APPENDIX 18

Crudine Ridge Wind Farm Investigation of Possible Impacts on Radiocommunication Services

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Crudine Ridge Wind Farm

Electromagnetic & Communication System 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

EXECUTIVE SUMMARY

Wind Prospect CWP is developing a proposal for the construction of the Crudine Ridge Wind Farm midway between Mudgee and Bathurst and near the town of Pyramul in NSW.

A number of existing ACMA registered radiocommunication services are located in the general area and six point-to-point radio services cross 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. The residences in the area surrounding the wind farm are provided with TV, FM Sound and other services from high power transmitters located on Mt Canobolas (Central Tablelands) or Mt Cenn Cruaich (Central Western Slopes). Low power stations near Kandos, Mudgee, Capertee, Oberon and Bathurst may also provide services to a few residences in the area. The TV/Sound broadcasting Licensees providing service to the area have been identified facilitating correspondence with the organisations involved to request an impact assessment on these services.

This Report provides an analysis of each of the radio facilities registered near the wind farm and 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.

1 INTRODUCTION

Two proposed layouts of wind turbines are being considered for the site, one with up to 90 metre diameter rotors and the other with up to 120 metre diameter rotors. The coordinates of the wind turbines for both cases provided by Wind Prospect CWP are shown in Attachment 1.

1.1 Objective of this Study

The objective of this study and Report 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 proposed turbine layouts meet the required clearance criteria is also undertaken.

1.2 Scope

The criteria for clearance of obstructions from point-to-point link ray lines have been well established in the literature, including for the specific case of rotating turbines. 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 is the SA DTEI guidelines prepared by Telstra where an exclusion zone for the SA – GRN 400 MHz mobile radio base stations has been derived. This Report considers the factors involved in the specific services in the area 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

The source of data for the existing services in the area is the ACMA database for licensed radiocommunication services both from a recently issued CD and the ACMA public web site. The accuracy of the location of towers is contained 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 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.

2 WIND TURBINE IMPACTS ON RADIO COMMUNICATIONS

A paper, Ref 1, by D. F. Bacon in 2002, issued by Ofcom, the regulator for the UK communications industries, appears to have 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:

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 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 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 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 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 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 the Bacon paper 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, Ref. 2, the RCS of turbines were modelled and validated with actual field measurements. This study was focused on the aviation radar signatures of wind farms and measurements were carried out with radar in the 1 to 3 GHz range. Peak RCS values can significantly exceed the physical area of the turbine but they will occur over narrow arcs. The wind generator nacelle and the general shape of the tower itself can make significant contributions. A 100metre tall tower with 45 metre turbine blades was estimated to have a maximum peak RCS of 25000 m². According to the Report 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

The Bacon paper was written for the point-to point-radio link situation and no omnidirectional system (e.g. mobile radio base station) was considered. The DTEI guidelines have been developed for omnidirectional mobile services from the Bacon paper 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 CRUDINE RIDGE WF

From the latest ACMA database, maps have been prepared showing registered radio sites and point-to-point links in the area. Attachment 2 shows the situation for systems with frequencies below 1000 MHz with zoomed views in Attachments 3 & 4. Attachment 5 shows the links and sites for systems operating on frequencies above 1000 MHz with zoomed views in Attachments 6 & 7. Typical calculations of required clearances are shown in Attachment 8 using the formulas in Bacon's paper. It should be noted that site numbers displayed in Attachments 2 & 5 may not be the actual ones associated with a 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 6 Point-to-point links in the 42 MHz, 400 MHz, 4 GHz, 7.5 GHz and 8 GHz bands operated by TransGrid, NSW Rural Fire Service, Telstra, Optus and Soul Pattinson Telecommunications on 6 paths which nominally cross the site. Two 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 or 0.6x 1st Fresnel zone clearances at mid-path and at 1 KM are shown in Tables 1 & 2. No radio sites located within the wind farm boundaries were identified from an analysis of the ACMA data. The locations of the turbines for both layouts 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
34905-36251	29.4	4000	Telstra	33.2	12.0
34905-36900	42.0	7500	Soul Pattinson	29.0	8.8
34905-9011806	13.8	8000	Optus	22.8	8.5
9013962-9012144	37.57	8000	Optus	26.5	8.5

TABLE - 2VHF/UHF LINK CLEARANCES

PATH ACMA Site ID's	Total Path Dist. km	Frequency MHz	Operator	Mid Path 0.6x 1st Fresnel Zone Distance m	1 Km Fresnel Zone Distance m
34905-35200	29.6	400	NSW RFS	44.7	16.2
10712-35956	107.3	42	TransGrid	262.6	50.5

The calculation of the reflection/scattering zone using the Bacon formula 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 TV & FM Broadcasting Stations at Kandos, Mudgee & Capertee.

Nearby low power TV and FM Broadcasting stations for Kandos, Mudgee & Capertee are located on Baldy Peak, Endicott Hill and 2 km south of Capertee respectively (ACMA Site ID's 40833, 11345 & 153525). These sites are about 28.4, 34.3 & 39.4 km respectively from the nearest turbines. Low power TV/FM Sites also exist to serve the Portland/Wallerwang, Oberon and Bathurst areas at greater distances. All of these sites are separated from the wind farm by sufficient distances to not have the TV coverage impacted by wind turbines. From some past special purpose ACMA data it appears that the Kandos and Capertee stations receive TV main stations signals off-air from the Mt Canobolas main TV station. The Mudgee station appears to receive signals off-air from Mt Cenn Cruaich for the commercial stations or have a satellite signal input for the ABC and SBS stations. Examination of the signal paths between the main stations and these repeaters indicates that the path to the Kandos station from Mt Canobolas passes near the Crudine Ridge turbines but the other two paths to the Mudgee and Capertee stations are well clear of turbines. In this case the separation distance to the nearest turbine location at the southern end of the wind farm is 2.6 km which appears to be adequate to eliminate any turbine disturbance of the input signal to the Kandos TV repeater station.

