ATTACHMENT D

ELECTROMAGNETIC AND COMMUNICATION ASSESSMENT

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Bulgana Wind Farm

Electromagnetic and Communication Assessment

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Final

This report examines the possible impacts of the proposed wind farm on existing radiocommunications and broadcasting services in the area and proposes interference mitigation strategies where necessary

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DISCLAIMER

This Report has been prepared on the basis of ACMA radiocommunications licensing data and broadcasting information and other reference material available in the public domain at the date of production of the report. The Report does not imply that any conclusions are not subject to change

EXECUTIVE SUMMARY

The site of the proposed Bulgana Wind farm covers approximately 7,524 hectares of private and public land located within the Bulgana, Joel Joel, South Joel, Congongella and Great Western districts, in central western Victoria. It lies approximately 11.7 kilometres north of Ararat, at its southern extent, and 11.2 kilometres east of Stawell, at its north-west extent. Great Western is the nearest significant sized settlement approximately two kilometres to the south-west of the site

A number of existing Australian Communications and Media Authority (ACMA) registered radiocommunication services are located in the general area and one point-to-point radio service crosses the wind farm nominal site boundaries. To ensure that the locations of turbines will not degrade the performance of radio systems minimum separation distances and exclusion zones have been established for the turbine structures.

Residences in the area surrounding the wind farm are provided with TV, FM Sound and other services from high power transmitters located on Lookout Hill (the Ballarat stations). Low power transmitters in the general area at Halls Gap, Cobden and Horsham are not predicted to provide coverage around the wind farm site. The other Western Victoria high power stations at Mt Dundas are also not predicted to cover the area. Based on Australian Broadcasting Corporation(ABC) and Department of Broadband, Communications and the Digital Economy(DBCDE) interactive prediction maps some dwellings in the area may currently have variable TV coverage from the terrestrial services and may need to rely on the Viewer Access Satellite Television(VAST) or pay TV satellite services. The TV/Sound broadcasting Licensees providing services to the area have been identified for advice for information to be initiated.

This Assessment provides an analysis of each of the radio facilities registered near the wind farm. It also establishes recommended clearances based on accepted industry criteria for radio links crossing the wind farm and any required buffer zones for other radiocommunications sites. A study of the signal paths from the main TV stations to the low power TV repeaters has been made to identify any potential interference to their input signals by wind turbines.

Comments are also provided on the radio interference and human exposure impacts from electric and magnetic fields from powerlines and power transmission infrastructure associated with the wind farm.

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1 INTRODUCTION

The proposed Bulgana Wind Farm comprises a maximum of 67 wind turbines and associated permanent and temporary infrastructure. Permanent infrastructure will include:

- Approximately 53 km of site access tracks,
- Creation and improvement of up to 9 access points from public roads,
- Permanent anemometry masts,
- Approximately 47 km of underground cabling,
- Approximately 11.4 km of overhead wires,
- A collector substation and connection of underground cables to overhead line,
- A terminal substation and connection to the existing SP Ausnet 220kV high voltage transmission line located at the northern end of the site.

The following permanent infrastructure is proposed:

- 67 wind turbines of between 2MW and 4MW rated capacity each. The grid coordinates proposed are shown in Attachment 1.
- Turbine configurations generally consisting of hub heights up to 140 metres, rotor diameters up to 128 metres and tip heights up to 196 metres. The turbines will be constructed from tubular steel or concrete sectional towers and will support a nacelle, nose cone and blade assembly. Four turbine models have been selected to aid in assessment and modelling for environmental and planning purposes, these are listed below. However, the specific height and configuration of the turbines to be installed on the Bulgana Wind Farm site will be determined following a commercial tendering process that will occur after a planning permit is granted. The turbines selected through the commercial tendering process will be within the envelope provided by the aforementioned dimensions. Turbine types that are being considered for the project include, but are not limited to, the following:

  Acciona AW 116 (100m hub height, approximate blade tip height 158m)
  Acciona AW 125 (120m hub height, approximate blade tip height 182.5m)
  Siemens SWT 113 (92.5m hub height, approximate blade tip height 149m)
  Enercon E115 (92m hub height, approximate blade tip height 149.5m)

The general wind farm layout is shown in Attachment 13.

1.1 Objective of this Assessment

The objective of this Assessment is to determine the clearance requirements for the radio services in the area to allow a turbine layout to be planned so that there will be no detrimental effects on the performance of the existing services. The object also is to derive a minimum required buffer zone for the omnidirectional services including mobile radio base stations and any nearby TV/ FM Broadcasting transmitting station, ensuring an acceptable grade of protection to the coverage required in the service areas of each service. A check that the currently proposed turbine layout meets the required clearance criteria for the various radio links and radio sites has also been undertaken.

1.2 Scope

Criteria for clearance of obstructions from point-to-point link ray lines have been well established in the literature, including the specific case of rotating turbine blades. For omnidirectional mobile and other services, however, any need for a buffer zone is usually dismissed on the basis of the accepted variability of coverage to/from the mobile or hand held terminals in the normal operational environment. The known exception to this are the South Australian Department of Transport Energy and Infrastructure (SA DTEI) guidelines prepared by Telstra for the derived exclusion zone for the SA – GRN 400 MHz mobile radio base stations. This Assessment considers the factors involved in the specific services in the locality of the Project site and proposes what are considered to be acceptable clearance zones.

The possible impact on Free-to Air TV and Radio Broadcasting services to residents near the wind farm is also discussed.

1.3 Assumptions

Data for the existing services in the area was sourced from the Australian Communications and Media Authority (ACMA) database for licensed radiocommunication services - both from a recently issued CD ROM and the ACMA public web site. The accuracy of the location of towers specified in the database, is shown in some cases to be within 10 metres and in the others within 100 metres. No check survey has been carried out.

It is also assumed that modern wind generators are well electromagnetically shielded to international standards and are not the source of any significant generated electromagnetic interference in the frequency bands used by radio services in the area. This report considers the reflection, scattering or obstruction of signals to the radio services, potentially caused by close spacing of the turbines to the radio link ray lines between transmitting and receiving site pairs.

2 WIND TURBINE IMPACTS ON RADIO COMMUNICATIONS

A paper by D. F. Bacon in 2002 (Reference 1), issued by Ofcom, the regulator for the UK communications industries, has become the most used reference by the industry for the calculation of clearance zones from turbines to the ray line and antennas for point to point links. The Paper identifies three principal mechanisms which are relevant to a wind turbine in proximity to a microwave link. These are near-field effects, diffraction and reflection, and are discussed in detail below.

2.1 Near-field Effects

A transmitting or receiving antenna has a near-field zone where local inductive fields are significant, and within which it is not simple to predict the effect of other objects. Bacon's paper (Reference 1) provides the well known formulae for calculation of the near-field distance depending on the gain or physical aperture of antenna. The near field distance is a function of frequency and the physical dimensions or gain of the antenna.

2.2 Diffraction

An object detrimentally modifies an advancing wavefront when it obstructs the wave's path of travel. Here the formula applied is for the classical Fresnel zone distance where diffraction will be insignificant if obstructions are kept outside a specified volume of revolution around a radio path.

2.3 Reflection

The physical structure of the turbine and in particular the rotating turbine blades reflect interfering signals into the receiving antenna of a fixed link. A formula is given in Bacon's paper (Reference 1) to derive a distance from the radio path where any reflected/scattered signal will be of an amplitude sufficiently smaller than the direct signal arriving at the receiver. The acceptable Carrier/Interference (C/I) ratio will depend on the modulation and coding schemes of the link. Bacon's paper (Reference 1) provides formulas to calculate the distance from the link path where the C/I will be below a desirable level depending on the link parameters.

The calculation of the scattering level of Radio Frequency (RF) signals from turbines is complex and varies with RF frequency, physical dimensions of the turbine blades and their twist, tilt and orientation. Radar Cross-Section (RCS) values are used in the Bacon paper (Reference 1) and elsewhere to account for the scattering characteristics of individual turbines. A wide spread of values appear in the literature for typical modern turbines which makes the estimation of the scattered signal levels uncertain. It is noted that Bacon's paper (Reference 1) uses an RCS value of 30 m² whereas the SA DTEI guidelines use a value of 480 m² which is the total area of the 3 blades based on an assumed width of 4 metres each and lengths of 40 metres. In another British study (Reference 3), the RCS of turbines were modelled and validated with actual field measurements. This study focused on the aviation radar signatures of wind farms and measurements were carried out with radar in the 1 to 3 GHz range. It was indicated that Peak RCS values can significantly exceed the physical area of the turbine but they will occur over narrow arcs. It was concluded that the wind generator nacelle and the general shape of the

tower itself can make significant contributions. It was stated that a 100 metre tall tower with 45 metre turbine blades was estimated to have a maximum peak RCS of 25000 m². According to Reference 3, this high peak was probably associated with a particular style of nacelle and tower. For the purposes of this study a peak of 1000 m² associated with the blades is considered appropriate. The RCS will, of course, vary with wind direction, blade pitch and other design factors including rotor tilt and coning angle. Multiple turbine interference from a wind farm will also be additive on a power basis due to the uncoordinated sources.

2.4 Omnidirectional Services

Bacon's paper (Reference 1) was written for the point-to point-radio link situation. No omnidirectional system (e.g. mobile radio base station) was considered. The SA DTEI guidelines (Reference 2) have been developed for omnidirectional mobile services from Bacon's paper (Reference 1) by applying the formula for the point-to-point link reflection/scattering case to an omnidirectional service. It further derives another criterion for the case where the remote mobile/portable unit is located at points where a turbine is in line with the transmission path to the base station. A criterion of no more than 10% of the Fresnel zone width being blocked by a blade width of 4 metres appears to have been employed to derive an exclusion zone. This purports to limit signal variations as a result of the turbine to 0.5 dB.

3 RADIO SERVICES LOCATED NEAR BULGANA WF

From the latest ACMA database, maps have been prepared showing registered radio sites and point-to-point links in the locality of the Project site. Attachment 3 shows the situation for systems with frequencies below 1000 MHz with a zoomed view in Attachment 4. Attachment 5 shows the links and sites for systems operating on frequencies above 1000 MHz with zoomed views in Attachments 6, 7, 8, and 9. Typical calculations of required clearances are shown in Attachment 10 using the formulas in Bacon's paper (Reference 1). It should be noted that site numbers displayed in Attachments 3 and 5 may not be the actual ones associated with a particular point to point links due to label overlap of close spaced site labels.

3.1 Point-to-point Systems

The radio link maps have been examined and the links crossing the wind farm site and near radio sites have been identified from the ACMA data. There are 2 point-to-point links in the microwave bands operated by 2 operators over paths which nominally cross or are adjacent to the site. A number of radio sites which are located outside the wind farm boundaries but are close enough to be considered from a buffer zone point of view have also been examined. A summary of the calculated 2nd Fresnel zone clearances at mid-path and at 1 km are shown in Table 1. No radio sites located within the wind farm boundaries were identified from an analysis of the ACMA data. There are no UHF links which cross or are close to the wind farm boundaries. The locations of the turbines have been shown in the link maps generated in MapInfo and were used to confirm that distances from radio link ray lines and the turbine tower centrelines meet the clearance criteria.

TABLE 1 - MICROWAVE LINK CLEARANCES

PATH ACMA Site ID's	Total Path Dist. km	Frequency MHz	Operator	Mid Path 2nd Fresnel Zone Distance m	1 Km Fresnel Zone Distance m
51170 - 300696	41.41	7500	Vodafone	28.8	8.8
51170 - 133134	12.68	11000	NBN Co	13.1	7.1

The calculation of the reflection/scattering zone using Bacon's formula (Reference 1) requires iteration with increasing values of the distance from the path bore sight at each distance from the terminal until the required C/I value is reached. As the recommended clearance distances above are calculated for the mid path for each link (where the clearances are at a maximum) scattering from turbines near a radio site will be low.

