Environmental Impact Assessment

September 2017

Sri Lanka: Wind Power Generation Project
Appendices 6–10

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APPENDICES

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MANNAR WIND POWER PROJECT
Shadow flicker assessment

E305674
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Executive summary

Shadow flicker modelling was carried out for the proposed 100 MW Mannar Wind Power Project, using a method corresponding to the World Bank Environmental, Health, and Safety Guidelines for Wind Energy [1], and the German Shadow Flicker guidelines [2] which are the basis of the World Bank requirements, adopted in this case by the Asian Development Bank. These guidelines recommend a process for modelling a 'worst-case' scenario and comparing with limits of 30 hours per year and 30 minutes per day on the worst affected day.

The proposed wind farm configuration of 39 wind turbines (Scenario A) with a rotor diameter of 130 m and hub height of 90 m has been defined as the worst case and hence likely maximum impact for assessing shadow flicker impacts on receptors. It is noted that wind turbine models offered for the project will probably include wind turbines with an individual capacity of around 3.3 MW, so that 31 wind turbine locations is a likely configuration for the 100 MW project – this has been modelled as Scenario B.

The modelled shadow flicker significantly exceeds the recommended limits at locations along the coastline which are 300 m or less from wind turbine locations. These include (considering either Scenario A and B):

- The Shell Coast resort. Annual shadow flicker hours are calculated as up to 164 hours.
- The two Kaluthota Investment Cabanas. Annual shadow flicker hours are calculated as between 77 and 267 hours, depending on the exact location considered, and whether Scenario A or B is considered. However it is noted these properties may be acquired by CEB, which would negate their status as receptors.
- Vaadi, naval outpost and camps, the fish meal factory and sea cucumber hatchery, and other assorted structures located along the coast, where the potential for shadow flicker exists on many days each year (from 100 days up to almost every day).

The Scenario B layout significantly mitigates shadow flicker at some specific receptors (such as the sea cucumber hatchery) located adjacent to the 'removed' wind turbine locations (WTs 4, 7, 8, 17, 22, 27, 28, 31), however shadow flicker remains significant at other locations.

Shadow flicker can be mitigated by turning off wind turbines during time periods when there is potential for shadow flicker at receptors (typically around sunrise and sunset). Shadow flicker could be completely mitigated with an estimated energy loss equivalent to approximately 1.5% of the annual energy output of the wind farm for Scenario A, or 1.0% for Scenario B.

The precise shutdown regime for shadow flicker mitigation will be determined after the wind turbine model is selected by CEB's tender process, and further investigation of the sensitivity of each potential receptor, to shadow flicker. An automatic shutdown regime will be implemented on the individual wind turbines that exceed limits to reduce the hours of modelled shadow flicker to within the required 30 hours annually. Based on the final wind turbine configuration, the precise time of day when shadow flicker is present will be modelled for each day of wind farm operational life. Post-constructon monitoring and consultation should be undertaken to determine whether the automated shutdown shadow flicker mitigation has been effectively implemented.

Blade glint is not expected to cause any issue, provided the wind turbine supplier ensures that blades supplied are coated with a low reflectivity treatment.

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1. Introduction

The rotating blades of wind turbines can cast intermittent shadows to a person located in the shadow of the wind turbine – termed shadow flicker. Because wind turbines are tall structures, shadow flicker can be observed at considerable distances but usually only for a brief time at any given location. In some circumstances for some people shadow flicker may cause annoyance, however it is not generally associated with adverse health impacts [4].

A detailed consideration of the phenomenon of shadow flicker is presented in the referenced UK report [4], which reviews the results of numerous studies, including the evidence for shadow flicker impacts on health and residential amenity.

A primary concern of planning authorities has been whether wind turbine shadow flicker can lead to photosensitive epileptic seizures in individuals – there is little or no evidence of any such incidents ever occurring.

Statistically (in the UK), approximately 0.5% of the population suffers from epilepsy, of these between 3.5% to 5% are photosensitive, and of these less than 5% are sensitive to the 'low' freqeuencies in the range 2.5 – 3 Hz, with the remainder sensitive to higher frequencies up to 30 Hz.

Modern large wind turbines rotate more slowly than previous generations of wind turbines, and produce shadow flicker at a frequency of between 0.3 to 1.0 Hz. As such, the rotational frequency of wind turbine shadow flicker is much lower than the flickering light conditions that are associated with photosensitive epileptic seizures in an extremely small percentage of the population. As such, and based on their own surveys, organisations such as the UK epilepsy society have concluded the risk is minimal [7].

The extent to which shadow flicker is a nuisance to individuals is more difficult to gauge. However for the short durations mandated by the guidelines below, the nuisance impact of shadow flicker is minimal.

1.1 Reference guidelines

Sri Lanka does not have any specific guidelines for wind farm shadow flicker. The World Bank Environmental, Health, and Safety Guidelines for Wind Energy [1] refers to international sources of good practice, and Asian Development Bank has confirmed the German guidelines [2] for shadow flicker should be applied to this project.

These guidelines include detailed limits:

- 30 hr/yr and 30 min/day modelled shadow flicker at 'receptors'
- 8 hr/yr actual shadow flicker in a realistic scenario considering meteorological parameters

The guidelines include a detailed method and assumptions to be used in calculations including:

- continual sunshine in cloudless skies from sunrise to sunset

- sufficient wind for continually rotating wind turbine blades
- minimum angle of the sun above the horizon of three (3) degrees
- model the Sun as a point
- include effects of topography
- do not adjust for atmospheric refraction
- receptor height 2 m above ground (or window height)
- Receptor locations are all dwelling entry points (windows and balconies)
- distance between rotor place and tower axis is negligible
- rotor is perpendicular to the incident direction of the sunlight
- document assessment for at least a one year period (365 days, 24 h/day)

Possible mitigating circumstances and supporting evidence for limits and approaches is also included, and exceptions may typically occur by agreement with a landowner.

The German guideline does not provide a specific distance beyond which shadow flicker will not occur. For this assessment, Entura will adopt the assumption that shadow flicker is not experienced beyond 10 rotor diameters, as per standards used in the United Kingdom [4].

Modelling for comparison against the 30-hour limit applies the most conservative assumption at each step, to produce a 'worst-case' estimate of total hours of exposure. Modelling is used as it provides a benchmark; however it is widely recognised as considerably overestimating actual exposure and the exposure limit has been set to account for this.

1.2 Mitigations

The actual observed shadow flicker at receptors is less than the modelled results, because of the following items:

- If the sun is blocked by cloudy skies, wind turbines do not cast pronounced shadows.
- When the wind turbine rotor is not oriented perpendicular to the line between the sun and the receptor, the region of shadow flicker is thinner than modelled, and may not therefore be cast over the receptor.
- When the wind turbine is not rotating due to low wind, no moving shadows will be cast and no shadow flicker would occur.
- If the wind turbine is screened by vegetation or other structures the amount of shadow flicker at the receptor will be reduced.
- Shadow flicker impact is generally most noticeable when experienced in a confined indoor space, where sunlight through a narrow window opening is the predominant light source [4].

As such, the hours of shadow flicker calculated in this report are more than the hours of shadow flicker that will be experienced in practice.

As noted in the previous section, the 30-hour limit for modelled shadow flicker takes into account that mitigations related to meteorological factors (including some of the above) will typically reduce actual exposure considerably.

However, individual cases may differ, and additional mitigations such as physical screening or scheduling of wind turbine operation may be introduced. For this reason, the German guidelines provide an alternate limit for assessments that take into account these mitigations. As stated earlier, if mitigation measures are to be relied upon then this limit is 8 hr/yr actual shadow flicker in a realistic scenario considering meteorological parameters.

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2. Method

Entura has used the DNV-GL WindFarmer 5.2.11 software package to model the occurrence of shadow flicker at the wind farm site.

In completing this analysis, Entura has used the following inputs

- Wind turbine coordinates consisting of 39 locations provided by Ceylon Electricity Board on 30/11/2017, shown in Appendix A. This layout of 39 locations is referred to as 'Scenario A' in this report.
- A subset of 31 locations, representing a typical layout that satisfies the 100 MW installed capacity limit with 31x 3.3 MW wind turbines. WTs 4, 7, 8, 17, 22, 27, 28, 31 have been removed from the 39 locations. This layout is referred to as 'Scenario B' in this report.
- Residence coordinates for all residences, public facilities, fisher camps and navel outposts within 2 km of any turbine ('Receptors'). A list of 'receptor' locations has been developed and is provided in Appendix A. This list has been developed by the Asian Development Bank's environmental and social safeguard consultants, with some additional building locations that Entura has identified through observations of Google Earth aerial imagery.
- A generic wind turbine model of 130 rotor diameter and 90 m hub height.
- Contour map file of site extending a minimum of 2 km in all directions from the wind turbine locations and residences of interest.

The modelling parameters and settings in Table 2.1 show the recommendations of the German guideline [2], the values used in this analysis.

Table 2.1: Shadow Flicker modelling parameters

Model parameter	**Value required by guideline**
Zone of influence of shadows	10 x rotor diameter, 1300 m
Minimum angle to the Sun	3 degrees
Shape of the Sun	Point source
Time and duration of modelling	2018 (one full non-leap year)
Orientation of the rotor	Disk facing the sun
Offset between rotor and tower	None
Time step	10 min
Effects of topography	Include
Receptor height	2 m
Grid size for mapping	25 m

3. Results

3.1 Shadow flicker modelling

The full results of the modelling are presented in Appendix A, and the distribution of shadow flicker annual totals is shown across the site in the map in Appendix B.

We note the following key observations from the results:

- Shadow flicker hours at the Shell Coast resort are up to 164 hours (or less depending on the exact location modelled).
- Shadow flicker hours at the' Kaluthota Investment Cabanas' and 'St' Jude Rd, Kaluthota Investment Cabanas' are between 77 and 267 hours, depending on the exact location considered, and whether Scenario A (39 WTG) or Scenario B (31 WTG) is considered. it is noted these properties may be acquired by CEB which would negate their status as receptors.
- The majority of Vaadi and naval outposts and camps, the fish meal and sea cucumber factories, and other assorted structures located along the coast and between wind turbine locations are calculated to receive shadow flicker well in excess of 30 hours.
- The Scenario B layout significantly mitigates shadow flicker at some specific receptors located adjacent to the 'removed' wind turbine locations (WTs 4, 7, 8, 17, 22, 27, 28, 31)
- Where shadow flicker hours exceed 30 hours per year, there are a large number of days (typically > 100) where the 30 min per day limit is exceeded.
- Other sensitive locations surrounding the wind farm are have less than 30 hours of shadow flicker per year and less than 30 minutes per day.

3.2 Mitigations

The high number of hours of modelled shadow flicker at many locations close to wind turbines far exceeds the 30 hour limit of the guidelines. Partially mitigating the amenity concern, is research that suggests when wind turbines are rotating at below 2.5 Hz (as they will be for this project), they will hardly cause any nuisance [4].

The impact on amenity is perhaps most critical for patrons of the Shell Coast resort, and in future at the two Cabanas under construction. For these locations, with shadow flicker unmitigated (e.g. by shutdown as discussed in Section 3.3), the average daily duration is roughly 30 minutes (but probably less in most cases), which could conceivably cause some annoyance.

It is common practice to consider 'meteorological' mitigations in the event that some locations exceed 30 hours of shadow flicker. Some potential mitigations are discussed in the Sections below. However because shadow flicker hours greatly exceed 30 hours, meteorological mitigations do not alter the conclusion that shadow flicker at many locations along the coastline exceeds the guidelines.

3.2.1 Rotor azimuth

A relatively simple first step for further analysis is to test the assumption that the rotor is always orientated perpendicular to the sun. In practice, the wind turbines at Mannar will be oriented along a 40° / 220° axis for most of the year, and when shadow flicker hours are modelled with the rotor fixed in this orientation, the number of shadow flicker hours at many locations reduces significantly – see Table A.4.

3.2.2 Cloud cover, rainfall and periods of calm

Figure 3.1 displays monthly shadow flicker hours across the receptors, monthly rainfall at Mannar Island [5], and the number of hours where wind speed is below the typical 3 m/s cut-in wind speed of wind turbines. The following observations are noted:

- High monthly shadow flicker totals generally coincide with months of relatively high rainfall (January, November, December). This implies that cloud cover may obscure a larger proportion of shadow flicker hours than typically expected (although a firm link between rainfall and consistent cloud cover has not been confirmed for this site). As a consequence of this analysis, we note the potential for some mitigation due to significant cloud cover from November through January. This does not alter the basic conclusion that the 30 hour per year limit will be greatly exceeded at receptors close to wind turbines.
- Additionally, periods of calm may occur when shadow flicker is modelled. Taking November as an example, the wind turbines may be stationary for approximately 14% of the time due to low wind speeds, however across the year there is not a strong correlation between months with low wind speeds and months with high shadow flicker. As such, consideration of periods of calm does not alter the basic conclusions about the high level of shadow flicker at some locations.

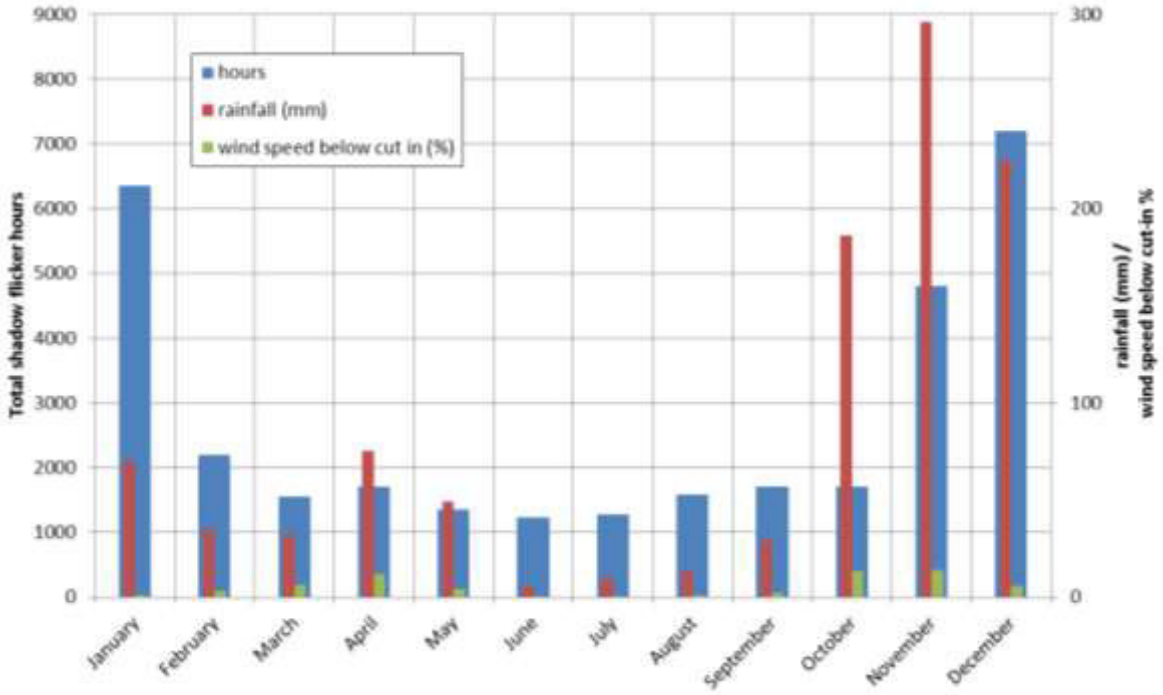

Figure 3.1: Monthly shadow flicker hours, average rainfall, and low wind speeds

3.2.3 Rotor size

The wind turbine has been modelled with a 130 m rotor and 90 m hub height based on the maximum likely size of wind turbine. The actual wind turbine size may be smaller than 130 m (e.g. 110 m), and in such a case, the number of shadow flicker hours will be reduced.

3.3 Wind turbine shutdown

For locations where shadow flicker exceeds guidelines, shadow flicker may be mitigated by implementing control algorithms to shut down the wind turbines responsible for shadow flicker during the specific times when shadow flicker would impact receptors.

It may not be feasible to completely mitigate shadow flicker at all locations, however due to the clustering of many of these locations, operational constraints on selected wind turbines will significantly reduce the impact of shadow flicker.

Entura estimates that operational constraints implemented at selected wind turbine locations could completely mitigate the shadow flicker at affected receptors, with a resulting shutdown period equivalent to 1.5% of the annual time period for Scenario A (39 wind turbines) or 1.0% of the annual time period for Scenarion B (31 wind turbines). Assuming a 1:1 relationship between time and energy loss, this represents the annual energy loss due to shadow flicker for each scenario.

The precise shutdown regime and associated energy loss is highly dependent on the number of wind turbine locations (likely less than 39), the wind turbine model and size, and whether the affected receptors are occupied and sensitive to shadow flicker during the relevant time periods (generally morning and evening). The estimated 1.5% energy loss (or 1.0% for Scenario B) is likely to overstate the loss, given these factors.

The precise shutdown regime for shadow flicker mitigation will be determined after the wind turbine model is selected by CEB's tender process, and further investigation of the sensitivity of each potential receptor, to shadow flicker. An automatic shutdown regime will be implemented on the individual wind turbines that exceed limits to reduce the hours of modelled shadow flicker to within the required 30 hours annually. Based on the final wind turbine configuration, the precise time of day when shadow flicker is present will be modelled for each day of wind farm operational life. Post-constructon monitoring and consultation should be undertaken to determine whether the automated shutdown shadow flicker mitigation has been effectively implemented.

Entura is not aware of a proven and commercial viable system to assess meteorological conditions in real time and determine when to implement shutdown to prevent shadow flicker, however adaption of cloud cover detection systems used in forecasting for solar arrays is a potential solution for investigation, if shadow flicker losses have a significant financial impact.

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4. Blade glint

Blade glint can potentially be produced when the sun's light is reflected from the surface of wind turbine blades.

All major wind turbine blade manufacturers currently finish their blades with a low reflectivity treatment. This prevents a potentially annoying reflective glint from the surface of the blades and the possibility of a strobing reflection when the turbine blades are spinning. Therefore the risk of blade glint from a new development is considered to be very low.

Provided the wind turbine specifications require that blades supplied are coated with a low reflectivity treatment, no issue is foreseen.

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5. Conclusions

The shadow flicker impacts on receptors in the vicinity of Mannar Wind Power Project have been assessed.

Shadow flicker impacts are dependent on proximity to wind turbines, hence the impacts on receptors in the vicinity of the wind farm can be grouped as follows;

- Locations 800 m or further from the wind turbines, which are unaffected or experience impacts that are within shadow flicker guidelines requirements of 30 hours per year and a maximum 30 minutes per day. Local villages and permanent residences fall within this category.
- Locations along the coastline 300 m or less from wind turbine locations, which exceed the guideline requirements by a large number of hours and for a large number of days. These include:
    - The Shell Coast resort. Annual shadow flicker hours are calculated as up to 164 hours.
    - The two Kaluthota Investment Cabanas. Annual shadow flicker hours are calculated as between 77 and 267 hours, depending on the exact location considered, and whether Scenario A (39 wind turbines) or Scenario B (31 wind turbines) is considered. It is noted these properties may be acquired by CEB which would negate their status as receptors.
    - Vaadi, naval outpost and camps, the fish meal and sea cucumber factories, and other assorted structures located along the coast, where the potential for shadow flicker exists on many days each year (from 100 days up to almost every day)
    - The Scenario B layout significantly mitigates shadow flicker at some specific receptors located adjacent to the 'removed' wind turbine locations (WTs 4, 7, 8, 17, 22, 27, 28, 31)

Shadow flicker can be mitigated by stopping wind turbines during time periods when there is potential for shadow flicker at receptors. It is estimated that shadow flicker at receptors could be completely mitigated, with a resulting loss of energy equivalent to approximately 1.5% of the annual energy output of the wind farm if 39 wind turbines are considered, or a 1.0% loss if 31 wind turbines are considered.

The precise shutdown regime and associated energy loss is highly dependent on the number of wind turbine locations (likely less than 39), the wind turbine model and size, and whether the affected receptors are occupied and sensitive to shadow flicker during the relevant time periods (generally morning and evening). The estimated 1.5% / 1.0% (39 / 31 wind turbine) energy loss is likely to overstate the loss, given these factors, but is a reasonable estimate for the purpose of assessing the energy output of the project at this point in time

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6. References

[1] World Bank IFC Environmental, Health, and Safety Guidelines for Wind Energy, August 7, 2015.

[2] Federal States Committee for Pollution Control, Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen [Information on Identifying and Assessing the Optical Emissions from Wind Turbines], (2002).

[3] Planning for Renewable Energy: A Companion Guide to PPS22 Office of the Deputy Prime Minister (2004)

[4] Update of UK Shadow Flicker Evidence Base, PB Power, Prepared for the UK Department of Energy and Climate Change.

[5] Proposed 100 MW Mannar Wind Power Project, Initial Environmental Examination (IEE) Report, April 2016

[6] Mannar wind power project, wind resource, wind turbine suitability and energy production report, Entura report E305674, April 2016 draft.

[7] https://www.epilepsy.org.uk/about/position-statements/wind-turbines

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Appendices

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A Locations and results

A.1 Wind turbines

Table A.1: WTG layout

Turbine number	X coordinate	Y coordinate
WT 1	373,744	995,733
WT 2	373,477	995,973
WT 3	373,136	996,277
WT 4	372,859	996,524
WT 5	372,582	996,767
WT 6	372,294	997,017
WT 7	371,999	997,250
WT 8	371,695	997,487
WT 9	371,398	997,717
WT 10	371,105	997,950
WT 11	370,507	998,397
WT 12	370,200	998,612
WT 13	369,882	998,832
WT 14	369,586	999,033
WT 15	369,246	999,257
WT 16	368,935	999,462
WT 17	368,614	999,667
WT 18	368,285	999,867
WT 19	367,979	1,000,059
WT 20	367,649	1,000,250
WT 21	367,309	1,000,444
WT 22	367,006	1,000,609
WT 23	366,476	1,000,904
WT 24	366,211	1,001,046
WT 25	365,953	1,001,183
WT 26	365,684	1,001,324
WT 27	365,415	1,001,463

Turbine number	X coordinate	Y coordinate
WT 28	365,144	1,001,588
WT 29	364,873	1,001,714
WT 30	364,605	1,001,843
WT 31	364,343	1,001,963
WT 32	364,043	1,002,092
WT 33	363,772	1,002,196
WT 34	371,158	998,958
WT 35	370,797	999,215
WT 36	370,484	999,434
WT 37	370,184	999,641
WT 38	369,868	999,852
WT 39	369,503	1,000,099

Coordinate reference: WGS84 / UTM zone 44P. Shaded locations are removed from Scenario B

A.2 Receptors

Table A.2: Receptor list

Nearby WT	ID	Receptor name	Easting (m)	Northing (m)	Distance to nearest wind turbine (m)
	1	Thalvupadu	374870	994562	1625
	2	Thottavelly-Thalvupadu Rd	374475	996332	945
	3	N1 Thoddaveli Water Board Office	374610	996618	1238
	4	N2 Mr Mariyadas	372979	997738	995
	5	Konniankuduiruppu village and church	373383	997683	1217
	6	Konniankuduiruppu	374340	996759	1167
	7	Konniankuduiruppu	373894	997101	1119
	8	Konniankuduiruppu	373544	997385	1103
	9	Konniankuduiruppu	372959	997586	875
WT 1	10	Naval observation unit	373853	995455	299
WT 1	11	Vadi	373809	995533	210
	12	Vadi	373829	995556	196
	13	Vadi	373817	995564	184
	14	Vadi	373824	995573	179
	15	Vadi	373837	995574	185
	16	Vadi	373800	995576	167

Nearby WT	ID	Receptor name	Easting (m)	Northing (m)	Distance to nearest wind turbine (m)
	17	Vadi	373815	995578	171
	18	Vadi	373809	995578	168
WT 1 and 2	19	Industrial unit (fish meal manufacturing company) boundary	373496	995860	115
	20	Industrial unit (fish meal manufacturing company) boundary	373639	996013	166
	21	Industrial unit (fish meal manufacturing company) boundary	373733	995954	221
	22	Industrial unit (fish meal manufacturing company) boundary	373661	995697	90
	23	Industrial unit (fish meal manufacturing company) estimated location	373568	995816	182
WT 4 and 5	24	Naval Camp - boundary	372741	996424	179
	25	Naval Camp - boundary	372880	996603	124
	26	Naval Camp - boundary	372550	996609	161
	27	Naval Camp - boundary	372687	996766	106
	28	Naval Camp (building)	372692	996656	156
	29	Naval Camp (building)	372773	996494	138
WT 7 and 8	30	Vadi	371800	997235	199
	31	Vadi	371843	997235	156
	32	Vadi	371801	997250	198
	33	Vadi	371845	997254	154
	34	Vadi	371760	997262	235
	35	Naval observation unit	371757	997279	217
	36	Vadi	371774	997281	221
	37	Vadi	371706	997292	196
	38	Sea cucumber hatchery and accommodation	371797	997312	203
	39	Vadi	371764	997314	186
	40	Vadi	371739	997314	178
	41	Vadi	371770	997322	182
	42	Vadi	371771	997324	180
	43	Fishermen's rest room	371768	997333	170
	44	Tea kiosk	371783	997336	175
	45	Vadi	371646	997348	148
	46	Vadi	371677	997382	108
	47	Residential unit - Konniankuduiruppu	372959	997594	880
	48	Residential unit - Konniankuduiruppu	372936	997607	872
	49	Residential unit - Konniankuduiruppu	372907	997617	858

Nearby WT	ID	Receptor name	Easting (m)	Northing (m)	Distance to nearest wind turbine (m)
	50	Residential unit - Konniankuduiruppu	372790	997705	848
WT 8 and 9	51*	Kalthota Finance Hotel (under construction) - boundary	371824	997619	183
	52*	Kalthota Finance Hotel (under construction) - boundary	371707	997679	192
	53*	Kalthota Finance Hotel (under construction) - boundary	371811	997726	265
	54*	Kalthota Finance Hotel (under construction) - boundary	371751	997764	282
WT 9 and 10	55	Vadi	371140	997761	192
WT 10 and 11	56	Vadi	370907	997982	201
	57	Vadi	370888	997999	223
	58	Vadi	370873	998007	239
WT 10 and 11	59	Shell Coast Hotel - boundary	370770	998142	366
	60	Shell Coast Hotel - boundary	370723	998172	312
	61	Shell Coast Hotel - boundary	370947	998404	440
	62	Shell Coast Hotel - boundary	370905	998436	400
	63	Shell coast resort B	370881	998362	375
WT 12	64	Naval observation unit	370171	998500	116
WT 13	65	Vadi	369853	998753	84
WT 17	66	Naval observation unit	368425	999674	190
	67	Olaiththoduvai	372627	998956	1469
	68	Olaiththoduvai Church	372637	998802	1487
	69	Olaiththoduvai School	372650	999016	1493
	70	Residential unit - Uvary village and church	371517	999660	789
	71	Residential unit - Uvary village and church	371572	999697	847
	72	Residential unit - Uvary village and church	371525	999728	853
WT 17	73*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	368920	999781	320
	74*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	368931	999793	331
	75*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	368688	999852	199
	76*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	368822	999864	286
	77*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	368716	999918	270
WT 22 and 23	78	Naval Camp - Nadukuda - boundary	366705	1000673	308
	79	Naval Camp - Nadukuda - boundary	366806	1000608	200
	80	Naval Camp - Nadukuda - boundary	366839	1000657	173
	81	Naval Camp - Nadukuda - boundary	366748	1000717	280

Nearby WT	ID	Receptor name	Easting (m)	Northing (m)	Distance to nearest wind turbine (m)
	82	Naval Camp - Nadukuda - boundary	366738	1000700	283
	83	Naval Camp - Nadukuda - boundary	366725	1000705	297
WT 22 and 23	84	Tea kiosk	366663	1000680	292
	85	Tea kiosk	366681	1000705	286
	86	Fishermen's rest room	366735	1000715	291
	87	Church	366752	1000818	288
WT 24	88	Naval observation unit	366162	1000961	98
	89	Nadukudda	367265	1001684	1106
	90	N5 House, Naddukkuda	367682	1001397	1023
	91	Residential unit - Nadukuda	367670	1001365	989
WT 30 and 31	92	Vadi	364358	1001787	176
	93	Vadi	364393	1001824	147
	94	Vadi	364379	1001827	140
	95	Vadi	364388	1001846	125
	96	Naval observation unit	364314	1001859	107
WT 32 and 33	97	Vadi	363921	1001969	173
	98	Vadi	363938	1001997	141
	99	Vadi	363950	1001999	132
	100	Vadi	363948	1002005	129
	101	Vadi	363938	1002011	133
WT 33	102	Vadi	363431	1002204	341
	103	Vadi	363424	1002209	348
	104	Vadi	363428	1002221	345
	105	Vadi	363412	1002222	361
	106	Residential unit - KeelaiyanKuduiruppu	365518	1002322	823
	107	Residential unit - KeelaiyanKuduiruppu	365484	1002328	814
	108	Residential unit - KeelaiyanKuduiruppu	365519	1002351	850
	109	Residential unit - KeelaiyanKuduiruppu	365476	1002359	839
	110	Navy Camp - Selvary	364797	1003133	1255
WT 33	111	Vadi	363098	1002427	712
	112	N4 Julian Dias, Pesale	370200	1003437	3410
	113	N6 Bishop House	362710	1003504	1685
	114	N7 Old peir (Navy camp)Thalimannar	360523	1003453	3484
	115	N8 Housae Thalimannar	360075	4340	3484