3.3 Air Services Facilities

There are no registered Air Services Radar sites within line of site of the turbines. Non Directional Beacons (NDB's) or other VHF services are located at sites 11329 and 134023 in the Mudgee and

Bathurst areas. Due to the separation distance between the wind farm boundaries and these sites, no addition buffer zones are required

3.4 Point to Multipoint (PMP) Services

The 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
205668/Rylstone	450	Mid W. Regional Council	UHF
11344/Mudgee	450	State Water	UHF
35200/Bocoble	450	State Water	UHF
35956/Kandos	450	Endeavour Energy	UHF
250204/Mudgee	3400	Optus	Microwave
150302/Hill End	3600	Murray River Regional Telecoms	Microwave
205693/Ben Bullen	151.5	Met Bureau	VHF

Given that the 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. It would be prudent to advise the operators of the PMP Services of the wind farm proposal.

3.5 Radio Sites in Close Proximity to Wind Turbines

There are no radio sites within the general wind farm site envelope. There are two sites (34905& 35898) at the southern end of the wind farm, on Monkey Hill, within about 2.4 km of the nearest wind turbine. There are a large number of radio systems installed on these two towers. Apart from point to point radio systems covered in the map study there are a number of services including mobile radio base stations, Telstra cellular mobile base stations and a NSW Rural Fire Service(NSW RFS) Paging service transmitter. In addition an FM broadcasting service and a CB UHF Repeater are installed. All of the services have been examined for any possible impacts of wind turbines located 2.4 km and beyond from these towers. 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 Telstra cellular base stations and the CB UHF repeater. The current spacing to the nearest turbine of 2400 metres should be adequate to avoid any wind turbine impacts on all services on Monkey Hill.

4 TV COVERAGE IN THE AREA

A study has been carried out on the TV stations potentially available for residents in the area surrounding the wind farm. Using ACMA lists of broadcasting stations and the ABC internet prediction service of available coverage (based on post codes or town names) a number of services are potentially available, although availability will vary depending on actual locations around the wind farm site. From the ABC predictions coverage from the TV transmitting stations shown in Table 4 may be possible depending on specific terrain profiles to the stations.

TABLE 4 - TV STATION TRANSMITTER SITES

Central Tablelands (main station)	Mt Canobolas
Central Western Slopes (main station)	Mt Cenn Cruaich
Kandos (low power)	Baldy Peak
Mudgee (low power)	Endicott Hill
Capertee (low power)	2 km SE of Capertee
Portland /Wallerwang (low power)	Garlands Hill
Oberon (low power)	Falls Hill

These ABC predictions are based on post codes and the lower powered TV stations may not in fact be available in the areas around the wind farm. Pyramul, Sofala, Ilford and Crudine were used for the predictions, being the towns closest to the wind farm. A phone or field survey would need to be carried out to determine the actual TV station(s) utilised at individual residences in the area. There is some possibility that Interference to analogue TV reception at residences that are in the forward scatter zone from turbines in the received direction of the TV stations and where the residence is close to the turbines. It is expected that reception of digital signals will be less impacted by turbine interference in reasonable signal level areas.

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

Replacement or reposition of TV antenna
Use of a digital set top box or digital TV receiver
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 Crudine Ridge wind farm in conjunction with other proposed or existing adjacent wind farms. A map issued by NSW Planning & Infrastructure and updated on 18 April 2011 and reproduced in Attachment 13 shows the locations of wind farms approved, operating or where an application has been received for them. The adjacent wind farms to Crudine Ridge are listed in Table 5:

TABLE 5 - WIND FARMS ADJACENT TO CRUDINE RIDGE WIND FARM

Wind Farm	Status	Approx Distance from Crudine Ridge Wind Farm km
Bodangora	Application received	62
Uungala	Application received	50
Hampton	Operating	65
Black Springs	Approved	70
Flyers Ck	Application received	60
Blaney	Operating	50

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 50 km shown in Table 5 the scattered signal from adjacent wind farm turbines will be negligible around the Crudine Ridge farm area. Also no adjacent wind farm are/ will be sited sufficiently close to any TV station to impact on the general TV coverage in the station's service area.
No Cumulative interference to TV reception is therefore likely.

6 POWER TRANSMISSION INFRASTRUCTURE ELECTRIC AND MAGNETIC FIELDS

The project will involve the construction of the following power distribution components:

- A main collector substation comprising cable marshalling, switchgear high voltage transformers and associated protections and communications assets;
- A secondary collector substation to be located within the southern Cluster comprising cable marshalling, switchgear and medium voltage transformers;
- Underground electrical interconnection lines (up to 33 kilovolt (kV)) and control cables within each of the wind turbine Clusters, connecting to the main and secondary collector substations;
- Internal overhead electrical interconnection lines (up to 66 kV double circuit) and control cables between the main and secondary collector substations;
- A switching station to be located at the point of connection adjacent to the existing TransGrid owned 132 kV line, east of the Project;
- External overhead electrical interconnection lines (up to 132 kV double circuit) and associated communications cables between the main collector substation and the switching station

Attachment 12 is a map of the wind farm site showing the route of the HV powerlines proposed. The 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 main transmission lines from the wind farm substation to the grid will employ 132 kV overhead lines with specifications consistent with the HV lines throughout the network. The height of the lines and the easement width will be in accordance with TransGrid recommendations which will ensure magnetic and electric fields will be within acceptable limits for human exposure and electromagnetic interference levels at dwellings in the area and for accessible public access areas. For a 132 KV line the usual easement width is 45 metres. Depending on the number of circuits carried, the lower 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 of 2.4 km 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 DISCUSSION

The Bacon paper 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.