3.2 Off-Air Links to TV and FM Broadcasting Stations at Halls Gap, Ararat and Stawell.

Nearby low power TV and FM Broadcasting stations for towns in the general area are located at sites as shown in Table 2 below:

TABLE 2 – LOCAL TV AND SOUND BROADCAST STATIONS

Town	Site ID	Type	Distance to nearest WT km
Halls Gaps	36653	TV	30.2
Ararat	11729, 51170	FM	12.0, 13.3
Stawell	51170	FM	13.3

The nearest of these broadcasting sites is about 12 km from the closest turbines. All listed sites are separated from the wind farm by sufficient distances to not have their TV or FM coverage impacted by wind turbines. From some past special purpose ACMA data it appears that the Halls Gap (Mt William) station receives TV main stations signals off-air from the Ballarat main TV station. Examination of the signal path between the Ballarat main station and this repeater indicates that the path is sufficiently clear of turbines to not cause any turbine disturbance of the input signals.

3.3 Air Services Facilities

The nearest Aerodrome is at Stawell. There are no registered Air Services Radar sites within line of site of the turbines. VHF Ground – Air services are located at site 901800 (Mt William), 135871, 9013416 and 909447 for AirServices Australia, Ararat Hospital, North Grampian shire and Department of Environment and Primary Industries. Due to the separation distance between the wind farm boundaries and these sites of 12.5km or more and the nature of the services operated, no additional buffer zones are required

3.4 Point to Multipoint (PMP) Services

Table 3 lists sites within the Study area which are specified as point to multipoint services. Usually only the base stations are ACMA registered for PMP systems, so the remote (subscriber or device) end is not known. It is therefore not possible to determine if there could be any turbine obstruction in the paths between the base and the fixed remote end.

TABLE 3 - POINT TO MULTIPONT SYSTEMS IN THE AREA

Site/Service	Frequency Band MHz	Operator	Comment
302772, 11734,11733	450	Grampians W. M. Water	UHF
9019657, 305839, 404211, 9012292, 304776	450	Central Highlands Water	UHF
305839, 304776	450	Stawell Gold Mines	UHF
300696	1800	Aussie Broadband	Microwave
133134	2300	NBN Co	Microwave

Given that most base station locations are remote from the wind farm site there is a low probability that any path to the remote (subscriber or device) would cross the wind farm. The NBN PMP licences are recent and the site 133134 is about 3.99 km from the nearest turbine. There is some possibility that any NBN customers to the East of the site could have their broadband services affected by turbines. It would be prudent to advise NBN and the other operators of the PMP Services of the wind farm proposal.

3.5 Bureau Of Meteorology Weather Radar

There are no listed weather radar sites within the study area of 50 km the wind farm and therefore no impacts on these facilities are expected.

3.6 Radio Sites in Close Proximity to Wind Turbines

There are no radio sites within the Project site. Sites external to the wind farm have been considered based on the nature of the radio service and the distance from the nearest turbines. Apart from point to point radio systems shown in Attachments 3 and 5, a number of services including point to multipoint and mobile radio base stations including cellular mobile base stations operated by Telstra, Optus and Vodafone exist. There a number of CFA VHF base stations also in the area. All of the services have been examined for any possible impacts of wind turbines located 4km and beyond from the radio sites. Near-field calculations for the worst case point to point antennas have also been calculated. The worst case microwave system (6.7 GHz, 3.0 metre parabolic antenna) has a near field of approx. 600 metres. Based on SA - GRN requirements for a Paging service, however, the NSW RFS paging service would require a buffer zone of 1000 metres. It is believed that a clearance of 1000 metres would also be adequate for the mobile base stations. The current spacing to the nearest turbine of 3.7 km would have negligible effects on all services operating from the sites surrounding the turbines.

4 TV COVERAGE IN THE AREA

An investigation was undertaken to identify TV stations potentially available for residents in the locality of the Project site. Using ACMA lists of broadcasting stations and the ABC and DBCDE internet prediction service of available coverage (based on post codes or town names), two services are potentially available, although availability will vary depending on actual locations around the wind farm site. From the ABC predictions, coverage from the Ballarat TV transmitting station shown in Table 4 is most likely. There may be a few instances where the Western Victoria station is used by residents depending on specific terrain profiles between the residences and the TV stations. From the ABC prediction maps in Attachment 16 the area surrounding the wind farm is in the primary coverage area of the Ballarat service areas. The TV channels now available and after planned channel changes from stations in the area are shown in Attachment 2.

TABLE 4 - TV STATION TRANSMITTER SITES

SERVICE AREA	SITE LOCATION
Ballarat (main station)	**Lookout Hill**
Western Victoria (main station)	**Mt Dundas**

From predictions by the ABC and DCBDE coverage of the area around the wind farm site will be from the Ballarat station and coverage is unlikely from the Western Victoria station. It is expected that reception of digital signals will be less impacted by turbine interference in reasonable signal level areas than for the now-switched-off analogue transmitters.

Mitigation techniques for TV interference from turbines at residences could include the following:

- Replacement or reposition of TV antenna
- Use of an alternative terrestrial TV station
- Use of the new VAST Satellite TV service

5 CUMULATIVE IMPACTS WITH PROPOSED WIND FARMS

Consideration has been given to the potential cumulative impacts to radiocommunications links and broadcasting reception of the Bulgana wind farm in conjunction with other proposed or existing adjacent wind farms. A map in Attachment 15 shows the locations of adjacent wind farms approved, operating or where an application has been received for them. The closest boundary and centre to centre distances to the Bulgana project are listed in Table 5:

TABLE 5 - WIND FARMS ADJACENT TO BULGANA WIND FARM

Wind Farm	Status	Approx Distance from Bulgana Wind Farm km	
		Closest Boundaries	Centre to Centre
Ararat	Under Construction	1.5	16.5
Crowlands	Under Construction	9.5	19.2
Challicum Hills	Operating	24.8	34.9
Stockyard Hill	Approved	37.3	60.3

Regarding the impacts on point to point radiocommunications, each wind farm will be planned to ensure that there is adequate clearance between crossing radio paths and the individual turbines so that any radio path traversing any wind farm will not experience interference. There will therefore be no cumulative interference. Any impact on TV reception at dwellings is unlikely to occur beyond 5 km from any turbine. With the adjacent wind farm minimum separations of 24.8km for Challicum Hills and 37.7km for Stockyard Hill wind farms shown in Table 5 the scattered signal from these adjacent wind farm turbines will be negligible around the Bulgana wind farm area. Both the Crowlands and Ararat wind farms are located in the direction of the Lookout Hill TV stations as seen from some residences on the west side of the Bulgana wind farm. There is therefore some chance of cumulative TV interference depending on the exact location and distance of residences to the neighbouring wind farm turbines. As both the Crowlands and Ararat wind farms are likely to be operational before Bulgana any additional interference to TV reception experienced would need to be dealt with as part of the commitments for TV reception restitution for those projects.

No adjacent wind farms are/ will be sited sufficiently close to any TV station to impact on the general TV coverage in the station's service area.

6 POWER TRANSMISSION INFRASTRUCTURE ELECTRIC AND MAGNETIC FIELDS

As indicated in Section 1 the project will involve the construction of the following power distribution components:

- Approximately 47 kilometres of underground cabling between the turbines and to the point of collection prior to transitioning to overhead wires (see below).
- Approximately 11.4 kilometres of overhead wires on approximately 6 metre high poles connecting the wind farm electrical system to the project terminal substation.
- A collector substation will be located at approximately grid coordinate X:673564, Y:5889234, WGS84, UTM Zone 54S, with a footprint of 0.015 hectares, containing a marshalling point for underground cables for connection to overhead line.
- A terminal substation will be located at approximate grid coordinate X:676398, Y:5899357, WGS84, UTM Zone 54S, comprising a compound of approximately 3 hectares, containing metering, control and transformation equipment to connect the wind farm electrical system to the adjacent 220 kV transmission line.

The overhead transmission lines can be up to 50 m in height comprising two cross arms with insulators with a typical span length for various voltages as show in the Table 6 below:

TABLE 6 – TYPICAL OVERHEAD TRANSMISSION LINE DIMENSIONS

Voltage	Easement Width	Height of Tower/Pole	Typical Span Distance
220 kV	40 m	40 m	250 – 450 m
132 kV	45 m	35 m	200 – 300 m
66 kV	30 m	30 m	150 – 250 m
33 kV	30 m	20 m	150 m

Power generated by the wind turbines will be exported to the transmission grid via purpose built substations and high voltage transmission lines using conventional designs to meet standards applying

to the State network at large. Substations will be designed and sited to reduce the electric and magnetic fields to acceptable levels at the boundary fence. The height of the lines and the easement width shown above are in accordance with industry recommendations to ensure magnetic and electric fields are maintained within acceptable limits for human exposure. Electromagnetic interference levels at dwellings in the area and for accessible public access areas will also be minimised at these distances. Depending on the number of circuits carried and the voltage used, the power lines would be suspended from cross arms at 15 or 20 metres above ground level with human exposure limits met at ground level. HV powerlines and substations are required to meet the standards of the Australian Standard AS/NZS 2344: 1997 Amendment 1:2007 which protects broadcasting and radiocommunications reception from unacceptable interference. The overhead power lines are not expected to obstruct the radiocommunications systems which cross the wind farm in view of their relative low height above ground. The distance to the nearest radiocommunications site will also ensure that EMI from the power infrastructure will have no impact on radio system receivers at that site.

7 MONITORING MASTS AND CONSTRUCTION ACTIVITY

Permanent monitoring masts, up to 100 m high, are proposed to be installed. These masts will need to be positioned so that they do not obstruct the ray lines of the existing radio link crossing the wind farm site. It is recommended that the clearances derived for the wind turbine locations be applied to these masts. Of course the masts can be installed closer to the ray lines of links that wind turbines because the turbine blade length is not involved.

Although it is unlikely to be a problem, the use of large cranes on site during the wind farm construction period may need to be considered to avoid the link ray lines. It is understood that the cranes are positioned on the hard standing areas around the wind turbine towers and will be within a blade length from the tower and therefore will be in the safe area for obstruction of links.

8 DISCUSSION

Bacon's paper (Reference 1) suggested second Fresnel zone clearance has been used for clearance criteria calculated for the path midpoint for microwave links. This is reasonably conservative, and as such, protects against any inaccurate coordinates of radio sites in the ACMA database. This is useful for turbines that are close to one end of the links. For VHF/ UHF links, a "free space" criteria of 0.6x 1st Fresnel zone has been adopted based on advice from David Bacon (pers. comm. <24/07/2009>).

The Telstra SA – GRN Guidelines have additional criteria for omnidirectional services which cover the operation of mobile or portable radio units in situations where a turbine is located in the first Fresnel zone of the path to/from the base station. This, of course, applies to both ends of the link, that is, near the base station and near the mobile/ portable unit. A number of reports available on radio system clearances to wind farms have not considered this issue. Reference 5 (BCL NZ) stated that a clearance of 600 metres was derived for VHF mobile base stations, while Reference 4 (Kordia NZ) stated a clearance of 320 metres for both VHF and UHF mobile bases. Differences in assumptions about turbine RCS and safety margins appear to account for the differences in distance in these two reports.