Note *: These properties may be acquired by CEB

Coordinate reference: WGS84 / UTM zone 44P

A.3 Modelling results

Table A.3: Receptor modelling results

			Scenario A - 39 WTG			Scenario B - 31 WTG		
Nearby WT	ID	Receptor name	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded
	1	Thalvupadu	none			none		
	2	Thottavelly-Thalvupadu Rd	19:10	60	0	19:10	60	0
	3	N1 Thoddaveli Water Board Office	none			none		
	4	N2 Mr Mariyadas	9:10	35	0	none		
	5	Konniankuduiruppu village and church	none			none		
	6	Konniankuduiruppu	16:30	70	0	16:30	70	0
	7	Konniankuduiruppu	none			none		
	8	Konniankuduiruppu	none			none		
	9	Konniankuduiruppu	25:00	88	0	none		
WT 1	10	Naval observation unit	none			none		
WT 1	11	Vadi	none			none		
	12	Vadi	none			none		
	13	Vadi	none			none		
	14	Vadi	none			none		
	15	Vadi	none			none		
	16	Vadi	none			none		
	17	Vadi	none			none		
	18	Vadi	none			none		
WT 1 and 2	19	Industrial unit (fish meal manufacturing company) boundary	195:10	129	125	195:10	129	125
	20	Industrial unit (fish meal manufacturing company) boundary	502:20	286	254	502:20	286	254
	21	Industrial unit (fish meal manufacturing company) boundary	220:20	165	154	220:20	165	154
	22	Industrial unit (fish meal manufacturing company) boundary	617:00	221	220	617:00	221	220
	23	Industrial unit (fish meal manufacturing company) estimated location	340:30	174	171	340:30	174	171

			Scenario A - 39 WTG			Scenario B - 31 WTG		
Nearby WT	**ID**	**Receptor name**	**annual shadow flicker [hh:mm]**	**number of days with flicker**	**number of days for which the limit is exceeded**	**annual shadow flicker [hh:mm]**	**number of days with flicker**	**number of days for which the limit is exceeded**
WT 4 and 5	24	Naval Camp - boundary	251:50	214	205	133:10	132	127
	25	Naval Camp - boundary	446:10	236	199	69:50	71	64
	26	Naval Camp - boundary	183:20	174	161	18:00	39	6
	27	Naval Camp - boundary	833:20	319	317	833:20	319	317
	28	Naval Camp (building)	189:50	145	130	30:00	41	32
	29	Naval Camp (building)	727:50	305	294	60:30	70	59
WT 7 and 8	30	Vadi	465:20	337	321	83:50	100	88
	31	Vadi	602:00	340	329	82:10	91	84
	32	Vadi	404:10	298	274	75:00	90	77
	33	Vadi	599:30	364	354	64:20	76	69
	34	Vadi	298:00	253	232	68:00	90	79
	35	Naval observation unit	285:00	239	218	59:40	80	67
	36	Vadi	312:20	241	231	54:00	74	62
	37	Vadi	215:10	212	192	56:30	81	70
	38	Sea cucumber hatchery and accommodation	356:10	203	200	19:20	41	10
	39	Vadi	301:50	197	194	29:30	51	34
	40	Vadi	255:30	196	191	37:40	60	42
	41	Vadi	296:10	188	185	20:20	41	11
	42	Vadi	301:30	186	181	18:20	38	8
	43	Fishermen’s rest room	284:00	176	171	10:40	28	0
	44	Tea kiosk	291:50	172	168	1:00	6	0
	45	Vadi	157:20	165	158	33:40	59	33
	46	Vadi	168:20	136	129	1:20	8	0
	47	Residential unit - Konniankuduiruppu	26:10	91	0	none		
	48	Residential unit - Konniankuduiruppu	31:20	115	0	none		
	49	Residential unit - Konniankuduiruppu	35:30	110	0	none		
	50	Residential unit - Konniankuduiruppu	8:30	38	0	none		
WT 8 and 9	51*	Kalthota Finance Hotel (under construction) - boundary	248:50	241	198	131:50	156	118
	52*	Kalthota Finance Hotel (under construction) - boundary	201:20	200	180	201:20	200	180
	53*	Kalthota Finance Hotel (under construction) - boundary	128:00	187	92	128:00	187	92
	54*	Kalthota Finance Hotel (under construction) - boundary	161:10	198	154	161:10	198	154

			Scenario A - 39 WTG			Scenario B - 31 WTG		
Nearby WT	**ID**	**Receptor name**	**annual shadow flicker [hh:mm]**	**number of days with flicker**	**number of days for which the limit is exceeded**	**annual shadow flicker [hh:mm]**	**number of days with flicker**	**number of days for which the limit is exceeded**
WT 9 and 10	55	Vadi	258:20	218	210	204:10	154	144
WT 10 and 11	56	Vadi	372:20	247	243	372:20	247	243
	57	Vadi	343:30	218	214	343:30	218	214
	58	Vadi	309:40	206	202	309:40	206	202
WT 10 and 11	59	Shell Coast Hotel - boundary	87:10	86	76	87:10	86	76
	60	Shell Coast Hotel - boundary	61:10	71	62	61:10	71	62
	61	Shell Coast Hotel - boundary	122:50	212	75	122:50	212	75
	62	Shell Coast Hotel - boundary	149:20	231	115	149:20	231	115
	63	Shell coast resort B	164:10	200	159	164:10	200	159
WT 12	64	Naval observation unit	173:20	200	145	173:20	200	145
WT 13	65	Vadi	235:10	215	200	235:10	215	200
WT 17	66	Naval observation unit	460:00	365	301	108:50	180	96
	67	Olaiththoduvai	none			none		
	68	Olaiththoduvai Church	none			none		
	69	Olaiththoduvai School	none			none		
	70	Residential unit - Uvary village and church	12:10	40	0	12:10	40	0
	71	Residential unit - Uvary village and church	11:40	38	0	11:40	38	0
	72	Residential unit - Uvary village and church	14:10	42	0	14:10	42	0
WT 17	73*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	267:00	285	199	77:30	149	52
	74*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	252:00	285	185	77:40	152	51
	75*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	178:30	214	154	178:30	214	154
	76*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	151:10	208	140	151:10	208	140
	77*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	149:20	187	128	149:20	187	128
WT 22 and 23	78	Naval Camp - Nadukuda - boundary	204:50	194	163	67:50	108	66
	79	Naval Camp - Nadukuda - boundary	416:30	315	275	92:40	132	94
	80	Naval Camp - Nadukuda - boundary	487:40	229	225	86:30	98	88

			Scenario A - 39 WTG			Scenario B - 31 WTG		
Nearby WT	ID	Receptor name	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded
	81	Naval Camp - Nadukuda - boundary	233:00	150	146	56:00	78	66
	82	Naval Camp - Nadukuda - boundary	250:10	168	163	64:30	89	80
	83	Naval Camp - Nadukuda - boundary	228:00	164	158	62:20	88	77
WT 22 and 23	84	Tea kiosk	165:30	186	139	58:30	110	52
	85	Tea kiosk	191:50	166	160	59:40	96	71
	86	Fishermen's rest room	229:20	154	149	57:30	80	70
	87	Church	232:00	162	148	230:30	153	148
WT 24	88	Naval observation unit	257:50	274	188	240:00	261	182
	89	Nadukudda	none			none		
	90	N5 House, Naddukkuda	none			none		
	91	Residential unit - Nadukuda	15:10	60	0	15:10	60	0
WT 30 and 31	92	Vadi	350:50	296	241	333:30	256	235
	93	Vadi	421:30	322	287	407:20	289	281
	94	Vadi	354:20	290	243	341:10	259	235
	95	Vadi	345:50	260	225	333:40	234	220
	96	Naval observation unit	207:40	201	161	198:10	174	154
WT 32 and 33	97	Vadi	114:50	161	103	39:10	78	30
	98	Vadi	246:30	242	191	171:10	167	122
	99	Vadi	242:40	241	190	164:40	165	123
	100	Vadi	293:40	259	208	216:10	185	142
	101	Vadi	350:20	272	222	277:40	202	159
WT 33	102	Vadi	152:50	170	126	152:00	170	126
	103	Vadi	145:10	165	121	144:20	165	121
	104	Vadi	144:20	160	119	143:40	160	119
	105	Vadi	135:50	156	114	135:30	156	114
	106	Residential unit - KeelaiyanKuduiruppu	13:50	57	0	3:00	18	0
	107	Residential unit - KeelaiyanKuduiruppu	11:20	43	0	none		
	108	Residential unit - KeelaiyanKuduiruppu	11:20	43	0	none		
	109	Residential unit - KeelaiyanKuduiruppu	12:20	50	0	none		
	110	Navy Camp - Selvary	none			none		
WT 33	111	Vadi	43:10	81	36	43:10	81	36
	112	N4 Julian Dias, Pesale	none			none		
	113	N6 Bishop House	none			none		

			Scenario A - 39 WTG			Scenario B - 31 WTG		
Nearby WT	ID	Receptor name	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded	annual shadow flicker [hh:mm]	number of days with flicker	number of days for which the limit is exceeded
	114	N7 Old peir (Navy camp)Thalimannar	none			none		
	115	N8 Housae Thalimannar	none			none		

Note *: These properties may be acquired by CEB

Table A.4: Receptor modelled shadow flicker with rotor azimuth of 40°/220° (Scenario A)

ID	Receptor name	Rotor perpendicular to sunlight (hours)	Fixed rotor azimuth of 40°/220° (hours)
19	Industrial unit (fish meal manufacturing company) boundary	195	77
20	Industrial unit (fish meal manufacturing company) boundary	502	404
21	Industrial unit (fish meal manufacturing company) boundary	220	121
22	Industrial unit (fish meal manufacturing company) boundary	617	477
23	Industrial unit (fish meal manufacturing company) estimated location	340	144
24	Naval Camp - boundary	252	94
25	Naval Camp - boundary	446	310
26	Naval Camp - boundary	183	63
27	Naval Camp - boundary	833	494
28	Naval Camp (building)	190	2
29	Naval Camp (building)	728	514
30	Vadi	465	298
31	Vadi	602	451
32	Vadi	404	247
33	Vadi	599	331
34	Vadi	298	170
35	Naval observation unit	285	145
36	Vadi	312	147
37	Vadi	215	111
38	Sea cucumber hatchery and accommodation	356	124
39	Vadi	302	103
40	Vadi	255	89
41	Vadi	296	102
42	Vadi	301	102

ID	Receptor name	Rotor perpendicular to sunlight (hours)	Fixed rotor azimuth of 40°/220° (hours)
43	Fishermen's rest room	284	96
44	Tea kiosk	292	108
45	Vadi	157	51
46	Vadi	168	59
48	Residential unit - Konniankuduiruppu	31	26
49	Residential unit - Konniankuduiruppu	35	32
51*	Kalthota Finance Hotel (under construction) - boundary	249	133
52*	Kalthota Finance Hotel (under construction) - boundary	201	90
53*	Kalthota Finance Hotel (under construction) - boundary	128	70
54*	Kalthota Finance Hotel (under construction) - boundary	161	100
55	Vadi	258	119
56	Vadi	372	161
57	Vadi	343	124
58	Vadi	310	109
59	Shell Coast Hotel - boundary	87	12
60	Shell Coast Hotel - boundary	61	0
61	Shell Coast Hotel - boundary	13	70
62	Shell Coast Hotel - boundary	149	86
63	Shell coast resort B	164	77
64	Naval observation unit	173	61
65	Vadi	235	52
66	Naval observation unit	460	266
73*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	267	216
74*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	252	204
75*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	178	104
76*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	151	109
77*	Kalthota Finance Hotel (under construction) St Jude Road - boundary	149	99
78	Naval Camp - Nadukuda - boundary	205	103
79	Naval Camp - Nadukuda - boundary	416	255
80	Naval Camp - Nadukuda - boundary	488	214
81	Naval Camp - Nadukuda - boundary	233	99
82	Naval Camp - Nadukuda - boundary	250	110
83	Naval Camp - Nadukuda - boundary	228	100
84	Tea kiosk	165	81
85	Tea kiosk	192	86

ID	Receptor name	Rotor perpendicular to sunlight (hours)	Fixed rotor azimuth of 40°/220° (hours)
86	Fishermen's rest room	229	102
87	Church	232	144
88	Naval observation unit	258	87
92	Vadi	350:50	289
93	Vadi	421	284
94	Vadi	354	238
95	Vadi	346	216
96	Naval observation unit	208	126
97	Vadi	115	74
98	Vadi	246	134
99	Vadi	243	123
100	Vadi	294	170
101	Vadi	350	231
102	Vadi	153	105
103	Vadi	145	101
104	Vadi	144	97
105	Vadi	136	90
111	Vadi	43	14

Note *: These properties may be acquired by CEB

B Map

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TA 9085-SRI: WIND POWER GENERATION PROJECT
Visual Impact Assessment Report

E305674
30 August 2017

Prepared by Hydro-Electric Corporation
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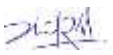
Approved by	Ranjith Perera		29/08/2017
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Executive summary

This landscape and visual impact assessment of the 100 MW Mannar Wind Power Project evaluates the existing landscape character in order to understand the degree of visual change likely to occur with the development of the Mannar Wind Farm. In this assessment 39 wind turbine locations were analysed.

The report has been prepared to meet the requirements of The World Bank Environmental, Health, and Safety Guidelines for Wind Energy [1], which has been adopted by the Asian Development Bank as the appropriate guidelines for assessing the Mannar Wind Power Project.

With respect to the visual impact of the wind farm, the following points are noted:

- The beach photomontages show the importance of configuration, scale, proportion and spacing of the WTGs. The sleek form of the structure lends elegance with the proviso that they should be vertical to the ground and well maintained.
- It appears that the beach is occupied mainly by the fisher community who are more engrossed in their occupation than in the aesthetic aspects of the surrounding landscape.
- The importance of the low beach vegetation as a screen of the bases of the WTGs allows more integration with the landscape.
- The importance of having a belt of vegetation, particularly tall trees which allow screening or only filtered views is made evident by the photomontages from Nadukuda. Detailed study of locations and options for screening has not been undertaken, however it should be considered as an option post-construction for locations such as tourist facilities in close proximity to wind turbines, should these stakeholders request such screening. It is noted that such screening would be minimal and in keeping with the existing vegetation, so as to not create new habitat and attract additional fauna to the area.
- Distant views, while not intrusive, would harmonize better in the landscape with less contrast in colour, if the WTGs are grey coloured.
- The exact number of wind turbines has not yet been finalised through the tender process, and it is likely that fewer than 39 locations will be used to obtain the required 100 MW project. In such case, it is recommended that if any of the rear array is needed to obtain the required number of locations for a 100 MW project, a minimum of 3 locations from the rear array should be used. It is also recommended that the regular arrangement of the front array be maintained to the greatest extent possible.
- It is recommended that a uniform size and design of wind turbines is maintained across the wind farm, and it is understood this is requirement of the wind farm technical specifications.
- Photomontages have not been produced for the Shell Coast Resort nor the two new tourist Cabanas, which are each likely to be within about 500 m of the nearest wind turbines (depending on which of the 39 locations are used). However viewpoint B-327 provides an example of the scale of wind turbines from this close vantage point, although some screening is likely from these vantage points, such as shown from vantage points C-165 and C-215 (near Nadukudda village). Nonetheless, the wind turbines will be a very prominent feature of the landscape in the vicinity of these tourist facilities. It is noted the two new tourist cabanas may be acquired by CEB which would negate their status as receptors.

- In the present scenario, the WTGs do not present a major visual impact, however the ancillary structures to the wind farm have to be considered, particularly the transmission of power between Nadukuda and the main grid on the mainland.
- In the future development of Mannar Island, and potential uses, the identification of Landscape Character Units, conservation of vegetation, land use policy and developmental guidelines should be formulated for the carrying capacity of the island.
- The comments given in this report are on the WTGs in the landscape. However, in the operation of a wind farm further ancillary structures are imperative – the transmission sub-station, and transmission line as well as supporting accommodation, utilities, parking and vehicular movement and offices for staff, and the proposed temporary pier. These have not been considered in detail this report.

Contents

Annexure

List of figures

1. Introduction

1.1 Scope of work

The landscape and visual impact assessment of the 100 MW Mannar Wind Power Project aims to evaluate the existing landscape character and understand the degree of visual change likely to occur with the development of the Mannar Wind Farm. In this assessment 39 wind turbine locations were analysed.

The report has been prepared to meet the requirements of The World Bank Environmental, Health, and Safety Guidelines for Wind Energy [1], which has been adopted by the Asian Development Bank as the appropriate guidelines for assessing the Mannar Wind Power Project. This guideline recommends zone of visual influence (ZVI) maps, wire-frame images and photomontages to inform a visual impact assessment and consultation process.

The primary purpose of the visual simulations is to accurately portray a proposed activity, modification or change in the viewed landscape. Visual simulations are useful when assessing proposals that produce changes to the visual landscape, by providing realistic 'before and after' depictions. They assist in visualising the potential impacts a proposed development could have on an area from an array of viewpoints that have been recorded digitally. They can also be used to illustrate projections of how a development will appear over time; growth of vegetation screening for example.

This report presents a number of photomontages from selected viewpoints in the vicinity of the wind farm, and comment on the visual amenity is provided. ZVI maps have not been produced, as the flat terrain means that the wind farm will be seen as far as visibility extends, except where obscured by surface features (e.g. trees or buildings).

1.2 Site visits

A team lead by Resource Management Associates (Pvt) Ltd visited the wind farm site on 30 November – 1 December 2016, and using detailed instructions from Entura, photographs were acquired from selected viewpoints in order to prepare photomontages of the proposed wind farm.

Ms Shereen Amendra participated in the site visit, selection of viewpoints, and in the comments on visual amenity that follow in this report. Ms Amendra is a qualified Landscape Architect with lengthy experience in landscape design and visual amenity in Sri Lanka.

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2. Landscape character

The natural, cultural and physical characteristics of the landscape can be described as distinct Landscape Character Units (LCUs). Globally, there is a plethora of literature relating to the protection of landscape values and LCUs, in particular, with reference to large scale developments such as wind farms. The European Landscape Convention of 2001 is much cited. The Sri Lanka Institute of Landscape Architects (SLILA) was formed in 2009 and is a member of the International Federation of Landscape Architects (IFLA). An IFLA-APR-Landscape Charter was proposed to UNESCO for addressing landscapes in the Asia Pacific Region. SLILA was a signatory to the IFLA-APR-Landscape Charter in 2014.

Sri Lanka is promoted as a paradise and scenic destination for tourists. However, high population density and limited available land have resulted in developmental pressures impinging negatively on many scenic and treasured landscapes. LCUs have generally not been identified or catalogued in Sri Lanka. Additionally, there is no specific legislation or policy to protect LCUs however, some measure of protection derives from other legislation focusing on wildlife, forestry, archaeology, land use, coast conservation and others. The landscape description contained in this assessment of the visual impacts of the proposed Mannar Wind Farm is without precedent in Sri Lanka.

Mannar Island is a populated island on the North-West coast of Sri Lanka. It has an elongated and slightly curved plan-form being concave towards the South. It is approximately 28 km long and ranges in width from approximately 3.6 km at the narrower western tip to 6.5 km at the widest point closer to Erukkalampiddy. It is separated from India by the 33 km wide Palk Strait and connected to mainland Sri Lanka by a 3.5 km causeway and bridge and also by the railway which bridges across islands in the Venkalai Sanctuary.

2.1 Spatial considerations

Areas on Mannar Island which can be considered as sensitive landscapes are declared as sanctuaries/archaeological preserves through legislation. Mannar Island can be described as topographically flat or near-flat and open at the overall scale. However, spatial variations occur due to above ground elements lending vertical contrast to otherwise largely horizontal elements. Comparing the anthropogenic elements with natural elements of varying heights, a variety of spatially defined modulations to the overall landscape can be identified. The main transport networks occupy the somewhat central ‘spine’ of the island with minor roads and tracks extending outwards towards beach areas. Both road and railway are pulled to the Northern edge at Pesalai. The long edges of the island are not evident from these main arteries, being visually well buffered and screened mainly by vegetation. The most spatially open area is experienced crossing the causeway through Vankalai Sanctuary. The vast horizontal plane is sliced through by the man-made causeway with its appurtenant vertical utility transmission elements intruding the natural space. There are many identifiable LCUs in Mannar District and Mannar Island.

2.2 Line (near, median and distant visual ‘horizons’)

On Mannar Island, line can be appreciated mainly due to vegetation and water bodies (Figure 2.1). Ponding of water near the southern beach forms reflective pools in still weather which, depending

on the viewpoint, reflect vertical elements and horizontal line. Line is dependent on the shape and the form of the above ground elements.

Figure 2.1: Line – Horizontals predominate on Mannar Island

Open and predominantly horizontal landscapes are punctuated by vertical elements, mainly palmyrah palms (*Borassus flabellifer*) among the natural elements on Mannar (Figure 2.2). In isolation the stately unbending vertical trunk and rounded head of palmyrah stands out. In groups, particularly when naturally regenerated, the disposition and leaf form provides a slightly uneven 'rough' line. Palmyrah varies in height from young plants of a few meters to mature plants of up to 30 m. Introduced coconut palms used in homesteads and as a plantation crop provides a 'softer' line with more slender and less stiff trunk and pliant leaf form. This particularly applies to mature T x T *cocos nucifera* variety coconut palms which reach heights of 30 m. Young dwarf variety coconut plantations reach heights of 12 m to 18 m and provide a more 'evenly soft' characteristic line. Beach and scrubland vegetation of 2 m height or less can mostly be appreciated as line when viewed across water bodies, fields or beach. The shape and form is often seen as an undulating series of mounds in the lower horizontal part of the viewing plane. 'Smooth', 'soft' or 'ruffled' undulations of line are species dependent (e.g. Acacia spp. and Calotropis spp.). The dominant type of line appears as the 'variable' with tall and dwarf coconut, and palmyrah palms at varying stages of growth. Such a line, in foreground or middle-ground give glimpses of elements beyond. Of the trees on the island, Margosa (*Azadirachta indica*) among others is more prominent, however, few contribute to line.

Figure 2.2: Rough line of Palmyrah trees. The long edges of the island are screened with vegetation. The predominant colours of green and blue

Other than in Mannar Town, built structures are generally not more than 2 floors, and do not lend themselves to line especially when ensconced with taller vegetation surrounds. A particular and emerging characteristic of Mannar Island is the puncturing of horizontal line by many tall vertical utility structures. The water tower in Mannar Town is the most 'heavy' due to its mass in the visual scenery. Communication and transmission towers are mostly steel tracery structures of varying shape and form though predominantly vertical up to 80 m such as the wind monitoring structure at Nadukuda.

2.3 Colour

Colour in the context of Mannar is the blend of varying shades and tones of green vegetation and blues and blue-greys of sea and sky (Figure 2.2). Sea and sky colour are very much modulated by atmospheric conditions. The beige-yellows of beach sand are a foil to the general scenery. Bright saturated hues of red, orange, pink, etc., are few and restricted to the cultural landscape elements, characterizing Mannar Island by their near absence. Colour saturation is highest and contrasts most visibly on bright clear days. Natural colour contrast is limited to the white of the breakers on seashore and high altitude clouds in clear weather, with sporadic flocks of the avifauna such as gulls, terns and egrets flashing white. The early part of the SW monsoon will bring lower altitude puffy white cumulus clouds. Rainy weather brings a dullness to the scenery, particularly if the sky vault is a uniformly overcast grey. On the southern beach, modulation due to sea spray was negligible as there did not appear to be a rocky shore or nearshore underwater formation for large breakers to contribute to sea-spray. However, much movement (wind transport) of fine beach sand was observed, which will impact the scenery more by inconveniencing viewers rather than obscuring the scenery. The cumulative effect of sea spray, high humidity and long viewing distances reduces visibility considerably.

2.4 Scale and proportion

Scale and proportion is a consideration taken into account relative to the viewer and viewing points. Mannar Island is characterized by strong contrasts of horizontal and vertical line with much dependent of the balance of scale of elements in the two planes. Other than Mannar Town, as yet with only a few tall buildings, there is little gradation between the planes.

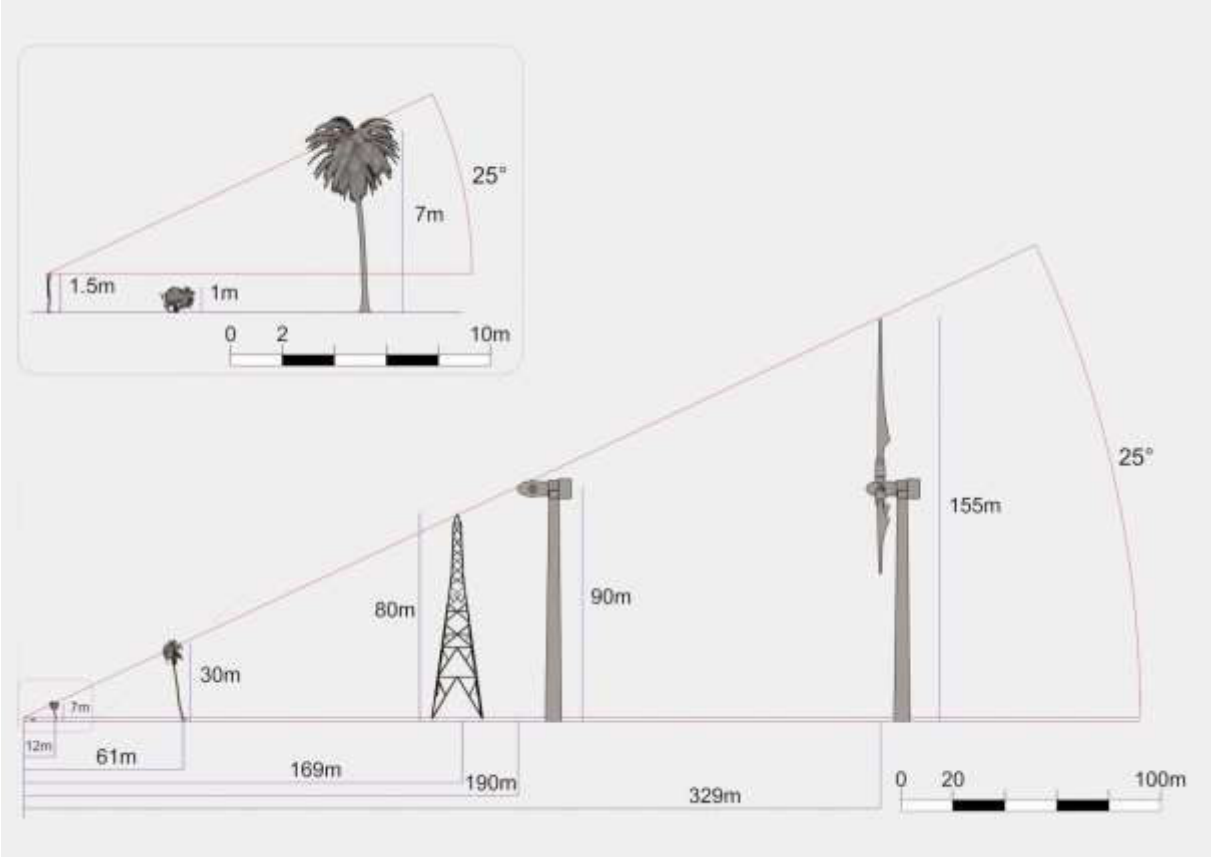

Figure 2.3: Scale and proportion of wind turbines

3. Viewer

3.1 Physiology

There are many physiological variations that influence viewing ability (e.g. height of viewer). For this assessment the following viewer assumptions, based on an average viewer with normal binocular vision, have been used:

- Viewing height of 1.5 m.
- Field of view 25 degrees upward and 15 degrees downward vertically and 30 degrees to both the left and right horizontally.

3.2 Perceptions

Perceptions of the visual landscape are subjective to the viewer assessing their surroundings and the response of each viewer will be necessarily varied. Fishermen coming in to land from the sea may look for landmarks and visual cues to bring them home. A visitor to the area may bring cultural and individual attitudes from elsewhere. A resident of Nadukuda village would experience the same landscape with little change, bound with the same outlook daily.

There is some familiarity with wind farms to residents on Mannar Island as the Puttalam and Kalpitiya Wind Farms are familiar to the resident fisher community. The wind farm in the highland at Ambewala would be less familiar. Informal comments provided by local fishers on viewing wind farms at a distance indicate that they have a 'vague attraction', or observing movement of the rotors, are 'restful, like watching fish in an aquarium'. Also, a description that can be termed 'ephemeral' as the wind turbines are in light or shadow with overhead passing clouds casting shadows in fine weather conditions.

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4. Proposed wind turbine generators

4.1 Location and configuration

Wind turbine generators (WTGs) is a description used in this assessment to include the tower, rotor blades, hub and nacelle that typically comprise a wind turbine. The Mannar Wind Farm proposes to install 39 WTGs placed somewhat centrally to the total length of the South facing coastline. The frontal (or seaward) array of 33 WTGs and a rear array of six WTGs at 140 m and 830 m landward are in a near regular arrangement of two curvilinear rows following the landform pattern. Two gaps in the frontal array provide a relief in the regularity forming three linear sectors of 10, 12 and 11 WTGs from East towards West respectively. This is aesthetically more acceptable than a regularly continuous line of 33 WTGs. An overly long array in excess of this number could impact negatively on the visual landscape. The spacing is sufficiently far apart (300m – 350m) to avoid a sense of visual enclosure. A reduced spacing will impact negatively on the visual landscape. The fewer WTGs as a rear array very nearly centrally placed to the frontal array enhances the configuration, particularly as they are on slightly higher ground.