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. For example, two reports (Refs 4 & 5) which considered base station clearances to turbines derived the clearances required using the scattering criteria. In one (Ref 5, BCL NZ) a clearance of 600 metres was derived for VHF mobile base stations and the other (Ref 4, Kordia NZ) 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.

7.1 Point-to-Point Links

As shown in the Tables 1 & 2 above, link paths require Fresnel zone clearance of between 22.8 and 262.6 metres at the mid path of the link 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. The two VHF/UHF systems which nominally cross or are near the boundaries of the wind farm site are single channel analogue or low capacity data links. It is generally accepted that a second Fresnel turbine clearance should be applied to higher frequency microwave links of multi-channel capacity, and is desirable for lower frequency links. It could be argued, however, that it is not essential to apply it to the VHF or UHF links, considering the low impact on these links. These calculated corridor widths should be reviewed with the link operators if their application significantly reduces the utility of the site (through reduced number of turbines). The other links are multichannel microwave link and the full clearance should be maintained. Path profiles for the two microwave links are shown in Attachments 10 & 11.

7.2 TV & 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 that may occur over a large area. Regarding the local low power TV and FM stations mentioned above, however, there is a considerable distance to the nearest turbines, with negligible impacts expected from wind turbines. 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. As indicated in section 3.5 above there is a low power FM station operating on site 35898 which is close to the southern end of the wind farm. It is considered that the 2.4 km separation to the nearest turbines is sufficient to have minimal impact on the coverage of the station.

7.3 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 (Ref. 2), however, recommend buffer zones of 1200 metres for emergency services radio base stations and Paging Services.

8 RECOMMENDATIONS

8.1 Point-to-point Links

As there are six paths which cross or are close to the site, horizontal corridor clearances are required, details of these are summarised below. Path profiles are shown in Attachments 9, 10 and 11. These horizontal clearances are specified because sufficient vertical clearance may not be achieved when turbine blade tips are considered. As mentioned previously, 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 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 6 should be maintained for the six relevant links: (Please note the comments in the table below regarding a review of the clearance distance for the TransGrid link if it is too restrictive on the site layout).

TABLE 6 – 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 Z55	SITE B COORDS GDA 94 Z55
34905-36251	66.4	E741192 N6342205	E 757517 N 6366625
34905-36900	58.0	E741192 N6342205	E 779724 N6358966
34905-9011806	45.7	E 741192 N6342205	E768811 N6342838
9013962-9012144	53.1	E729008 N6342345	E757506 N6366706
34905-35956	89.4	E741192 N6342205	E757556 N6366798
10712-35956	525.3*	E684476 N6308835	E779820 N6358931

* 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, 120 metres, the centre line of the turbine towers should be at least 66.4/2 + 120/2 = 93.2 metres from the 1st listed radio link ray line.

The radio link paths and the turbine layouts superimposed on the MapInfo maps show that the required clearances are met for all of the radio links which traverse the wind farm site for both the 90 metre and 120 metre diameter rotor alternatives. If any micro-siting of turbines is required, however, the specified buffer zones must be maintained.

8.2 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 sites: 34905 & 35898). This is based on the SA - GRN guidelines for emergency services omnidirectional services which include paging services. All radio sites are at least 2400 metres from the nearest turbines in the current layouts so no buffer zones are required.

8.3 Interference to Television reception

The wind farm area is in the Southern New South Wales TV1 Licence area. The Central Tablelands and Central Western Slopes Main Television stations at Mt Canobolas and Mt Cenn Cruaich would generally service the area, with transmission from lower power translator stations at Kandos, Mudgee and Capertee possibly received by a few residents.
The prediction of TV interference at individual dwellings as a result of turbine interference has been shown to be generally unreliable. As indicated above, there is a possibility that interference to analogue TV reception at some residences may occur (if they are located in the forward scatter zone, in the received direction of the TV stations) where they are particularly close to turbines. It is expected that reception of digital signals will be less impacted by turbine interference in reasonable signal level areas. A number of possible mitigation methods are available to restore interference free television to dwellings as listed above.

Television operators in the area are:

- ABC
- SBS
- Australian Capital Television Pty Ltd
- Prime Television (Southern) Pty Ltd
- WIN Television NSW 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.

8.4 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. As indicated above

9 CONCLUSIONS

For both current alternative layouts 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.

The project interconnecting power lines and substations will be constructed and located to industry standards which will 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.

10 REFERENCES

[1] Fixed-Link wind-turbine exclusion zone method, Version 1.1, 28 October 2002, D.F. Bacon, UK Radio Communications Agency,

