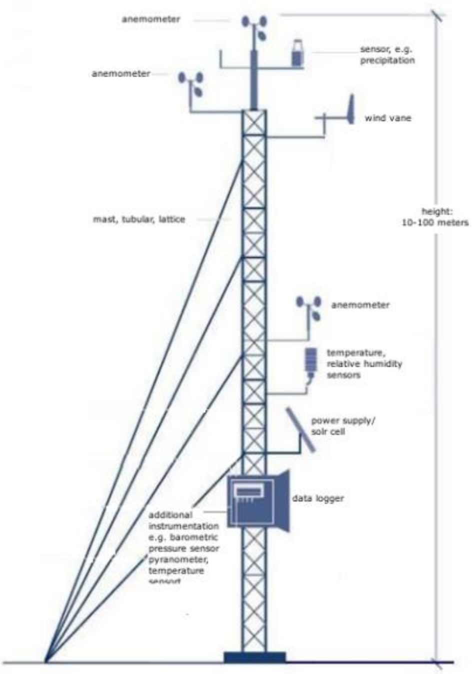
3. Wind Measurement Options

3.1 Measurement technologies

Meteorological masts (met masts), Light Detection and Ranging (LiDAR), and Sonic Detection and Ranging (SoDAR) are all methods employed for wind and atmospheric condition measurement, especially in the context of wind energy assessment and meteorological research. Each method has its own set of advantages and disadvantages.

3.1.1 Meteorological masts



Meteorological masts (met masts) are usually lattice or tubular guyed towers. They have calibrated anemometers and wind vanes mounted on booms to reduced interference of the tower wake on measurements to provide a good estimate of the free stream wind resource. The met masts may also be instrumented with temperature, humidity and pressure sensors to allow inference of air density and atmospheric stability.

Met masts should be of sufficient height to allow estimation of the wind speed, direction and turbulence intensity at hub height. A mast that is as close to hub height, and not less than 2/3 of hub height, is required, meaning that met masts of at least 80 m and as high as 150 m are typical.

Met masts are typically guyed structures requiring a location that allows guys to be fixed to anchors that are close in elevation to the met mast base, hence siting in complex terrain can be difficult. Further met masts usually require engineering certification and building compliance which adds cost.

The installation of a met mast can be a substantial financial commitment. Maintenance, especially in adverse weather conditions, poses inherent hazards and potential Health, Safety and Environmental (HSE) concerns but these are manageable through implementation of appropriate lightning protection. These structures are usually permanent structures, requiring permitting, aeronautical safety markings, and notifications. Installation of met masts may not align with government or developers' objectives as they are evident in the landscape and often publicly notifiable. Installation of met masts can be a lengthy process with approvals commonly taking several months to obtain.

3.1.2 Light Detection and Ranging (LiDAR)

Light Detection and Ranging (LiDAR) uses laser technology to measure wind speeds and directions at heights of up to 200 metres. LiDAR provide a measurement of turbulence intensity and are considered industry best practice and suitable for initial assessment. However the data they generate is not equivalent to that measured using a cup anemometer and as such LiDAR measurements alone may not be sufficient to support final investment decisions or turbine supply contracts and warranties.

LiDAR are ground-based and easily deployable. While data recovery is lower than met masts it is generally good, although is reduced during periods of high wind speed, clear air, and low cloud cover.

Whereas a cup anemometer makes measurements that are representative of a single point, a LiDAR measurement averages the wind across a large conical volume. In complex terrain, the wind flow curves as the terrain changes and flow curvature correction may need to be applied to LiDAR measurements. Some LiDAR are equipped to provide automatic detection and correction for flow curvature, hence model selection depends on where the LiDAR is to be installed.

The mobility and straightforward setup of LiDAR make them a cost-effective choice for short-term or temporary measurements. Although requiring a remote power supply and communications equipment, they can be transported using a regular sized trailer, towed by a light vehicle. Temporary fencing may be needed to prevent cattle or other livestock damage.

LiDAR are less costly to purchase and operate than met masts and can be leased but have greater unit cost than SODAR.