The exact number of WTGs has not yet been finalised through the tender process, and it is likely that fewer than 39 locations will be used to obtain the required 100 MW project.

A meteorological mast is currently installed at the site, and will likely remain in the future. An additional mast may be installed on a temporary basis at one of the proposed wind turbine locations for the purpose of post-construction power curve tests on the wind turbines. The visual impact of these meteorological masts will be minimal, particularly in relation to adjacent wind turbines.

A new substation and control building will be constructed near Nadukudda village. This facility will likely be visible from the adjacent road, however existing vegetation (seen in C-125 and C-215) will screen the facility from nearby residences.

4.2 Viewpoints

Nine viewpoints were selected for assessment (Figure 4.1). Viewpoints were selected to assess the visual impact on population centres (e.g. towns), regularly used places (e.g. beach) and sites of economic, cultural or natural significance. Photomontages were produced for all viewpoints. Viewpoints from Mannar Town were occluded by structures in the near foreground. Similarly, viewpoints from locations further inland of the wind farm, Tharapuram, Pesalai and Talaimannar, were separated from the location of the WTGs by a belt of vegetation comprising mainly palms of palmyrah and coconut with some trees. In general, the vertical viewing plane for normal viewing will be filled by trees of 30 m height, such as coconut (TxT) and mature palmyrah at a distance from the viewer of around 61 m beyond which the sky vault or other taller elements would be seen. Thus, tall vegetation as screening or forming an above ground vegetation line is an important factor. Any removal of vegetation should carefully consider views from strategic locations and make good losses. This is an important landscape consideration for policy planning, assessment, design, conservation and similar applications.

4.3 Zone of Visual Influence (ZVI)

"*ZVI analysis is the process of determining the visibility of an object in the surrounding landscape. The process is objective in which areas of visibility or non-visibility are determined by computer software using a digital elevation dataset. The output from the analysis is used to create a map of visibility" [14]*.

The term Zone of Theoretical Visibility (ZTV) is more appropriate as there are many intervening above ground elements which are not accounted for in the first instance. From a visual standpoint the term 'obstruction' can be used as in visually occluding, whether acceptable or unacceptable. In the absence of any such elements, the nacelle on a supporting tower of 90 m will fill the vertical plane field of view of a viewer, with an eye height of 1.5 m at a horizontal distance of 190m from the base of the tower, and similarly to the tip of a vertical rotor blade of sweep diameter 130 m, at a distance of 329 m on the horizontal plane from the base of the tower. Any distance exceeding these values reduces the prominence or proportions of the WTG as the background of the sky vault above the rotors increases, with the scale of the WTG structures being less dominating and more acceptable to the psyche of the viewer as it becomes more a part of the visual scenery.

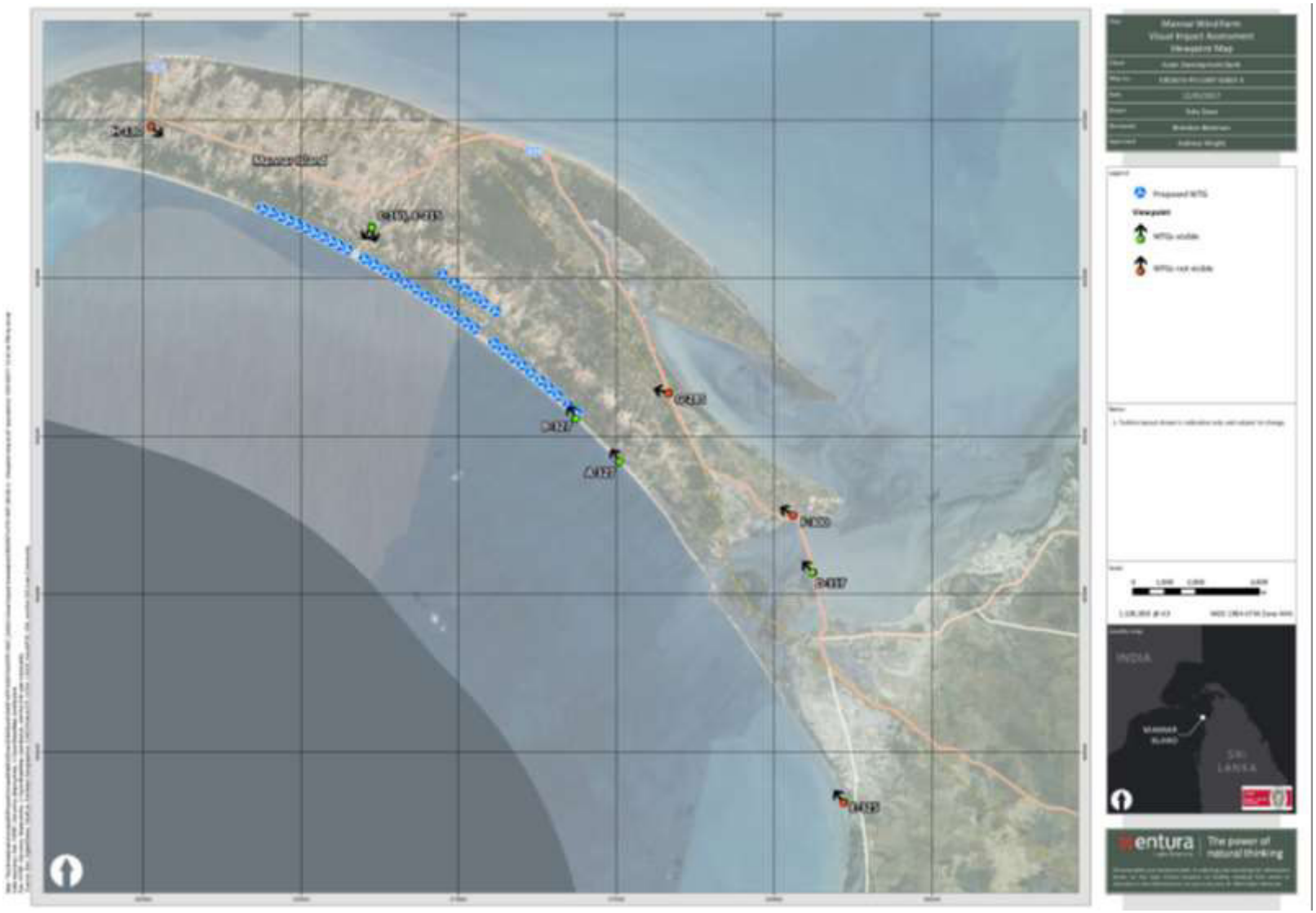

Figure 4.1: Mannar Wind Farm viewpoint map

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5. Photomontages

Photomontages for all viewpoints are presented in Appendix B. Viewpoints from where WTGs were visible are discussed below together with recommended actions to mitigate potential visual impacts.

5.1 The beach

Viewpoints A-327 and B-327 are located approximately 2.5 km apart along the beach from Thalvapadu and at close proximity to the first WTG in the longer frontal array (Figure 4.1).

A-327 shows a part of the frontal array in the middle ground. The fishing boats also form a regular series often with prows facing landward. The regularity of 'parking' the boats is made dissimilar by the colours of boats and the casual variability in parking. The wind farm structures are identical in form and regular in placement with visual relief to the regularity given by the gap between the groups of WTGs. The beach swept clean by the water is contrasted with the palpable lack of concern for orderliness shown by the scattered debris of the foreshore beach sands. The WTGs are at a comfortable distance where their formal arrangement is a foil to the casual temporary structures of the fishing community.

B-327 shows the strong contrast between horizontal plane and vertical elements. The slight slope of the beach and the low scrub beach vegetation serves as a positive element to merge the horizontal with the vertical, allowing for a soft transition. The lack of concern towards an aesthetic is reflected by the littered beach in the foreground. The strong dominance of the foreground WTGs becomes reduced as the view is carried to the middle ground horizon. The near view dominance of the WTG is made acceptable due to the slender clean lines and proportion of the structure. A distant view of the rear array is visible though merging with the background. It can be expected that the arrays will be visually prominent and stark on clear days, particularly for the few hours around sunset when the structures will be in silhouette.

In these two views, given the weather conditions, haze and reduced visibility, the WTG structures merge with the background overcast grey of the sky vault. However, on clear days with sunlight it can be expected that white colour allows for greater prominence especially closer to ground. White also allows for greater reflectivity in both sunlight and full phase moonlight on clear nights. Scudding clouds during pre-monsoonal periods cause the WTGs to appear in full sunlight and shadow (of the cloud) intermittently with apparent colour variation to the viewer.

<u>Recommendations for mitigation:</u>

- Structure, nacelle and rotor colour – A light grey WTG colour is recommended and can be expected to merge into the background and provide the least contrast to background over a large range of weather and light conditions.
- Conservation or addition of low beach vegetation is recommended to visually transit, merge and soften the base with the terrain. Re-instating of removed vegetation during construction phase is also necessary.
- Activities during construction phase are expected to be more visually disrupting than during operation. Airborne dust to be controlled and speed limits imposed on construction vehicles. Removal of all construction debris and equipment after completion that affects visual and environmental quality. Construction crane/s for installation will be temporary. Vegetation to

be re-instated and ground conditions made good at tower bases, underground cable paths and as otherwise used as access/camp during construction phase.

5.2 Nadukuda village

C –165 and D-125 viewpoints are on two separate bearings from over a kilometre landward of the frontal array. The near distance from the viewing point is host to several trees and an old coconut plantation of T x T variety. The plantation gives way to scrub and dune formation closer to the beach. Foreground and middle ground are given to vegetation. Ground cover, grass and leafy foliage with gaps allow screening of the background. The nacelle and rotors of the WTGs (19 and 20) are discernible as a filtered view through the crowns of the coconut trees. Only the upper part of the tower is visible.

D-125 is a more funnelled view focused down the road. The slender 80 m tall steel tracery of the wind measuring mast is barely discernible given the weather conditions. The WTG to the right of the road is similarly filtered by foreground coconut palms. As the view is across the pattern of the plantation grid, there is more occlusion due to the greater density of foliage than in C-165.

Recommendations for mitigation:

- Where practicable facilitate the conservation of addition of similar vegetation as a visual screen/filter to mitigate the near view impacts of the WTGs.

5.3 Causeway

The D-317 viewpoint is on the causeway to Mannar Island. Being in the Vankalai sanctuary there is much birdlife. The urbanised tall elements of the 'heavy' water tower and traceries of communication towers terminate on the shore with the WTGs in the distance. The nearest WTG is around 9 km distance. Both arrays can be seen, but not intrusive in the overall landscape. However, the separation distance between the frontal array and rear array does not give a sense of cohesion in the visual scene. It is likely that the young mangrove planting in the foreground will grow taller giving more interest in the foreground though not a full visual screen from this viewpoint.

Considering the Causeway viewpoint, the openness and uncluttered visual space is aesthetically pleasing. Visual intrusions occur along the causeway as utility structures and transmission lines. Visual impact of the planned power transmitting line and structures from the wind farm substation at Nadukuda to the main grid line are not part of the current assessment.

Recommendations for mitigation:

- It is visually recommended to confine all visual clutter to the causeway leaving an open landscape. It is noted that the railway structures are insignificant in the visual scene.

5.4 Wireframe images

Appendix C displays wireframe representations of the wind turbine layout viewed from the Shell Coast Resort (I-285), and the two new tourist Cabanas (J-300, K-280). Wireframes are typically used to illustrate the three-dimensional shape of the landscape and the wind turbines in the landscape. In this case, because the terrain is flat, and because the wireframes do not include the effects of screening vegetation, their usefulness is limited. However they provide an indication of the dominant size of the wind turbines in the landscape, as viewed from these tourist facilities. It is noted the two new tourist cabanas may be acquired by CEB which would negate their status as receptors.

6. Discussion

- The beach photomontages show the importance of configuration, scale, proportion and spacing of the WTGs. The sleek form of the structure lends an elegance with the proviso that they should be vertical to the ground and well maintained.
- It appears that the beach is occupied mainly by the fisher community who are more engrossed in their occupation than in the aesthetic aspects of the surrounding landscape
- The importance of the low beach vegetation as a screen of the bases of the WTGs allows more integration with the landscape
- The importance of having a belt of vegetation, particularly tall trees which allow screening or only filtered views is made evident by the photomontages from Nadukuda. Detailed study of locations and options for screening has not been undertaken, however it should be considered as an option post-construction for locations such as tourist facilities in close proximity to wind turbines, should these stakeholders request such screening.
- The exact number of wind turbines has not yet been finalised through the tender process, and it is likely that fewer than 39 locations will be used to obtain the required 100 MW project. In such case, it is recommended that if any of the rear array is needed to obtain the required number of locations for a 100 MW project, a minimum of 3 locations from the rear array should be used. It is also recommended that the regular arrangement of the front array be maintained to the greatest extent possible.
- It is recommended that a uniform size and design of wind turbines is maintained across the wind farm, and it is understood this is requirement of the wind farm technical specifications.
- Distant views while not intrusive would harmonize better in the landscape with less contrast in colour, if the WTGs are grey coloured.
- Photomontages have not been produced for the Shell Coast Resort nor the two new tourist Cabanas, which are each likely to be within about 500 m of the nearest wind turbines (depending on which of the 39 locations are used). However viewpoint B-327 provides an example of the scale of wind turbines from this close vantage point, although some screening is likely from these vantage points, such as shown from vantage points C-165 and C-215 (near Nadukudda village). Nonetheless, the wind turbines will be a very prominent feature of the landscape in the vicinity of these tourist facilities. It is noted two new tourist cabanas may be acquired by CEB which would negate their status as receptors.
- In the present scenario, the WTGs do not present a major visual impact, however the ancillary structures to the wind farm have to be considered, particularly the transmission of power between Nadukuda and the main grid on the mainland.
- In the future development of Mannar Island, and potential uses, the identification of LCUs, conservation of vegetation, land use policy and developmental guidelines should be formulated for the carrying capacity of the island.
- The comments given in this report are on the WTGs in the landscape. However, in the operation of a wind farm further ancillary structures are imperative – the transmission sub-station, and transmission line as well as supporting accommodation, utilities, parking and

vehicular movement and offices for staff, and the proposed temporary pier. These have not been considered in detail this report.

7. References

[1] World Bank Environmental, Health and Safety Guidelines, Wind Energy, August 7 2015

[2] Department of Environment, Land, Water & Planning (January 2016) *Policy and Planning Guidelines for the Development of Wind Energy Facilities in Victoria*. State of Victoria, Department of Environment, Land, Water & Planning, Melbourne. http://www.planning.vic.gov.au/__data/assets/pdf_file/0030/9696/Policy-and-Planning-Guidelines-for-Development-of-Wind-Energy-Facilities-in-Victoria_January-2016.pdf

[3] EDC Burgos Wind Power Corporation (January 2015), *Initial Environmental Impact Assessment (IEE), 150 MW Burgos Wind Power Project*. https://www.adb.org/sites/default/files/project-document/155552/48325-001-iee.pdf

[4] Herzog, T. R, Kaplan, S and Kaplan, R. (1982) *The prediction of preference for unfamiliar urban places. Population and Environment*.

[5] Kaplan, S. (1979) *Concerning the power of content identifying methodologies*. In Assessing amenity resource values. USDA Forest Service General Technical Report RM 68. Pp. 4-13.

[6] Kaplan, S. (1979) *Perception and landscape: Conceptions and misconceptions*. In Proceedings of Our National Landscape Conference. USDA Forest Service General Technical Report PSW 35. Pp. 241-248.

[7] Kaplan, S. (1982) *Where cognition and affect meet: A theoretical analysis of preference*. In P. Bart, A. Chen and G. Francescato (Eds.) Knowledge for design. Washington, D.C.: EDRA. Pp. 183-188.

[8] Kaplan, S. (1988) *Perception and landscape: Conceptions and misconceptions*. In J. L. Nasar (Ed.) Environmental aesthetics: Theory, research and application. New York: Cambridge University Press. Pp. 45-55. (Originally published in Our National Landscape, 1979.)

[9] Kaplan, S and Kaplan, R. (1982) *Cognition and environment: Functioning in an uncertain world*. New York: Praeger. (Republished by Ann Arbor, MI: Ulrich's, 1989.)

[10] Municipality of Grey Highlands (unknown). Landscape and Visual Assessment Guidance for Wind Energy Farm Development http://www.greyhighlands.ca/downloads/217.pdf

[11] Niijhuis, S. Visual Research in Landscape Architecture T. Tempesta, D. Vechchiato, (2015,) *Testing the differences between experts' and lay people's landscape preferences*, University of Padova, Italy, Firenze University Press

[12] Niijhuis, S. Lammeren, R. and Hoeven, F. (2011) *Exploring the Visual Landscape: Advances in Physiognomic Landscape Research,* TUDelft, Delft University of Technology, Netherlands

[13] University of Newcastle (2002) *Visual Assessment of Windfarms Best Practice*. Scottish Natural Heritage Commissioned Report F01AA303A.

[14] Watson, D. (unknown). Zone of Theoretical Visibility or Zone of Visual Influence http://www.davidwatson.info/zvi.php

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Appendices

A Visual studies – photographs

Photo credits: Shereen Amendra

4A - Tall erect and stately palmyrah palms as emergents in the general line

4B - Line is species dependent: The rounded series of convexes shaping line of acacia plants in middle ground.

4C - The open landscape of Vankalai sanctuary bisected by causeway with visual intrusions of utility elements in vertical plane and horizontal wires/cables.

4D - Mannar Town: Saturated colours of a cultural landscape. Line is characterized by buildings and hoardings as large as entire building façade. Vertical steel traceries of communication towers are the recent characteristic of Mannar Island.

4E - The Southward beach: Beach sands a colour foil to the blue-grey of sea and sky. Piers protrude into the flat open landscape. Touches of white contrast as wavetops and egrets fringe the interface of land and water.

4F - The railway bisects a flat open landscape as networks occupy the 'spine' of Mannar Island. The fringing vegetation occludes beach views. Built forms are low and ensconced in the vegetation

4G - Mobility pathways cross at Pesalai. The elevated railway affects the road gradient at the crossing. Utility vertical elements and varying natural forms of palms and trees. The fence in the middle ground is constructed of dried palmyrah leaves. Trees occlude distant views.

4H - Horizontal cable runs in foreground of 80m wind monitoring mast. The wavy line of beach dunes and low beach vegetation forming the base and ground for the scene.

4J - Merging horizontals with the verticals: Beach vegetation hiding the bases of palmyrah. A soft fringe to a service road.

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B Photomontages

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C Wireframe images

Terrestrial Survey of the Wind Power Project Site, Mannar Island

Methodology

A rapid survey of the project site[1] was conducted in order to prepare a plant species inventory in 39 locations, each having an area of 150 x 150 m (2.25 ha), demarcated in two rows (33 in the first row and 6 in the second row) along the southern part of Mannar Island for the proposed Wind Power Project. The first row is about 140 m from the coast and the second row is about 900m. All the plant species found in the 150 x 150 m area were recorded. The trees that will be removed within the hardstand (about 31% (0.7 ha) of the area demarcated for the wind turbine) were counted or the area covered by trees, as a percentage of the total hardstand area, was estimated. In some locations, the stems of *Acacia* trees are not visible and the crowns of the trees form a continuous canopy above ground. A list of plants found in each location was given in 39 tables and the plants/trees to be removed within the hardstand area were also listed in separate tables (see **Annex 1**). Photographs of each turbine location were also taken to show the habitat types found in these areas. Plants species found along nine water channels (Thonas) within the project area (two rows of wind turbines, **Fig. 1**) were also inventoried (**Table 4**).

Fig. 1 Locations of wind turbines 1-39 in Mannar Island. Proposed 220 kV transmission line (pink) is also marked.

Flora of the Project Area[2]

A total of 201 plant species (63 families and 185 genera) including 2 endemic and 178 indigenous species were recorded from 39 turbine locations, each having an area of 150x 150 m (2.25 ha). Twenty-one (21) plant species recorded in the study area are introduced species.

[1] Project site- 150 x 150 m area of all 39 locations including the hardstand

[2] Project area includes two rows of wind turbine locations and the area in between where water channels are found. 39 locations earmarked for the turbines (33 in the first row and 6 in the second row), proposed access roads, and underground cable routes (along the proposed access roads) up to Nadukuda GSS.

About 17 of them are now naturalized and this indicates that the area is comparatively less disturbed by human influence. All recorded flora species are not unique or restricted to the project locatiions. However, *Acacia planifrons* is the species that restricted to Mannar and some area of the mainland. It is the most common tree in Mannar island and forms a continuous canopy about 100-150 m from the coast. The highest number of trees to be removed in the hardstand of all locations is Acacia trees. Scrubland and sand dune vegetation is the main vegetation types found in the 12 km stretch of the first row of wind turbines. In addition to scrublands, Palmyra groves/ stands and coconut plantations are found within the turbine locations 34 to 39. Most of the recorded plant species are locally common in the area. **Table 5** gives the total number of trees affected in the project area whereas **Table 6** gives estimated costs for Terrestrial ecology monitoring.

Table 1. Number of plant species, threatened, endemic, indigenous and introduced species by life forms.

Life form	Total species	Nationally Threatened (NT)	Endemic	Indigenous	Introduced
Tree	40	1(3)	1	32	7
Shrub	57	3(3)	1	51	5
Herb	65	1(4)	-	59	6
Climber/Creeper/Liana	34	2(3)	-	31	3
Grass / Grass like	5	-	-	2	-
Total	**201**	**7(13)**	**2**	**175**	**21**

Table 1: Status of Terrestrial Ecology in the Project Area

Life form	Total species	National Red list 2012- Threatened (Near Threatened)	IUCN-GCS	Endemic	Indigenous	Introduced
Tree	40	1(3)	LC-7	1	32	7
Shrub	57	3(3)	LC-6	1	51	5
Herb	65	1(4)	LC-8	-	59	6
Climber/Creeper/Liana	34	2(3)	LC-2	-	31	3
Grass /Grass like	5	-	LC-1	-	2	-
Total	**201**	**7(13)**	**24**	**2**	**175**	**21**

Source: Ecological Survey 2016, LC- Least Concern.

None of the plants categorized by the National Red list (2012) as threatened (7) or near threatened (13) are having the status of more than LC in the IUCN Global Red list. Out of 20, threatened (7) and near threatened (13) seventeen are not yet been assessed (NA) and three are LC (see **Table 2**) in the Global Red List.

CEB will try the possibility of shifting the hardstand to avoid any endemic trees – e.g. for Neralu appears to be: T1, 3, 8, 36, and 37 and based on indicative design only T3 and T36 will result in loss endemic plants, 5no. in total. Pupula is an herb, observed in the project area but outside the hardstanding area and therefore it does not appear to be listed in **Table 3** or at any of the turbine locations per tables in the **Annex**.

Rare, threatened and endemic flora species in the study area[3]

Two plant species (*Vernonia zeylanica* - Pupula and *Cassine glauca* - Neralu) recorded during the field survey within the project site are endemic to the country. Seven (7) threatened species were also listed during the field survey (Table 2). Another thirteen (13) species recorded are in near threatened (NT) category and one species considered as data deficient (DD) according to the National Red List of 2012, Ministry of Environment, Sri Lanka. No any endemic species are in threatened or near threatened categories. All recorded endemic and indigenous flora species are not unique or restricted to the 39 turbine locations.

Table 2. Threatened plants (Red Data book, 2012 and Global Conservation Status- IUCN Global Red list) recorded in the turbine locations.

Threatened species						
Family	**Species**	**Sinhala Name**	**H**	**TS**	**NCS**	**GCS**
Fabaceae	*Vigna marina*	Lee ma	C	In	EN	NA
Menispermaceae	*Hyserpa nitida*	Niri-wel	C	In	EN	NA
Vahliaceae	*Vahlia dichotoma*		H	In	EN	NA
Fabaceae	*Indigofera oblongifolia*	Nari Mun	S	In	VU	LC
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	C	In	VU	NA
Rhamnaceae	*Colubrina asiatica*	Tel hiriya	S	In	VU	NA
Sapotaceae	*Manilkara hexandra*	Palu	T	In	VU	NA
Near Threatened and Data Deficient Species						
Family	**Species**	**Sinhala Name**	**H**	**TS**	**NCS**	
Menispermaceae	*Tinospora sinensis*	Rasa Kinda	C	In	DD	NA
Aizoaceae	*Sesuvium portulacastrum*	Maha-sarana	H	In	NT	NA
Aizoaceae	*Trianthema decandra*	Maha-sarana	H	In	NT	NA
Capparaceae	*Capparis brevispina*	Wal-dehi	S	In	NT	NA
Celastraceae	*Salacia chinensis*	Heen-himbutu-wel	C	In	NT	NA
Combretaceae	*Lumnitzera racemosa*	Beriya	T	In	NT	LC
Fabaceae	*Albizia amara*	Iha	T	In	NT	NA
Fabaceae	*Indigofera colutea*		H	In	NT	NA
Fabaceae	*Vigna trilobata*	Bin-me	C	In	NT	NA
Lythraceae	*Pemphis acidula*	Muhudu Wara	S	In	NT	LC
Olacaceae	*Olax imbricata*	Telatiya	S	In	NT	NA
Orobanchaceae	*Striga angustifolia*		H	In	NT	NA
Salvadoraceae	*Salvadora persica*	Malittan	T	In	NT	NA
Vitaceae	*Cyphostemma setosum*		C	In	NT	NA

(H- Herb, C - Creeper, T- Tree, S- Shrub, G - Grass, Gl-Grass like,) and the taxonomic status TS (In– Indigenous; E – Endemic; I – Introduced including naturalized exotics) and National conservation status NCS (EN- Endangered, VU- Vulnerable, NT- Near Threatened), GCS- Global Conservation Status: NA- Not Assessed, LC- Least Concern

The Revised Handbook to the Flora of Ceylon, Vol. X (pg.86-87) list the herbarium specimens of *C. galuca* (Neralu) were prepared from the specimens collected from localities in seven districts (Mannar, Vavunia, Puttalam, Anuradhapura, Trincomalee, Matale and Polonnaruwa) of Sri Lanka.

Two endemics, *Vernonia zeylanica* (Pupula) and *Cassine glauca* (Neralu) are categorized as LC in the National Red list (2012). The presence of endemic species triggers potential critical

[3] Study area- same as the project site, however, this includes proposed access roads as well

habitat; however, the project area has <1% global (Sri Lankan) population that justified that the project area is not trigger critical habitat. **Table 2** depicts that they are not nationally threatened though their IUCN conservation status (if any) is stated. It is noted they are not restricted to the 39 turbine locations, but also need to confirm if they are widespread in Sri Lanka and not restricted range species.