[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

ATTACHMENT 1

WIND TURBINE GRID COORDINATES CRUDINE RIDGE

ZONE 55 MGA94

100 m PLUS ROTOR			80 – 90 m ROTOR		
ID	Easting	Northing	ID	Easting	Northing
B1	751344	6356569	A1	751340.9	6356501
B2	751244	6356194	A2	751252	6356181
B5	748969	6355894	A3	750744	6356219
B4	749769	6356019	A4	750785.3	6355965
B6	749492	6355424	A5	750747.5	6355699
B7	749444	6355044	A6	749769	6356019
B3	750769	6355969	A7	749694	6355769
B8	750819	6355594	A8	749498.5	6355437
B9	751194	6355419	A9	749443	6355112
B10	751569	6355219	A10	751219	6355394
B11	751009.5	6355167	A11	751560.9	6355219
B12	750820	6354844	A12	750780	6355333
B13	750072.2	6354633	A13	750903.1	6355110
B14	750570.6	6354435	A14	750819	6354844
B15	749917.8	6354267	A15	750133	6354974
B16	750394	6354094	A16	750065.2	6354676
B17	749935.4	6353864	A17	749929.7	6354425
B18	750466.9	6353623	A18	749911.9	6354156
B19	750442.7	6353319	A19	749994	6353969
B21	750069	6353294	A20	750594	6354469
B20	749561	6353340	A21	750427.5	6354203
B22	749657.5	6353003	A22	750476.4	6353901
B23	750219.9	6352942	A23	750469	6353644
B24	749519	6352669	A24	750440.8	6353372
B25	749909	6352503	A25	750051.9	6353479
B26	749844	6352144	A26	749560.8	6353341
B28	749249	6352043	A27	750096.3	6353201
B27	749717.1	6351837	A28	749696.3	6352956
B29	749244	6351719	A29	750207.5	6352954
B31	748817	6351500	A30	749598.5	6352703
B30	749444	6351444	A31	750018.6	6352707
B32	748362.9	6351261	A32	749816.3	6352445
B33	749244	6351094	A33	749438.5	6352205
B34	747298.4	6351105	A34	749847.4	6352174
B36	748409.2	6350599	A35	749751.9	6351903
B37	747918.4	6350276	A36	749403	6351750
B38	746971.7	6350212	A37	749100.7	6351621
B39	746940.4	6349827	A38	749465.2	6351478
B40	746468.4	6349547	A39	748769	6351494
B41	746292	6349221	A40	749096.3	6351350

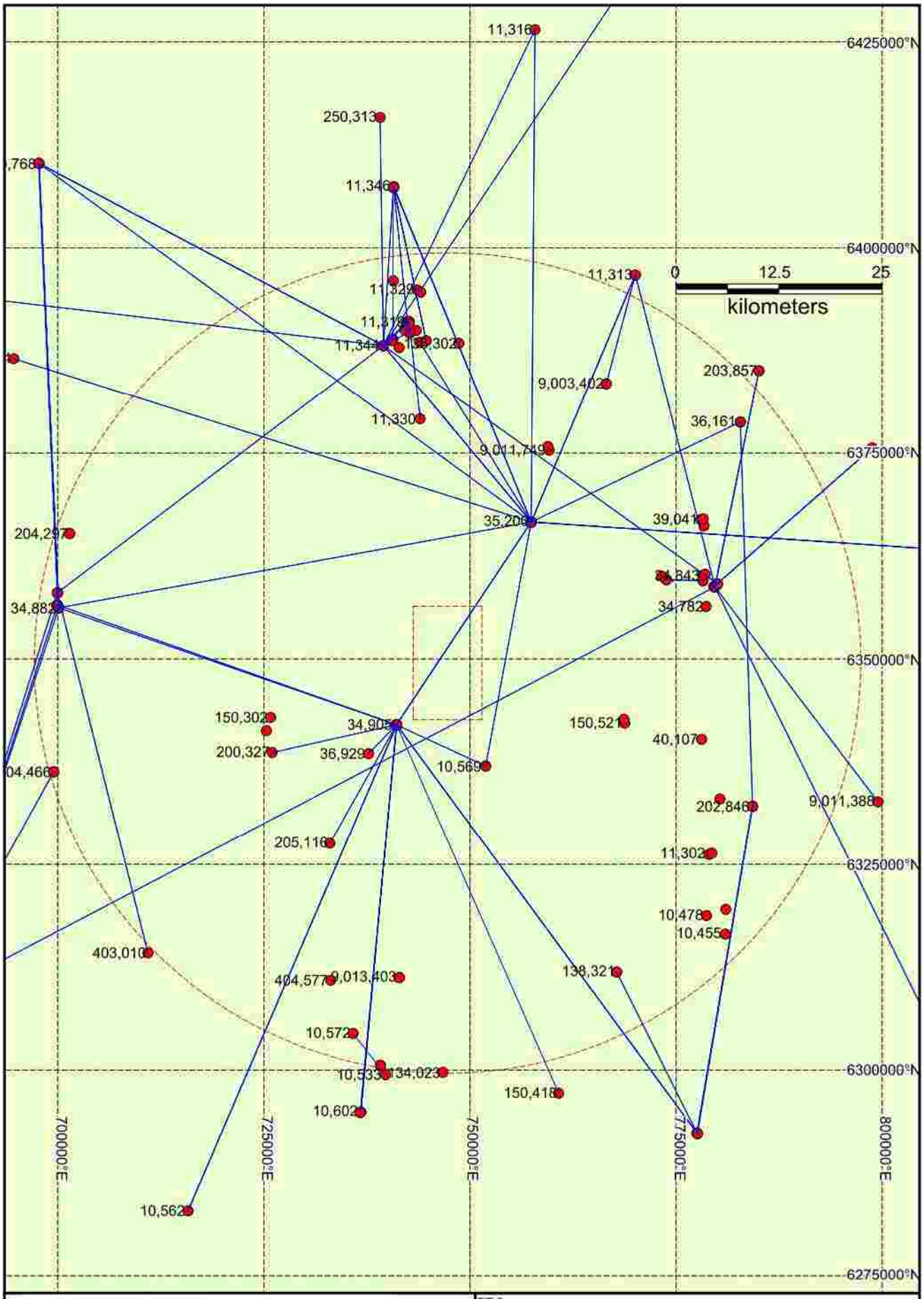
B42	746094	6348894	A41	748418.4	6351294
B43	744019	6349441	A42	748794	6351145
B44	744619	6349244	A43	749243	6351107
B45	743946	6349035	A44	747298.4	6351105
B48	745069	6348569	A45	748231.8	6351058
B47	744644	6348469	A46	748211.8	6350832
B46	744040.2	6348387	A47	748805.1	6350872
B49	744594	6348194	A48	748447.3	6350632
B50	743938.8	6348015	A49	748167.3	6350470
B51	744444	6347869	A50	747918.4	6350276
B52	743869.6	6347625	A51	747529.5	6350198
B53	744294	6347394	A52	746971.7	6350212
B54	743806.4	6347203	A53	746873.9	6349929
B55	743219	6346944	A54	746889.4	6349701
B56	744088.7	6346883	A55	746429.4	6349692
B57	743719	6346544	A56	746391.6	6349423
B58	744319	6346519	A57	746267.2	6349169
B59	743619	6346169	A58	746109.4	6348909
B60	744444	6346194	A59	744011.4	6349532
B61	744519	6345719	A60	743978.1	6349267
B62	744144	6345494	A61	744635.9	6349234
B63	744619	6345394	A62	743944.8	6349027
B64	744110.8	6345222	A63	744067	6348769
B65	744465.9	6344947	A64	744044.8	6348516
B66	743946	6344906	A65	743973.7	6348294
B67	743669	6344894	A66	745051.5	6348607
B68	744269	6344644	A67	744631.5	6348563
B69	743762.3	6344561	A68	744607.1	6348365
B71	743969	6344344	A69	744555.9	6348109
B70	743429.3	6344303	A70	743975.9	6347898
B72	743877	6344082	A71	744411.5	6347845
B73	743869	6343744	A72	743955.9	6347620
B74	743287	6343698	A73	744287	6347414
B75	743581.5	6343449	A74	743318.1	6347296
B76	743629	6343149	A75	743218.1	6346938
B77	743528.8	6342800	A76	743780.3	6347316
B35	748801	6350852	A77	743671.4	6347018
			A78	744169.2	6347131
			A79	744104.8	6346867
			A80	743960.3	6346658
			A81	743791.4	6346425
			A82	744318.1	6346529
			A83	744447	6346218
			A84	744407	6345956
			A85	744529.3	6345707
			A86	744169.2	6345618