8.1 Point-to-Point Links

As shown in the Table 1 above, link paths require Fresnel zone clearance of between 13.1 and 28.8 metres at the mid path of the links or near wind turbine positions depending on path length and operating frequency. The Fresnel zone clearance is tapered, increasing from 0 at both ends of the links with the maximum at the mid path points. It is generally accepted that a second Fresnel turbine clearance should be applied to the higher frequency microwave links of multi-channel capacity, and is desirable for lower frequency links. Path profiles for the two microwave links are shown in Attachments 11 and 12.

8.2 TV and FM Broadcasting Services

These are omnidirectional services and have similar requirements to mobile base stations with regard to clearance zones for scattering. Estimates based on scattering criteria, suggest that with a clearance of 300 metres, negligible impact on the service coverage would occur. When turbines or towers are

closely placed to transmitters, there is also the possibility of impacts on TV reception, such as ghosting and other effects. These impacts may occur over a large area. However, as there is a considerable distance to the nearest turbine, a negligible impact is expected upon local low power TV and FM stations mentioned above. There is still the potential, though, that TV reception from the main and local station(s) may be impaired at some residences close to the turbines. References 6, 7, 8 and 9 provide details of the mechanism and estimation of TV signal scattering from wind turbines. References 8 and 9 are recent ITU documents which specifically address the issue of the impact of wind turbines on digital television.

8.3 Mobile Radio Base Stations

Once again, the relevant criterion is the Scattering mechanism. Calculations for the Mobile and Paging base stations suggest a 200 metre clearance. The SA - GRN Guidelines (Reference 2), however, recommend buffer zones of 1200 metres for emergency services radio base stations and Paging Services.

9 RECOMMENDATIONS

9.1 Point-to-point Links

As there are 2 link paths which cross or are close to the site, horizontal corridor or vertical clearances are required. Details of these are summarised in Table 7 below. Path profiles of links that have wind turbines located close to the link ray lines are shown in Attachments 11 and 12. These horizontal clearances are specified because sufficient vertical clearance may not be achieved when turbine blade tip clearances are considered. As mentioned in Section 8.1, the Fresnel zone clearance requirement is tapered, increasing from a minimum distance near the link ends to a maximum distance at the mid path. However, it is proposed that for most links that a simple fixed width corridor be defined, and that the width is based on the maximum clearance, at the mid path, to cover all scattering clearances. The corridor clearances shown in Table 7 should be maintained for the 1 crossing or adjacent links.

TABLE 7 – RECOMMENDED CLEARANCES FOR RADIO POINT TO POINT LINK

LINK A – B (ACMA Link ID's)	TOTAL CORRIDOR WIDTH Metres Note 1	SITE A COORDS GDA 94 Z54	SITE B COORDS GDA 94 Z54
51170 - 300696	57.6	E659058 N5897594	E695270 N5877517
51170 - 133134	26.2	E659058 N5897594	E664571 N5886176

* If this clearance corridor is a significant impediment to the deployment of turbines on the site it should be reviewed. The link involved is operated on a low VHF frequency and the impact of a turbine in the clearance zone may be very small.

Note 1 No part of a turbine should protrude into the corridors. With a turbine rotor diameter of, for example, 128 metres, the centre line of the turbine towers should be at least 92.8 metres (i.e.: 57.6/2 + 128/2)from the 2nd listed radio link ray line.

The radio link paths and the turbine layout superimposed on the MapInfo maps show that the required horizontal clearances are met for all of the radio links which traverse or are adjacent to the wind farm site for a 128 metre diameter rotor. The path profile (Attachment 11) for the link 51170 – 300696 which crosses the wind farm also indicates that there is sufficient vertical clearance over the blade tip. All other radio links in the current array have sufficient horizontal clearance. In general if any micro-siting of turbines is required, the specified buffer zones must be maintained if vertical clearance is not maintained. The results of checking the clearance from the nearer turbines to the radio link ray lines and the required clearance are presented in Table 8 below:

TABLE 8 - RADIO LINK CLEARANCE COMPLIANCE

Wind Turbine ID	Scaled Distance from MapInfo	Calculated Required Clearance
BU-37	700m	92.8m
BU-40	930m	92.8m
BU-42	850m	92.8m
BU-48	3985m	77.1m

9.2 General Buffer Zones

Taking into account the scattering zone requirements of all omnidirectional services, and the near-field clearances required for the longer distance links, a clearance circle of 1200 metres radius (centred on the radio towers) is the worst case zone requirement (worst case typical site see Attachment 10). This is based on the SA - GRN guidelines for emergency services omnidirectional services which include paging services. All radio sites are at least 4000 metres from the nearest turbines in the current layout so no buffer zones are required.

9.3 Interference to Television Reception

The Project site is in the Regional Victoria TV1 Licence area. The Ballarat and Western Victoria main television stations at Lookout Hill and Mt Dundas would generally service the area, with transmission from lower power translator stations at Halls Gap.

The prediction of TV interference at individual dwellings as a result of turbine interference has been shown to be generally unreliable. As indicated in Reference 7, there is a possibility that interference to TV reception at some residences that are particularly close to turbines may occur (if they are located in the forward scatter zone, in the received direction of the TV stations). It is expected that reception of digital signals will be less impacted by turbine interference in reasonably high signal level areas. Based on experience in areas surrounding operational wind farms in Victoria and elsewhere there is some possibility that TV reception at some dwellings west of the Bulgana wind farm and within about 5km of wind turbines could be affected. Where residents' TV antennas are directed towards wind turbines in the path to Lookout Hill some interference could be experienced. The location of dwellings around the wind farm are shown in a map in Attachment 14. A number of possible mitigation methods are available to restore interference-free television to dwellings as listed in Section 4.

Television operators in the area are:

- Broadcast Australia – ABC and SBS
- Southern Cross Ten
- Prime Television (Southern) Pty Ltd
- WIN Television Vic Pty Ltd

It is recommended that these organisations and Broadcast Australia, who own and operate the ABC, SBS and shared commercial transmission facilities, be advised of the wind farm proposal and be requested to comment on any issues they have from a TV coverage impact point of view.

9.4 Interference to Radio Reception

Interference to AM radio reception is highly unlikely due to the propagation mechanism involved. No reported interference overseas or in Australia has been reported. FM radio reception interference, while theoretically possible, also has not been observed except in laboratory set-ups. It is therefore concluded that impairment of AM and FM radio reception around the proposed wind farm is highly unlikely.

10 CONCLUSIONS

For the current layout of wind turbines no adverse impacts on point to point or omnidirectional radio systems in the area are expected.

TV and radio broadcasting transmitting sites are sufficiently distant from turbines to not have any general service area coverage degradation.

Some individual dwellings close to turbines and in the forward scatter areas of TV transmissions may experience some reception impairment. However mitigation methods are available to return reception to at least preconstruction conditions.

Interconnecting power lines and substations will be constructed and located according to industry standards to ensure that magnetic and electric fields are well below the human exposure limits for public spaces and at private dwellings. EMI levels at power line easement boundaries will be required to meet the appropriate Australian Standard levels which will ensure that radio and TV reception and other radiocommunication services will not be impaired.

11 REFERENCES

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[2] Guidelines for Minimizing the Impact of Wind Farms on the SA - GRN, Issue 1, 22 October 2003, Rohan Fernandez, Telstra SA, Document TR049-SA

[3] Wind Farms Impact on Radar Aviation Interests-Final Report, September 2003, FES W/14/00614/00/REP, Contractor QinetiQ Prepared by Gavin J Poupart.

[4] Mahinerangi Wind Farm, Compatibility with Radio Services, 3 April 2007, Anton Pereira & Richard Brown, Kordia NZ

[5] Project Hayes, Compatibility with Radio Services, 7 July 2006, Duncan Chisholm, BCL NZ

[6] Electromagnetic Interference from Wind Turbines, Sengupta & Senior, Chapter 9, Wind Turbine Technology Ed. David E. Spera ASME Press 1994

[7] ITU, ITU-R Recommendation BT805 Assessment of Impairment Caused to Television Reception by a Wind Turbine 1992

[8] ITU, ITU-R, Recommendation BT.1893 Assessment of Impairment Caused to Digital Television Reception by a Wind Turbine May 2011

[9] ITU, ITU-R, Report BT.2142-1 The Effect of the Scattering of Digital Television Signals from a Wind Turbine

ATTACHMENT 1

WIND TURBINE GRID COORDINATES BULGANA WIND FARM

ZONE 54 MGA94

ID	ID2	E	N
1	BU_01	672343.9572	5897186.573
2	BU_02	672565.7095	5897026.728
3	BU_03	672836.1798	5897170.104
4	BU_04	673070.8035	5896900.578
5	BU_05	673799.8763	5897149.08
6	BU_06	674135.4181	5897196.444
7	BU_07	673834.2676	5896560.241
8	BU_08	674059.2189	5896418.7
9	BU_09	674327.5896	5896365.176
10	BU_10	674489.779	5896039.684
11	BU_11	674818.2303	5896039.048
12	BU_12	675200.6046	5894203.767
13	BU_13	675556.1969	5894170.302
14	BU_14	675892.1969	5894170.302
15	BU_15	672277.2299	5892970.281
16	BU_16	672660.8256	5892685.06
17	BU_17	672992.3919	5892663.98
18	BU_18	673510.6025	5892255.614
19	BU_19	673813.0271	5892560.59
20	BU_20	674176.9699	5892566.459
21	BU_21	674581.7723	5892195.911
22	BU_22	674862.8482	5892271.289
23	BU_23	675143.2035	5892601.75
24	BU_24	675563.3605	5892706.338
25	BU_25	675845.4561	5892932.144
26	BU_26	676149.0611	5893170.23
27	BU_27	672933.8967	5891851.344
28	BU_28	673423.8325	5891484.127
29	BU_29	669916.0285	5889919.012
30	BU_30	670218.0756	5889771.826
31	BU_31	670485.6122	5889421.97
32	BU_32	670947.1451	5889462.754
33	BU_33	671476.4999	5889305
34	BU_34	671870.7105	5889006.928
35	BU_35	672176.5597	5889133.039
36	BU_36	672493.6242	5889172.726
37	BU_37	672779.1989	5889186.152
38	BU_38	672683.8998	5888140.915
39	BU_39	673119.4179	5888566.648
40	BU_40	673432.2447	5888560.179
41	BU_41	674502.7933	5887683

ID	ID2	E	N
42	BU_42	674729.281	5887930.225
43	BU_43	673386.2047	5887442.775
44	BU_44	673881.1756	5887129.024
45	BU_45	673661.5289	5886746.179
46	BU_46	673914.5731	5886542.356
47	BU_47	674345.5255	5886994.084
48	BU_48	668363.3369	5887419.937
49	BU_49	668673.3836	5887519.3
50	BU_50	668997.9632	5887414.067
51	BU_51	669315.0708	5887302.987
52	BU_52	669602.664	5886987.845
53	BU_53	669874.7712	5886752.519
54	BU_54	670332.4029	5885185.436
55	BU_55	670615.5455	5885220.141
56	BU_56	670870.8241	5885364.761
57	BU_57	671123.1095	5885483.127
58	BU_58	671409.4449	5885568.813
59	BU_59	671770.3543	5885573.592
60	BU_60	671123.5891	5886347.98
61	BU_61	671436.4159	5886341.511
62	BU_62	672047.3976	5886258.649
63	BU_63	672595.2843	5886252.15
64	BU_64	673044.8912	5886280.584
65	BU_65	673250.144	5885910.044
66	BU_66	673531.6176	5885489.739
67	BU_67	673909.88	5884976.043