3.1.3 Sonic Detection and Ranging (SODAR)

Sonic Detection and Ranging (SODAR) is a weather observation device that uses sound waves to detect wind speed and direction at elevations above the ground. SODAR can measure vertical wind and temperature profiles, providing an estimate of atmospheric stability.

While SODAR provide a measure of the turbulence intensity it is not comparable to that measured using a cup anemometer. Further, the accuracy of SoDAR measurements is relatively poor and not, in isolation, sufficient to support final investment decisions or turbine supply and warranty contracts.

SODAR measurements can be affected by meteorological conditions (rain) and acoustic interference. Data recovery rates are typically lower than LiDAR, particularly at heights above 100 m, and hence a longer duration measurement campaign may be required.

As for LiDAR, SODAR can also be moved to different locations with ease, providing greater spatial coverage. If a monitoring campaign across a large area is required; it may be more cost-effective to use SoDAR than LiDAR.

3.2 Collection of wind data

The selection between these systems depends on specific wind farm project requirements, budget constraints and the environmental context. It is essential and industry standard to have at least one met mast for a wind farm project development. The height of the met mast is also very important, with the highest anemometer at least 2/3 of the hub height of the proposed wind turbine model (refer **Figure 3-1**).

The wind resource across a wind farm can vary substantially and it is recommended that measurements are made within 4 km of proposed turbine locations in flat and relatively simple terrain, and within 2 km of turbine locations in complex terrain. While met masts are required, they come with a substantial cost, and it may not be practical to install more than one at a proposed wind farm. In this case, remote sensing devices such as LiDARs and SODARs can be deployed to provide measurements across the wind farm.

Wind speed measurements made in investigating the feasibility of wind farms are governed by the IEC 61400-12-1:2022 Wind energy generation systems - Part 12-1: Power performance measurements of electricity producing wind turbines. This standard specifies the methods and guides the installation of a met mast including sensors. The standard describes the quality of sensors installed on the met mast including accuracy and reliability.