A87	744607.1	6345442
A88	744204.8	6345429
A89	744562.6	6345251
A90	744233.7	6345142
A91	743678.1	6344954
A92	743247	6344785
A93	744051.5	6344914
A94	744469.3	6344920
A95	744267	6344662
A96	743842.6	6344596
A97	743469.2	6344447
A98	743944.8	6344318
A99	743491.4	6344182
A100	743867	6344045
A101	743520.3	6343918
A102	743293.6	6343722
A103	743862.6	6343758
A104	743615.9	6343396
A105	743624.8	6343149
A106	743544.8	6342873

ATTACHMENT 2

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

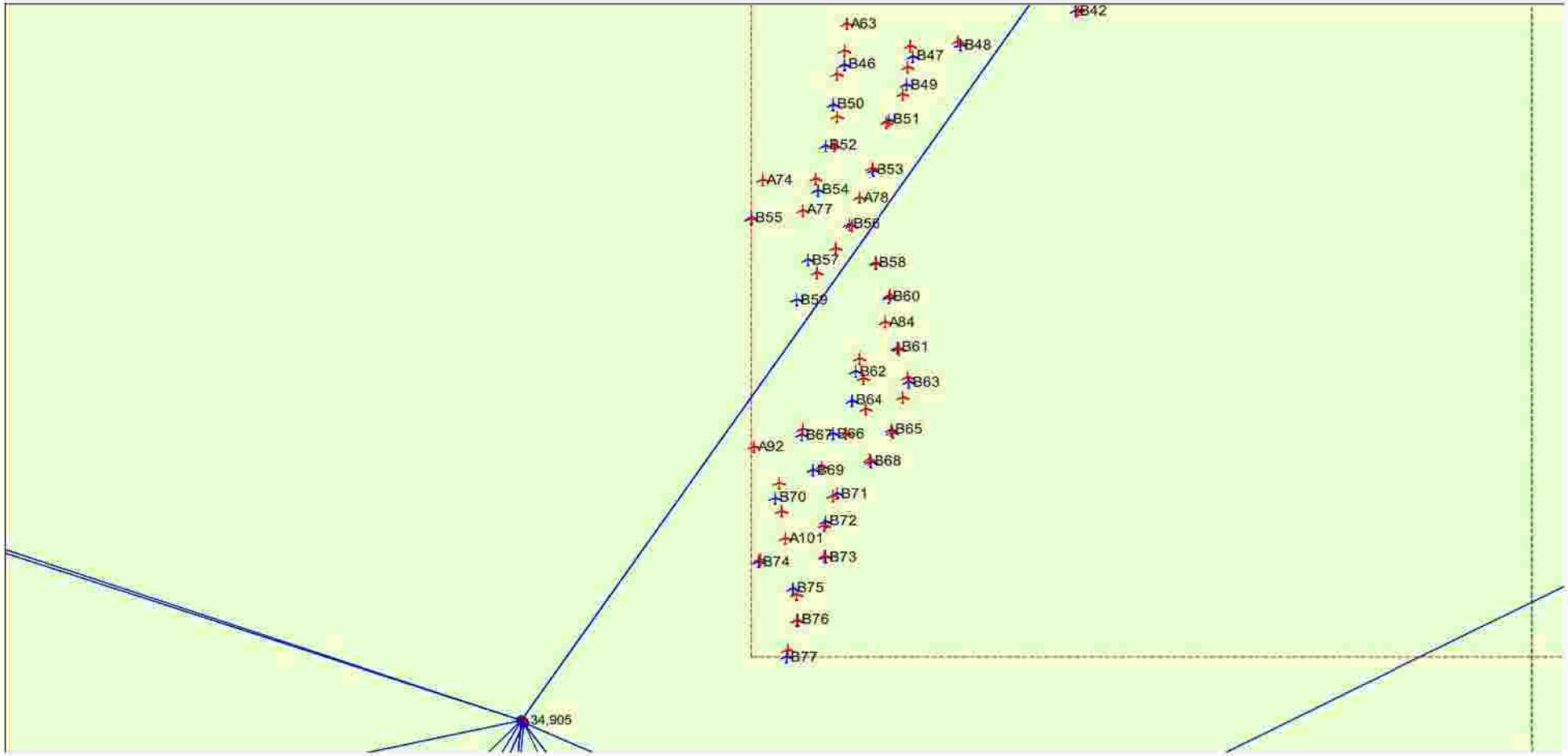
Postal: P.O. Box 3213, BELCONNEN ACT 2617
Telephone: 02 6253 2555
Facsimile: 02 6253 2800