ATTACHMENT 2 - TELEVISION STATIONS & CHANNELS - BULGANA WIND FARM AREA

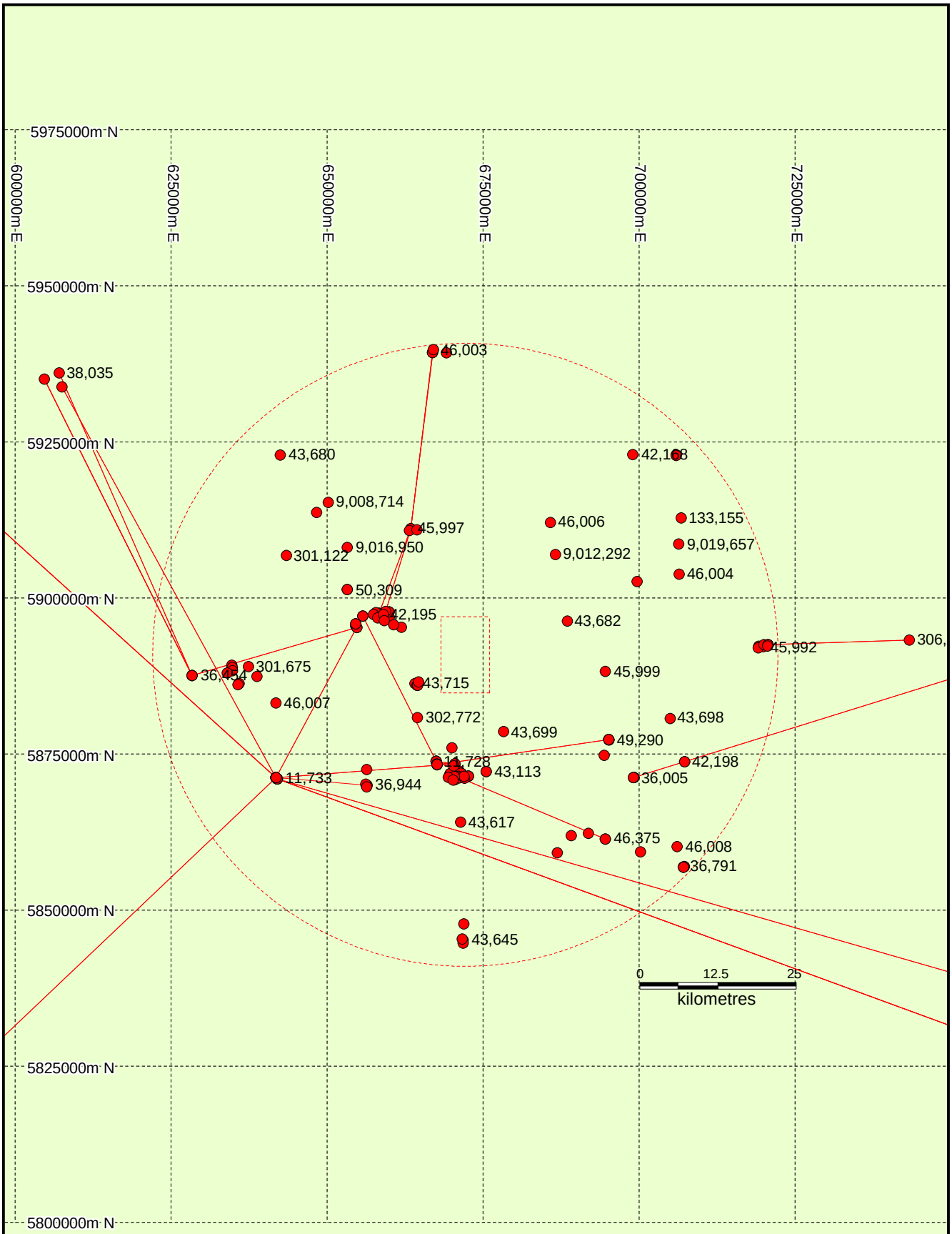
Transmitter Location/service	Operator	Current Digital Channels	*Retuned Digital Channels	Comment
Lookout Hill Ballarat	SBS	43H	34H	UHF
	ABC	41H	35H	UHF
	PRIME	46H	36H	UHF
	S/C	40H	38H	UHF
	WIN	37H	37H	UHF
Mt Dundas Western Victoria	SBS	7H	7H	VHF
	ABC	6H	6H	VHF
	PRIME	12H	12H	VHF
	S/C	11H	11H	VHF
	WIN	10H	10H	VHF

*Ballarat - 17/09/2014 switch over date as part of the channel retune process currently underway in Australia.

ATTACHMENT 3

MAP OF RADIO LINKS & SITES OPERATING BELOW 1000 MHz

Map shown on following page



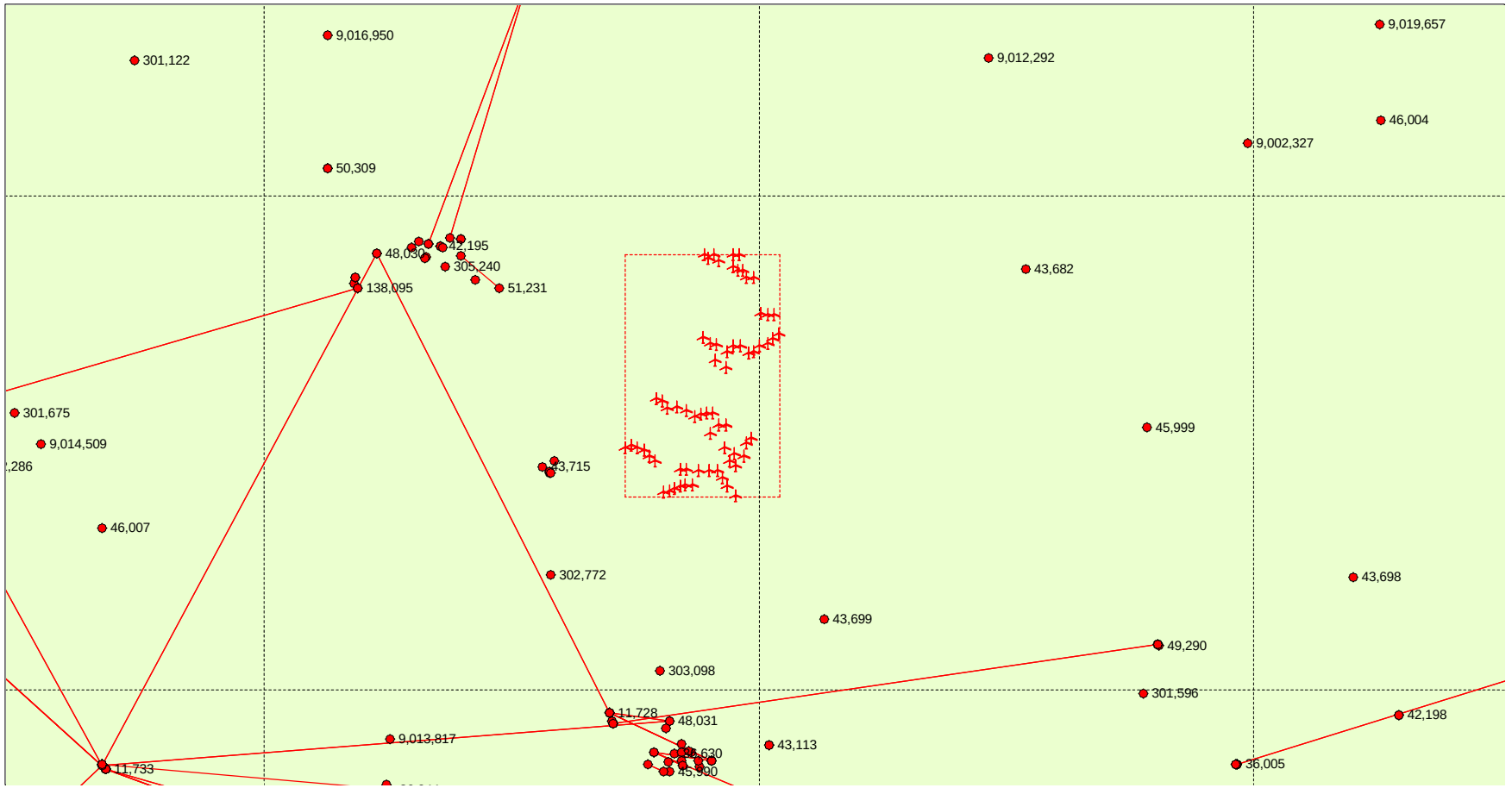
SPECTRUM ENGINEERING AUSTRALIA PTY LIMITED
A.C.N. 008 642 028
Radiocommunications Planning and Design
Postal: P.O. Box 3213, BELCONNEN ACT 2617
Telephone: 02 6253 2555
Facsimile: 02 6253 2800

TITLE: **40-999 MHz Assignments As Extracted from RRL Database**

FILENAME:	40-999 MHz Bulgana Wind Farm	DATE:	13/8/2014
PROJECT:	Bulgana Wind Farm	SCALE:	N/A
DRWG NO:	1	BY:	SEA

ATTACHMENT 4

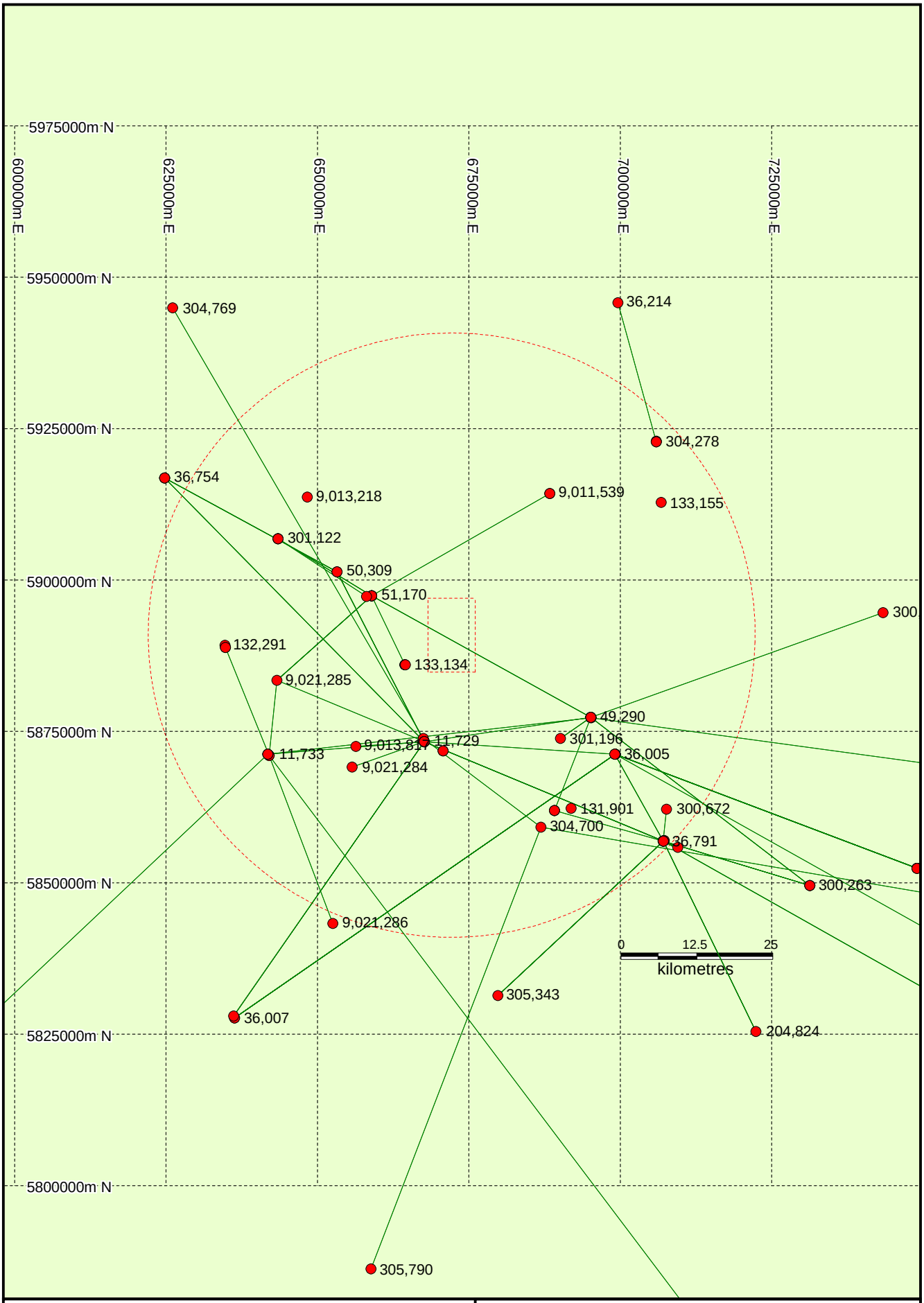
MAP OF RADIO LINKS OPERATING BELOW 1000 MHz –DETAIL 1