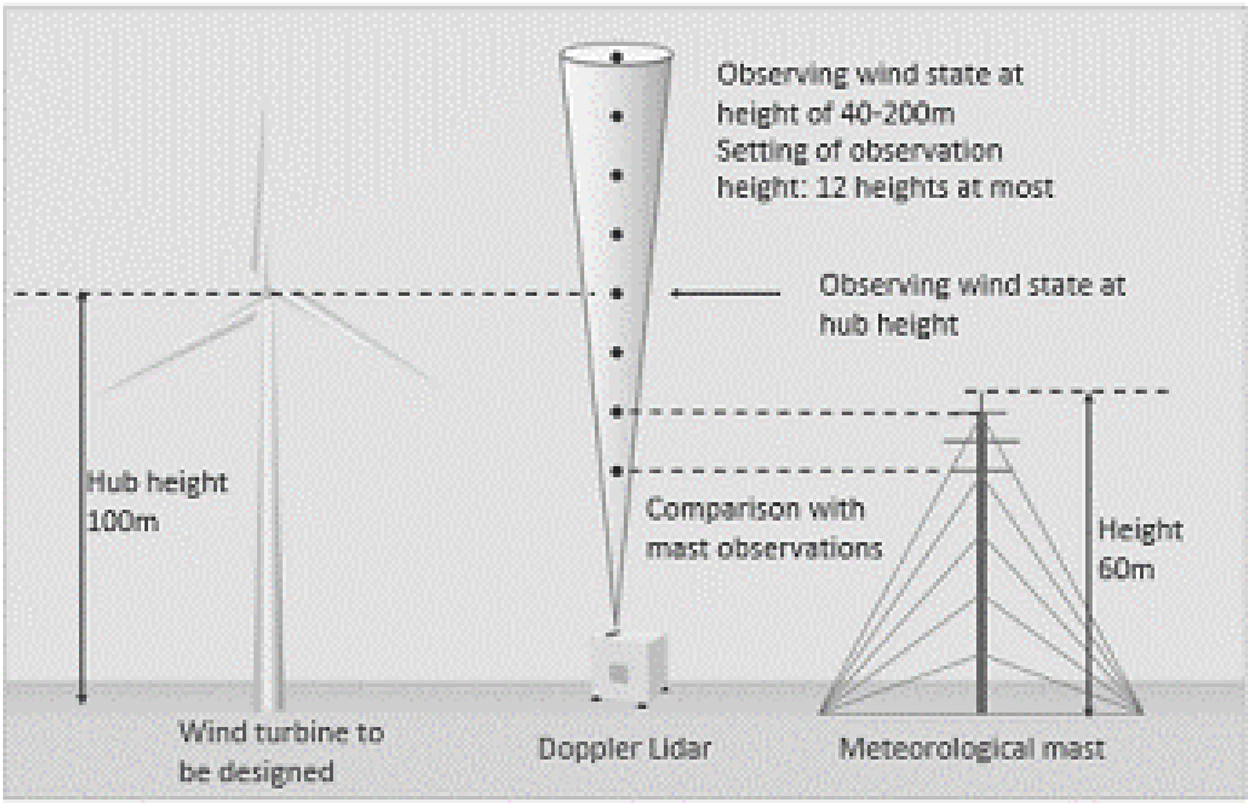


Figure 3-1. Wind condition measurement compliant with international standards

(Source: https://www.jwa.or.jp/english/service/wind-measurement/)

A high-level comparison between meteorological mast, LiDAR and SODAR are presented in **Table 3-1** below, cost estimates have a 25% contingency to cover transport, logistics and any other miscellaneous costs.

Table 3-1. Wind measurement technology cost comparison

Technology	Cost	Benefits	Negatives
Met Masts	~$250,000 – $400,000 (Purchase)	Permanent Accurate Industry standard data	Fixed High cost Lengthy approvals Siting Installation
LiDAR	~$200,000 (Purchase) ~ $8000 - $10 000 per month (Lease)	Mobile Easy to setup Good data quality	Not validated for turbulence intensity measurements Flow correction required in complex terrain Initial investment more expensive than SODAR
SODAR	~$100,000 (Purchase)	Mobile Easy to setup Cost effective	Not validated for turbulence intensity measurements Sensitive to acoustic interference Lower accuracy

(Source https://www.vaisala.com/en & *https://www.fulcrum3d.com/sodarf3d/)*

3.3 Approach to obtaining wind data

The Northern Territory Government aims to facilitate the publication of industry standard wind resource data that will attract the interest of developers and investors to guide their consideration of the Northern Territory as a potential location for wind development. This section outlines possible approaches and recommendations for capturing and reporting on wind data.

The following subsections delve beyond off-the-shelf wind data. They specifically address approaches for measuring wind data at the five prioritised sites identified in **Section 2.7**.

This information will inform the Northern Territory Government's policy development and decision-making regarding potential expenditure on Territory wind resource-mapping.

3.4 Gathering wind data

Assessing the wind resource potential of a site is crucial for successful wind power investments. Here are the key benefits of good wind resource potential:

- **Optimising energy production:** By understanding wind characteristics, developers can design wind farms that maximise energy production, leading to higher returns on investment.
- **Cost savings:** Analysing resource potential helps in identifying cost-effective sites for wind farms. Avoiding sub-optimal locations ensures higher energy output.
- **Economic viability:** Accurate wind resource analysis ensures projects are sited in areas with strong and consistent wind resources. This leads to increased energy production and better value for money for the Territory. Evaluating the economic feasibility of a wind project involves considering factors such as construction costs, land availability, maintenance expenses and potential revenue from power generation.

The lack of existing wind farms in the Territory is partially due to persistent challenges including: long distances from ports to suitable sites, availability of experienced development and construction staff, proximity to transmission, land and infrastructure corridor acquisition, planning and approval processes and poor understanding of wind resources. To encourage prospective investors, the government aims to reduce obstacles and support early project development stages, ultimately facilitating investment decisions.

3.4.1 Wind farm development process

Wind farm development generally follows a path from concept, establishing feasibility, planning and approvals and construction. As the project passes through the stages greater investment is required and needs to be supported by better data. At conceptual stages data from global data resources such as the Global Wind Atlas is likely adequate, establishing feasibility will require measurements made across the site, and for projects to attract sufficient investment to support construction (or be bankable) then measurements from a monitoring campaign that conforms to the principles of IEC61400-1-12 and meets industry standards will be necessary.