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

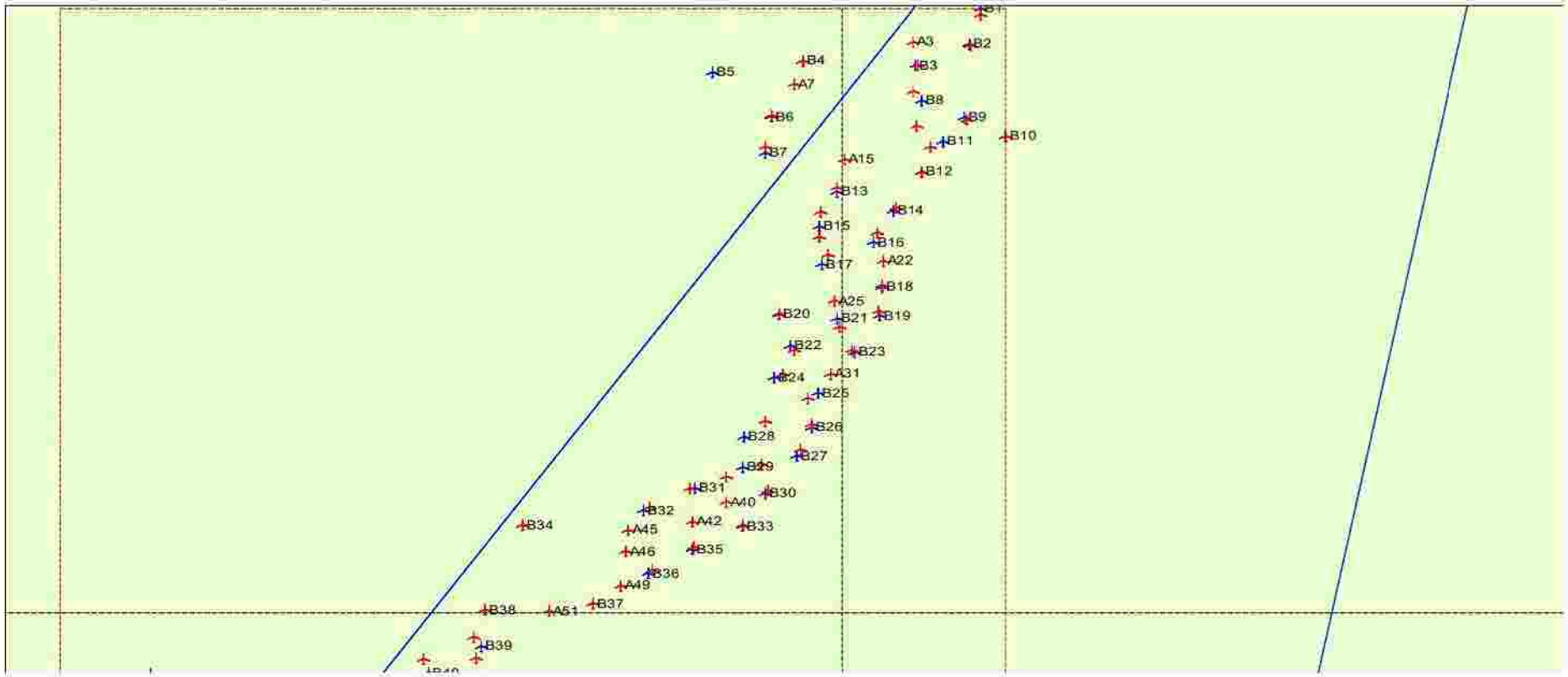
FILENAME: 40-999 MHz Crudine Wind Farm	DATE: 5/7/2011
PROJECT: Crudine Wind Farm	SCALE: N/A
DRWG NO: 1 of 2	BY: SEA