Table 3. Plant species recorded during the terrestrial survey in 39 locations, each 150 x 150 m (2.25 ha), demarcated for the proposed Wind Power Project

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	H	In	
Acanthaceae	*Dipteracanthus prostratus*	Nil-puruk	H	In	
Acanthaceae	*Avicennia marina*	Manda	S	In	
Aizoaceae	*Sesuvium portulacastrum*	Maha-sarana	H	In	NT
Aizoaceae	*Trianthema decandra*	Maha-sarana	H	In	NT
Amaranthaceae	*Achyranthes aspera*	Karal haba	H	In	
Amaranthaceae	*Aerva lanata*	Polpala	H	In	
Amaranthaceae	*Pupalia lappacea*	Wal karal heba	H	In	
Apocynaceae	*Carissa spinarum*	Heen-Karamba	S	In	
Apocynaceae	*Calotropis gigantea*	Wara	S	In	
Apocynaceae	*Dregea volubilis*	Kiri-Anguna	C	In	
Apocynaceae	*Hemidesmus indicus*	Iramusu	C	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	C	In	
Apocynaceae	*Pentatropis capensis*		C	In	
Apocynaceae	*Pergularia daemia*	Wissani	C	In	
Apocynaceae	*Secamone emetica*	Mudu Kiriya	C	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	C	In	
Arecaceae	*Borassus flabellifer*	Thal	T	I	
Arecaceae	*Cocos nucifera*	Pol	T	I	
Arecaceae	*Phonix pusilla*	Wal indi	T	In	
Aristolochiaceae	*Aristolochia indica*	Sapsanda	C	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	C	In	
Asteraceae	*Blumea obliqua*	Mudu-mahana	H	In	
Asteraceae	*Eclipta prostrata*	Kikirindi	H	In	
Asteraceae	*Emilia sonchifolia*	Kadupahara	H	In	
Asteraceae	*Epaltes divaricata*	Heen-mudu-mahana	H	In	
Asteraceae	*Launaea sarmentosa*		H	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	H	In	
Asteraceae	***Vernonia zeylanica***	Papula	S	E	
Asteraceae	*Wedelia chinensis*	Ranwan-kikirindi	H	In	
Asteraceae	*Wollastonia biflora*	Mudu-Gampalu	S	In	
Asteraceae	*Xanthium indicum*	Uru-kossa	H	In	
Boraginaceae	*Cordia monoica*	Lolu	T	In	
Boraginaceae	*Ehretia laevis*		S	In	
Boraginaceae	*Ehretia microphylla*	Hin-Thambala	S	In	
Boraginaceae	*Heliotropium curassavicum*		H	In	
Boraginaceae	*Heliotropium indicum*	Et-honda	H	In	
Cactaceae	*Opuntia dillenii*	Katu-pathok	S	I	

Family	Species	Sinhala Name	H	TS	NCS
Capparaceae	*Capparis brevispina*	Wal-dehi	S	In	NT
Capparaceae	*Capparis divaricata*	Wellangiriya	S	In	
Capparaceae	*Capparis sepiaria*	Rila Katu	C	In	
Capparaceae	*Capparis zeylanica*	Sudu-wellangiriya	S	In	
Celastraceae	***Cassine glauca***	Neralu	T	E	
Celastraceae	*Gymnosporia emarginata*	Katu pila	S	In	
Celastraceae	*Pleurostylia opposita*	Panakka	T	In	
Celastraceae	*Salacia chinensis*	Heen-himbutu-wel	C	In	NT
Cleomaceae	*Cleome viscosa*	Ran-manissa	H	In	
Colchicaceae	*Gloriosa superba*	Niyagala	C	In	
Combretaceae	*Lumnitzera racemosa*	Beriya	T	In	NT
Combretaceae	*Terminalia catappa*	Kottamba	T	I	
Commelinaceae	*Commelina benghalensis*	Diya-meneriya	H	In	
Commelinaceae	*Commelina petersii*		H	In	
Commelinaceae	*Cyanotis axillaris*		H	In	
Commelinaceae	*Murdannia spirata*		H	In	
Connvolvulaceae	*Cuscuta campastre*		H	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	C	In	
Connvolvulaceae	*Ipomoea pes-tigridis*	Divi-pahura	C	In	
Connvolvulaceae	*Ipomoea* sp.		C	In	
Connvolvulaceae	*Ipomoea violacea*		C	In	
Cucurbitaceae	*Citrullus lanatus*	Komadu	C	I	
Cucurbitaceae	*Coccinia grandis*	Kowakka	C	In	
Cucurbitaceae	*Momordica dioica*	Mal-thumba, Thumba karavila	C	In	
Cucurbitaceae	*Trichosanthes cucumerina*	Dum-mella	C	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	Gl	In	
Cyperaceae	*Cyperus javanicus*		Gl	In	
Cyperaceae	*Fimbristylis cymosa*		Gl	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	T	In	
Euphorbiaceae	*Acalypha indica*	Kuppameniya	H	In	
Euphorbiaceae	*Euphorbia antiquorum*	Daluk	T	In	
Euphorbiaceae	*Euphorbia hirta*	Bu-dada-kiriya	H	In	
Euphorbiaceae	*Euphorbia indica*	Ela-dada-kiriya	H	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu-dada-kiriya	H	In	
Euphorbiaceae	*Excoecaria agallocha*	Talakiriya	T	In	
Fabaceae	*Abrus precatorius*	Olinda	C	In	
Fabaceae	*Acacia chundra*	Rat-kihiriya	T	In	
Fabaceae	*Acacia eburnea*	Gini andara	S	In	
Fabaceae	*Acacia leucophloea*	Maha-Andara	T	In	
Fabaceae	*Acacia planifrons*		T	In	
Fabaceae	*Albizia amara*	Iha	T	In	NT
Fabaceae	*Alysicarpus vaginalis*	Aswenna	H	In	
Fabaceae	*Bauhinia acuminata*	Koboleela	T	I	
Fabaceae	*Bauhinia racemosa*	Maila	T	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	C	In	
Fabaceae	*Canavalia cathartica*		C	In	
Fabaceae	*Canavalia rosea*	Mudu-awara	C	In	
Fabaceae	*Crotalaria retusa*	Kaha-Andanahiriya	S	In	
Fabaceae	*Derris trifoliata*	Kala-wel	C	In	
Fabaceae	*Desmodium triflorum*	Heen-undupiyaliya	H	In	
Fabaceae	*Dicerma biarticulatum*		S	In	
Fabaceae	*Dichostachys cinerea*	Katu andara	S	In	
Fabaceae	*Indigofera colutea*		H	In	NT
Fabaceae	*Indigofera oblongifolia*	Nari Mun	S	In	VU
Fabaceae	*Indigofera tinctoria*	Nil-Awariya	S	In	
Fabaceae	*Mimosa pudica*	Nidi-kumba	H	I	
Fabaceae	*Prosopis juliflora*	Katu-siyambala	T	I	
Fabaceae	*Senna auriculata*	Ranawara	T	In	
Fabaceae	*Stylosanthes fruticosa*	Wal-Nanu	H	In	
Fabaceae	*Tamarindus indica*	Siyambala	T	I	
Fabaceae	*Tephrosia purpurea*	Katuru pila	S	In	
Fabaceae	*Tephrosia villosa*	Bu-Pila	S	In	
Fabaceae	*Vigna marina*	Lee ma	C	In	EN
Fabaceae	*Vigna trilobata*	Bin-me	C	In	NT
Gentianaceae	*Enicostema axillare*		H	In	
Gisekiaceae	*Gisekia pharnaceoides*	Atthiripala	H	In	
Goodeniaceae	*Scaevola taccada*	Takkada	S	In	
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	S	In	
Lamiaceae	*Anisomeles indica*	Yak-wanassa	H	In	
Lamiaceae	*Gmelina asiatica*	Demata	S	In	
Lamiaceae	*Hyptis suaveolens*	Ali thala	S	I	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	H	In	
Lamiaceae	*Ocimum americanum*	Heen-tala	H	In	
Lamiaceae	*Platostoma menthoides*		H	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	S	In	
Lamiaceae	*Vitex negundo*	Nika	T	In	
Lauraceae	*Cassytha filiformis*		S	In	
Lythraceae	*Ammannia baccifera*		H	In	
Lythraceae	*Pemphis acidula*	Muhudu Wara	S	In	NT
Malvaceae	*Hibiscus surattensis*	Hin-napiriththa	S	In	
Malvaceae	*Hibiscus tiliaceus*	Wal Beli	T	In	
Malvaceae	*Sida cordata*	Bevila	H	In	
Malvaceae	*Thespesia populnea*	Gansuriya	T	In	
Malvaceae	*Corchorus aestuans*	Jaladara	H	I	
Malvaceae	*Grewia orientalis*	Wel-keliya	S	In	
Malvaceae	*Melochia corchorifolia*	Gas-kura	H	In	
Malvaceae	*Triumfetta pentandra*	Epala	S	In	
Malvaceae	*Waltheria indica*	Punnikki	S	In	
Meliaceae	*Azadirachta indica*	Kohomba	T	I	

Family	Species	Sinhala Name	H	TS	NCS
Menispermaceae	*Hyserpa nitida*	Niri-wel	S	In	EN
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	C	In	VU
Menispermaceae	*Tinospora sinensis*	Rasa Kinda	C	In	DD
Molluginaceae	*Glinus oppositifolius*	Heen-ala	H	In	
Moraceae	*Ficus benghalensis*	Maha-Nuga	T	In	
Moraceae	*Ficus racemosa*	Attikka	T	In	
Moraceae	*Ficus virens*	Kalawalla	T	In	
Myrtaceae	*Syzygium cumini*	Ma-Dan	T	In	
Nyctaginaceae	*Boerhavia diffusa*	Pita-sudu-pala	H	In	
Nyctaginaceae	*Boerhavia eracta*		H	In	
Ochnaceae	*Ochna lanceolata*	Bo-Kera	S	In	
Ochnaceae	*Ochna obtusata*	Mal-Kera	S	In	
Olacaceae	*Olax imbricata*	Telatiya	S	In	NT
Olacaceae	*Olax scandens*		S	In	
Onagraceae	*Ludwigia hyssopifolia*		S	In	
Opiliaceae	*Cansjera rheedii*	Eta-Muru	S	In	
Orobanchaceae	*Sopubia delphinifolia*		H	In	
Orobanchaceae	*Striga angustifolia*		H	In	NT
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	S	In	
Passifloraceae	*Passiflora foetida*	Pada wel	C	I	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	H	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	H	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		H	In	
Phyllanthaceae	*Phyllanthus reticulatus*	Wel-Kaliya	S	In	
Phyllanthaceae	*Sauropus bacciformis*	Eth-pitawakka	H	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	S	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	S	In	
Plantaginaceae	*Bacopa monnieri*	Lunuwila	H	In	
Plantaginaceae	*Scoparia dulcis*	Wal koththamalli	H	I	
Poaceae	*Panicum repens*	Etora	G	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	G	In	
Putranjiavaceae	*Drypetes sepiaria*	Wira	T	In	
Rhamnaceae	*Colubrina asiatica*	Tel hiriya	S	In	VU
Rhamnaceae	*Scutia myrtina*		S	In	
Rhamnaceae	*Ziziphus mauritiana*	Dabara	T	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	S	In	
Rhizophoraceae	*Rhizophora mucronata*	Maha Kadol	T	In	
Rubiaceae	*Benkara malabarica*	Pudan	S	In	
Rubiaceae	*Canthium coromandelicum*	Kara	S	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	S	In	
Rubiaceae	*Hydrophylax maritima*	Mudu getakola	H	In	
Rubiaceae	*Ixora pavetta*	Maha-Rathambala	T	In	
Rubiaceae	*Morinda coreia*	Ahu	T	In	
Rubiaceae	*Oldenlandia biflora*	Heen kaududala	H	In	
Rubiaceae	*Oldenlandia umbellata*	Saummal	H	In	

Family	Species	Sinhala Name	H	TS	NCS
Rubiaceae	*Pavetta indica*		S	In	
Rubiaceae	*Paederia foetida*	Apasu madu	C	I	
Rubiaceae	*Spermacoce articularis*		H	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	H	In	
Rubiaceae	*Tarenna asiatica*	Tarana	S	In	
Rutaceae	*Limonia acidissima*	Divul	T	In	
Rutaceae	*Pleiospermium alatum*	Tunpath-Kurundu	T	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	C	In	
Salicaceae	*Flacourtia indica*	Uguressa	S	I	
Salvadoraceae	*Azima tetracantha*	Wel dehi	S	In	
Salvadoraceae	*Salvadora persica*	Malittan	T	In	NT
Sapindaceae	*Allophylus cobbe*	Kobbe	S	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	T	In	
Sapindaceae	*Filicium decipiens*	Pihimbiya	T	In	
Sapindaceae	*Lepisanthes tetraphylla*	Dambu	T	In	
Sapotaceae	*Manilkara hexandra*	Palu	T	In	VU
Solanaceae	*Physalis peruviana*		H	I	
Solanaceae	*Solanum melongena*	Ela-Batu	S	I	
Solanaceae	*Solanum trilobatum*	Wal-tibbatu	S	In	
Typhaceae	*Typha agustifolia*	Hambu-pan	S	In	
Urticaceae	*Pouzolzia zeylanica*		H	In	
Vahliaceae	*Vahlia dichotoma*		H	In	EN
Verbenaceae	*Lantana camera*	Rata-hinguru	S	I	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	H	In	
Verbenaceae	*Stachytarpheta urticaefolia*	Nil-nakuta	H	I	
Vitaceae	*Cissus quadrangularis*	Heeressa	C	In	
Vitaceae	*Cyphostemma setosum*		C	In	NT
Xanthorrhoeacea e	*Aloe vera*	Komarica	H	I	
Zygophyllaceae	*Tribulus terrestris*	Heen-nerenchi	H	In	

Plant family, species, Sinhala Name, life form LF (H = herb, C = creeper, T = tree, S = shrub, G = grass, Gl = grass like,) and the taxonomic status TS (In = indigenous, E = endemic, I = introduced including naturalized exotics) and National conservation status NCS (EN = endangered, VU = vulnerable, NT = near threatened).

Global Conservation Status (GCS): All species mentioned in the table above are NA = Not Assessed or LC = Least Concern.

The 3 EN species are listed in Table 3 above are recorded within the project area but outside the turbine locations. Project area includes two rows of wind turbine locations and the area in between where water channels are found. *Vigna marina* recorded from the coastal vegetation, that would not be affected by the project activities. Hence, they are not recorded at any of the turbine locations per tables in the Annex.

Table 4. Plant species found along nine water channels (Thonas) located in the wind power project site near Wind Turbine locations 6, 8, 16, 19, 21, 22, 23 26, and 32.

Family	Species	Sinhala Name	H	TS	NCS	GCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	LC	NA
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	LC	LC
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	LC	NA
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	LC	NA
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	LC	NA
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	LC	NA
Asteraceae	*Xanthium indicum*	Uru-kossa	h	In	LC	NA
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	NT	LC
Commelinaceae	*Commelina benghalensis*	Diya-meneriya	h/g	In	LC	LC
Commelinaceae	*Commelina petersii*		h/g	In	LC	NA
Connvolvulaceae	*Ipomoea violacea*		c/c	In	LC	NA
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	LC	NA
Cucurbitaceae	*Momordica dioica*	Mal-thumba, Thumba karavila	c/c	In	LC	NA
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	LC	LC
Euphorbiaceae	*Euphorbia rosea*	Mudu-dada-kiriya	s/g	In	LC	NA
Euphorbiaceae	*Excoecaria agallocha*	Talakiriya	s/c	In	LC	LC
Fabaceae	*Alysicarpus vaginalis*	Aswenna	h/g	In	LC	NA
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	LC	NA
Fabaceae	*Derris trifoliata*	Kala-wel	c/u-c	In	LC	NA
Goodeniaceae	*Scaevola taccada*	Takkada	s/u	In	LC	NA
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	LC	NA
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	LC	NA
Lauraceae	*Cassytha filiformis*		c/c	In	LC	NA
Malvaceae	*Hibiscus tiliaceus*	Wal Beli	t/c	In	LC	NA
Malvaceae	*Grewia orientalis*	Wel-keliya	s/u-c	In	LC	NA
Moraceae	*Ficus racemosa*	Attikka	t/c	In	LC	NA
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	LC	NA
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	LC	LC
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	LC	NA
Plantaginaceae	*Bacopa monnieri*	Lunuwila	h/g	In	LC	LC
Rhizophoraceae	*Rhizophora mucronata*	Maha Kadol	t/c	In	LC	LC
Rubiaceae	*Hydrophylax maritima*	Mudu getakola	h/g	In	LC	NA
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	LC	NA
Sapindaceae	*Allophylus cobbe*	Kobbe	s/u	In	LC	NA
Typhaceae	*Typha angustifolia*	Hambu-pan	s/u	In	LC	LC
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	LC	LC

H=Habit (h=herbaceous, s= shrub, t=tree or c= creeper) /strata (c=canopy, u=understory, – g=ground layer, e=emergent). Eg. h/g=herbaceous/ground layer, s/u=shrub/understory, c/u/creeper understory, t/u= tree understory, t/c=tree canopy, t/u-c=tree understory to canopy, TS= Taxonomic Status, In- indigenous, NCS=National Conservation Status: LC=Least Concerned, NT= Near Threatened, GCS-Global Conservation Status- NA- Not Assessed, LC- Least Concern

Table 5. Number of Palmyra and coconut trees that are found within the area of hardstand in each turbine location. These trees will be cut down during the construction of wind turbines in Mannar Island.

Tower No	Palmyra	Coconut	Tower No	Palmyra	Coconut
1	5	-	21	-	-
2	4	-	22	-	-
3	-	-	23	-	-
4	6	-	24	-	-
5	5	-	25	-	-
6	1	-	26	-	-
7	-	-	27	-	-
8	-	-	28	-	-
9	-	-	29	2	-

Tower No	Palmyra	Coconut	Tower No	Palmyra	Coconut
10	-	-	30	2	-
11	2	-	31	3	-
12	-	-	32	3	-
13	-	-	33	-	-
14	-	-	34	8	-
15	-	-	35	10	13
16	1	-	36	1	2
17	-	-	37	60	1
18	-	-	38	31	42
19	-	-	39	3	1
20	-	-	**Total**	**147**	**59**

Table 6: Total costs for terrestrial ecology mitigation and monitoring

No	Potential Impact	Proposed Mitigation measures	Monitoring Means and frequency	Responsibility	Performance Indicator	Approximate Cost US$
1	Removal of trees, degradation of habitats	Replanting and restoration	Every three months during the first three years of planting	CEB/ contractor	New plants, restoration of habitats	8,000

Annex 1

Plant species recorded in 150 x150 m area (2.25 ha) allocated for each turbine location and the number and percentage of tree cover within the hardstand (0.7 ha) of each turbine (where vegetation/ trees will be removed during the construction activities).

Table 1. Plant family, species and local name of plants recorded in Wind Turbine location- 1, Thoddaveli, near sea cucumber drying facility (WGS 84 Coordinates: 9.006176, 79.851371).

Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Carissa spinarum*	Heen-Karamba	s/u/c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Celastraceae	***Cassine glauca***	Neralu	t/u-c	E	
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	
Commelinaceae	*Commelina benghalensis*	Diya-meneriya	h/g	In	
Commelinaceae	*Cyanotis sp.*		h/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Euphorbiaceae	*Excoecaria agallocha*	Talakiriya	s/c	In	
Euphorbiaceae	*Micrococca mercurialis*		h/u	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	
Lamiaceae	*Gmelina asiatica*	Demata	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Malvaceae	*Thespesia populnea*	Gansuriya	t/c	In	
Malvaceae	*Grewia orientalis*	Wel-keliya	s/u-c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Ochnaceae	*Ochna obtusata*	Mal-Kera	t/u	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	h/g	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	
Salvadoraceae	*Salvadora persica*	Malittan	t/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Sapindaceae	*Allophylus cobbe*	Kobbe	s/u	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Solanaceae	*Solanum melongena*	Ela-Batu	s/u	I	
Vitaceae	*Cissus quadrangularis*	Heeressa	c/u-c	In	
Vitaceae	*Cyphostemma setosum*		c/u-c	In	

Habit (h = herbaceous, s = shrub, t = tree, c = creeper) / strata (c = canopy, u = understory, g = ground vegetation, e = emergent). Eg. h/g = herbaceous/ground vegetation, s/u = shrub/understory, c/u = creeper understory, t/u= tree understory, t/c = tree canopy, t/u-c = tree understory to canopy, In = indigenous, I = introduced; NCS = National Conservation Status: VU = vulnerable, NT = near threatened.

Table 1.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 1

Family	Species	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Arecaceae	*Borassus flabellifer*	Thal	t/e	5	6%
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	3	2%
Fabaceae	*Acacia planifrons*		t/c	50	40%
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/u-c	6	4%
Euphorbiaceae	*Excoecaria agallocha*	Talakiriya	t/c	6	4%
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	3	4%
Malvaceae	*Thespesia populnea*	Gansuriya	t/c	3	5%

Photographs of the habitat of turbine location 1- the person holding the WT number is in the centre of 150x 150m block

Plate 1 Turbine location 1, Thoddaveli

Plate 2 Turbine location 1

Plate 3 Turbine location 1

Plate 4 Turbine location 1

Table 2. Plant family, species and local name of plants recorded in Wind Turbine location- 2, Thoddaveli, close to the sea cucumber drying facility (Coordinates: 9.008341 79.84894).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Salvadora persica*	Malittan	t/c	In	NT
Sapindaceae	*Allophylus cobbe*	Kobbe	s/u	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Solanaceae	*Solanum melongena*	Ela-Batu	s/u	I	
Vitaceae	*Cissus quadrangularis*	Heeressa	c/u-c	In	
Vitaceae	*Cyphostemma setosum*		c/u-c	In	NT

Table 2.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 2

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	4	3%
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	5	4%
Acacia planifrons	Fabaceae		t/c	75	60%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	9	6%
Azadirachta indica	Meliaceae	Kohomba	t/c	5	4%
Salvadora persica	Salvadoraceae	Malittan	t/c	3	2%

Photographs of the habitats of turbine location 2

Wind Turbine location 02

Wind Turbine location 02

Wind Turbine location 02

Wind Turbine location 02

Table 3. Plant family, species and local name of plants recorded in Wind Turbine location- 3, Thoddaveli (Coordinates: 9.011081 79.845832).

Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Carissa spinarum*	Heen-Karamba	s/u/c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Celastraceae	***Cassine glauca***	Neralu	t/u-c	E	
Commelinaceae	*Cyanotis sp.*		h/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	t/u-c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	

Table 3.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 3

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		2%
Acacia planifrons	Fabaceae		t/c	120	70%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	6	4%
Azadirachta indica	Meliaceae	Kohomba	t/c	2	1%
Zizyphus oenopila	Rhamnaceae	Hin-Eraminia	s/u-c	3	4%
Cassine glauca	Celastraceae	Neralu	t/c	2	1%

Photographs of the habitats of turbine location 3

Wind Turbine location 03

Wind Turbine location 03

Wind Turbine location 03

Wind Turbine location 03

Table 4. Plant family, species and local name of plants recorded in Wind Turbine location- 4, Konniyankudiruppu (Coordinates: 9.013299 79.843304).

Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Boraginaceae	*Heliotropium curassavicum*		h/g	In	
Connvolvulaceae	*Evolvulus alsinoides*	Visnu-kranthi	h/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Solanaceae	*Solanum melongena*	Ela-Batu	s/u	I	
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	
Vitaceae	*Cyphostemma setosum*		c/u-c	In	NT

Table 4.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 4

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	6	6%
Calotropis gigantea	Apocynaceae	Wara			40%
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	1	2%
Acacia planifrons	Fabaceae		t/c	1	6%

Photographs of the habitats of turbine location 4

Wind Turbine location 04

Wind Turbine location 04

Wind Turbine location 04

Wind Turbine location 04

Table 5. Plant family, species and local name of plants recorded in Wind Turbine location- 5, Konniyankudiruppu (Coordinates: 9.01549 79.840771).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Passifloraceae	*Passiflora foetida*	Pada wel	c/u-g	I	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	
Salvadoraceae	*Salvadora persica*	Malittan	t/c	In	NT
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	
Vitaceae	*Cissus quadrangularis*	Heeressa	c/u-c	In	
Vitaceae	*Cyphostemma setosum*		c/u-c	In	NT

Table 5.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 5

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	5	6%
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		10%
Acacia planifrons	Fabaceae		t/c	60	55%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	15	9%

Photographs of the habitats of turbine location 5

Wind Turbine Location 5

Wind Turbine Location 5

Wind Turbine Location 5

Wind Turbine Location 5

Table 6. Plant family, species and local name of plants recorded in Wind Turbine location- 6, Konniyankudiruppu (Coordinates: 9.017743 79.838148).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	NT
Combretaceae	*Terminalia catappa*	Kottamba	t/c	I	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Euphorbiaceae	*Excoecaria agallocha*	Talakiriya	s/c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	
Fabaceae	*Derris trifoliata*	Kala-wel	c/u-c	In	
Fabaceae	*Tephrosia purpurea*	Katuru pila	s/u	In	
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Malvaceae	*Hibiscus tiliaceus*	Wal Beli	t/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus racemosa*	Attikka	t/c	In	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Plantaginaceae	*Bacopa monnieri*	Lunuwila	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Family	Species	Sinhala Name	H	TS	NCS
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	
Verbenaceae	*Lantana camera*	Rata-hinguru	s/u	I	
Vitaceae	*Cyphostemma setosum*		c/u-c	In	NT

Table 6.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 6

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	1	
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		10%
Acacia planifrons	Fabaceae		t/c		60%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		5%
Excoecaria agallocha	Euphorbiaceae	Talakiriya	t/c		2%
Hibiscus tiliaceus	Malvaceae	Wal Beli	t/c		3%
Zizyphus oenopila	Rhamnaceae	Hin-Eraminia	s/u-c		4%

Photographs of the habitats of turbine location 6

Wind Turbine Location 6

Wind Turbine Location 6

Wind Turbine Location 6

Wind Turbine Location 6

Table 7. Plant family, species and local name of plants recorded in Wind Turbine location- 7, Olaiththoduvai, close to the fisher camps, sea cucumber hatchery (Coordinates: 9.019844 79.835454).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Launaea sarmentosa*		h/g	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Commelinaceae	*Commelina benghalensis*	Diya-meneriya	h/g	In	
Commelinaceae	*Cyanotis sp.*		h/g	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	
Fabaceae	*Derris trifoliata*	Kala-wel	c/u-c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Solanaceae	*Physalis peruviana*		h/g	I	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 7.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 7

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		6%
Acacia planifrons	Fabaceae		t/c	22	35%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	13	8%

Photographs of the habitats of turbine location 7

Wind Turbine Location 7

Wind Turbine Location 7

Wind Turbine Location 7

Wind Turbine Location 7

Table 8. Plant family, species and local name of plants recorded in Wind Turbine location- 8, Olaiththoduvai, close to the fisher camps, sea cucumber hatchery (Coordinates: 9.021983 79.832688).

Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Launaea sarmentosa*		h/g	In	
Celastraceae	***Cassine glauca***	Neralu	t/u-c	E	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	

Family	Species	Sinhala Name	H	TS	NCS
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Nyctaginaceae	*Boerhavia diffusa*	Pita-sudu-pala	h/g	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	

Table 8.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 8

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		5%
Acacia planifrons	Fabaceae		t/c	1	20%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	10	8%

Photographs of the habitats of turbine location 8

Wind Turbine Location 8

Wind Turbine Location 8

Wind Turbine Location 8

Wind Turbine Location 8

Table 9. Plant family, species and local name of plants recorded in Wind Turbine location- 9, Olaiththoduvai (Coordinates: 9.024048 79.829981).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 9.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 9

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	10	10%
Acacia planifrons	Fabaceae		t/c	30	50%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	7	5%

Photographs of the habitats of turbine location 9

Wind Turbine Location 9

Wind Turbine Location 9

Wind Turbine Location 9

Wind Turbine Location 9

Table 10. Plant family, species and local name of plants recorded in Wind Turbine location-10, near Shell Coast Resort, Olaiththoduvai (Coordinates:9.026146 79.827307).

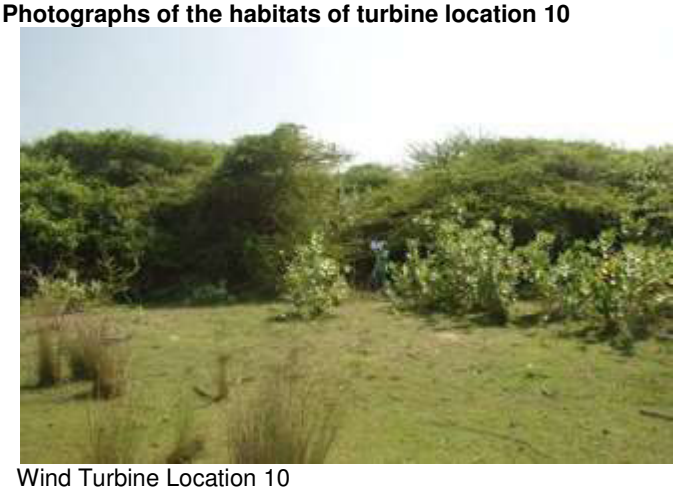
Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Launaea sarmentosa*		h/g	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Commelinaceae	*Commelina benghalensis*	Diya-meneriya	h/g	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	

Family	Species	Sinhala Name	H	TS	NCS
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Table 10.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 10

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Acacia planifrons	Fabaceae		t/c	40	40%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	10	6%
Zizyphus oenopila	Rhamnaceae	Hin-Eraminia	s/u-c		5%

Photographs of the habitats of turbine location 10



Wind Turbine Location 10

Wind Turbine Location 10

Wind Turbine Location 10

Wind Turbine Location 10

Table 11. Plant family, species and local name of plants recorded in Wind Turbine location-11, near Shell Coast Resort, Olaiththoduvai (Coordinates: 9.030169 79.821855).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Carissa spinarum*	Heen-Karamba	s/u/c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Launaea sarmentosa*		h/g	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Table 11.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 11

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	2	
Acacia planifrons	Fabaceae		t/c		30%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		45%
Zizyphus oenopila	Rhamnaceae	Hin-Eraminia	s/u-c		5%

Photographs of the habitats of turbine location 11

Wind Turbine Location 11

Wind Turbine Location 11

Wind Turbine Location 11

Wind Turbine Location 11

Table 12. Plant family, species and local name of plants recorded in Wind Turbine location-12, Olaiththoduvai (Coordinates: 9.032113 79.819051).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	

Family	Species	Sinhala Name	H	TS	NCS
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Table 12.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 12

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Acacia planifrons	Fabaceae		t/c		70%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		35%

Photographs of the habitats of turbine location 12

Wind Turbine Location 12

Wind Turbine Location 12

Wind Turbine Location 12

Wind Turbine Location 12

Table 13. Plant family, species and local name of plants recorded in Wind Turbine location-13, Olaiththoduvai (Coordinates: 9.03409 79.816153).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Table 13.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 13

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Acacia planifrons	Fabaceae		t/c		80%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		15%

Photographs of the habitats of turbine location 13

Wind Turbine Location 13

Wind Turbine Location 13

Wind Turbine Location 13

Wind Turbine Location 13

Table 14. Plant family, species and local name of plants recorded in Wind Turbine location-14, Olaiththoduvai (Coordinates: 9.035896 79.813455).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Family	Species	Sinhala Name	H	TS	NCS
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	

Table 14.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 14

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		15%
Acacia planifrons	Fabaceae		t/c		50%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		20%
Zizyphus oenopila	Rhamnaceae	Hin-Eraminia	s/u-c		6%

Photographs of the habitats of turbine location 14

Wind Turbine Location 14

Wind Turbine Location 14

Wind Turbine Location 14

Wind Turbine Location 14

Table 15. Plant family, species and local name of plants recorded in Wind Turbine location- 15, Olaiththoduvai (Coordinates: 9.037917 79.810354).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/g	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	

Family	Species	Sinhala Name	H	TS	NCS
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Bauhinia racemosa*	Maila	t/u-c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Gentianaceae	*Enicostema axillare*		h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Table 15.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 15

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		15%
Acacia planifrons	Fabaceae		t/c		55%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		12%

Photographs of the habitats of turbine location 15

Wind Turbine Location 15

Wind Turbine Location 15

Wind Turbine Location 15

Wind Turbine Location 15

Table 16. Plant family, species and local name of plants recorded in Wind Turbine location-16, Olaiththoduvai (Coordinates: 9.039753 79.807517).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Combretaceae	*Terminalia catappa*	Kottamba	t/c	I	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	

Table 16.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 16

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	1	
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	40	30%
Acacia planifrons	Fabaceae		t/c	40	35%
Syzygium cumini	Myrtaceae	Ma-Dan		3	2%

Photographs of the habitats of turbine location 16

Wind Turbine Location 16

Wind Turbine Location 16

Wind Turbine Location 16

Wind Turbine Location 16

Table 17. Plant family, species and local name of plants recorded in Wind Turbine location-17, near St' Jude road & Kalutota cabana (Coordinates: 9.041606 79.804595).