It is understood that the Northern Territory Government's aim is to provide a wind resource dataset that has sufficient accuracy and resolution to attract potential wind farm developers. Proponents will need to carry out further investigations to inform future investment decisions.

The most readily available resource for mapping the wind resource across the Territory is the Global Wind Atlas. While other data providers such as Vortex and WindLab may have wind resource atlases these products are not publicly available. The Global Wind Atlas provides average wind speeds, at a height of 100 m, at a horizontal resolution of 250 m. The mean wind speeds are derived from the ECMWF-ERA5 reanalysis dataset which has been downscaled (had resolution increased) using the wind atlas method (as employed in the wind flow software WaSP).

The major disadvantages with the Global Wind Atlas are:

- Limited validation – the only sites in the APAC region to be used in validation are in Papua New Guinea and these have a mean bias of up to 20%
- Use of global datasets to model topography and land cover – in complex terrain the topographic model may not resolve important features and the characterisation of vegetation using global resources may poorly characterise local areas
- Lack of time-series data – being a map the dataset does not provide information on diurnal, seasonal or interannual variation
- Relatively coarse spatial resolution
- The Wind Atlas method uses a simplistic atmospheric physics and does not model atmospheric stability, gravity or thermally driven wind patterns Models that use the Weather Research Forecasting (WRF), such as Vortex, apply more comprehensive physical models.

The usefulness of the Global Wind Atlas could be improved markedly by:

- Removing bias by scaling the atlas to measurements made at locations throughout the Territory
- Comparison of topographic and land use inputs with locally captured data (such as the LUMP data set[6])
- Integration with ERA5 time-series – a web data service could be made available so that data from the time-series from the ERA5 are scaled to the validated GWA product
- Variance in interannual, seasonal, and diurnal patterns could be understood, and adjustments made to ERA5 time-series to remove anomalies and bias
- Diurnal patterns of wind shear (atmospheric stability) should be understood and provided as an accompanying product.

[6] https://data.nt.gov.au/dataset/land-use-mapping-project-of-the-northern-territory-2016-current-lump

If the processes used to produce an improved Northern Territory Wind Atlas are well documented and published it may not be necessary to release measured datasets, allowing proprietary information to be used. If existing data is not available to undertake validation, then it will be necessary to undertake a monitoring campaign.

The dataset used for validation should use measurements made at locations where the potential for wind farm development is assessed as being relatively good, as determined in **Section 2.6**. The measurements should be made for a sufficient length of time such that seasonal and diurnal patterns are well resolved. It may not be possible to undertake a measurement campaign for a sufficiently long duration to understand differences in interannual variation (and climate oscillations due to El Nino and La Nina), hence obtaining data from existing sources will be useful. Measurements should be made at a height that is as close to hub height as practicable and scale the GWA product to that height.

In developing a wind farm, it is typical for measurements to be made at the wind farm site for a relatively short period of time (at least 12 months, but possibly less than 24 months). As there is significant interannual variance in wind speeds the site measurements are correlated to longer term reference wind speed time-series. While measurements made at a nearby meteorological station can be used as a long-term reference, in cases where there is a lack of surface measurements (as in the Territory) the results of a reanalysis model, such as ECMWF ERA5 or MERRA2, are used. The adjustment of the site measured wind resource to a longer term depends on the correlation to and consistency of the reanalysis model results. Uncertainty in the long-term adjustment could be reduced by ensuring there are no local anomalies in the reanalysis model results. A research study could be undertaken to understand the long-term consistency of reanalysis model results using wind speed measurements that have been made at meteorological stations or airports across the Territory.

While the validation process does not need to satisfy the requirements for bankability; providing data to inform site conditions assessments (turbulence intensity, temperature, and air density) will benefit developers.

3.4.2 Wind farm project uncertainty

On any wind project there is a range of factors that will result in uncertainty, such as resource measurements, economic assumptions, project construction logistics. Key uncertainties and recommended mitigations are outlined in **Table 3-2**.