ATTACHMENT 5

MAP OF RADIO LINKS & SITES OPERATING ABOVE 1000 MHz

Map shown on following page



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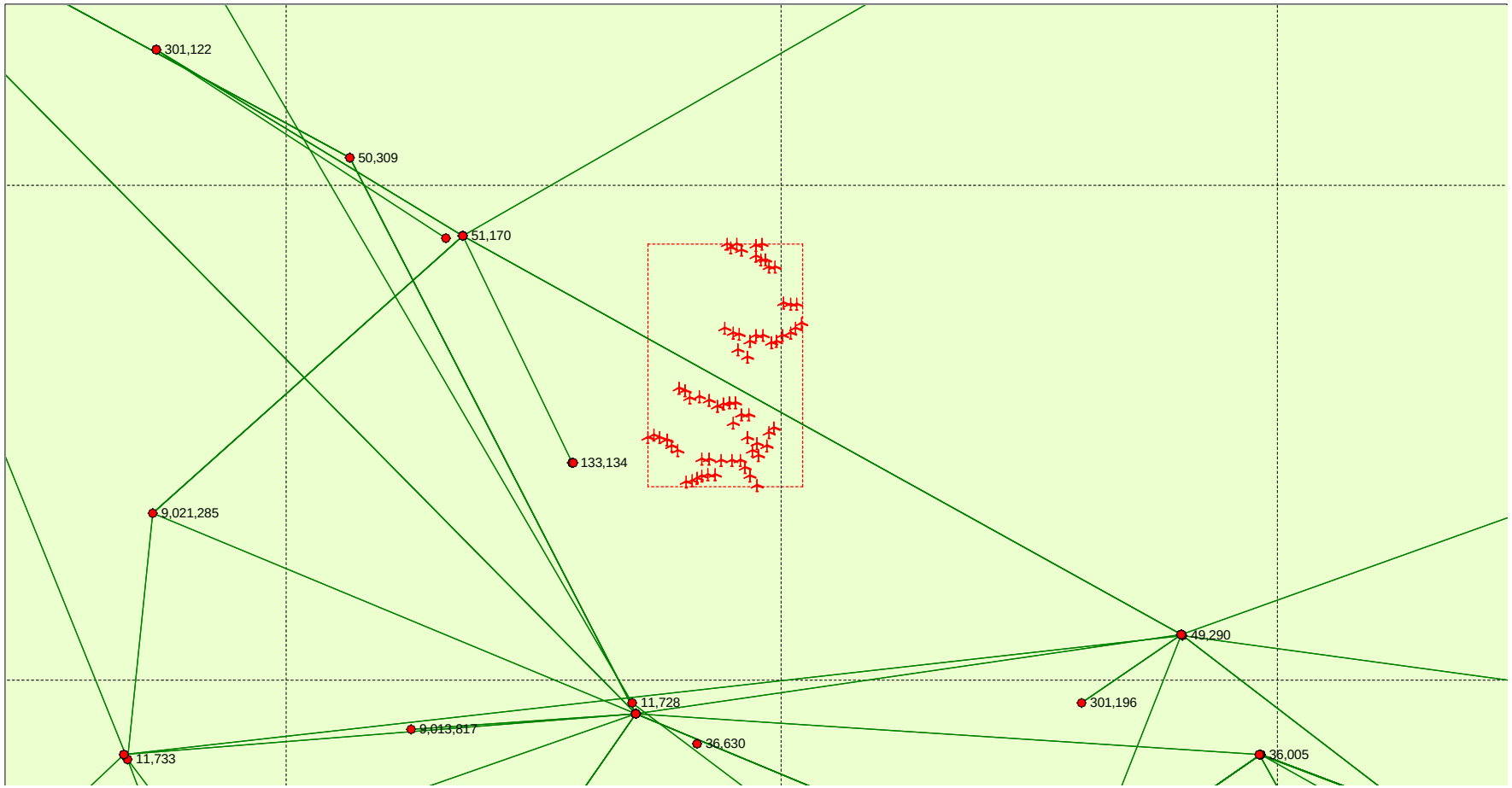
Telephone: 02 6253 2555
Facsimile: 02 6253 2800

TITLE: **Above 1 GHz Assignments As Extracted from RRL Database**

FILENAME: Above 1 GHz Bulgana Wind Farm	DATE: 13/8/2014
PROJECT: Bulgana Wind Farm	SCALE: N/A
DRWG NO: 2	BY: SEA