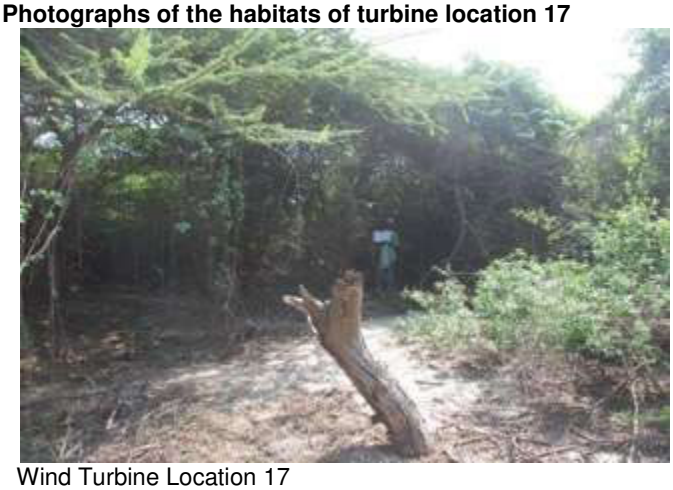
Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Caesalpinia bonduc*	Kumburu-Wel	c/u-c	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Hydrophylax maritima*	Mudu getakola	h/g	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Salvadora persica*	Malittan	t/c	In	NT
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	

Table 17.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 17

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		10%
Acacia planifrons	Fabaceae		t/c		65%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		15%

Photographs of the habitats of turbine location 17



Wind Turbine Location 17

Wind Turbine Location 17

Wind Turbine Location 17

Wind Turbine Location 17

Table 18. Plant family, species and local name of plants recorded in Wind Turbine location-18, near St' Jude road and Kalutota cabanas (Coordinates: 9.043403 79.801599).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Indigofera oblongifolia*	Nari Mun	h/u-c	In	VU
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Salvadora persica*	Malittan	t/c	In	NT
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 18.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 18

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		18%
Acacia planifrons	Fabaceae		t/c		30%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		4%

Photographs of the habitats of turbine location 18

Wind Turbine Location 18

Wind Turbine Location 18

Wind Turbine Location 18

Wind Turbine Location 18

Table 19. Plant family, species and local name of plants recorded in Wind Turbine location-19, Nadukuda (Coordinates: 9.045127 79.798808).

Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	NT
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Euphorbiaceae	*Excoecaria agallocha*	Talakiriya	s/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Alysicarpus vaginalis*	Aswenna	h/g	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Gentianaceae	*Enicostema axillare*		h/g	In	
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Nyctaginaceae	*Boerhavia diffusa*	Pita-sudu-pala	h/g	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Plantaginaceae	*Bacopa monnieri*	Lunuwila	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 19.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 19

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		30%
Acacia planifrons	Fabaceae		t/c		15%

Photographs of the habitats of turbine location 19

Wind Turbine Location 19

Wind Turbine Location 19

Wind Turbine Location 19

Wind Turbine Location 19

Table 20. Plant family, species and local name of plants recorded in Wind Turbine location-20, Nadukuda (Coordinates: 9.046843 79.795797).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Asteraceae	*Launaea sarmentosa*		h/g	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Alysicarpus vaginalis*	Aswenna	h/g	In	
Fabaceae	*Indigofera oblongifolia*	Nari Mun	h/u-c	In	VU
Fabaceae	*Tephrosia purpurea*	Katuru pila	s/u	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Hydrophylax maritima*	Mudu getakola	h/g	In	
Rubiaceae	*Oldenlandia umbellata*	Saya	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	

Table 20.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 20

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	13	7%
Acacia planifrons	Fabaceae		t/c	15	15%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	4	4%

Photographs of the habitats of turbine location 20

Wind Turbine Location 20

Wind Turbine Location 20

Wind Turbine Location 20

Wind Turbine Location 20

Table 21. Plant family, species and local name of plants recorded in Wind Turbine location-21, Nadukuda (Coordinates:9.04859 79.792699).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	NT
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Indigofera oblongifolia*	Nari Mun	h/u-c	In	VU
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Gentianaceae	*Enicostema axillare*		h/g	In	
Goodeniaceae	*Scaevola taccada*	Takkada	s/u	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Typhaceae	*Typha agustifolia*	Hambu-pan	S	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 21.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 21

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	5	6%
Acacia planifrons	Fabaceae		t/c	8	10%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	3	4%

Photographs of the habitats of turbine location 21

Wind Turbine Location 21

Wind Turbine Location 21

Wind Turbine Location 21

Wind Turbine Location 21

Table 22. Plant family, species and local name of plants recorded in Wind Turbine location-22, Nadukuda (Coordinates: 9.050075 79.789936).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	NT
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Indigofera oblongifolia*	Nari Mun	h/u-c	In	VU
Fabaceae	*Tephrosia purpurea*	Katuru pila	s/u	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 22.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 22

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	10	15%
Acacia planifrons	Fabaceae		t/c	15	20%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	11	7%
Lumnitzera racemosa	Combretaceae	Beriya	t/c		4%

Photographs of the habitats of turbine location 22

Wind Turbine Location 22

Wind Turbine Location 22

Wind Turbine Location 22

Wind Turbine Location 22

Table 23. Plant family, species and local name of plants recorded in Wind Turbine location- 23, Nadukuda (Coordinates: 9.052724 79.785108).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Bauhinia racemosa*	Maila	t/u-c	In	
Fabaceae	*Tephrosia purpurea*	Katuru pila	s/u	In	
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Plantaginaceae	*Bacopa monnieri*	Lunuwila	h/g	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Typhaceae	*Typha agustifolia*	Hambu-pan	S	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 23.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 23

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	15	8%
Acacia planifrons	Fabaceae		t/c	25	17%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	11	4%

Photographs of the habitats of turbine location 23

Wind Turbine Location 23

Wind Turbine Location 29

Wind Turbine Location 23

Wind Turbine Location 23

Table 24. Plant family, species and local name of plants recorded in Wind Turbine location-24, Nadukuda (Coordinates:9.054001 79.782691).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Bauhinia racemosa*	Maila	t/u-c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 24.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 24

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	1	2%
Acacia planifrons	Fabaceae		t/c	5	10%
Calotropis gigantea	Apocynaceae	Wara	s/u-c		2%

Photographs of the habitats of turbine location 24

Wind Turbine Location 24

Wind Turbine Location 24

Wind Turbine Location 24

Wind Turbine Location 24

Table 25. Plant family, species and local name of plants recorded in Wind Turbine location-25, Nadukuda (Coordinates: 9.055228 79.780341).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Tephrosia purpurea*	Katuru pila	s/u	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Verbenaceae	*Phyla nodiflora*	Herimana-detta	h/g	In	

Table 25.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 25

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	1	2%
Acacia planifrons	Fabaceae		t/c	12	18%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	2	4%

Photographs of the habitats of turbine location 25

Wind Turbine Location 25

Wind Turbine Location 25

Wind Turbine Location 25

Wind Turbine Location 25

Table 26. Plant family, species and local name of plants recorded in Wind Turbine location- 26, Nadukuda (Coordinates: 9.056499 79.777886).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Combretaceae	*Lumnitzera racemosa*	Beriya	t/c	In	NT
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Clerodendrum inerme*	Wal-Gurenda	s/u-c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Malvaceae	*Hibiscus tiliaceus*	Wal Beli	t/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Menispermaceae	*Tinospora cordifolia*	Rasa-Kinda	c/u-c	In	VU
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Zizyphus oenopila*	Hin-Eraminia	s/u-c	In	
Rhizophoraceae	*Rhizophora mucronata*	Maha Kadol	t/c	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	

Table 26.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 26

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	8	10%
Acacia planifrons	Fabaceae		t/c	44	40%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	18	8%
Calotropis gigantea	Apocynaceae	Wara	s/u-c	12	3%

Photographs of the habitats of turbine location 26

Wind Turbine Location 26

Wind Turbine Location 26

Wind Turbine Location 26

Wind Turbine Location 26

Table 27. Plant family, species and local name of plants recorded in Wind Turbine location-27, Keeliyakudiruppu (Coordinates: 9.057745 79.775434).

Family	Species	Sinhala Name	H	TS	NCS
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	

Table 27.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 27

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	3	2%
Acacia planifrons	Fabaceae		t/c	36	40%

Photographs of the habitats of turbine location 27

Wind Turbine Location 27

Wind Turbine Location 27

Wind Turbine Location 27

Wind Turbine Location 27

Table 28. Plant family, species and local name of plants recorded in Wind Turbine location-28, Keeliyakudiruppu (Coordinates: 9.058868 79.772969).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu Dadakiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Solanaceae	*Solanum trilobatum*	Wel-tibbatu	s/u-c	In	

Table 28.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location – 28

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		8%
Acacia planifrons	Fabaceae		t/c		35%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		6%
Calotropis gigantea	Apocynaceae	Wara	s/u-c		2%

Photographs of the habitats of turbine location 28

Wind Turbine Location 28

Wind Turbine Location 28

Wind Turbine Location 28

Wind Turbine Location 28

Table 29. Plant family, species and local name of plants recorded in Wind Turbine location- 29, Keeliyakudiruppu (Coordinates: 9.060004 79.770502).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus benghalensis*	Maha-Nuga	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	

Table 29.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 29

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	2	6%
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c		2%
Acacia planifrons	Fabaceae		t/c		80%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		4%

Photographs of the habitats of turbine location 29

Wind Turbine Location 29

Wind Turbine Location 29

Wind Turbine Location 29

Wind Turbine Location 29

Table 30. Plant family, species and local name of plants recorded in Wind Turbine location- 30, Keeliyakudiruppu (Coordinates: 9.061155 79.768055).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus benghalensis*	Maha-Nuga	t/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	

Table 30.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 30

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e		4%
Acacia planifrons	Fabaceae		t/c		65%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		12%

Photographs of the habitats of turbine location 30

Wind Turbine Location 30

Wind Turbine Location 30

Wind Turbine Location 30

Wind Turbine Location 30

Table 31. Plant family, species and local name of plants recorded in Wind Turbine location-31, Palavi (Coordinates: 9.062232 79.765671).

Family	Species	Sinhala Name	H	TS	NCS
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	

Table 31.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 31

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e		
Acacia planifrons	Fabaceae		t/c		75%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		8%

Photographs of the habitats of turbine location 31

Wind Turbine Location 31

Wind Turbine Location 31

Wind Turbine Location 31

Wind Turbine Location 31

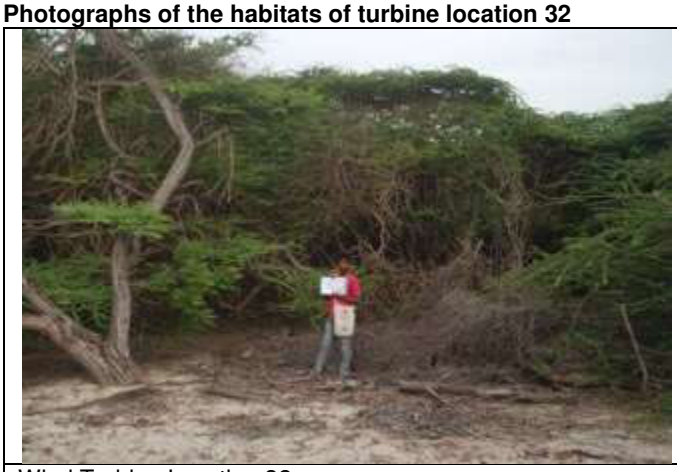
Table 32. Plant family, species and local name of plants recorded in Wind Turbine location-32, Palavi (Coordinates: 9.063394 79.762935).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus benghalensis*	Maha-Nuga	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	

Table 32.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 32

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	3	6%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		8%
Acacia planifrons	Fabaceae		t/c		70%

Photographs of the habitats of turbine location 32



Wind Turbine Location 32

Wind Turbine Location 32

Wind Turbine Location 32

Wind Turbine Location 32

Table 33. Plant family, species and local name of plants recorded in Wind Turbine location-33, Palavi (Coordinates: 9.064326 79.760467).

Family	Species	Sinhala Name	H	TS	NCS
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Pergularia daemia*	Wissani	c/u-c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Connvolvulaceae	*Ipomoea pes-caprae*	Mudu-bin-thamburu	c/g	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	

Family	Species	Sinhala Name	H	TS	NCS
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Poaceae	*Spinifex littoreus*	Maha-rawana-revula	g/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	

Table 33.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 33

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c		8%
Acacia planifrons	Fabaceae		t/c		42%

Photographs of the wind turbine location -33

Wind Turbine Location 33

Wind Turbine Location 33

Wind Turbine Location 33

Wind Turbine Location 33

Table 34. Plant family, species and local name of plants recorded in Wind Turbine location-34, Uvari (Coordinates: 9.035265 79.827757).

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u-c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/e	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u-c	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/u-c	In	
Cactaceae	*Opuntia dillenii*	Katu-pathok	s/u	I	

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Capparaceae	*Capparis zeylanica*	Sudu-wellangiriya	s/c	In	
Celastraceae	*Pleurostylia opposita*	Panakka	s/u	In	
Colchicaceae	*Gloriosa superba*	Niyagala	c/u-c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	t/u-c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu-dada-kiriya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Desmodium triflorum*	Heen-undupiyaliya	h/g	In	
Fabaceae	*Vigna trilobata*	Bin-me	c/g	In	NT
Lamiaceae	*Gmelina asiatica*	Demata	s/u-c	In	
Lamiaceae	*Leucas zeylanica*	Geta-Thumba	h/g	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus racemosa*	Attikka	t/c	In	
Moraceae	*Ficus* sp.		t/c	In	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	h/g	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Sauropus bacciformis*	Eth-pitawakka	h/g	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Phyllanthaceae	*Phyllanthus amarus*	Pitawakka	h/g	In	
Rhamnaceae	*Scutia myrtina*		s/u-c	In	
Rhamnaceae	*Ziziphus mauritiana*	Dabara	t/c	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Hydrophylax maritima*	Mudu getakola	h/g	In	
Rubiaceae	*Oldenlandia biflora*	Heen kaududala	h/g	In	
Rubiaceae	*Spermacoce articularis*		h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/c	In	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Verbenaceae	*Stachytarpheta urticaefolia*	Nil-nakuta	h/u	I	
Vitaceae	*Cissus quadrangularis*	Heeressa	c/c	In	

Table 34.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 34

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	8	6%
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	6	6%
Acacia planifrons	Fabaceae		t/c	9	30%

Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	5	4%
Azadirachta indica	Meliaceae	Kohomba	t/c	6	2%
Syzygium cumini	Myrtaceae	Ma-Dan	t/c	10	10%

Photographs of the wind turbine location -34

Wind Turbine Location 34

Wind Turbine Location 34

Wind Turbine Location 34

Wind Turbine Location 34

Table 35. Plant family, species and local name of plants recorded in Wind Turbine location-35, Uvari (Coordinates: 9.037579 79.824465).

Species	Family	Common Name	Life form/strata	Taxonomic Status	Conservation Status
Asystasia gangetica	Acanthaceae	Puruk	h/u-c	In	
Aerva lanata	Amaranthaceae	Polpala	h/g	In	
Calotropis gigantea	Apocynaceae	Wara	s/g	In	
Hemidesmus indicus	Apocynaceae	Iramusu	c/g	In	
Tylophora indica	Apocynaceae	Mudu-bin-nuga	c/u	In	
Borassus flabellifer	Arecaceae	Thal	t/c	I	
Cocos nucifera	Arecaceae	Pol	t/c	I	
Phonix pusilla	Arecaceae	Wal indi	t/u	In	
Gymnosporia emarginata	Celastraceae	Katu pila	s/u	In	
Ipomoea violacea	Connvolvulaceae		c/c	In	
Diospyros vera	Ebenaceae	Kaluhabaraliya	t/u	In	
Acacia planifrons	Fabaceae		t/c	In	
Alysicarpus vaginalis	Fabaceae	Aswenna	h/g	In	

Species	Family	Common Name	Life form/strata	Taxonomic Status	Conservation Status
Desmodium triflorum	Fabaceae	Heen-undupiyaliya	h/g	In	
Dichostachys cinerea	Fabaceae	Katu andara	s/c	In	
Tephrosia purpurea	Fabaceae	Katuru pila	s/u	In	
Vigna trilobata	Fabaceae	Bin-me	h/g	In	NT
Enicostema axillare	Gentianaceae		h/g	In	
Gmelina asiatica	Lamiaceae	Demata	s/u-c	In	
Leucas zeylanica	Lamiaceae	Geta-Thumba	h/g	In	
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	In	
Cassytha filiformis	Lauraceae		c/c	In	
Azadirachta indica	Meliaceae	Kohomba	t/u-c	I	
Ficus racemosa	Moraceae	Attikka	t/u-c	In	
*Ficus*sp.	Moraceae		t/u	In	
Syzygium cumini	Myrtaceae	Ma-Dan	t/c	In	
Pandanus odorifer	Pandanaceae	Mudu keyiya	t/u-c	In	
Phyllanthus maderaspatensis	Phyllanthaceae		h/g	In	
Sauropus bacciformis	Phyllanthaceae	Eth-pitawakka	h/g	In	
Breynia vitis-idaea	Phyllanthaceae	Gas-kayila	s/u	In	
Flueggea leucopyrus	Phyllanthaceae	Heen Katu pila	s/u	In	
Phyllanthus amarus	Phyllanthaceae	Pitawakka	h/g	In	
Ziziphus mauritiana	Rhamnaceae	Dabara	s/u-c	In	
Catunaregam spinosa	Rubiaceae	Kukuruman	s/u-c	In	
Morinda coreia	Rubiaceae	Ahu	t/u-c	In	
Oldenlandia umbellata	Rubiaceae	Saummal	h/g	In	
Toddalia asiatica	Rutaceae	Kudu-Miris	s-c/u-c	In	
Dodanaea viscosa	Sapindaceae	Et-Werella	s/u	In	
Phyla nodiflora	Verbenaceae	Herimana-detta	h/g	In	
Stachytarpheta urticaefolia	Verbenaceae	Nil-nakuta	s/u	I	
Cissus quadrangularis	Vitaceae	Heeressa	c/u	In	

Table 35.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 35

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/c	10	
Cocos nucifera	Arecaceae	Pol	t/c	13	
Acacia planifrons	Fabaceae		t/c	(15)	25%
Gmelina asiatica	Lamiaceae	Demata	t/u-c	6	
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	(7)	5%
Azadirachta indica	Meliaceae	Kohomba	t/c	2	
Syzygium cumini	Myrtaceae	Ma-Dan	t/c	(9)	4%
Ziziphus mauritiana	Rhamnaceae	Dabara	s/u-c	(2)	2%
Catunaregam spinosa	Rubiaceae	Kukuruman	s/u-c	(3)	2%

Photographs of the wind turbine location -35

Wind Turbine Location 35

Wind Turbine Location 35

Wind Turbine Location 35

Wind Turbine Location 35

Table 36. Plant family, species and local name of plants recorded in Wind Turbine location-36, Uvari (Coordinates: 9.03955 79.821612).

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Sapindaceae	*Allophylus cobbe*	Kobbe	s/u	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/e	I	
Arecaceae	*Cocos nucifera*	Pol	t/e	I	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Capparaceae	*Capparis zeylanica*	Sudu-wellangiriya	S	In	
Celastraceae	***Cassine glauca***	Neralu	t/u-c	E	
Colchicaceae	*Iphigenia indica*		h/g	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	gl/g	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	t/u-c	In	
Euphorbiaceae	*Euphorbia rosea*	Mudu-dada-kiriya	s/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Dichostachys cinerea*	Katu andara	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus* sp.	Nuga	t/c	In	
Moraceae	*Ficus amplissima*	Ela Nuga	t/c	In	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Opiliaceae	*Cansjera rheedii*	Eta-Muru	s/c	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Oldenlandia umbellata*	Saummal	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salicaceae	*Flacourtia indica*	Uguressa	s/u	I	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Sapotaceae	*Manilkara hexandra*	Palu	t/c	In	VU
Vitaceae	*Cissus quadrangularis*	Heeressa	c/u-c	In	

Table 36.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location - 36

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Cocos nucifera	Arecaceae	Pol	t/e	2	
Borassus flabellifer	Arecaceae	Thal	t/e	1	
Acacia planifrons	Fabaceae		t/c	16	35%
Cassine glauca	Celastraceae	Neralu	t/u-c	3	3%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	18	20%
Diospyros vera	Ebenaceae	Kaluhabaraliya	t/u-c	3	
Syzygium cumini	Myrtaceae	Ma-Dan	t/c	5	8%

Photographs of the wind turbine location -36

Wind Turbine Location 36

Wind Turbine Location 36

Wind Turbine Location 36

Wind Turbine Location 36

Table 37. Plant family, species and local name of plants recorded in Wind Turbine location-37, Uvari (Coordinates: 9.041413 79.818876).

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Amaryllidaceae	*Crinum zeylanicum*		s/g	In	VU
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Apocynaceae	*Leptadenia reticulata*	Jeewanthi	c/c	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Cocos nucifera*	Pol	t/i	I	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Celastraceae	***Cassine glauca***	Neralu	t/u-c	E	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Cucurbitaceae	*Momordica dioica*	Thumba karavila	c/c	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	t/u-c	In	
Euphorbiaceae	*Acalypha indica*	Kuppameniya	h/g	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Bauhinia racemosa*	Maila	t/u-c	In	
Fabaceae	*Tamarindus indica*	Siyambala	t/c	I	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Lamiaceae	*Vitex negundo*	Nika	t/u-c	In	
Malvaceae	*Grewia orientalis*	Wel-keliya	s/u-c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Moraceae	*Ficus amplissima*	Ela Nuga	t/c	In	
Moraceae	*Ficus benghalensis*	Maha-Nuga	t/c	In	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	h/g	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Ziziphus mauritiana*	Dabara	t/u-c	In	
Rubiaceae	*Catunaregam spinosa*	Kukuruman	s/u-c	In	
Rubiaceae	*Ixora pavetta*	Maha-Rathambala	s/u	In	
Rubiaceae	*Oldenlandia umbellata*	Saummal	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Sapindaceae	*Allophylus cobbe*	Kobbe	s/u	In	
Verbenaceae	*Stachytarpheta urticaefolia*	Nil-nakuta	s/u	I	

Table 37.1 Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location – 37

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Cocos nucifera	Arecaceae	Pol	t/e	1	
Borassus flabellifer	Arecaceae	Thal	t/e	60	
Acacia planifrons	Fabaceae		t/c	8	20%
Azadirachta indica	Meliaceae	Kohomba	t/c	14	10%
Ficus benghalensis	Moraceae	Maha-Nuga	t/c	2	4%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	3	2%

Photographs of the wind turbine location -37

Wind Turbine Location 37

Wind Turbine Location 37

	
Wind Turbine Location 37	Wind Turbine Location 37

Table 38. Plant family, species and local name of plants recorded in Wind Turbine location-38, Uvari (Coordinates: 9.043312 79.815996).

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Acanthaceae	*Asystasia gangetica*	Puruk	h/u	In	
Apocynaceae	*Oxystelma esculentum*	Usepale	c/c	In	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Cocos nucifera*	Pol	t/i	I	
Asteraceae	*Vernonia cinerea*	Monorakudumbiya	h/h	In	
Commelinaceae	*Commelina petersii*		h/g	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/c	In	
Cucurbitaceae	*Momordica dioica*	Mal-thumba, Thumba karavila	c/c	In	
Cyperaceae	*Cyperus arenarius*	Mudu-kalanduru	g/g	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	t/u	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Fabaceae	*Vigna trilobata*	Bin-me	h/g	In	NT
Fabaceae	*Crotalaria retusa*	Kaha-Andanahiriya	h/g	In	
Fabaceae	*Dichostachys cinerea*	Katu andara	s/u-c	In	
Gentianaceae	*Enicostema axillare*		h/g	In	
Lamiaceae	*Gmelina asiatica*	Demata	s/c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Ochnaceae	*Ochna obtusata*	Mal-Kera	t/u	In	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	h/g	In	
Phyllanthaceae	*Sauropus bacciformis*	Eth-pitawakka	h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u	In	

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u	In	
Rhamnaceae	*Ziziphus mauritiana*	Dabara	t/c	In	
Rubiaceae	*Oldenlandia biflora*	Heen kaududala	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rubiaceae	*Pavetta indica*		s/u	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/c	In	
Salicaceae	*Flacourtia indica*	Uguressa	s/u	I	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Verbenaceae	*Stachytarpheta urticaefolia*	Nil-nakuta	h/u	I	

Table 38.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location – 38

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	21	
Cocos nucifera	Arecaceae	Pol	t/e	42	
Acacia planifrons	Fabaceae		t/c	1	3%
Gmelina asiatica	Lamiaceae	Demata	t/u-c	2	1%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	6	5%
Syzygium cumini	Myrtaceae	Ma-Dan	t/c	1	1%

Photographs of the wind turbine location -38

Wind Turbine Location 38

Wind Turbine Location 38

Wind Turbine Location 38

Wind Turbine Location 38

Table 39. Plant family, species and local name of plants recorded in Wind Turbine location-39, Uvari (Coordinates:9.045535 79.812668).

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Amaranthaceae	*Aerva lanata*	Polpala	h/g	In	
Acanthaceae	*Asystasia gangetica*	Puruk	h/u-c	In	
Apocynaceae	*Carissa spinarum*	Heen-Karamba	s/u/c	In	
Apocynaceae	*Calotropis gigantea*	Wara	s/u-c	In	
Apocynaceae	*Tylophora indica*	Mudu-bin-nuga	c/u	In	
Arecaceae	*Borassus flabellifer*	Thal	t/i	I	
Arecaceae	*Cocos nucifera*	Pol	t/i	I	
Arecaceae	*Phonix pusilla*	Wal indi	t/u	In	
Asparagaceae	*Asparagus racemosus*	Heen hathavariya	c/c	In	
Celastraceae	*Pleurostylia opposita*	Panakka	t/u-c	In	
Connvolvulaceae	*Ipomoea violacea*		c/c	In	
Cucurbitaceae	*Coccinia grandis*	Kowakka	c/u-c	In	
Ebenaceae	*Diospyros vera*	Kaluhabaraliya	t/u-c	In	
Fabaceae	*Acacia planifrons*		t/c	In	
Lamiaceae	*Gmelina asiatica*	Demata	s/u-c	In	
Lamiaceae	*Premna obtusifolia*	Maha-midi	s/c	In	
Lauraceae	*Cassytha filiformis*		c/c	In	
Malvaceae	*Grewia orientalis*	Wel-keliya	s/u-c	In	
Meliaceae	*Azadirachta indica*	Kohomba	t/c	I	
Myrtaceae	*Syzygium cumini*	Ma-Dan	t/c	In	
Ochnaceae	*Ochna obtusata*	Mal-Kera	t/u	In	
Pandanaceae	*Pandanus odorifer*	Mudu keyiya	s/c	In	
Pedaliaceae	*Pedalium murex*	Et-Nerenchi	h/g	In	
Phyllanthaceae	*Phyllanthus maderaspatensis*		h/g	In	
Phyllanthaceae	*Breynia vitis-idaea*	Gas-kayila	s/u-c	In	
Phyllanthaceae	*Flueggea leucopyrus*	Heen Katu pila	s/u-c	In	
Putranjiavaceae	*Drypetes sepiaria*	Wira	t/c	In	
Rhamnaceae	*Scutia myrtina*		s/u	In	
Rhamnaceae	*Ziziphus mauritiana*	Dabara	t/u-c	In	

Family	Species	Sinhala Name	Life form/strata	Taxonomic Status	Conservation Status
Rubiaceae	*Oldenlandia umbellata*	Saummal	h/g	In	
Rubiaceae	*Spermacoce hispida*	Hin-geta-kola	h/g	In	
Rutaceae	*Toddalia asiatica*	Kudu-Miris	c/u-c	In	
Salvadoraceae	*Azima tetracantha*	Wel dehi	s/u	In	
Sapindaceae	*Dodanaea viscosa*	Et-Werella	s/u	In	
Sapotaceae	*Manilkara hexandra*	Palu	t/c	In	VU
Vitaceae	*Cissus quadrangularis*	Heeressa	c/u-c	In	

Table 39.1. Number of trees/ shrubs (or percentage of the area covered by vegetation) found in the hardstand area of Wind Turbine location – 39

Species	Family	Common Name	Life form/strata	Number of Individuals	Percentage of hardstand area covered by vegetation
Borassus flabellifer	Arecaceae	Thal	t/e	3	
Cocos nucifera	Arecaceae	Pol	t/e	1	
Acacia planifrons	Fabaceae		t/c	4	3%
Azadirachta indica	Meliaceae	Kohomba	t/c	3	2%
Premna obtusifolia	Lamiaceae	Maha-midi	s/u-c	10	8%
Pandanus odorifer	Pandanaceae	Mudu keyiya	s/c	1	2%
Syzygium cumini	Myrtaceae	Ma-Dan	t/c	6	5%

Photographs of the wind turbine location -39

Wind Turbine Location 39

Wind Turbine Location 39

Wind Turbine Location 39

Wind Turbine Location 39

Appendix 9

Report on Provisions for Future Potential of Tourism Activities in Mannar Island

Mannar Wind Power Project

Ceylon Electricity Board

June 2016

(edited for EIA in May 2017)

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Provisions for Future Potential of Tourism Activities in Mannar

1.0 Introduction

The project area along the southern coast of Mannar island has been identified by the Tourism Authority of Sri Lanka as a potential site for future tourist attraction and stressed on keeping reservation area at least 200 m from permanent vegetation line for the future tourism related activities. As per the present micro siting of wind power plant, WTGS are positioned 130~150 m off the shore line considering the flowing factors;

During the project approval process, the main project approving agency CCD (Coast Conservation Department) consulted key stakeholders including Tourism Authority of Sri Lanka, Department of Wildlife. During the final project approving meeting due consideration was given to issues such as promotion of wildlife tourism, allowing unobstructed access to beach users, appearance of the wind farm etc. After carefully considering the potential impacts, final approval for project was granted subject to the following:

a. The CCD after considering the recommendations given by the Department of Wildlife sanctions the entire North West section of the Wind Farm scrapping number of turbine footprints since the critical habitat of the island are concentrated North West corner of the Island. It is to be noted that the North-Western section of the Mannar Island has been identified by the Department of Wildlife to promote wildlife based tourism. In view of this, Department of Wildlife requested CEB to support the promotion of wildlife based tourism activities as a CSR project by way of facilitating the setting up of proposed Bird Monitoring Center. CEB will support this venture through necessary financial support.

b. The Wind Turbines in the proposed Wind Farm are free standing turbines without fencing or any other obstruction. This is envisaged in the Wind Farm design with the recommendation of CCD to facilitate unrestricted access to the beach front for fishing community, local/foreign tourists and any other visitors.