ATTACHMENT 3

MAP OF RADIO LINKS OPERATING BELOW 1000 MHz –DETAIL A 90 &120 METRE ROTOR LAYOUTS



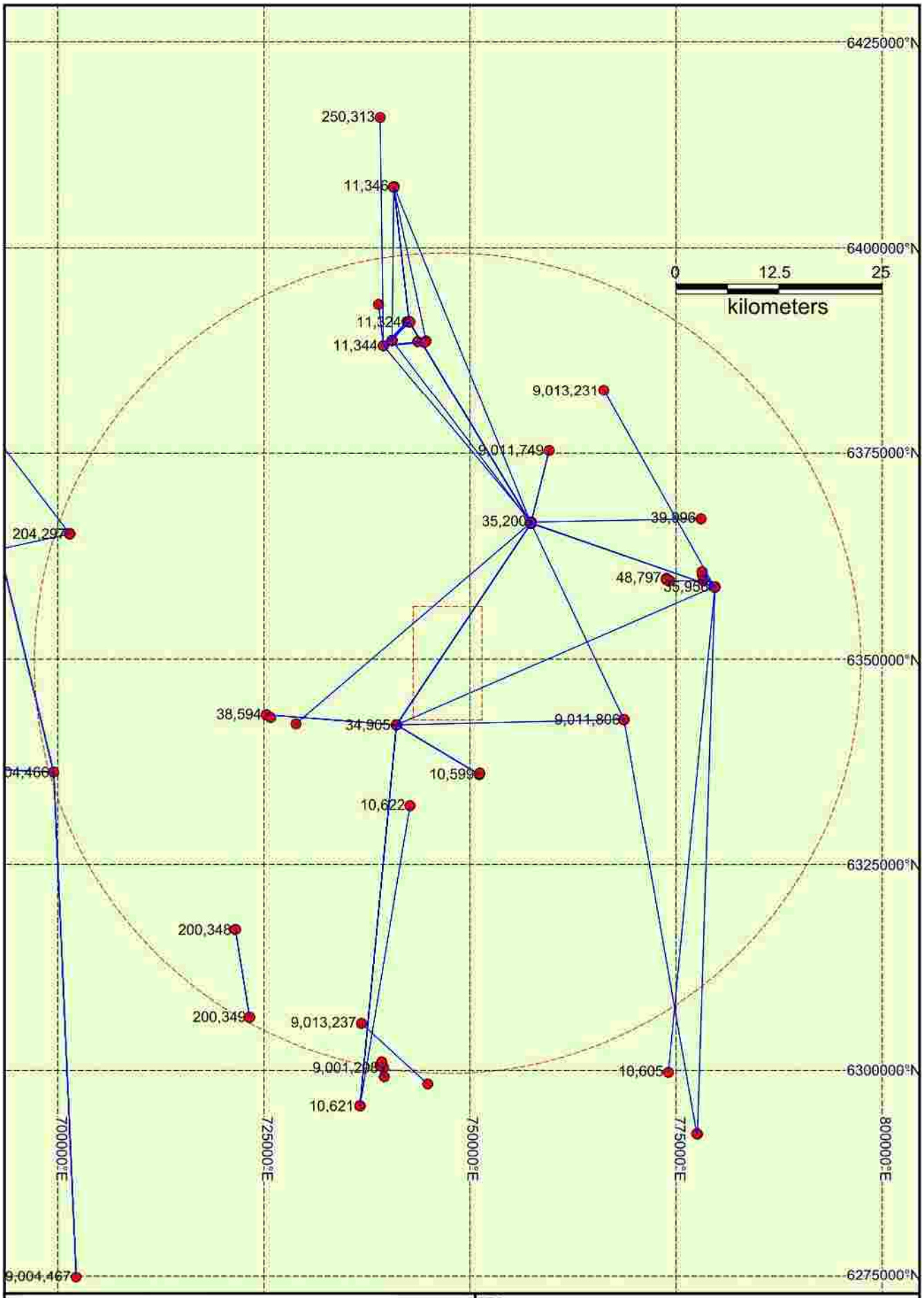
ATTACHMENT 4
MAP OF RADIO LINKS OPERATING BELOW 1000 MHz – DETAIL B 90 &120 METRE ROTOR LAYOUT