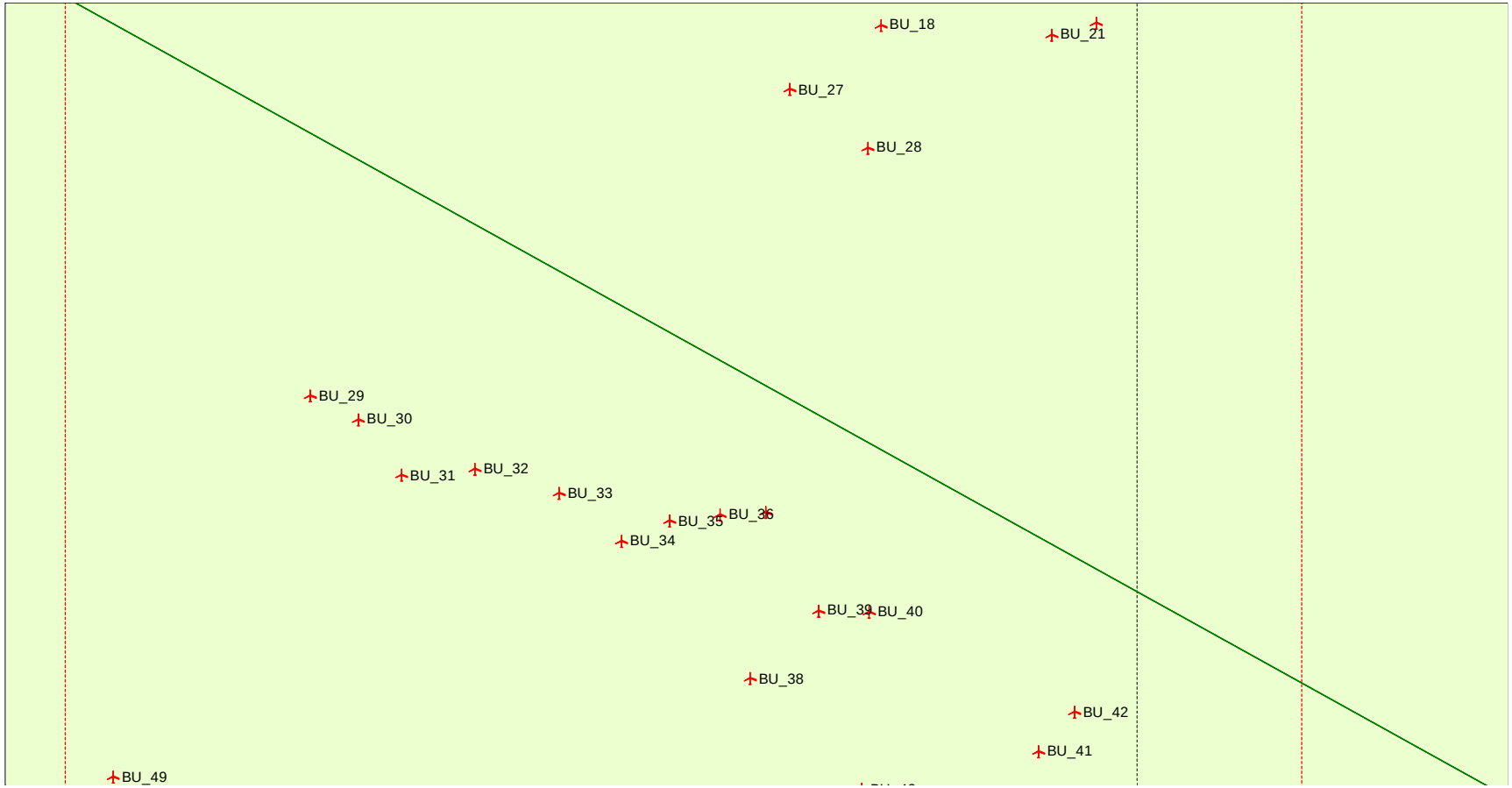
ATTACHMENT 6

MAP OF RADIO LINKS OPERATING ABOVE 1000 MHz – DETAIL 1



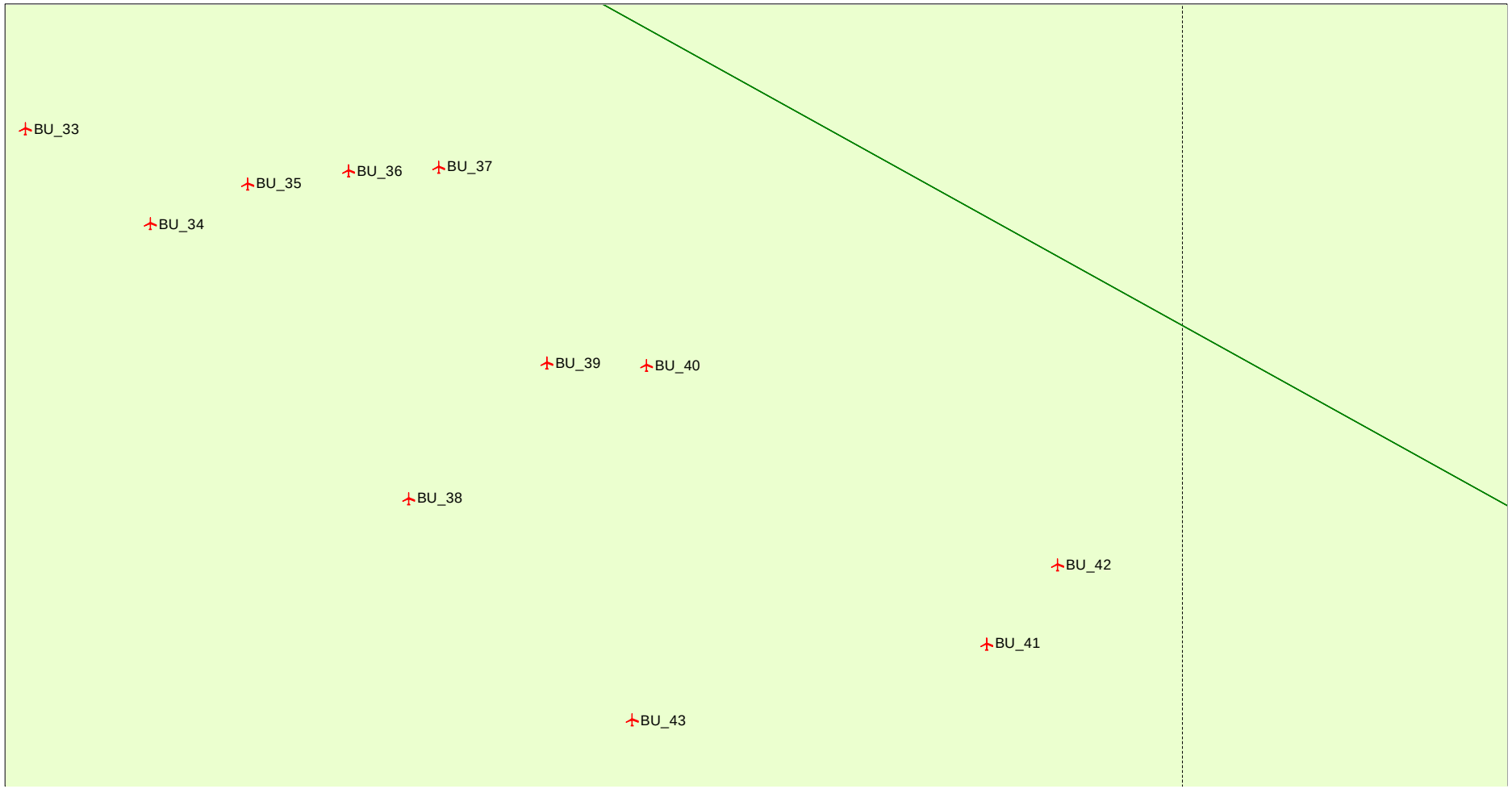
ATTACHMENT 7

MAP OF RADIO LINKS OPERATING ABOVE 1000 MHz – DETAIL 2



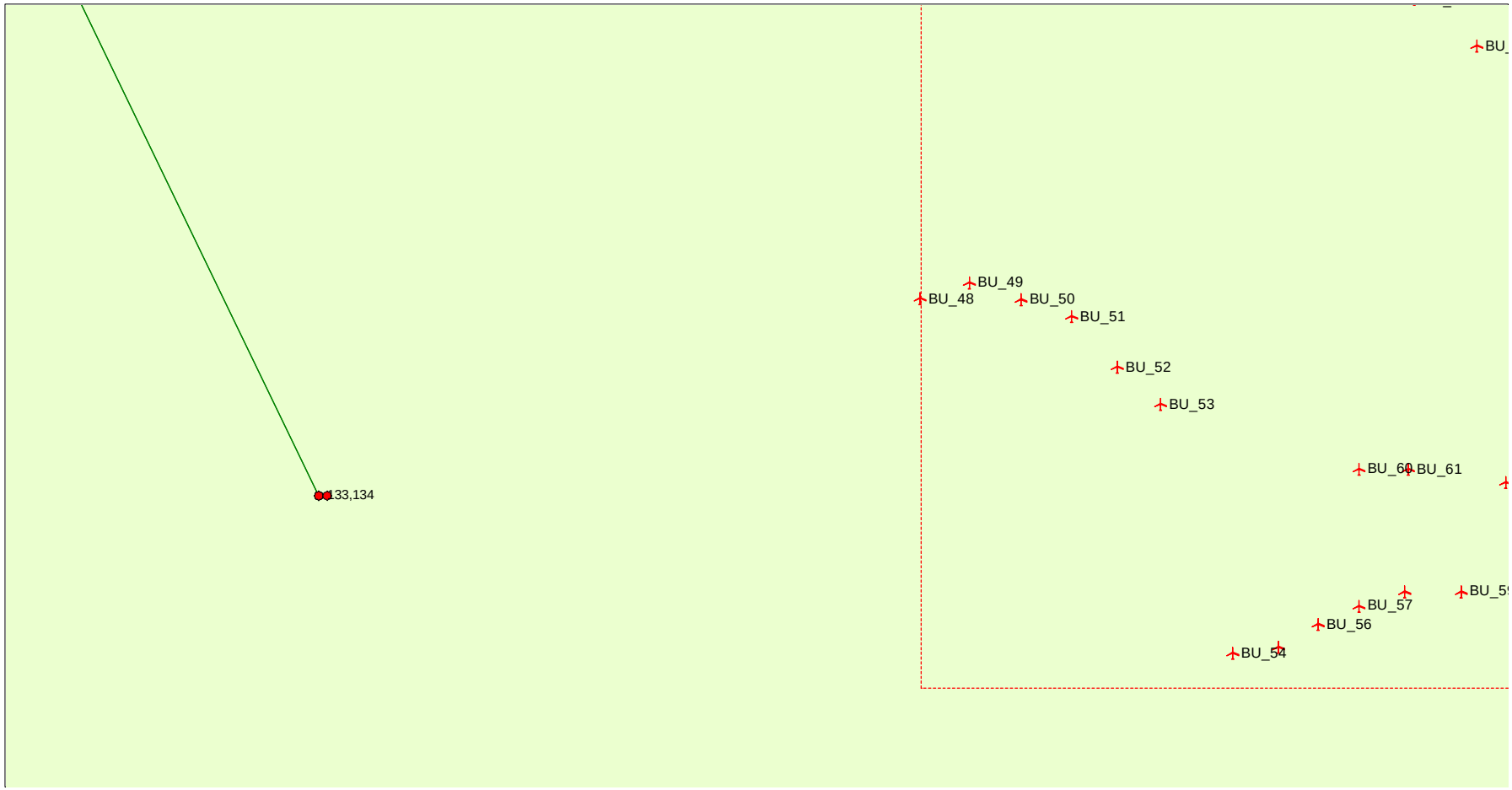
ATTACHMENT 8

MAP OF RADIO LINKS OPERATING ABOVE 1000 MHz – DETAIL 3



ATTACHMENT 9

MAP OF RADIO LINKS OPERATING ABOVE 1000 MHz – DETAIL 4



ATTACHMENT 10

SAMPLE CALCULATIONS OF CLEARANCE ZONES

The calculations below are examples for near field, second Fresnel zone and scattering clearances for the point-to-point and omnidirectional services. The results of all calculations are in tables in the body of the Assessment. The formulas used are taken from Reference 1

1. Point-to-point Link 55450 to 6909 TransGrid

(a) Near Field Zone
Frequency 45 MHz
Antenna Gain 8.2 dB

D_{nf} = $0.1\ 10^{0.1G} / f$
= $0.1x\ 10^{0.1 \times 8.2} /0.045$
= 14.7 metres

Second Fresnel Clearance
Path Distance 119km
Mid Path distance 59.5km

$$R_{F2} = \sqrt{\frac{2\,\lambda\, d_1 d_2}{d_1 + d_2}}$$

$$= \sqrt{2x(300/45)x59500x59500/119000}$$

....=630. metres (mid path)

$$= \sqrt{2x(300/45)x1000x118000/119000}$$

= 115 metres @ 1km from tower

(b) Reflection/Scattering Clearance Zone

The ratio, expressed in dB, of the wanted signal level received from the direct T-R path divided by the worst-case signal level received from the indirect T-W-R path, is given by:

R_{ci} = $71 + S + 20 \log (s_1 s_2) - 20 \log (D_p) + G_1(0) + G_2(0) - G_1(\theta_1) - G_2(\theta_2)$ (dB)

where:

$s_{1,2}$ = $\sqrt{d_{1,2}^2 + D_s^2}$ (km)

S = $10 \log(\sigma)$ (dB)
σ = Worst-case radar cross section of turbine (m^2)
$G_{1,2}(0)$ = Antenna boresight gains (dBi)
$G_{1,2}(\theta_{1,2})$ = Antenna gain at off-boresight angles θ (dBi)
$\theta_{1,2}$ = angle (D_s , $d_{1,2}$)

For each pair of $d_{1,2}$ values, equations above are used to evaluate R_{ci} for D_s incremented from zero (from a non-zero but small distance in the vicinity of the terminals) upwards in suitably small increments until the required value of C/I ratio, given by R_{ci}, is obtained. A guide as to a suitable increment for D_s is that the resulting zone should be defined by a smooth curve.

Antenna Type Scalar Y103 – 203 Vert
Turbine Radar Cross Section (RCS) assumed 1000 metres²

C/I Ratio required >40dB

An Excel spread sheet was set up to with the formulas above implemented to carry out the iteration required for d_1, d_2 values for increasing values of D_s. At 1.0km from the tower a C/I value of 40 dB was achieved at <100 metres off the rayline. Beyond 1 km the C/I value is achieved even on boresight. These indicates that scattering can be ignored 1 km and beyond the end sites. The published Radiation Pattern Envelope (RPE) for the antenna types for the actual link was used in the calculation

2. **Telstra Point to Multipoint Radio Base Stations – Omnidirectional Covera**ge

(a) Near Field Zone
Frequency 3.4 GHz
Antenna Gain 10dB

D_{nf} = $0.1\ 10^{0.1G} / f$
= $0.1x\ 10^{0.1x10}/3.4$
= 0.3 metres

(b) Reflection/Scattering Clearance Zone
Turbine RCS = 1000 m²
Wanted C/I >30dB

The C/I ratio is:

$$r_{ci} = \frac{l_i}{l_d} = \frac{4\pi s_1^{\ 2} s_2^{\ 2} g_1(0)\, g_2(0)}{\sigma\, D_p^{\ 2}\, g_1(\theta_1)\, g_2(\theta_2)}$$

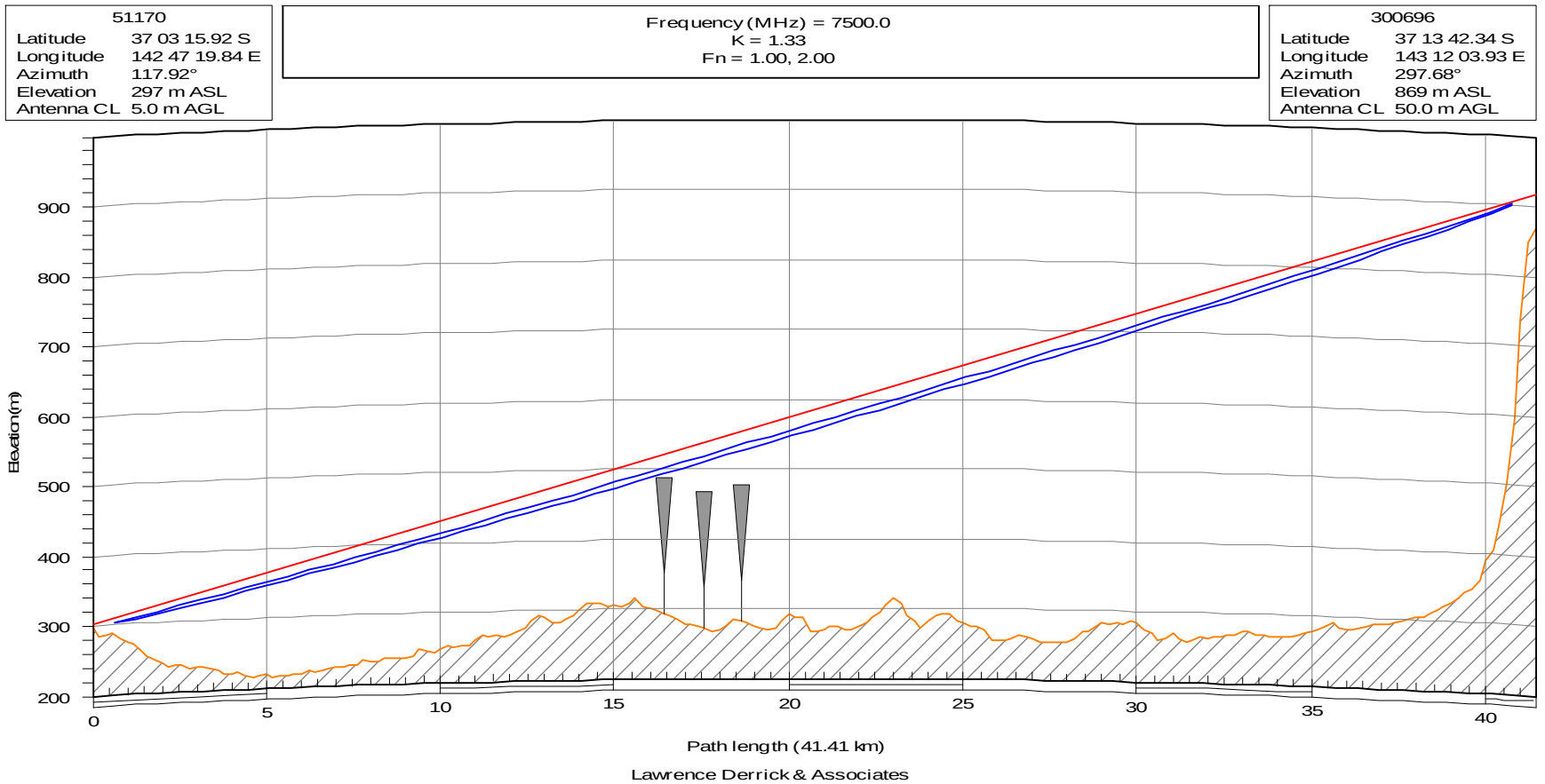
For the omnidirectional case $g_1(0) = g_1(\theta)$ & $g_2(0) = g_2(\theta)$
It can also be assumed that S_1 will approx equal D_p