1.1 Design Considerations

- As per the wind resource distribution statistics the most favorable wind is available closer to the sea shore within 100 m band from the shore. However, considering the factors such as Coastal Setback, Minimal disturbance to fishing community and prevention of turbine foundations from sea erosion, the WTG line was moved about 60~70 m further resulting 150m away from the permanent vegetation line.

- If the WTG line is set up further inland beyond 200m, the energy extraction from both monsoonal winds specifically from NE monsoon get reduced typically by 18% due to the increase surface roughness factors. Therefore 11 number of additional WTGs would be required for generation of equivalent amount of energy which is not possible with the existing scenario.

- Moreover, disturbance to the villager's properties, Insufficient distance to attenuate noise generations at the human settlements and increased number of valuable Palmira & Coconut tree removal would be required causing increased damages to the properties and unfair perception among the village community about the project.

1.2 Mitigation measures for the concerns of Sri Lanka Tourism Authority.

- Giving due considerations to the interests of Sri Lanka Tourism Authority CEB decided to abandon 6 WTG locations (now within Adam's Bridge National Park) which resulting 2.5 km long no WTG zone that could be reserved for future tourist recreation area.

  The 6 WTG positions located far most North-Western end closer to the Mud-Flats had been selected as per the preferences of Department of Wild Life Conservation and the Bird loving tourists too. Certainly, this area is closer to the recently declared Adams Bridge National Park and may be the area where most probable tourist attraction area along the southern coast.

- At the initial stage itself, considering the provisions for tourism expansion adjacent to the only tourist resort along the southern coast of Mannar island, the Shell Coast Resort, an 850 m wide stretch was kept as no WTG zone by omitting one turbine locations.

  The gap between the two turbines (WTG 10& 11 according to the final layout) is approximately 750m. These two turbines (WTG 10 &11) which are either side of the Shell Coast will be constrained in operation to meet the applicable noise limits if required. The gap between WTG 10 & 11 was increased to 750m by revising the originally proposed layout (removing one turbine) in order to keep sufficient distance to Tourist resort.

- Furthermore, CEB identified that the existing topography of another two WTG locations may facilitate establishing the particular locations 200m far from the permanent vegetation line without losing much of the energy generation and affections to the villagers' properties. Such locations can be shown to the representatives of Sri Lanka Tourism Authority to comment on and for the recommendations.

If the Tourist Authority may submit tourism development plan for the Mannar region and the detailed statistics of tourist arrivals for the Mannar area specifically the southern coast of Mannar Island, it will be easier for CEB to optimize the detail designs of Wind Park by addressing and harmonizing the concerns of both Wild Life Authorities and Tourist Authorities.

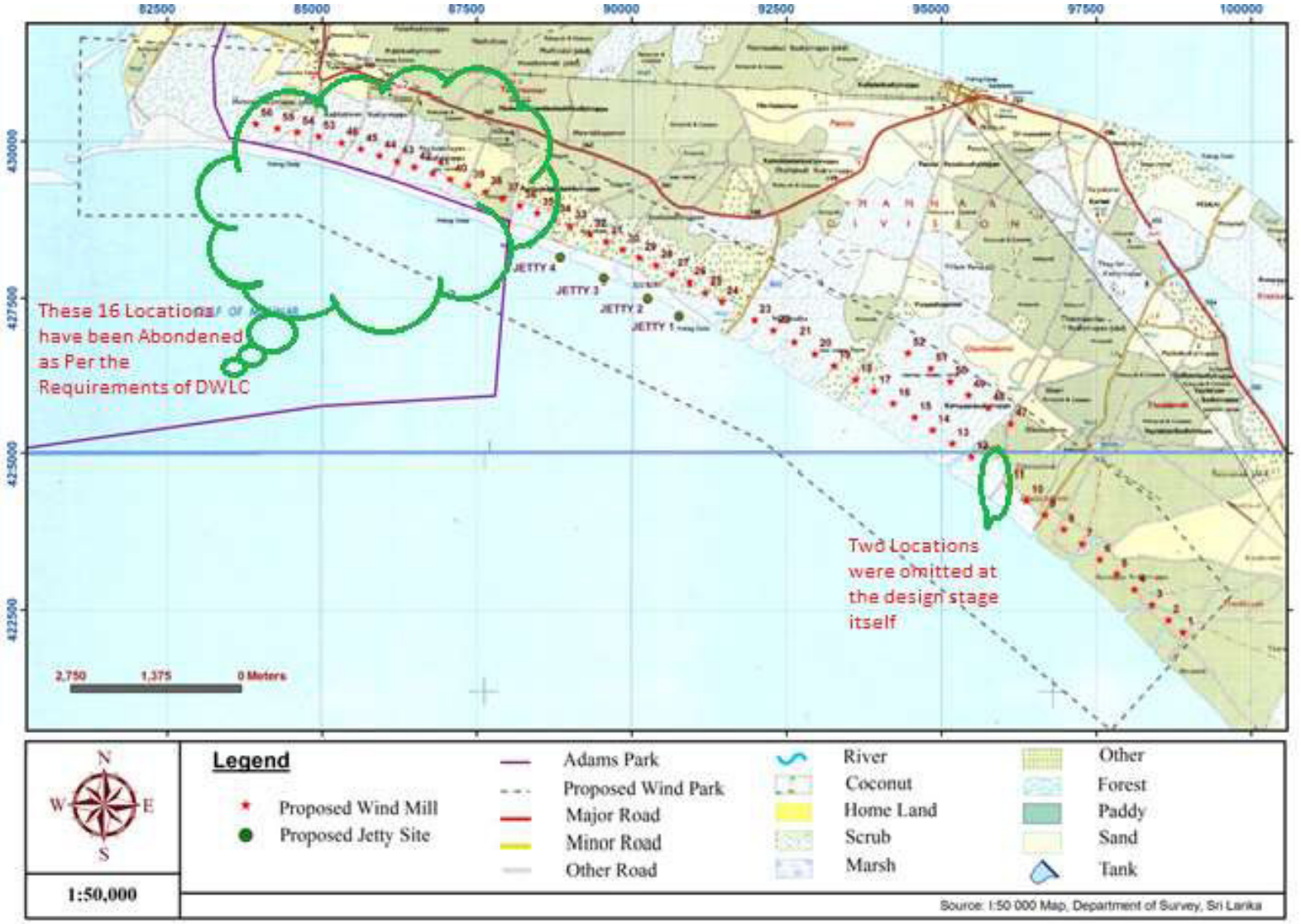

Fig 1.1 Map showing the removed WTG Locations by CEB for Tourism Development

1.3 Existing Environment

The area demarcated for 100 MW wind power plant is having more than 20 fishing camps and an ongoing construction of fish meal factory and hence the probability of tourist visiting may be minimal.

1.4 Alternative sites for Sri Lanka Tourism Authority.

It has been observed that the following beach areas may have better tourism potential than the Wind power plant site with a reasonable justification.

1. From South Bar beach extend via Thalupadu up to Thoddaweli *(6.5 km long beach)* which is situated outside the project area. The famous Keeri Beach which is popular among the community even at present itself fallen within this stretch of South Eastern Coast of Mannar Island.

2. From Erukalampiddy up to Manthai *(7.5 km long beach)* situated along the North-Eastern coast of Mannar island.

3. From Thalaimannar Pier up to Old pier at Southern coast at the North-Western Boundaries *(9.0 km long beach)* adjacent to Mud flats and archeological monuments.

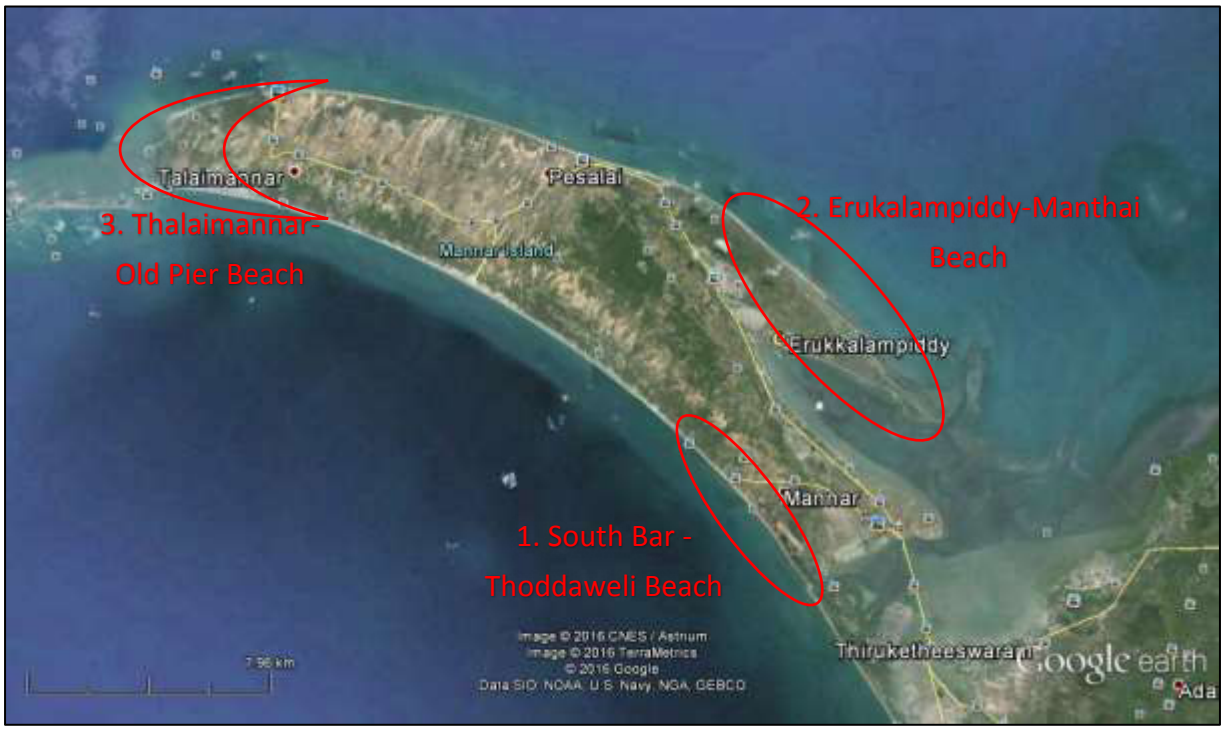

Fig 1.2 Map showing the alternative locations of Tourism Potential

Currently, Shell coast Resort and other infrastructures are available and hence the tourists will come. However, these beaches also correlate almost perfectly with critical habitats of the birds and therefore there is a need to avoid tourism infrastructure or disturbance in areas of critical habitat which can be addressed through the BMP and tourism authority through consultation. In order, that the amenity be safeguarded CEB will address issues related to critical habitat and the Tourism Authority will be consulted in future developments in the Mannar region.

1.5 Conclusion

From the conceptual stage itself, one of the major concerns of CEB is to benchmark green energy concepts to our national plans and we are certain that the blessings of people including the local community and the tourists for such a project is the utmost importance.

Hence, CEB shall not restrict any movements of the people including local community, fishing communities and bird lovers & other tourists in the vicinity of project structures and the project access roads so that all can entertain the improved infrastructure facilities as they wish.

RMA
Energy Consultants

entura
Hydro Tasmania

ACTION PLAN

Wind power development in the Mannar region

30 August 2017

Prepared by Hydro-Electric Corporation
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Document title	Action Plan
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Revision 1

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Executive summary

This report provides an update of the estimated total potential wind farm capacity in the Mannar District of Sri Lanka, and proposes an Action Plan that could be implemented to achieve future wind power development, beyond the 100 MW project currently being developed by the Ceylon Electricity Board (CEB).

Mannar district wind power potential

Without considering key social and environmental impacts, it is estimated that a total wind project capacity of up to 200 MW is potentially available for development on Mannar Island, in addition to the current 100 MW project. This upper limit estimate is based on the following obvious constraints and key assumptions:

- The Adam's Bridge National Park and Vankalai bird sanctuary are to be avoided
- A buffer of 600 m between wind turbines and permanent settlements is necessary
- A large future wind turbine size of 4 to 5 MW, and a 130 to 140 m rotor is assumed. A smaller wind turbine size (e.g. current 3 to 3.5 MW wind turbines such as proposed for the current 100 MW project) will result in a lower maximum capacity.

The feasibility of up to 200 MW on Mannar Island will depend significantly on factors that have not been addressed by this report, namely:

- Environmental sensitivities regarding the proximity to Adam's Bridge National Park and Vankalai bird sanctuary, and the Northern coastline of Mannar Island (a 130 m setback from the coastline has been assumed)
- Environmental and social sensitivities regarding vegetation clearance
- Environmental sensitivities regarding impacts on bird life. In particular, statements regarding the minimal impact of the first 100 MW, may not be applicable to further development inland (the cumulative impact on migrating birds)
- Whether there are communications paths (e.g. Naval) that will be affected and necessitate the removal of wind turbine locations
- Any new developments and dwellings, or exclusion zones
- Land acquisition activities
- Community attitudes that form on the basis of the first 100 MW.

Given these likely constraints, it should not be assumed that any additional capacity is feasible on Mannar Island without further study and consultation with key stakeholders.

This estimated maximum capacity of 300 MW on Mannar Island is consistent with the wind development master plan completed in 2014 by the Government of Sri Lanka, and CEB's plans for transmission infrastructure in the region. However a critical difference based on our analysis, is the significantly reduced land area identified as potentially suitable for development, and the greater size of wind turbines that will be required to achieve a 300 MW capacity.

The Silavathurai area in the south of the Mannar District was previously identified in the master plan as an area with potential for 75 MW of wind development. It was noted that land-related issues and human settlement in Silavathurai area was potentially a limiting factor. Based on recent discussions with the Urban Development Authority on economic and social development plans in the region, and the small parcels of agricultural land between villages, we conclude that large scale wind development in this area is unlikely.

Action Plan

The key activities identified as part of the Action Plan for developing the potential on Mannar Island include the following:

- Addressing and managing environmental and stakeholder issues and the cumulative impact should be considered a very high priority for future wind power development
- An improved wind measurement network should be developed, initially through a small number of tall and high quality wind monitoring masts, coupled with relocatable remote sensing units (lidar or sodar).
- It is recommended that lessons from overseas are applied to develop alternative methods for land acquisition in Sri Lanka, such as 'option to lease' agreements that encourage early buy-in from landowners. It is highly recommended that CEB takes early steps to secure land (including 'buffer zones') for the development of further potential projects on Mannar Island.
- It is proposed that CEB monitors, evaluates and learns from the impacts of the current 100 MW project, the first of this size in Sri Lanka, including the plant's technical performance, impacts on livelihoods (positive and negative), noise and shadow flicker impacts, bird mortality rate and overall perception of the project by the local community
- It is proposed that CEB monitors and evaluates any network intermittency issues that result from the current 100 MW project
- It is proposed that CEB assesses the performance of the wind power forecasting system to be supplied as part of the current 100 MW project
- Landing of wind turbine components on Mannar Island via barge is feasible, however further engagement with the Government of Sri Lanka and the Navy should be considered, leading to a more permanent pier solution for landing of large wind turbine components.
- It is proposed that the Government takes early action to draft renewable energy and wind energy specific standards into existing national regulatory guidelines to provide a more certain regulatory environment for project developers, and other stakeholders.
- It is recommended that action is taken to prevent the situation where new developments (residential, commercial or industrial) hinder wind project development even after an area has been declared a wind development zone.

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1. Introduction

In early 2014, the Government of Sri Lanka, with assistance from the Asian Development Bank (ADB), prepared a master plan for wind power development in the Mannar region. As Phase I of this master plan, the Ceylon Electricity Board (CEB) is currently developing a 100 MW wind power plant sited along the southern coast of the Mannar Island. According to the master plan the total Mannar District (Mannar Island and the mainland coastal stretch extending southwards) wind potential was tentatively estimated as 375 MW.

Entura, in association with Resource Management Associates (Pvt) Limited, has been engaged by the ADB under a Project Preparatory Technical Assistance project. The main focus of the engagement is on CEB's 100 MW wind power project currently under development, termed Phase I of the technical assistance, as detailed in the Inception report [1].

The purpose of Phase II, this report, is to present an 'Action Plan' that highlights some of the key issues relating to the development of the remaining wind power potential in Mannar. The main outputs of this report are:

- Assessment of wind power potential in the Mannar region
- Proposed activities of the Action Plan

As wind power development is steadily expanding in Sri Lanka, it seems necessary to streamline the future project development process so as to harmonise it with the developments taking place in other sectors and the power sector in particular. This action plan provides recommended actions towards meeting this objective.

Planning is a dynamic process that has to track the changing circumstances in the economy. It is hoped that this action plan will be reviewed, discussed and refined by the relevant stakeholder institutions who will take it forward as a constantly evolving plan.

Finally, the report also includes an introduction to the concept of offshore wind farm development in Sri Lanka.

1.1 Limitations

The feasibility of further development on Mannar Island depends significantly on factors that have not been addressed by this report, namely:

- Environmental sensitivities regarding the proximity to Adam's Bridge National Park and Vankalai bird sanctuary, and the Northern coastline of Mannar Island
- Environmental and social sensitivities regarding vegetation clearance
- Environmental sensitivities regarding impacts on bird life
- Whether there are communications paths (potentially Naval) that will be affected and necessitate the removal of wind turbine locations
- The individual capacity of wind turbines that are selected for the project

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2. Background

2.1 Mannar district description

The Mannar district is located in the north-western part of Sri Lanka. It is bordered to the west by the Gulf of Mannar, to the north by Kilinochchi District, to the south by Wilpattu National Park and to the east by Anuradhapura (as shown in Figure 2.1). The district covers 2,002 km^2 of land area and has a coastline of 222 km (including lagoons), a fresh water area of 4,867 ha and a brackish water area of 3,828 ha. The land area is relatively flat and sits at low elevations but the terrain is gently undulating towards the interior.

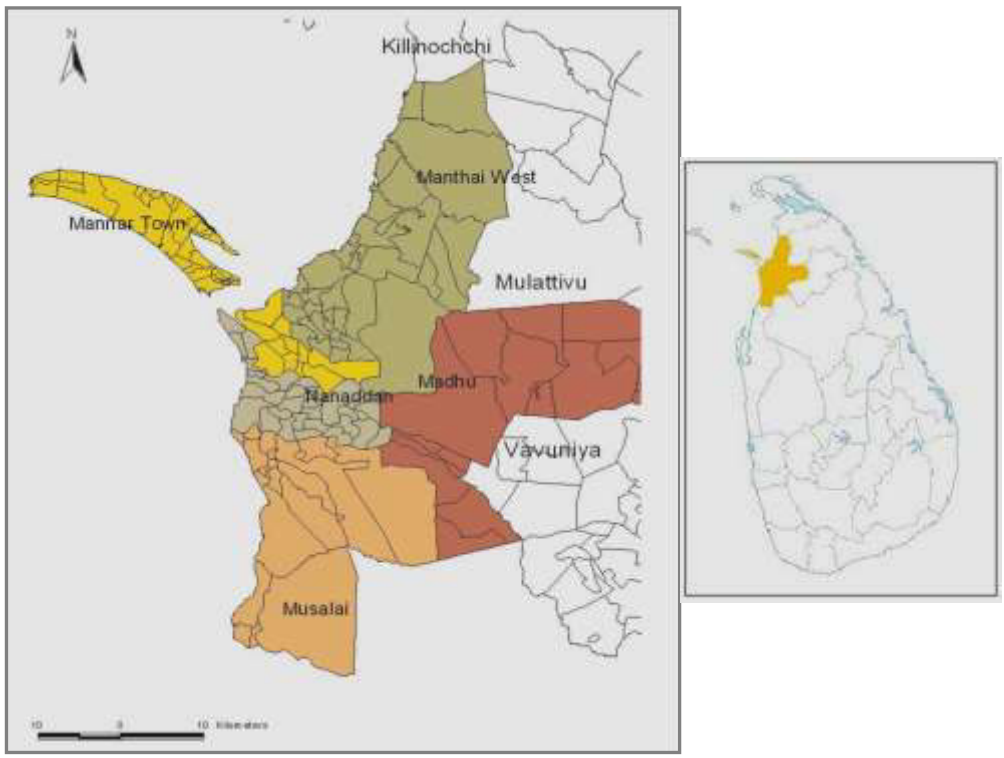

Figure 2.1: Geography of the Mannar district

Annual rainfall in the western part of the district, including Mannar Island is less than 1000 mm while in the rest of the district it is between 1000-1250 mm. The area experiences heavy rains from October to December (during the north-east monsoon). During the remaining months the rainfall is very low.

Mannar is a sparsely populated district with a population density of 50 per sq.km. Of the total population of nearly 100,000 people, almost 50% are residing on Mannar Island which accounts for only 10% of the total land area of the district. Hence, parts of Mannar Island are relatively crowded with an average population density of about 240 persons per sq.km.

The land use pattern of the coastal areas of Mannar District varies across the region. The dominant land uses in the district are forest, barren land, scrubland, paddy, mixed crops, home garden and

built-up areas. Other habitats include coastal types such as mangroves, salt marsh, sand dunes and beaches as well as inter tidal habitats including coral reef, algal communities and sea grass meadows.

Southwest monsoon winds coming from the Arabian Sea from May to September accelerate through the Gulf of Mannar which lies in the 'valley' between the Western Ghats mountain range of India and the Central Massif of Sri Lanka. The Island is geographically oriented that it is well exposed to these winds – both the southwest winds and northeast winds coming from the Bay of Bengal in northern winter. As the Mannar Island is topographically flat, monsoon winds sweep across the island without much spatial variation in the strength of winds. Mannar Island is rated as one of the highest and most consistent wind sites in Sri Lanka.

Floristically the Mannar Island and the mainland belong to the 'Coastal and Marine belt' and 'Dry and Arid Lowlands' floristic regions of the country. The typical natural climax vegetation types found in these zones are marine, mangroves, salt marsh, sand dunes, strand vegetation and tropical dry-mixed evergreen forests, tropical thorn forest, and scrublands.

Mannar Island and the adjacent areas in the mainland are home to a considerably rich fauna, especially birds. Its various coastal habitats including the lagoons, mud flats and salt marshes are highly important as feeding grounds for many migrant birds that visit Sri Lanka during the winter migratory period. As the island is located in the migratory path of these birds, it has an additional importance for them.

2.2 Previous wind resource studies

The presence of strong wind resources in the Mannar region was historically realised by CEB in the wake of detailed wind studies carried out in the Kalpitiya peninsula that lies in the same wind belt. In order to assess this potential in detail, CEB installed a 40 m high wind mast in Nadukkuda[1] but was abandoned in 2002 due to the then prevailing civil conflict in the region. The brief set of data, nevertheless proved that Mannar was among the best wind sites in Sri Lanka. The wind atlas prepared by the National Renewable Energy Laboratory (NREL) in the US in 2003 (Figure 2.2) further supported this assessment and rated Mannar Island's wind potential as "Excellent" with a modelled annual average wind speed in the range of 7.2 – 8.0 m/s.

The Sri Lanka Sustainable Energy Authority (SLSEA) expanded wind resource studied in the Mannar region in 2011 by installing a network of 50 m high wind masts in Nadukkuda, Nanattan and Silavathurai. This was followed by a detailed wind study implemented by SLSEA under the TA:7837 SRI - Part 2: Wind and Solar Resource Assessment[2][2]. The main objective of the study was to perform a long-term wind field calculation / simulation for the height 80 m above ground level covering the entire Mannar Island.

[1] Situated roughly half-way between Talaimannar and Thalvapadu

[2] This study was carried out jointly by Resource Management Associates in partnership with Geo-Net Umwelt consulting in Hannover, Germany.

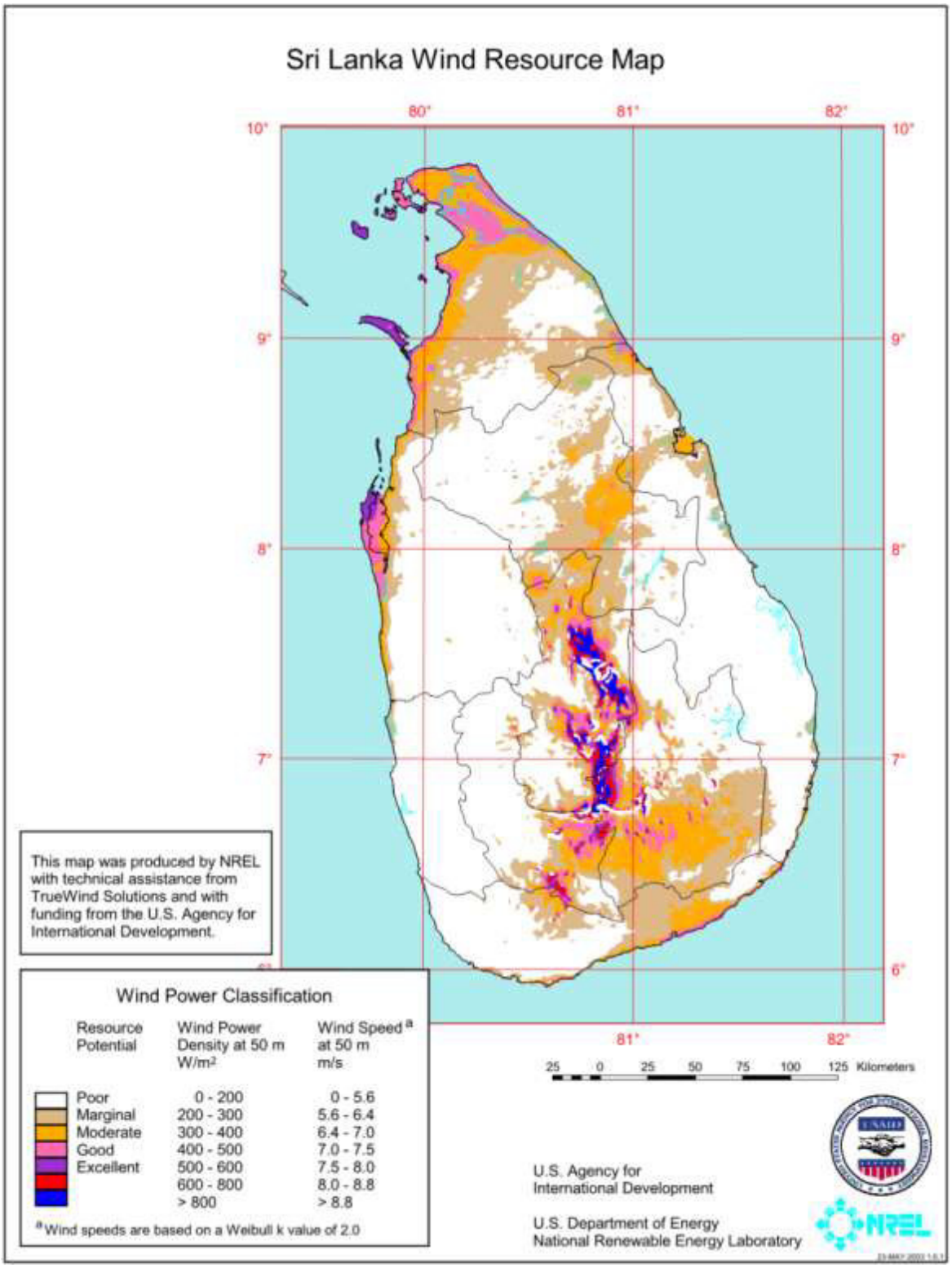

Figure 2.2: Sri Lanka wind atlas prepared by NREL in 2003

This study was carried out using the 3-dimensional meso-scale flow and dispersion model FITNAH 3D[3]. One year of high-quality on-site wind measurements, quality checked reanalysis products and observed wind data at a met-station were used in this study.