Table 3-2. Key uncertainties and suggested mitigations

Uncertainty factor	Mitigation	Comments
Wind resource data	Measurements should span a sufficient duration in locations across the Territory to allow validation of GWA products. The data from the monitoring campaign should be publicly available to allow developers to undertake bespoke analyses.	Data provided by NT Government will potentially support developers' business cases for proceeding feasibility assessments.
Availability of experienced contractors to deliver project(s)	Utilise organisations such as NT Industry Capability Network (ICN) to enable developers to identify interested NT, national and international companies that may wish to be involved in work.	While there are wind farm development projects in progress in many states of Australia and NT may leverage skills and experience from existing developers, the global competition for skilled staff means it is preferable to grow and educate a local NT talent.

	NT ICN can establish EOI process for interested contractors and suppliers on behalf of developers	
Procurement – availability and willingness of contractors to be involved	NT Government or developers need to engage with industry early to outline the plans and opportunities so that contractors can be understand the project requirements and resource accordingly. There are already skills shortages within the NT and Australian infrastructure industries and likely competition across major projects, for resources.	There may be reluctance from local NT contractors to take on a project such as this in the NT, with no prior experience of wind projects developed in the region. This may require partnering with interstate businesses who may be willing to share their knowledge. Careful planning and industry engagement will need to be undertaken to address this risk.
Logistics and infrastructure capacity	NT Government has identified projects such as the infrastructure corridor, road upgrades and logistics hubs designed to support projects of this nature. Ongoing engagement between potential developers and government will be critical to future planning and securing funding.	Current infrastructure may not have capacity required to transport turbine components. Distance from highways/ports will potentially add to project costs and impact viability.
Mobilisation of personnel to site and workforce needs	Developers will need to have workforce, recruitment, and retention strategies in place to attract skilled and qualified workforce. Early engagement with the trade sector and workforce organisations will be critical to plan for future needs.	Adequate infrastructure and services may impact on ability to recruit workforce to sites located in remote areas. This is a common challenge for NT projects. There may be a need to establish new housing and services for staff, and there may be a need to establish a quarry and adequate road, power, and telecommunications infrastructure for the construction phase.
Power Purchase Agreements (PPA)	Developers will need to identify customers in advance to demonstrate a revenue stream to financiers.	This is a responsibility of developers, not government.
Land tenure	As part of planning phase, investigation into land tenure of proposed sites will need to be undertaken along with potential negotiations with private owners or Traditional Owners to secure land access and agreement. For Aboriginal owned land this will need to be through land councils and the Aboriginal Area Protection Authority (AAPA).	Both private and Aboriginal landowners may be open to economic benefits of project development, but time will need to be allocated for negotiations and buy in. Negotiations through the Land Councils is often a lengthy process, given numerous major projects competing for NLC time and resources.
Government policy	Government needs to be clear on policy position and associated processes to manage potential wind projects and to enable 'fast tracking' so that projects can be established in	Something to be considered by NT Government as potential projects are identified. The demand for 'fast tracking' needs to be balanced with community trust and allow for appropriate

	a timely manner that aligns with their financial model.	consultation to be undertaken in all stages of a project.

3.4.3 Wind measurement technology implementation

Implementation of any selected wind measurement technology requires a reasonably standard approach. The key steps and estimated timeframes are provided below, noting that for the Northern Territory Government, where they own the land, not all of these steps will be required:

1. Land access agreement

As part of the planning phase, investigation into land tenure of proposed sites will need to be undertaken along with potential negotiations with private owners or Traditional Owners to secure land access and agreement.

A range of environmental and/or other regulatory approvals will be required from both Territory and Federal governments and can take a minimum of 3-6 months (likely longer) to secure, depending on statutory process. After the access is granted, it is possible to start mobilisation for the measurement system of preference.

2. Procurement of measurement system

There are companies that specialise in manufacturing and supply of wind measurement systems whether it is a met mast or a remote sensing device (LiDAR-SODAR). Because of the nature of the business, some companies provide both systems. Typical lead times can be 6-12 months for a met mast and 3-6 months for LiDAR-SODAR systems.