then

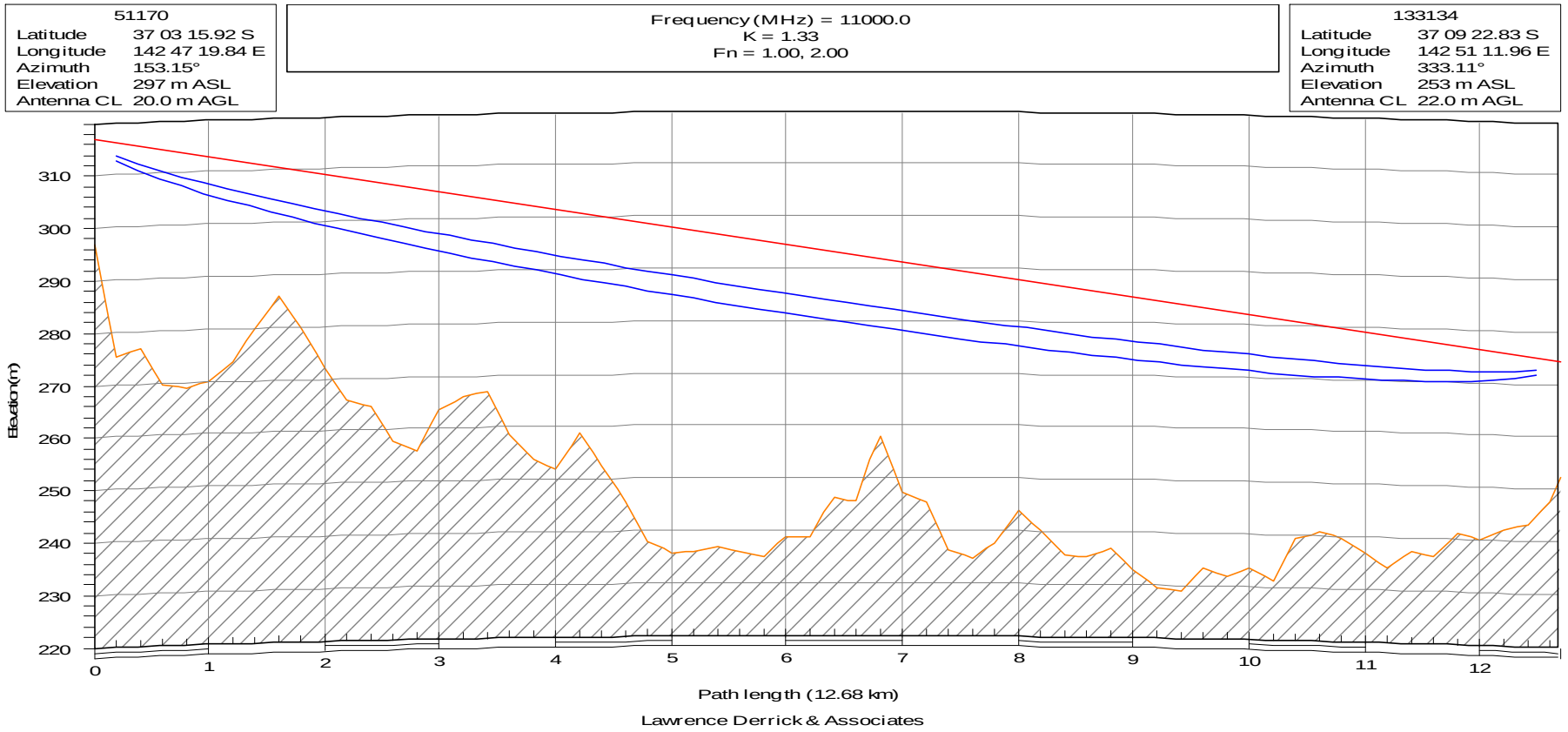
$$r_{ci} = \frac{l_i}{l_d} = \frac{4\pi S_2^{\ 2}}{\sigma}$$