The model area for the calculation of the wind field had size 35 km x 35 km (Mannar Island). The single grid cell mesh size was 50 m x 50 m. The land use structures were obtained by digitised topographical maps and the information from on-site inspection. The relief structure was obtained by the Shuttle Radar Topographic Mission (SRTM) elevation model of the NASA space shuttle mission 2000 (USGS 2004). The wind map that was developed is replicated in Figure 2.3.

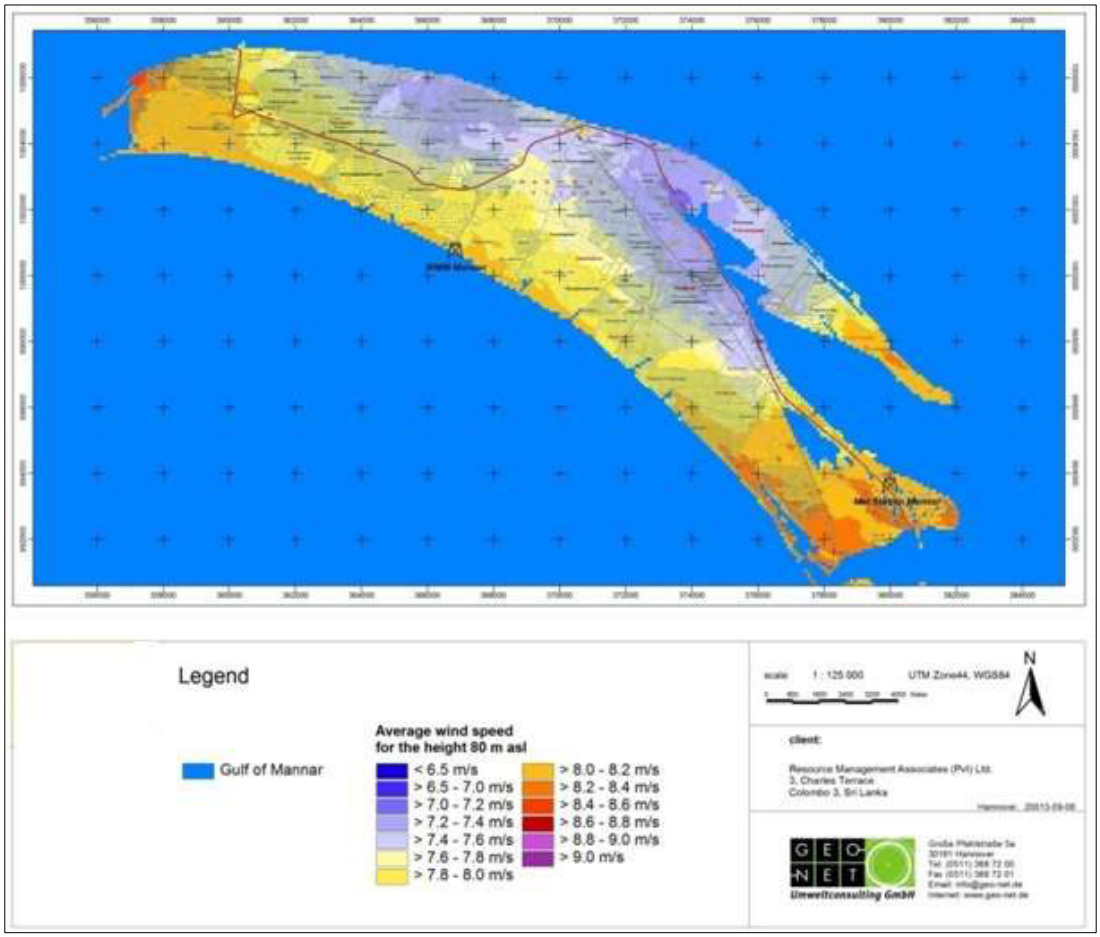

Figure 2.3: Simulated Wind Field in the Mannar Island at 80 m AGL[2] as per 2011 study

[3]*Flow over Irregular Terrain with Natural and Anthropogenic Heat Sources* (FITNAH), developed by Prof.Dr. G. Groß was used for wind field modelling.

2.3 Previous plans for wind project development

The SLSEA first proposed the idea of developing *Energy Parks* for wind and solar energy development in 2009. The objective of this concept was to enable planned development of these energy sources which could bring benefits both to the state and private developers. Under this concept, the government carries out the necessary resource assessment studies, delineates high-potential regions for phased development, acquires land rights (through outright purchase or lease agreement), obtains environmental and other statutory clearances and builds the necessary infrastructure facilities. The government will then invite (through a competitive bidding process) prospective project developers to build their power plants within the declared energy parks.

The *Energy Parks* initiative was supported by ADB under Part 2 of the TA-8167 SRI: Capacity Building for Clean Power Development (Contract No.104396 – S52072) by developing a Wind Development Master Plan (WDMP) for the Mannar District[3]. Key outputs of the master plan study were:

- Selection of fifteen land blocks, each capable of supporting 25 MW of installed wind capacity (Figure 2.4). The following land uses were excluded in the selection process due to probable adverse impacts from wind development in these areas:
    - *Home garden* – this included village settlements (closely spaced houses clustered within a village), dispersed houses and small scale cultivations
    - *Built-up areas* – Mannar Town and small townships
    - *Wildlife sanctuary / forest* – mainly the part of Wilpattu sanctuary extending to the Mannar district
    - *Environmentally sensitive areas* – mainly the eastern edge of the island that is interspersed with tracts of marshlands inhabited by migratory birds

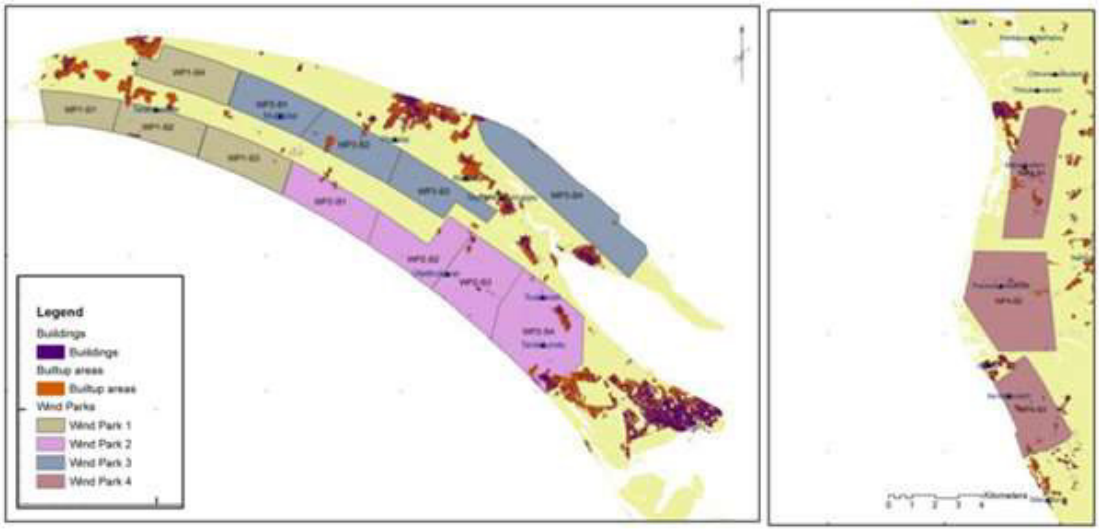

Figure 2.4: Land block arrangement for wind power development as proposed in the master plan. Each rectangle corresponds to a 25 MW capacity. Colours refer to wind parks comprising 4x25MW capacity in the mainland and 3x25 MW in the mainland

- Potential land route options for transporting wind turbine equipment (unit capacity was limited to 2 MW) to the selected sites were identified in a preliminary manner. Recommendations were made to carry out detailed studies on the marine transport options.
- Preliminary design of a power transmission network connecting the selected wind project sites to the grid substation being built in Mannar was developed
- Options for business models (and related contract documents) for private sector participation in wind power development

2.4 Constraints to wind project development

The wind power development master plan had identified potential sites to develop 375 MW of wind capacity in the Mannar district (300 MW on the Island and 75 MW along the coastal belt leading to Silavathurai). The selection of potential sites was carried out giving due consideration to social and environmental issues, though at a preliminary level. However, since finalising the WDMP in 2014, the Department of Wildlife Conservation has declared additional areas in the western edge of the Mannar Island as a reservation thus limiting a sizeable part of the windy southern coastal belt from wind power development. This curtailed the available land for CEB's 100 MW wind project and forced them to alter the original plant layout.

Besides this, CEB is also facing several constraints in project development, mostly arising from estimated wind turbine noise levels and perceived impacts on bird mortality rates. The situation has been aggravated by the emergence of other economic activities (hotels, industries) within the project area causing further curtailment of land availability. This highlights the need to seek close collaboration with other stakeholders in planning wind development on a regional scale.

Further, social and regulatory attitudes towards wind development in the Sri Lankan context differ in comparison to international guidelines with respect to wind development. Specifically, international guidelines (as applied in localities such as Europe, North America, and Australia) require significant setbacks between wind turbines and existing surrounding residential, institutional, commercial, and industrial structures in the vicinity of the wind farm. These setbacks are generally for reasons of amenity, in relation to wind turbine noise output, and shadow flicker.

It is noted that previous wind developments in Sri Lanka have involved placement of wind turbines in relatively close proximity to existing structures, at distances closer than international guidelines would generally allow.

3. Assessment of wind power potential

This section provides a revised assessment of wind power potential in the Mannar district based on current land uses.

The master plan for wind development in Mannar prepared in 2014 previously estimated the *developable* wind power potential in the district. It has been reported that several new areas of concern have emerged in relation to wind development in the Mannar region since the development of the master plan. Attempts to address these concerns, which are primarily converging on competing land uses, and social and environmental issues, were taken up with the Urban Development Authority (UDA) as part of this current investigation, with limited success.

3.1 Identification of land for future wind development

3.1.1 Competing land uses

The current 100 MW CEB wind project is experiencing difficulties associated with competing land use, despite being located in an area on Mannar Island that is relatively free of permanent settlements. Given these difficulties, it was decided that identification of potential wind development sites in the proposed action plan should be carried out after excluding areas that are earmarked for other development activities by the relevant stakeholder institutions. Accordingly, a request was sent to the Director of the Urban Development Authority (UDA) in the Northern Province seeking information on competing land uses. Even though this correspondence was followed up with two visits to the UDA office in Jaffna to discuss this matter, UDA failed to provide the requested information.

In the absence of information from UDA on the land identified for future development programmes in the Mannar district, the present action plan adopted the officially available land use information to prepare a map depicting land that might be potentially available for future wind farms.

3.1.2 Wind mapping

The long term wind resource estimate for Mannar Island has been updated based on wind speed and direction data from the 81.5 m Nadukkuda mast for the period June 2012 to August 2016. In a comparison with modelled synoptic data, and including an adjustment (mean of monthly means) to remove seasonal bias caused be incomplete years, this is estimated to represent the long term wind resource [4].

The value of this updated base wind map is limited, because no additional wind monitoring locations are available to improve the modelling of spatial variation relative to the original wind map produced by SLSEA for the master plan study. However the updated modelling does include updated roughness mapping due to field verification conducted by CEB on the actual land use in comparison to reported land uses by the Survey Department.

3.1.3 Constraints mapping

Land uses such as dwellings, village settlements, towns, home gardens (collectively classified as "built up areas"), and environmentally sensitive areas were excluded from the base map when identifying the land that may be potentially available for future wind farms. A buffer of 600 m was applied around the aforementioned exclusions to minimise the impact of noise output from wind turbines. A 100 m buffer was also applied to the road network to keep wind turbines away from roads to account for the topple distance (and potential shadow flicker and glint issues). A constraints map is shown in Figure 3.1.

Areas potentially available for locating future wind farms in the Mannar Island are shown in Figure 3.2.

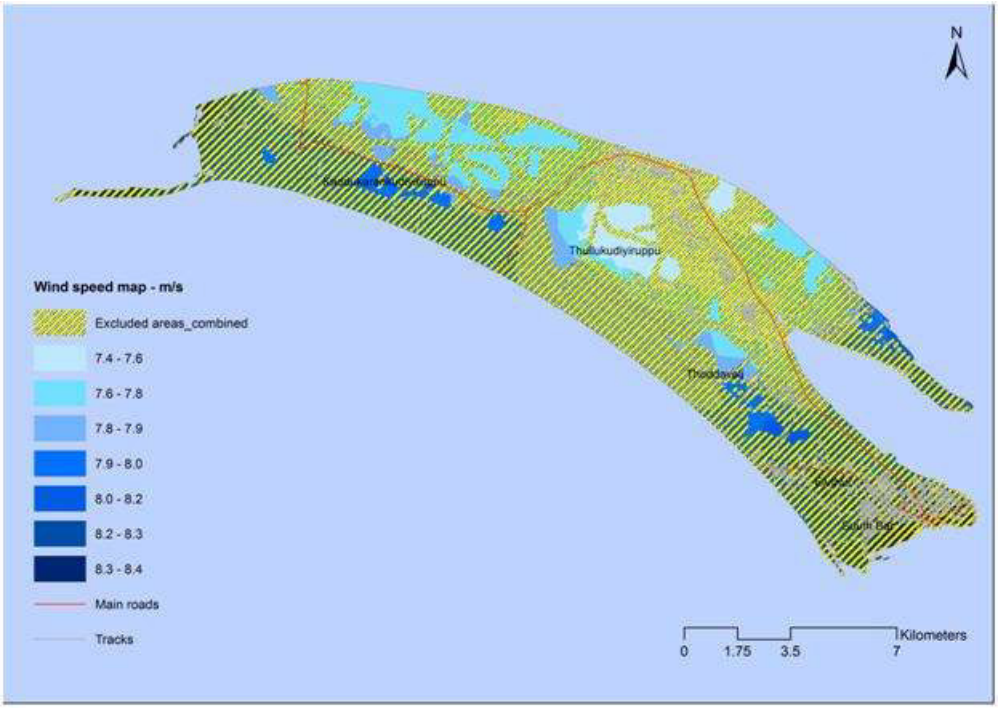

Figure 3.1: Map of land use exclusions in Mannar Island

Figure 3.2: Areas potentially available sites for future wind farm development in the Mannar Island (only blue areas inside the rectangles A & B)

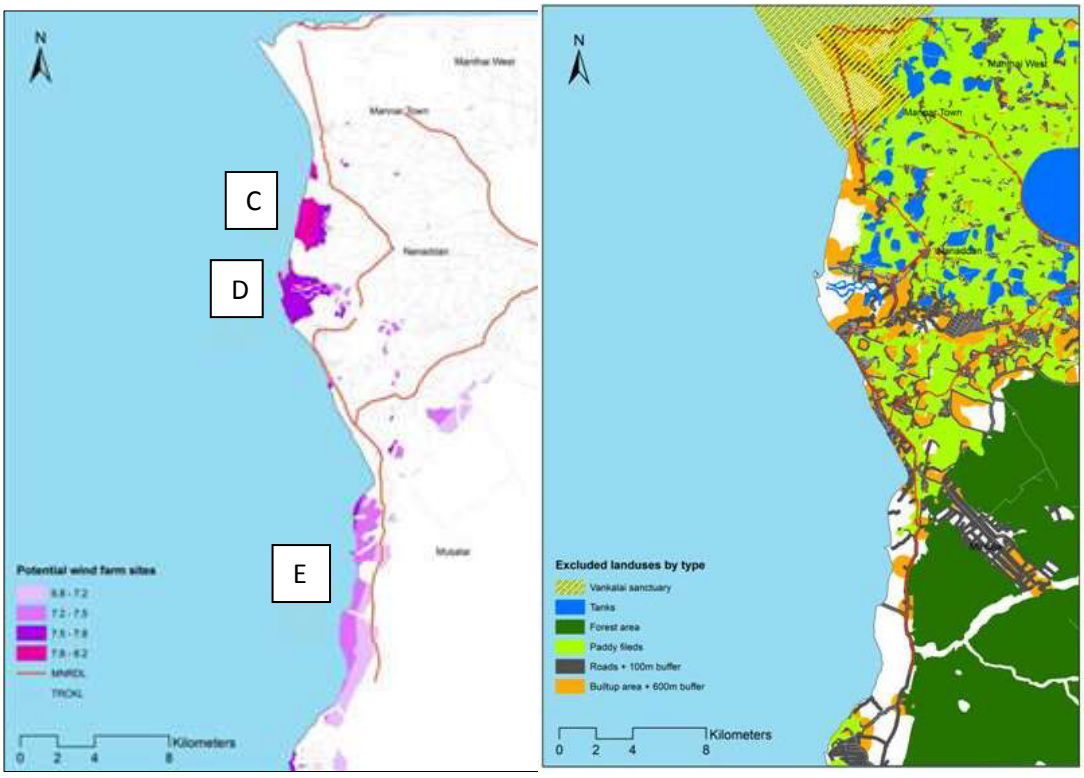

Figure 3.3: (a) Map of land use exclusions and (b) potential locations for wind farms – Silavathurai area

3.2 Developable wind power potential

For estimation of the wind power potential, indicative wind farm layouts were developed for each block of land that was selected as "potentially available". The layouts were based on spacing of approximately 3 rotor diameter x 7 rotor diameter (3D x 7D), for an assumed rotor diameter of 130 m to 140 m – a typical size of wind turbine that will be available from major suppliers in the near future. Estimated total wind power capacity that can be installed in these land blocks is based on a generator size of 4 MW, and is referred to as the 'developable wind power potential' (Table 3.1).

Even though the Survey Department's 1:50,000 maps do not show any dwellings in these areas, it is quite possible that isolated dwellings and home-gardens may be found in these areas. Such site-specific constraints including issues related to access and transportation were not considered in preparing these layouts. Buffers that envelop the roads were ignored from capacity estimation on the assumption that all or some of the minor roads could be re-routed to make way for a contiguous land block for a wind farm.

Smaller patches of developable wind farm areas were ignored from the analysis, though some of them may be able to support smaller wind farms in the region of 6-8 MW depending on localised siting considerations.

Sites A and B on Mannar Island are observed in aerial photographs to consist of tracts of land that are relatively free from existing infrastructure or inhabitants. Further, these locations are sufficiently close (5-10 km) to the proposed Nadukkuda substation that connects via a medium-voltage network that improves the possibility of being financially feasible.

Site C in Silavathurai area is observed to consist of coastal lagoons and agricultural area further inland. It is bordered by villages to the North, South and East. An estimated capacity of 20 MW is conceived for this area, however the lack of any transmission infrastructure will affect the viability.

Site D in Silavathurai area is drained by several rivulets during the north east monsoon season, and the terrain is likely unsuitable for construction of a wind farm, hence this capacity was ignored.

Site E stretches along the coastal fringe of the Wilpattu National Park, although some publicly available maps show the national park extending to the coastline. Regardless, the proximity of this narrow landmass to the national park is very likely to preclude large wind farm development, and hence site C too was excluded from the analysis.

Thus, the total developable wind power potential in the entire Mannar region is summarised by Table 3.1. It should be noted however, that feasibility stage investigations of future wind projects could influence this estimate.

Table 3.1: Estimated potential capacity at each location

Region	Potential capacity (MW)
Mannar Island – Site A	120
Mannar Island – Site B	80
Silavathurai area – Site C	Negligible
Silavathurai area – Site D	Negligible
Silavathurai area – Site E	Negligible

4. Proposed activities of the Action Plan

4.1 Environmental and stakeholder management

An extensive range of environmental studies have been completed as part of the 100 MW project. Development of further capacity on Mannar Island may be guided and facilitated by some of the studies already completed, however it is strongly recommended that CEB reviews the current status of environmental studies, and determine where gaps exist and what updates or new studies will be needed for future wind farm development given the cumulative impact of additional capacity.

Entura notes there are significant environmental sensitivities regarding the following:

- The proximity to Adam's Bridge National Park and Vankalai bird sanctuary, and the Northern coastline of Mannar Island
- Vegetation clearance
- Impacts on bird life. In particular, statements regarding the minimal impact of the first 100 MW, may not be applicable to further development inland (cumulative impact on migrating birds)

These environmental issues are closely linked to the stakeholder management process, including local residents and interested parties such as environmental Non-Government Organisations (NGOs).

Addressing and managing these environmental and stakeholder issues should be considered a very high priority for future wind power development on Mannar Island.

4.2 Improving the wind measurement network

Collection and analysis of high quality wind data is a fundamental prerequisite for wind power development. Currently, there is only one high-quality wind mast operating in the Mannar Island – situated on the southern coast in Nadukkuda. Data gathered from this four-year old wind mast was used for the design of the on-going CEB wind project. This data was used in wind flow modelling for estimating the spatial distribution of wind resources along the 15 km project site. Additional data sources would reduce the uncertainty in the wind resource estimate and improve the prospects of projects that later require financing. Locations further inland on Mannar Island will likely experience a slightly different wind climate due to surface roughness effects. Additional wind measurement locations are required to characterise the wind resource variation over Mannar Island. It is proposed that wind monitoring on the island is expanded to cover the 'project sites' referred to in section 5.3.

It is proposed that future wind monitoring initially include a small number of tall, high quality wind monitoring masts, coupled with the use of remote sensing units, such as Sodar or Lidar. Remote sensing units measure wind resource at multiple elevations above ground level. Wind speed is measured in three dimensions, which is usually converted to a horizontal wind speed, wind direction, and vertical wind speed (or inflow angle). Sodar operates by sending pulses of sound into the sky, and detecting the change in frequency (Doppler Effect) of the sound wave as it reflects back to the unit from the varying temperature structure within the atmosphere. Lidar operates by sending pulses

or beams of light into the sky, and detecting the change in frequency (Doppler Effect) of the backscatter of light reflected off naturally occurring aerosols (such as salt or dust) in the atmosphere.

Sodar data is primarily used for prospecting and feasibility studies, but is increasingly being accepted in bankable wind resource assessments and energy estimate. There is a strong consensus in the wind industry that lidar (in particular the Windcube and the ZephIR models) are fully proven technologies for standalone wind resource assessment in simple terrain. This is supported by independent reviews undertaken by DTU Wind Energy, Deutsche WindGuard, DNV-GL, ECN, and Ecofys[5][6][7].

The advantages of remote sensing over wind monitoring masts are significant. Overall, sodar and lidar result in wind monitoring programs that are safer, less costly, and depending on how they are used, can reduce wind resource uncertainty relative to fixed wind monitoring masts. Sodar and lidar can normally be installed without planning permission, enabling quicker deployment and a longer data record. They require less expertise to install, and can be deployed discretely during early stages of project investigation, without attracting public attention. Lidar and sodar is generally viewed as less hazardous to birds.

Sodar and lidar can be moved to different locations around a wind farm site, reducing uncertainty in the overall wind resource at a site. By correlating lidar or sodar data with a fixed reference mast, such as the Nadukkuda mast, measurements can be acquired for a short duration (e.g. 3 months) at a location of interest, and the unit can then be transported to another location of interest. The result substantially extends the spatial distribution of measurements with little penalty given a good correlation with the reference mast.

Sodar and lidar measure at multiple heights, generally up to about 200 m, with measurements at any possible hub height. Wind turbine hub heights are often higher than fixed mast measurements. Sodar and lidar can be removed from a site and relocated elsewhere should priorities change, and hence retain capital value.

In Entura's experience, the real and perceived limitations of sodar and lidar have progressively diminished, to the point where the benefits are overwhelming. Nonetheless, the following limitations require consideration.

- Data quality (project financing): Financiers, guided by their engineers, are necessarily cautious. Adoption of lidar and sodar for wind monitoring has first required a body of evidence to support their reliability and accuracy. ZephIR and Windcube lidar are now widely accepted as providing finance-grade wind data for large wind farm projects in non-complex terrain, without reference to wind monitoring mast data. Sodar is also being used extensively for finance-grade wind data for large wind farm developments, but most often with periodic deployment against a reference mast to demonstrate the accuracy. This is in alignment with guidelines established by organisations such as the International Energy Agency [8], Measnet [9] and consultants such as DNV [10].
- Data availability: Data availability from sodar and lidar is impacted by atmospheric conditions. Therefore, there is some risk that for a new site the data availability will be lower than expected. In particular, rain can be a problem for sodar. This risk is mitigated if there is a reasonable reference wind data source from which correlated data can be used to fill gaps. Further, analysis of the data availability and any bias will ultimately inform uncertainty estimates for a system, when assessed over a number of sites. A robust process for this will be included in the revised IEC 61400-12 standard. Data availability may also be impacted by reflections from nearby obstacles, if the unit is placed close to obstacles such as trees, buildings, wind turbines or monitoring masts.

- Complex terrain: In complex or forested terrain, there are differences between lidar (and sodar) and cup anemometer measurements. This is because lidar and sodar sample wind speed across a volume, while anemometers are a single point measurement. And in complex terrain, there may be variations in wind across the volume of measurement. In summary, there is additional uncertainty in lidar and sodar measurements in complex terrain, however given the terrain under consideration for wind development in Sri Lanka is not complex, this is not an important consideration.
- Turbulence measurements: Wind turbines are usually designed to meet Category A, B or C turbulence levels, as defined by the IEC 61400-1 standard. When assessing the suitability of a wind turbine for a given site, the measured turbulence intensity is compared back to these standards. There are not significant limitations regarding lidar turbulence measurements, although some caution during interpretation of results is required. In our experience sodar turbulence measurements are not directly comparable with cup anemometer data, and there has been limited reporting on this issue. As such, determination of turbulence Category using sodar is currently problematic.
- Extreme wind speeds: Extreme wind speeds at a proposed wind farm site are characterised both in terms of maximum 10-min average wind speed, and maximum gust wind speed. The ability of lidar and sodar to measure extreme wind speed has not seen significant study. It is noted that 50 year extreme wind speed estimates for a wind farm project are subject to significant uncertainty, regardless of the wind monitoring technology used.
- Hub-height temperature measurements: Increasingly, temperature differentials between ground level and at higher elevations measured at a mast are being used to analyse the state of the atmosphere (stable, neutral, unstable) to refine flow modelling. This is not possible with lidar or sodar, and is a minor limitation. Also, hub height estimates of air density will need to be extrapolated from ground measurements of temperature, pressure and humidity.

For future projects in the Mannar region, it is proposed to use sodar – or where higher data quality is needed lidar – for all preliminary wind resource monitoring. Of particular importance are the inherent safety benefits, the ease and speed of installation, and the cost effectiveness in measuring wind resource at a large number of locations.

The limitations of sodar and lidar are not overly detrimental to preliminary wind resource assessment. However the following issues need to be considered:

- Are there local obstructions that will interfere with lidar or sodar measurements?
- For lidar, can power supply requirements be met?
- What is the likelihood that data availability will be lower than usual due to adverse atmospheric conditions (e.g. rain, low aerosol counts), or interference from other noise sources (e.g. frogs, insects)?
- What is the impact on the project if data availability is lower than expected?
- How can security of equipment be ensured when left in remote locations?
- Prior to the final investment decision, additional data from fixed wind monitoring masts is likely necessary.

4.3 A policy on land lease for wind projects

Wind farms are mostly located in rural areas. The population in these regions are mostly engaged in agriculture; either in commercial scale farming, subsistence cultivation or home gardening. In all three cases, the owners derive benefits from their land holdings either in cash or in kind depending on the type of agriculture that they adopt. For CEB's current 100 MW project, tourist facilities are increasingly impacting the development area.

Land acquisition has been a thorny issue in practically all wind projects built to date in Sri Lanka. This has turned out to be one of the most challenging pre-project activities of CEB's 100 MW wind project and would mostly likely remain so in future wind projects as well. It is therefore proposed that a policy be developed for land acquisition / leasing that would to lead to a win-win situation for the land owners and project developers. Implementation of a mutually beneficial land acquisition / leasing policy could reduce the project development period by a considerable margin.

Leasing land to 'host' a wind turbine is common elsewhere in the world. For example, compensation packages adopted for landowners hosting wind turbines can typically be structured in one of four ways: (a) one time lump sum payment, (b) fixed payment at scheduled intervals (i.e. a set amount per wind turbine per year); (c) royalty payments based on gross revenues (i.e. a certain percentage per year); or (d) combination of above payment methods.

Agreements for neighbours to the wind farm who are not actually hosting wind turbine locations are become increasingly common, and can help generate goodwill in the community.

A common arrangement internationally is an 'option to lease' agreement. During the project development phase landowners may enter into such an agreement with the project developer, allowing the developer to access the property to assess wind farm feasibility, with an option to move into a lease agreement at a later stage when the project is confirmed. Such agreements are usually binding on the landowner, but the developer may withdraw at any stage before construction commences. This provides the landowner with an upfront payment, and an incentive to be involved in the project as it develops, and it provides the developer with some certainty on land access.