All technologies have different lead times, and this must be considered within the procurement process. Met masts and SODARs are manufactured locally in Australia, however at present we are not aware of any local LiDAR manufacturers. Met masts are generally the system with the longest lead time, as they may require engineering and manufacturing of the truss elements to suit the location however, off the shelf met masts are becoming more readily available.

There are existing companies within the Territory with wind measurement equipment they lease out to private and government clients.

3. Installation, commissioning, and maintenance

Normally ownership of a measurement system lies with the developer however, they may use sub-contractors for the installation, repair and maintenance of the systems.

Installation of any system will require site access.

Installation of a met mast would require between 2-4 weeks considering foundations would need to be constructed for the anchorage and the foundation.

However, for LiDAR and SODAR, installation can be performed in one day on site once the system has been transported.

Scheduled maintenance for met masts is typically annual which includes a check of the datalogger, cables and structural wiring around the met mast. Unscheduled maintenance for met masts is required when any of the systems is not performing as it should be. Typically, a team will go to the site to investigate, and maintenance may require replacement of a specific part within the system that is not working properly. For example, sensors, cables or other.

For LiDARs and SODARs, no scheduled maintenance is generally required as devices are maintenance free when they are performing without any issues. LiDARs, may need to have wiper water refilled which is part of the system used when it is raining.

4. Data handling, storage and presentation

For all systems, data is stored in 10-minute intervals. In met masts, all measured data is stored in the datalogger and sent to the owner via email daily. The data received from the met masts can later be stored on a server for internal and external use. For LiDAR and SODAR, the collected data is stored on a server by the manufacturer and the owner accesses it through a web interface. With that access, it is possible to visualise and analyse the data using presentation portals, dashboards or similar.

The most practical way to provide data publicly is via a web interface. The overall characteristics of the data (mean wind speed, direction, turbulence intensity, etc) can be shared visually. This will be valid for all measurement systems.

5. Decommissioning

The decommissioning of a met mast would require a minimum 1-2 days onsite depending on whether the concrete foundations need to be removed. If structures and foundations need to be removed, a 1-2 weeks' timeframe would apply.

LiDARs and SODARs do not require any special decommissioning apart from removal from the site (as well as fencing removal if in place).

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[PDF] LIDAR and SODAR Measurements of Wind Speed and Direction in Upland Terrain for Wind Energy Purposes | Semantic Scholar

The Energy Charter, various guides - The Energy Charter

Previous work undertaken by Jacobs.

Appendix A. Criteria

Table A-1. Wind Compatibility Criteria Used

Criteria	Rationale	Source
Wind Speed	Promote areas with higher wind speeds having greater energy generation potential. Ranges applied: ▪ Moderate Compatibility: wind speeds 6-7m/s ▪ High Compatibility: wind speeds 7-9m/s ▪ Very High Compatibility: wind speeds 9+ m/s	Global Wind Atlas
Slope	Wind turbines require construction on relatively flat terrain. Ranges applied: ▪ Low Compatibility: slope 20<25^{o} ▪ Moderate Compatibility: slope 10<20^{o} ▪ Very High Compatibility: slope <10^{o}	SRTM
Geology	Certain geologies, such as granite, basalt, gabbro, schist, gneiss, limestone, and sandstone, are particularly suitable for construction projects due to their strength, stability, and load-bearing capacity. Special caution is needed in carbonate formations due to the potential for karst development (sinkholes) caused by the rock's reactivity with water. Subsidence due to high groundwater withdrawal is also of concern, especially in areas with high-volume groundwater extraction.	NT DEPWS/NT Strike
Tenure	Land currently having titles over which may impact or inhibit the development of wind power infrastructure. Pastoral land - areas of existing agriculture land use, Crown Land – government owned/managed.	DIPL Cadastre

Table A-2. Wind Compatibility Criteria Considered but not used

Criteria	Rationale	Source
Soils	No acceptable data sources.	NA
Bushfire	Entire assessment area considered a bushfire risk; criteria removed as it does not add value to the assessment.	NA
Solar irradiance	Entire assessment area covered by high score; criteria removed as it does not add value to the assessment.	Global Solar Atlas
Lightning days	No acceptable data source	NA