= 4x π x 300²/1000
=1130 or 30.5dB at 300 metres

ATTACHMENT 11 – VODAFONE LINK PATH PROFILE SITE 51170 to SITE 300696

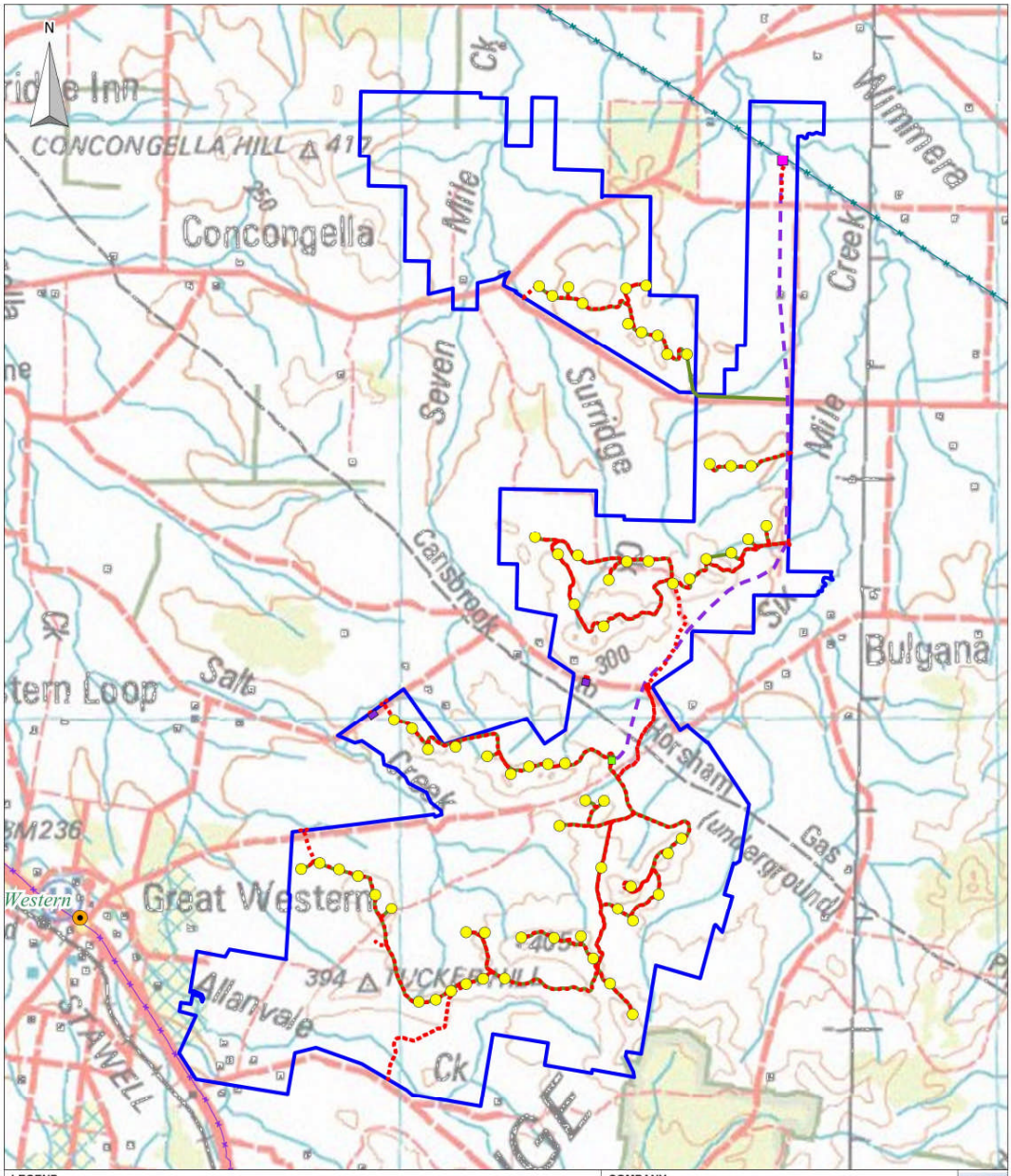


ATTACHMENT 12 – NBN CO. LINK PATH PROFILE SITE 51170 to SITE 133134



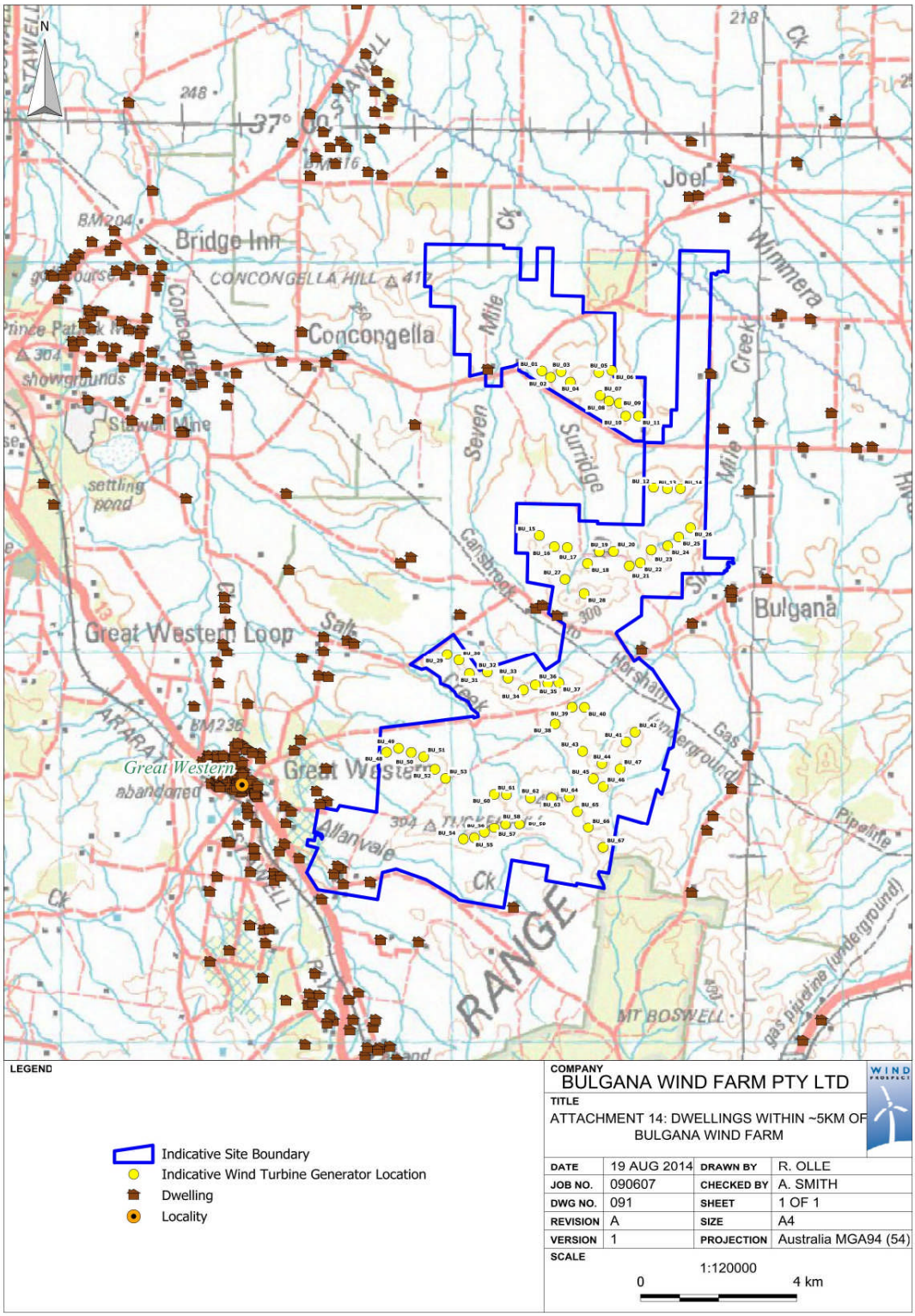
ATTACHMENT 13

BULGANA WIND FARM SITE LAYOUT



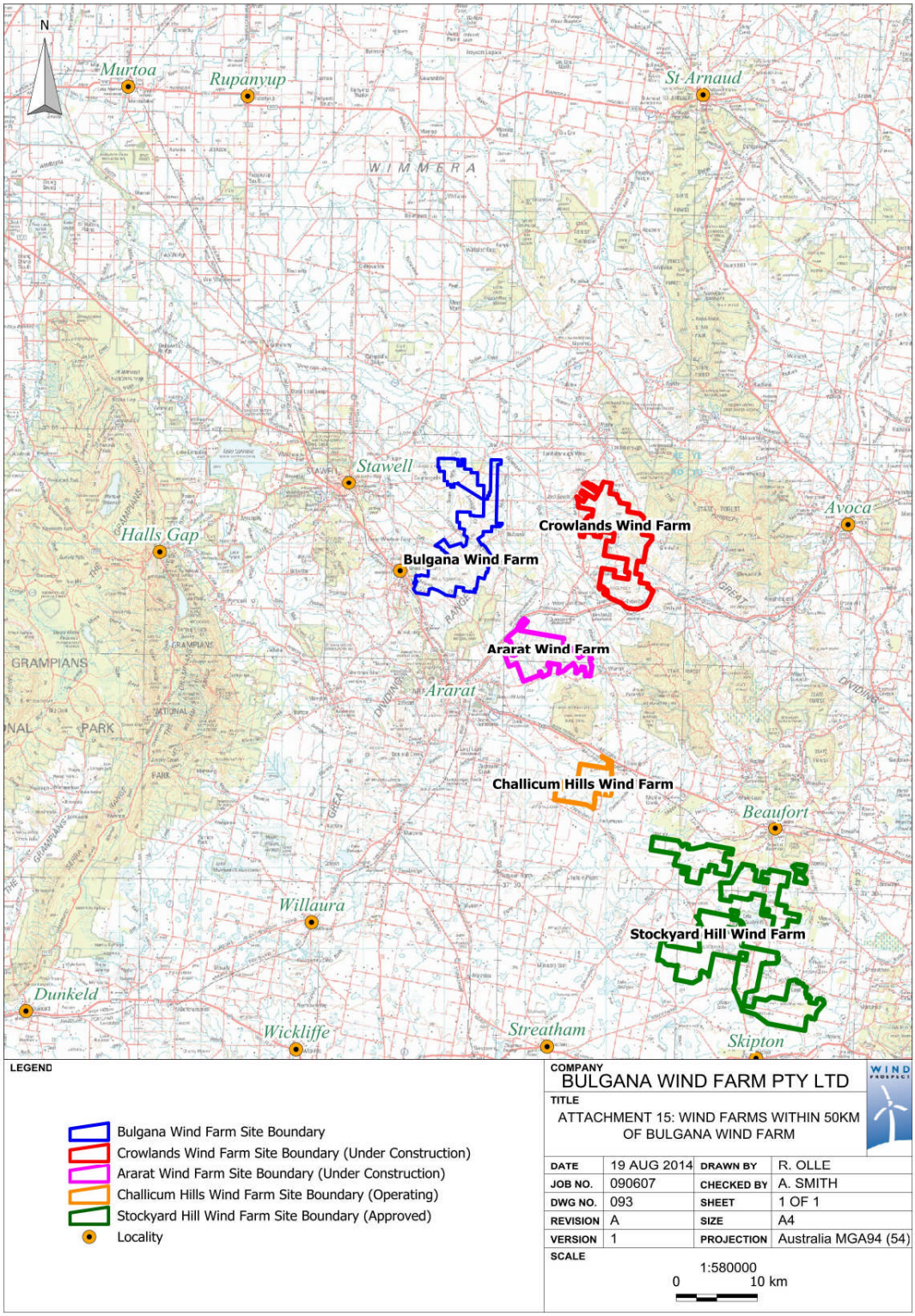
ATTACHMENT 14

BULGANA WIND FARM SITE - DWELLINGS WITHIN 5KM

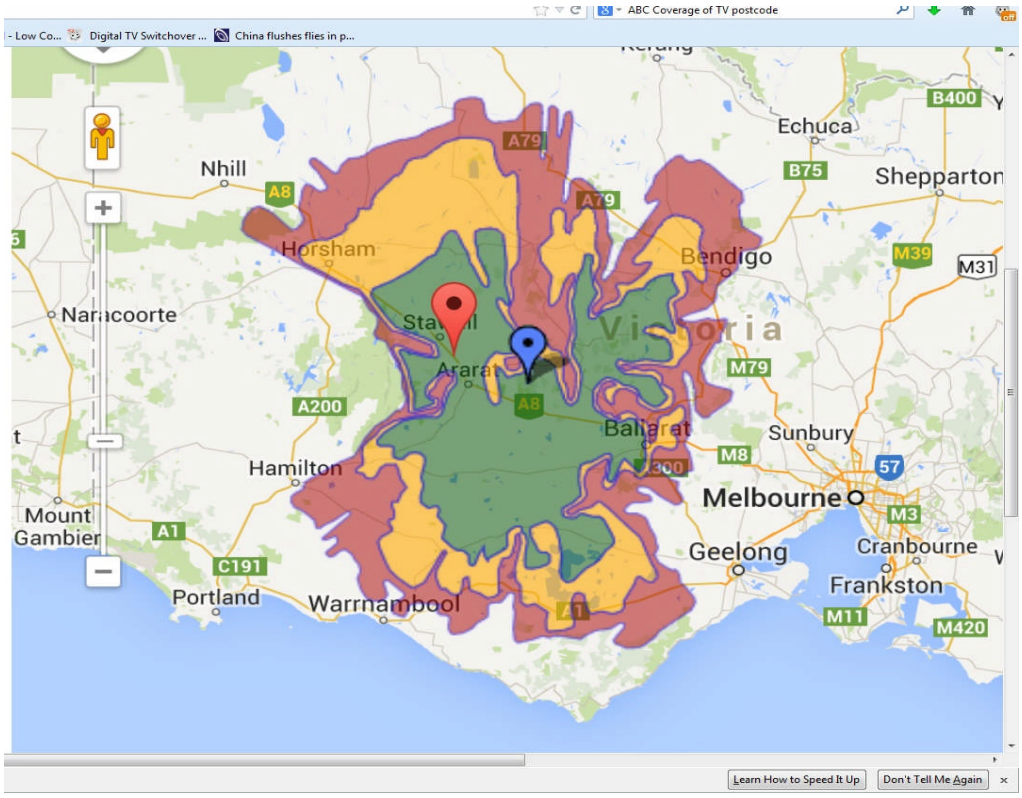


ATTACHMENT 15

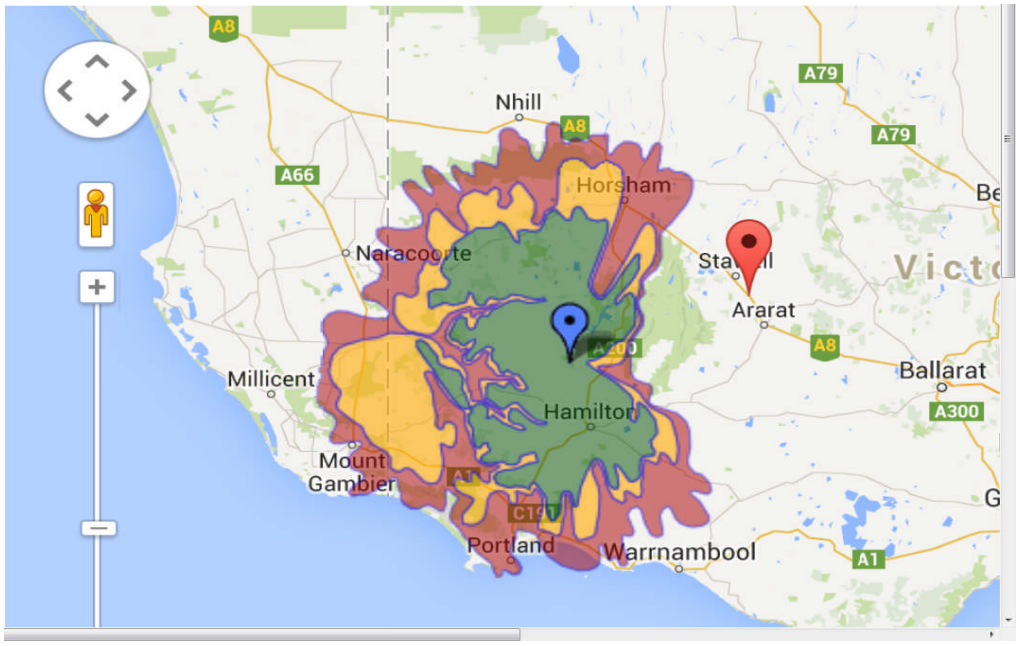
MAP OF WIND FARMS ADJACENT TO BULGANA WIND FARM



ATTACHMENT 16– ABC PREDICTED TV COVERAGE FOR MAIN STATIONS AT LOOKOUT HILL AND MT DUNDAS



BALLARAT



WESTERN VICTORIA

Map Keys

+ Primary Coverage:
(+ expand for details)
+ Secondary Coverage:
(+ expand for details)
+ Tertiary Coverage:
(+ expand for details)

Transmitter Icon - Blue
Bulgana Wind Farm Location Icon - Orange