It is highly recommended that CEB takes early steps to secure land for the development of further potential on Mannar Island.

4.4 Monitoring and evaluation of CEB's wind power plant

CEB's 100 MW wind power project currently under development is going through a process of stringent social and environmental scrutiny by the Asian Development Bank, which includes consultation with local stakeholders. Some of the issues raised by local stakeholders may be real and others imaginary; expecting worst scenarios.

When the first-ever commercial wind project in Sri Lanka (situated in the Kalpitiya peninsula) was developed, it faced considerable objections from religious institutions, local communities and interest groups all focusing on perceived impacts of the project on the local population, their agriculture and bird mortality. Evidently, after six (6) operational years of this project, there have not been reports of adverse social and environmental impacts. This may be due to several reasons; absence of adverse impacts, absence of a formal independent post evaluation of these projects, or natural adjustment of the local population (and animals) to the changing environment. Nevertheless, these same agitations are likely to continue into the future and create problems for new wind projects so long as the project proponents remain unable to counter the arguments with hard facts.

It is therefore proposed that an independent organisation (e.g. SLSEA) be entrusted with the task of carrying out monitoring and evaluation (M&E) of CEB's 100 MW project with clear terms of reference. M&E may include the plant's technical performance, impacts on livelihoods (positive & negative), noise / shadow flicker impacts, bird casualties and overall perception of the project by the local community. Findings may be disseminated in the form of reports, regular media discussions, and newspapers. It is proposed that CEB uses M&E outputs to prepare and implement mitigation measures when such interventions would be needed.

As it stands, the Environmental Management Plan for the 100 MW project includes a monitoring plan.

4.5 Study of intermittency of wind farm output

Intermittency of wind resources is likely to be a major power system-related issue with high wind power penetration. This requires special attention if the intermittent generation is above the power system reserve and available frequency control ancillary service in the system. There are a number of wind projects in Sri Lanka, however we are not aware of any detailed analysis of the severity of impact of wind intermittency on CEB's network or the dispatch plan.

In order to identify power intermittency and power quality issues, the Mannar wind farm is designed with high resolution power quality monitors. These monitors record power variation in every electrical cycle (20 ms). CEB can use the recorded data to thoroughly analyse actual power variation (intermittency). This analysis will provide ample evidence whether wind power intermittency is a serious issue for the Sri Lankan network.

If the power intermittency results in unacceptable frequency deviation then CEB can investigate how their frequency control ancillary services are dispatched, and/or use wind forecasting to constraint wind generation to avoid substantial power variation in wind energy output.

4.6 Wind power forecasting system

Wind power forecasting is a tool used to reduce economic and financial risks associated with uncertainty in wind power production, due to the inherent variability of the wind resource. The primary driver in Sri Lanka for considering wind power forecasting is for power system operations, including scheduling, unit commitment, and dispatch decisions. Sri Lanka does not operate an electricity market such as found in many regions worldwide, so there is not presently a need to forecast wind power output for the purpose of energy trading.

Wind power forecasting systems focus on three distinct timescales:

1. Very short-term for predicting events on timescale of a few seconds or minutes up to a few hours, including sudden events such as ramps
2. Short-term for predicting events on a timescale of a few hours to a few days in advance
3. Medium-term for predicting events up to a 7 to 10 days in advance

Wind power forecasting is achieved through modelling the wind resource and/or wind farm power output. Models currently in use world-wide can be divided into two categories:

1. Numerical weather prediction (NWP) or physical models, which are based on a physical model of the earth's atmosphere, with a resulting wind forecast that is converted into a wind farm power output via the technical details of the specific wind farm under consideration. These

methods are generally suitable for short to medium term forecasts, but are less suitable for very short-term predictions.

2. Statistical or artificial intelligence (AI) methods, which are built from a set of historical time-series data to predict the wind resource or power output or a wind farm, and are generally used to improve very short-term predictions (and also very long range forecasts). These statistical models can be combined with NWP models in a 'hybrid model', to increase accuracy.

Lessons from wind power forecasting in Europe, America and Australia will be applicable to Sri Lanka, however the distinct monsoonal climate will influence what methods are best and how accurate predictions can be derived, and this may differ from experiences elsewhere. In India, with a similar monsoonal climate, the Central Electricity Regulatory Commission imposed mandatory wind power forecasting on project owners in 2012, however projects have struggled to predict their day-ahead generation within the 30% band required by the authority. The experience in India demonstrates the importance of assessing actual performance of forecasting systems in the local context before making assumptions about the performance of forecasting systems or assuming they can be used to facilitate system operation.

Entura proposes that a centralised forecasting capability within CEB might best fulfil the requirements of CEB as the system operator, rather than the alternative of requiring individual projects to provide individual forecasts of their power output. This centralised forecasting capability would be best procured through an external consultant, who is able to bring expertise from elsewhere in the world, and develop a model for Sri Lanka.

However as a first step in developing a centralised capability, it is a requirement of the tender documents for CEB's 100 MW Mannar wind power plant that the contractor provide a forecasting system for the project. An assessment of the accuracy of this system in the Sri Lankan context is an important first step in determining the extent to which CEB will be able to use wind power forecasting to manage their system.

4.7 Grid integration of wind power

There are number of power system studies conducted in Sri Lanka to facilitate long term generation and transmission planning [12][13]. Specifically, the system study conducted by Manitoba HVDC Research Centre [22] studied the system impact of Mannar Island wind development on the Sri Lankan electricity grid. The Manitoba HVDC study concluded there are no significant impacts to the Sri Lankan electricity network for a 375 MW wind farm at Mannar Island. Entura has also conducted a detailed system study for the 100 MW wind farm and based on the results we expect no major technically challenging issues when connecting up to 250 - 300 MW of wind generation in the Mannar region.

Since the planned Mannar island wind park is connected to Sri Lankan electricity grid through 220 kV double circuit line, the 220 kV transmission line has significant capacity to absorb the feasible wind farm capacity that land use on Mannar Island will allow.

4.8 Logistics issues

Experience with the development of CEB's 100 MW wind project suggests that wind power development in the Mannar region is likely to encounter numerous siting restrictions, forcing future wind projects to either scale down the total capacity or deploy larger wind turbines. The latter approach would confront some challenges in term of transport logistics. However the Logistics study

conducted as part of CEB's ongoing project has shown that it is practically possible to transport wind turbines of about 130 -140 m rotor diameter to the Mannar Island using barges. The study had proposed several options to bring barges alongside with each option having its own operational limitations. Entura notes that projects under development elsewhere in the world with similar geographic features (i.e. water access) are planning for wind turbines of capacity around 5 MW.

According to CEB, the local fishermen had expressed reservations about building a jetty for the proposed barge option on the grounds of obstruction to *madel fishing* in the area. Coast Conservation Department too had granted only temporary approval for the jetty due to perceived environmental impacts arising from such constructions. It is proposed that these issues are addressed in greater detail through a broad-based consultative process with the participation of all stakeholders to arrive at a mutually acceptable marine transport option for future projects. Engagement with the Government of Sri Lanka and the Navy may result in a more permanent pier solution for landing of large wind turbine components.

4.9 National regulatory guidelines

Renewable energy technologies have their own technology-specific environmental impacts. Noise, visual disturbances and bird mortality are commonly ranked as the major environmental impacts associated with wind power development. The gravity of these impacts becomes increasingly acute with the spatial distribution of wind development and increasing scale of wind projects. This trend became noticeable in the process of developing CEB's 100 MW wind project and is likely to become worse if wind development becomes more widespread in the Mannar region.

What has become particularly evident in the development of CEB's 100 MW project was the lack of wind project specific standards in the existing national regulatory guidelines particularly those related to wind turbine siting, noise[4], aviation, communication, distortion of radar signals, electromagnetic interference etc. Countries that are aiming for high levels of wind energy penetration have addressed these issues to a great extent and considerable volume of literature on these subjects is freely available. It is proposed that the Government takes early action to draft renewable energy and wind energy specific standards into existing national regulatory guidelines. Examples of national guidelines in relation to separation distances of wind turbines are readily available [14].

4.10 Planning regulations

CEB's current 100 MW project is within an area allocated by the Sri Lanka Sustainable Energy Authority for development of wind power, and as such CEB has an expectation that no activities within the area shall delete the renewable energy resource. However this has not prevented new developments (commercial and industrial) from adversely impacting CEB's project, and leading to a reduction in the feasible wind turbine locations after noise constraints are considered.

It is recommended that action is taken to prevent this situation where new developments (residential, commercial or industrial) hinder wind project development after an area has been

[4] Noise levels are specified in the CEA standards, however noise assessment methods for other industrial noise sources are not necessarily appropriate for wind farm development, where noise sources are distributed across many point sources (wind turbines) over a large area, and where source noise and background noise is highly dependent on the external environmental conditions at any given time (in particular wind speed)

declared a wind development zone and especially so once the project development has reached an advanced stage. A framework for managing competing interests of developers is needed, and it needs to be thoroughly communicated at both national and local levels.

5. Prospects for offshore wind development

As discussed in previous chapters, space for wind power development in the Mannar district is constrained by competing land uses that are emerging as part of socio-economic development in the region. Environmental concerns exacerbate this situation further. In view of this trend the Urban Development Authority (UDA) in the Northern Province wants wind power development to be planned in harmony with other economic and social development plans in the region most of which are expected to be bringing direct benefits to the local population. Therefore, in all probability UDA will give priority to economic and social development programmes over wind power development when allocating the scarce land resources. This is a political reality that must be viewed in the context of post-conflict economic development in the Northern Province as a whole.

With increasing planning restrictions for land-based wind power development, there is a worldwide trend to build wind power plants offshore in countries that offer the right conditions. In this respect, Sri Lanka seems to be in a favourable situation having a shallow Continental Shelf that links the land mass of India and Sri Lanka in-continuum across the portion of Gulf of Mannar, Adam's Bridge, Palk Bay and Palk Strait. This chapter makes a cursory examination of the prospects for wind development off the shores of Mannar Island and the mainland area in the vicinity of Silavathurai.

5.1 Global status

Building wind farms offshore was initiated in Europe in the early 1990s mainly to alleviate the difficulties in getting approvals for siting land-based wind farms due to existing land uses and numerous social and environmental concerns. In addition to these reasons, there is also the positive aspect that wind flow is less turbulent, spatially better distributed and more powerful over the sea than over land. Lower turbulence levels make a direct contribution to lower fatigue loads on wind turbine rotors.

Deployment of offshore wind power technology was spearheaded by Europe by installing its first offshore wind farm (Vindeby) in Denmark in 1991. Since then deployment of offshore wind in Europe and elsewhere has been growing steadily. According to the Global Wind Energy Council [15], 14,384 MW of offshore wind capacity had been installed in 14 different markets by 2016. About 88% of this capacity was in coastal waters of European countries (largely the UK – 36%, and Germany – 29%), with the remaining 12% in China, Japan, South Korea and the United States.

Similar trends are visible outside of Europe with China, Japan, South Korea and Taiwan setting ambitious targets for offshore wind development. The United States has excellent wind resources offshore, and many projects are under development. The GWEC-led FOWIND consortium is developing an offshore wind roadmap for India, and other markets, such as Brazil, have raised interest in future offshore development.

Building wind farms offshore is more difficult than land based wind turbines and has entailed considerable technical challenges in all aspects of wind farm construction, e.g. building deep-water foundations, mid-sea turbine installation, submarine cabling etc. These have now been resolved to a large extent and newer approaches are being developed to mainstream the technology for widespread applications. Growth of offshore wind is depicted in Figure 5.1.

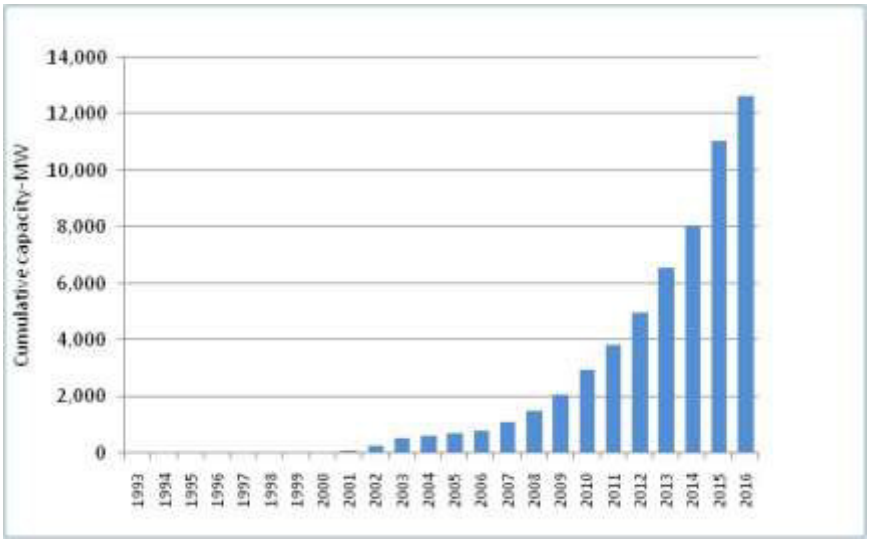

Figure 5.1: Cumulative offshore wind capacity in Europe[16]

5.2 Technology description

In principle, offshore wind turbines are similar in design to onshore machines except for the substructure and foundation. The types of foundation vary from *monopile* (a large steel tube with a diameter of up to 6 m) for depths in the range of 5 to 30 m to floating structure for deep sea applications [17]. In addition to the typical loads encountered by onshore wind turbines, offshore wind turbines have to cope with several other engineering challenges, e.g. the depth and geology of the seabed, wave loading, corrosive marine environment, etc. Installation of offshore wind facilities also requires special types of transport vessels and cranes. Submarine power transmission systems are used to get the power to the land-based substation. All these complexities collectively account for the increased cost of offshore wind projects. The positive aspects of offshore wind development are the stronger and less turbulent winds found over the sea and the fact that projects are sited far away from population centers.

The size of wind turbines deployed in the first offshore wind farm was 450 kW [19] in Vindeby, Denmark in 1991. Since then the unit capacity of offshore wind turbines has grown considerably reaching an average capacity of 4.2 MW in 2015 [16]. Wind turbines of capacity 8 MW have now been installed during 2017.

Some key statistics [16] on the situation with offshore wind farms in Europe are presented below:

- In 2015, the average capacity of new wind turbines installed offshore was 4.2 MW, a significant increase from 3.0 MW in 2010, reflecting a period of continuous development in turbine technology to increase energy yields at sea. The deployment of 4-6 MW turbines seen in 2015 will be followed by the gradual introduction of 6-8 MW turbines closer towards 2018.
- In the last five years, the average offshore wind farm size has more than doubled, from 155.3 MW in 2010 to 337.9 MW in 2015.
- Offshore wind farms have moved further from shore and into deeper waters. At the end of 2015, the average water depth of grid-connected wind farms was 27.1 m and the average distance to shore was 43.3 km. This is primarily the result of increased deployment in Germany during 2015, where sites are an average of 52.6 km from shore. By comparison, UK projects

were on average 9.4 km from the shoreline and Dutch projects an average of 31.4 km away from shore.

5.3 Environmental issues

While the offshore wind industry has grown dramatically over the last several decades, especially in Europe, there is still a great deal of uncertainty associated with how the construction and operation of these wind farms affect marine animals and the marine environment.

Common environmental concerns associated with offshore wind developments include:

- The risk of seabirds being struck by wind turbine blades or being displaced from critical habitats;
- The underwater noise associated with the installation process of driving monopole foundations into the seabed;
- The physical presence of offshore wind farms altering the behavior of marine mammals, fish, and seabirds with attraction or avoidance;
- The potential disruption of the near-field and far-field marine environment from large offshore wind projects.

5.4 Costs

According to a report by the UK's Offshore Wind Programme Board, offshore wind costs for projects reaching a final investment decision in 2015-16 fell to USD 125 per MWh [11]. The relatively higher cost of offshore wind projects is due to the costly project elements such as offshore cabling, constructing seabed foundations, transportation and installation using specially designed vessels and the wind turbines themselves that are designed to withstand harsh marine environment (Figure). In addition, the O&M costs remain higher than onshore wind farms due to the harsh marine environment and the costs of access. Therefore, even though offshore wind offers the opportunity to have comparatively higher capacity factors, the electricity production cost remain higher in offshore wind farms. As is to be expected, offshore wind farm costs tend to increase with the depth of the seabed and distance to the shore.

5.5 Potential region for offshore wind development

Sri Lanka and India sit on the same continental shelf which includes the Palk Strait. While the continental shelf drops rapidly along the east coast of Sri Lanka, the sea remains shallow off the coastline from Jaffna to Mannar. To the south of Adam’s Bridge (a chain of sandbars that connect Mannar Island with the southern tip of India) lies the Gulf of Mannar. The Sri Lankan side of the Gulf of Mannar lies off the landmass extending from Mannar to Silavathurai

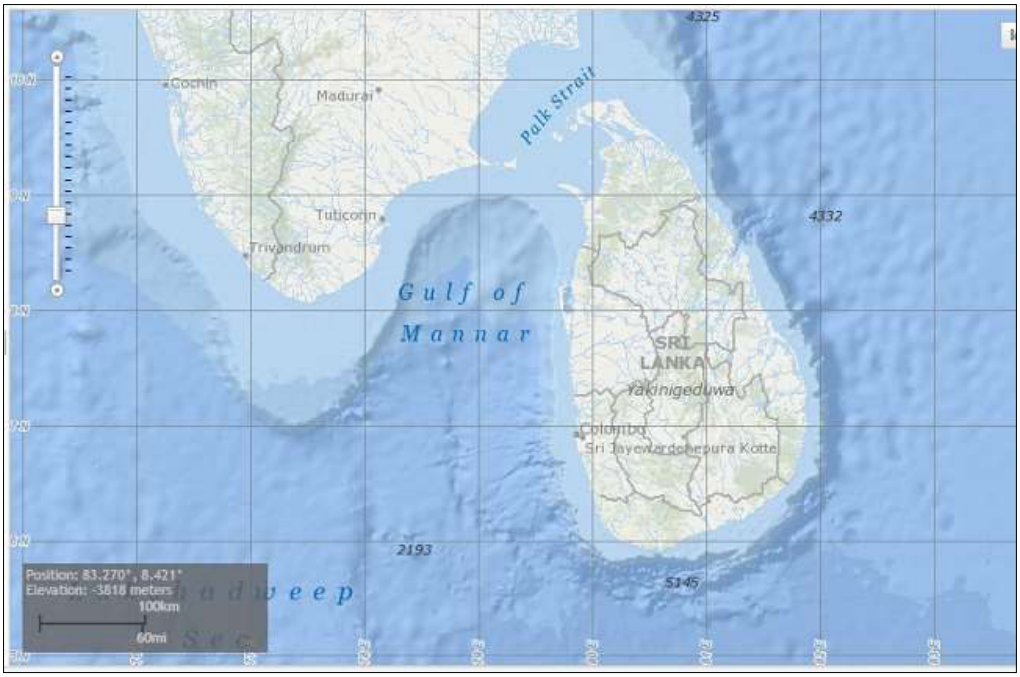

Figure 5.2: Continental shelf around Sri Lanka. Note the shallow area of the continental shelf (light blue) lying to the north and south of the Mannar Island. Source: National Oceanic and Atmospheric Administration of the US Government (https://maps.ngdc.noaa.gov/viewers/bathymetry/)

The sea bed lying south of Mannar Island remains shallow to a considerable distance. The 10 m bathymetric contour is situated at a distance of about 20 km from the shorelines of Mannar Island and the Mannar mainland extending southward towards Silavathurai (Figure 5.3). The stretch of sea bed shown by the thick blue line in Figure 5.3 is tentatively proposed as a potential area for offshore wind development in the initial phase. Two rows of wind turbines with unit capacity of 8 MW would enable the installation of about 800 – 1000 MW of offshore wind capacity in the proposed area.

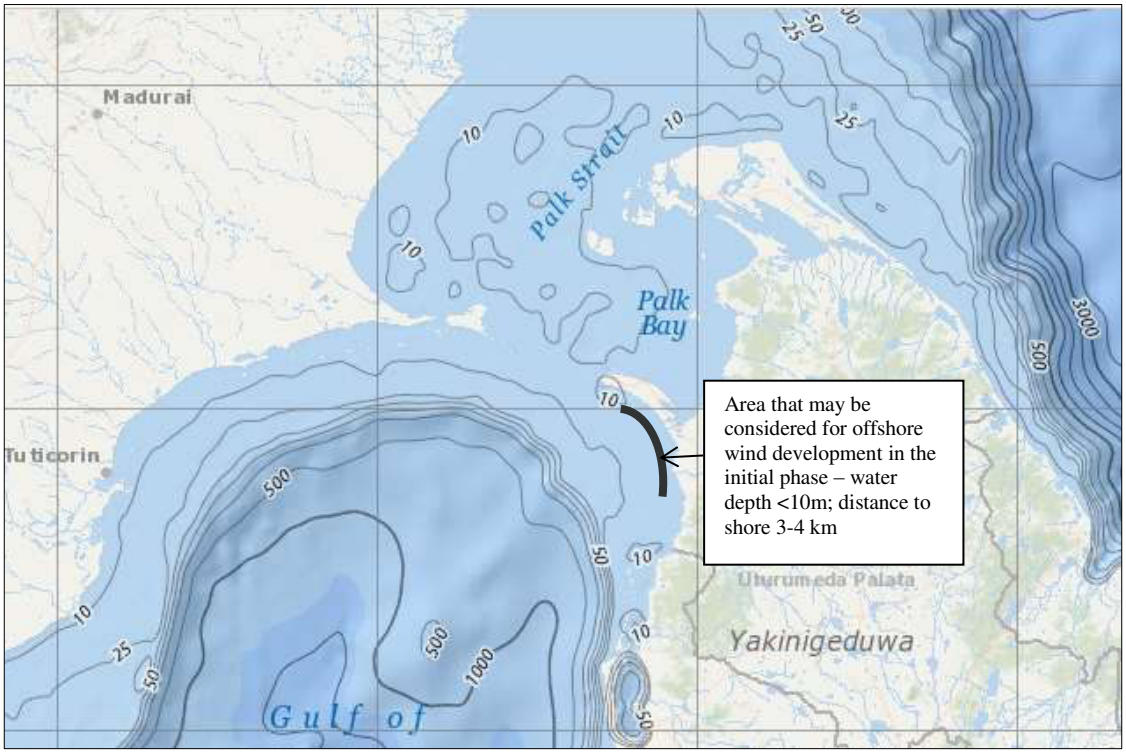

Figure 5.3: Ocean bathymetry in the Gulf of Mannar. Source: National Oceanic and Atmospheric Administration of the US Government (https://maps.ngdc.noaa.gov/viewers/bathymetry/)

5.6 Key issues

5.6.1 Fishery

According to a recent study on illegal fishing activities in and around Mannar Island [20], the sea around the Mannar Island is rich in fish resources with a major part of the productive fishing ground lying in Palk Bay and the Gulf of Mannar. These two coastal waters, including the continental shelf contain a variety of species of fin-fish, shell fish and holothurians. Due to the abundance of fish resources in this region, close to 40% of the Island's people are engaged in the fishery indicating the extent of dependence of the local population in this economic activity.

Besides this, the Gulf of Mannar is reported to be one of the richest areas in terms of marine biodiversity comprising coral reefs, sea grass and mangroves accompanied by salt marshes and algal communities [21]. The region is reported to be the home to turtles, pearl oysters, sea cucumbers, balano-glossus, dolphins, sea horses, barracuda, herrings and sprats. This situation needs to be considered if and when offshore wind development is considered in Sri Lanka.

5.6.2 Environment

The Gulf of Mannar is supposed to be an ecologically important critical habitat shared by India and Sri Lanka. According to a recent report by scientists in NARA [14], the Palk Bay and the Gulf of Mannar covering an area of 10,500 km^2 are biologically rich and rated among the highly productive seas of the world. The biodiversity of the ecosystems in the Gulf of Mannar is reported to be very high and supports economically important resources such as finfish, crustaceans, mollusks and marine plants. It is also the area of distribution of the endangered dugong and sea turtles. The

shallow sea area in the northern parts comprises islands, sand dunes, forest, beaches and near-shore environment, including a marine component with algal communities, sea grasses, coral reefs, pearl banks, salt marshes and mangroves.

The report also refers to extensive coral reef ecosystems in the Gulf of Mannar from Kalpitiya Peninsula to Mannar Island. There are four large coral reefs namely the Bar Reef on the west of the Kalpitiya Peninsula, Silavathurai, Arippu and Vankalai. These large coral reefs are mainly 'patch reefs' located offshore from 1-2 km to more than 10 km away from the coastline. All of these coral banks are in very shallow water up to about 5 m depth and the deepest coral banks do not exceeding 15 m.

In view of this situation, offshore wind development in the Gulf of Mannar will have to be planned with due consideration given to its critical ecosystem.

5.6.3 Petroleum resources development

Numerous attempts were made by the government to develop petroleum resource in the Gulf of Mannar on a commercial scale. Although some evidence of presence of hydrocarbons was found in the 1980s no serious efforts were made to extract oil, as it was said to be commercially unviable, given the depth of reserves and technology available at the time. Recent studies have identified the existence of hydrocarbon potential parallel to the continental shelf margin of the country, spreading out from the south to the east and north.

Sri Lanka's Petroleum Resources Development Secretariat (PRDS) has identified several blocks for offshore oil exploration in Mannar Basin and Cauvery Basin. The blocks comprise both shallow and deeper waters. The study areas are situated at a substantial distance from the Mannar Island but seem to be quite close to land (approximately 3-4 km) along Silavathurai coastal region. Any future efforts to develop offshore wind in this region will have to be undertaken in close consultation with PRDS.

6. References

[1] TA 9085-SRI: Wind power generation project, Inception Report, Entura, 10/11/2016

[2] TA: 7837 SRI - Part 2: Wind and Solar Resource Assessment

[3] TA-8167 Sri: capacity building for clean power development part b: preparation of renewable energy development and wind park master plans and Business model for wind park – Final Report, March 2014

[4] Mannar wind power project wind resource, wind turbine suitability and energy production report, Entura, 1 June 2017

[5] Can the wind industry bank on wind lidar?, Wind Power Monthly Expert Report, Windpower Monthly, ZephIR, 2014

[6] FGW TR 6 standard (Technical Guidelines for Wind Turbines, Part 6: Determination of Wind Potential and Energy Yields, published by FGW e.V. – Fördergesellschaft Windenergie und andere Erneuerbare Energien), Sept 2014

[7] Improved Bankability, The Ecofys position on LiDAR use, 2013,

[8] International Energy Agency, Ground-based vertically-profiling remote sending for wind resource assessment, Expert group study on recommended practices, 1st Edition, January 2013

[9] Measnet, Evaluation of Site-Specific Wind Conditions, Version 1, 2009, Annex C, Alternative Wind Measurement Procedure

[10] DNV, DNV-RP-J101, Use of Remote Sensing for Wind Energy Assessments, April 2011

[11] Windpower Monthly, 24/1/2017, http://www.windpoweroffshore.com/article/1421825/offshore-wind-costs-fall-32-2011

[12] Ceylon Electricity Board, Transmission and Generation Planning Branch, Long Term Generation Expansion Plan 2015 -2034, dated July 2015.

[13] Ceylon Electricity Board, Transmission and Generation Planning Branch, Long Term Transmission Development Plan 2015-2024, dated May 2016.

[14] Wind Turbines: Planning and Separation Distances, NIAR 767-13: Research and Information Service, Northern Ireland Assembly, Room 139, Parliament Buildings, Belfast BT4 3XX - September 2013

[15] http://www.gwec.net/global-figures/global-offshore/

[16] The European offshore wind industry, key trends and statistics 2016, Wind Europe

[17] IEA-ETSAP and IRENA© Technology Brief E07 – March 2016 www.etsap.org – www.irena.org

[18] https://www.boem.gov/Offshore-Wind-Energy/

[19] https://en.wikipedia.org/wiki/Vindeby_Offshore_Wind_Farm

[20] Augustin Siluvaithasan SOSAI: 2015, ILLEGAL FISHING ACTIVITY – A NEW THREAT IN MANNAR ISLAND COASTAL AREA (SRI LANKA), Transylv. Rev. Syst. Ecol. Res. 17.1 (2015), "The Wetlands Diversity"

[21] http://natureconservation.in/gulf-of-mannar-marine-national-park-complete-detail-updated/

[22] Manitoba HVDC Research Centre, "Final Report, Part 4: Technical Assessment of Renewable Energy Scenarios: Study on Impact of the Mannar Wind Power Development Zone: TA-8167 SRI: Capacity Building for Clean Power Development, leading towards the Sri Lanka Renewable Energy Master Plan, dated December 2014.

[23] Wind Energy Easements and Leases: Compensation Packages – Windustry, 2105 First Avenue South, Minneapolis, MN 55404, email: info@windustry.org web: www.windustry.org

[24] Land-Use Requirements of Modern Wind Power Plants in the United States: Paul Denholm, Maureen Hand, Maddalena Jackson, and Sean Ong, Technical Report NREL/TP-6A2-45834, August 2009

[25] Template for Submission of Scientific Information to Describe Areas Meeting Scientific Criteria for Ecologically or Biologically Significant Marine Areas – H.B. Jayasiri, Principal Scientist,; S.S,K, Haputhantri, Principal Scientist, Marine Biological Resources Division, National Aquatic Resources Research and Development Agency