Table A-3. Economics Assessment Criteria Used

Criteria	Rationale	Source
Port Distance	Wind farm infrastructure requires transportation of large/heavy wind turbine components from international suppliers / manufacturers. Promote proximity to Ports, closer attracts a higher ranking. Ranges applied: ▪ Moderate Compatibility: 750<1,000km ▪ High Compatibility: 500<750km ▪ Very High Compatibility: <500km	NT DIPL
Logistics - Road/Rail	Wind farm infrastructure requires transportation of large/heavy wind turbine components from international suppliers / manufacturers. Proximity to Roads (major arterials)/Rail - closer attracts a higher ranking. Ranges applied: ▪ Moderate Compatibility: 100<200km ▪ High Compatibility: 50<100km ▪ Very High Compatibility: <50km	NT DIPL
Strategic Importance	Areas of strategic importance for future development – gas/hydrogen/minerals Promote proximity areas of strategic importance, including existing major projects.	NT DIPL/NT DITT
Strategic Infrastructure	Areas of strategic importance for future development – infrastructure/transmission. Including the proposed NT Infrastructure Corridor. Promote proximity areas of strategic importance, for power transmission and supporting infrastructure.	NT DIPL/NT DITT
Resources / Mining Tenements and other industrial land uses	Land occupied by an operating mine or quarry; industry may benefit using renewal power source (decarbonisation). Opportunity to co-locate wind/solar and minimise operational costs of mine. Promote proximity to supply industry with power generation.	NT DEPWS/NT Strike

Table A-4. Economics Assessment Criteria considered but not used

Criteria	Rationale	Source
Transmission Distance	Removed due to the absence of electrical transmission lines in all regions but the top end of the Territory. Criteria is not considered useful to the assessment as it focusses on existing areas.	NA

Table A-4. Land Sensitivity Assessment Criteria Used

Criteria	Rationale	Source
Conservation Areas/ Public Reserves and Parklands	Land occupied by a conservation area or public reserves. Areas to protect Australian native landscapes, including native flora and fauna. Community concerns about construction in or adjacent to a national park could adversely impact on the time taken to engage with the community and to secure approvals.	NT DIPL / NT DEPWS
Significant Biodiversity Areas	Land and the associated landscapes identified as being significantly important for conserving biological diversity. No regulatory or legislative protection above that of the existing threatened flora and fauna, however there is an obligation to ensure further steps are taken to manage conservation values.	NT DEPWS
Nationally Important Wetland surrounds	Ramsar wetlands are those that are representative, rare, or unique wetlands, or are important for conserving biological diversity (migratory species). Australia's commitments under the Ramsar Convention (international treaties) and responsibilities under the EPBC Act. Wind turbines pose some threat to migratory birds, areas surrounding these wetlands should be considered sensitive also. Buffer to be applied to Ramsar wetlands.	DCCEEW
Historical Heritage - Commonwealth	Any item or place identified on Commonwealth Land. Areas listed in the Commonwealth Heritage List. Protected under The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), Commonwealth Heritage List and UNESCO.	DCCEEW
Resources and Mining Tenements	Land occupied by an operating or historic mine or quarry may have tailings or excavations that may place barriers to wind farm construction. Conversely an operating mine may require power and thus a wind farm constructed nearby will be advantageous.	NT DEPWS/NT Strike
Residential Areas/Township adjacent	Community concerns of construction near residential areas could delay planning approvals. Buffer zones applied around residential urban centres and localities based on planning zones and cadastral parcels.	Census Urban-Centres and Localities
Commonwealth Land	Actions on or affecting Commonwealth land have the potential to require an EPBC Act Referral.	NT DIPL
Tourist Roads	Roads that are consistently travelled by tourists.	NT DIPL

Table A-5. Land Sensitivity Assessment Criteria considered but not used

Criteria	Rationale	Score
Native Vegetation	No acceptable data sources	NA
Groundwater	No acceptable data sources	NA
Historical Heritage – Territory	Restricted data – not accessible	NA

Criteria	Rationale	Score
Indigenous Heritage – Territory	Restricted data – not accessible	NA
Indigenous Land Use Agreement (ILUA)	Restricted data – not accessible	NA
Contamination Areas	No acceptable data sources	NA