ATTACHMENT 5

MAP OF RADIO LINKS & SITES OPERATING ABOVE 1000 MHz

Map shown on following page



SPECTRUM ENGINEERING AUSTRALIA *Pty Limited A.C.N. 008 642 028*

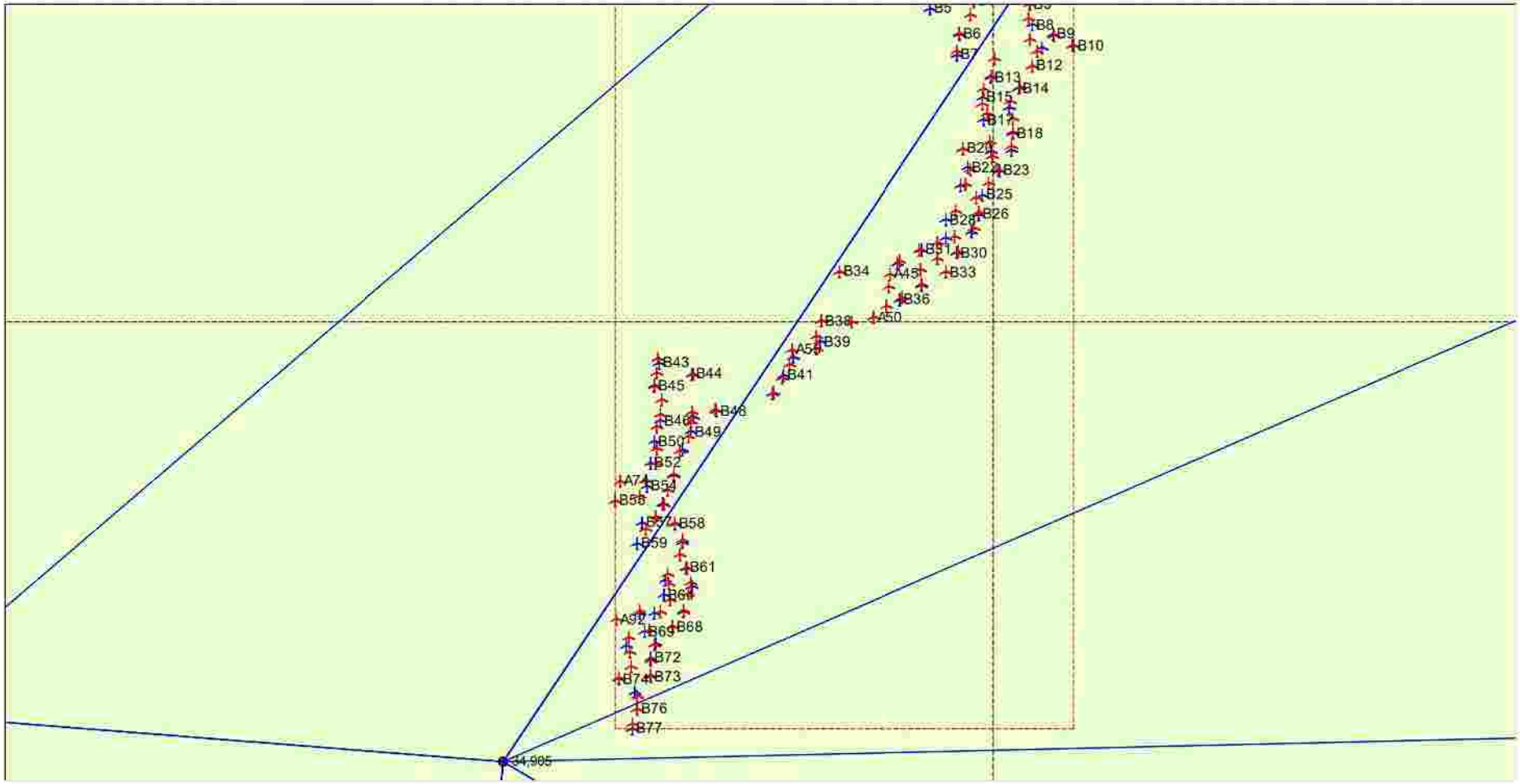
Radiocommunications Planning and Design

Postal: P.O. Box 3213, BELCONNEN ACT 2617
Telephone: 02 6253 2555
Facsimile: 02 6253 2800

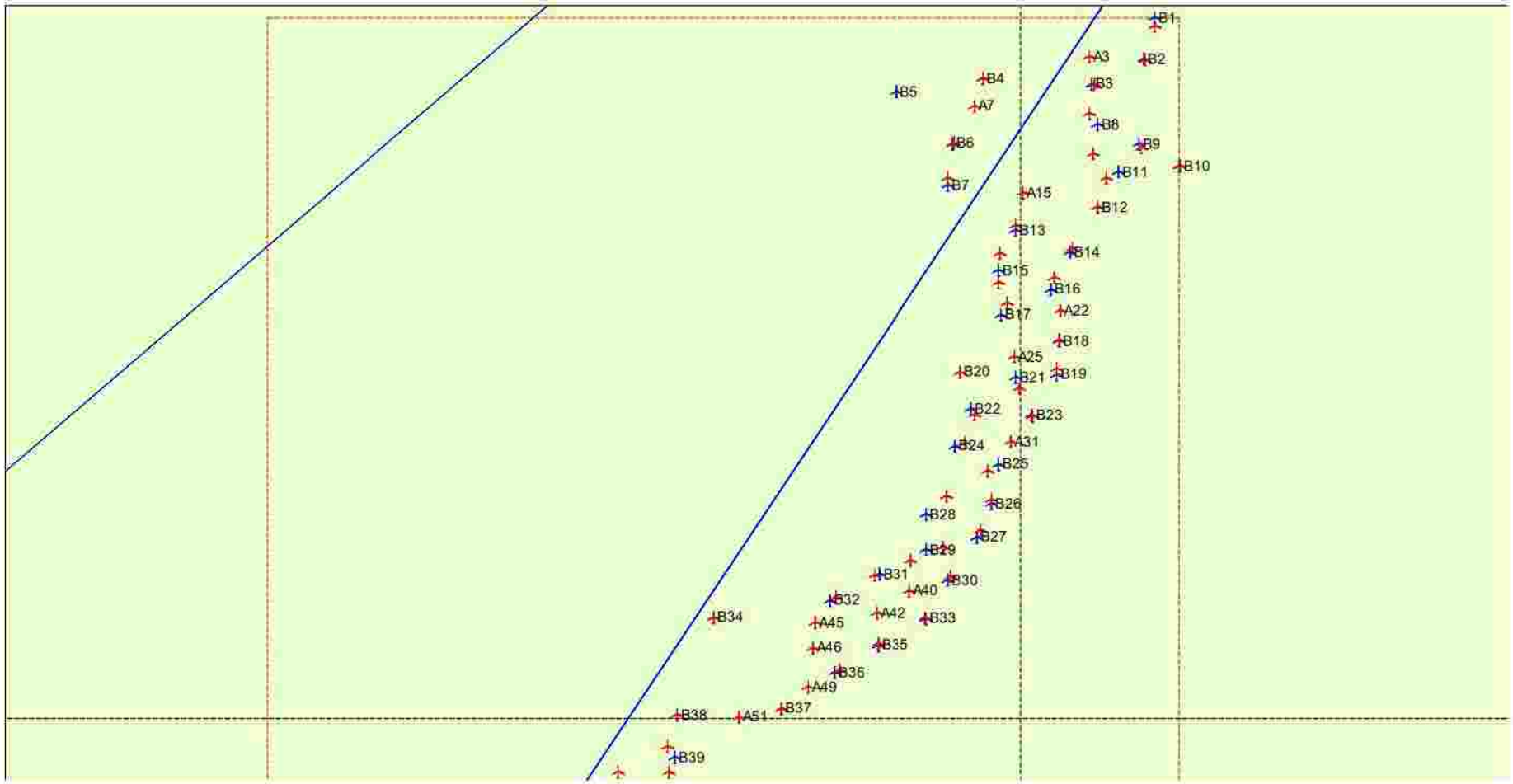
TITLE: **Above 1 GHz Assignments As Extracted from RRL Database**

FILENAME: Above 1 GHz Crudine Wind Farm	DATE: 5/7/2011
PROJECT: Crudine Wind Farm	SCALE: N/A
DRWG NO: 2 of 2	BY: SEA

ATTACHMENT 6
MAP OF RADIO LINKS OPERATING ABOVE 1000 MHz – DETAIL A 90 &120 METRE ROTOR LAYOUT



ATTACHMENT 7
MAP OF RADIO LINKS OPERATING ABOVE 1000 MHz – DETAIL B 90 &120 METRE ROTOR LAYOUT



ATTACHMENT 8
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 Report. The formulas used are taken from Ref. 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:

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

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 Coverage**

(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:

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

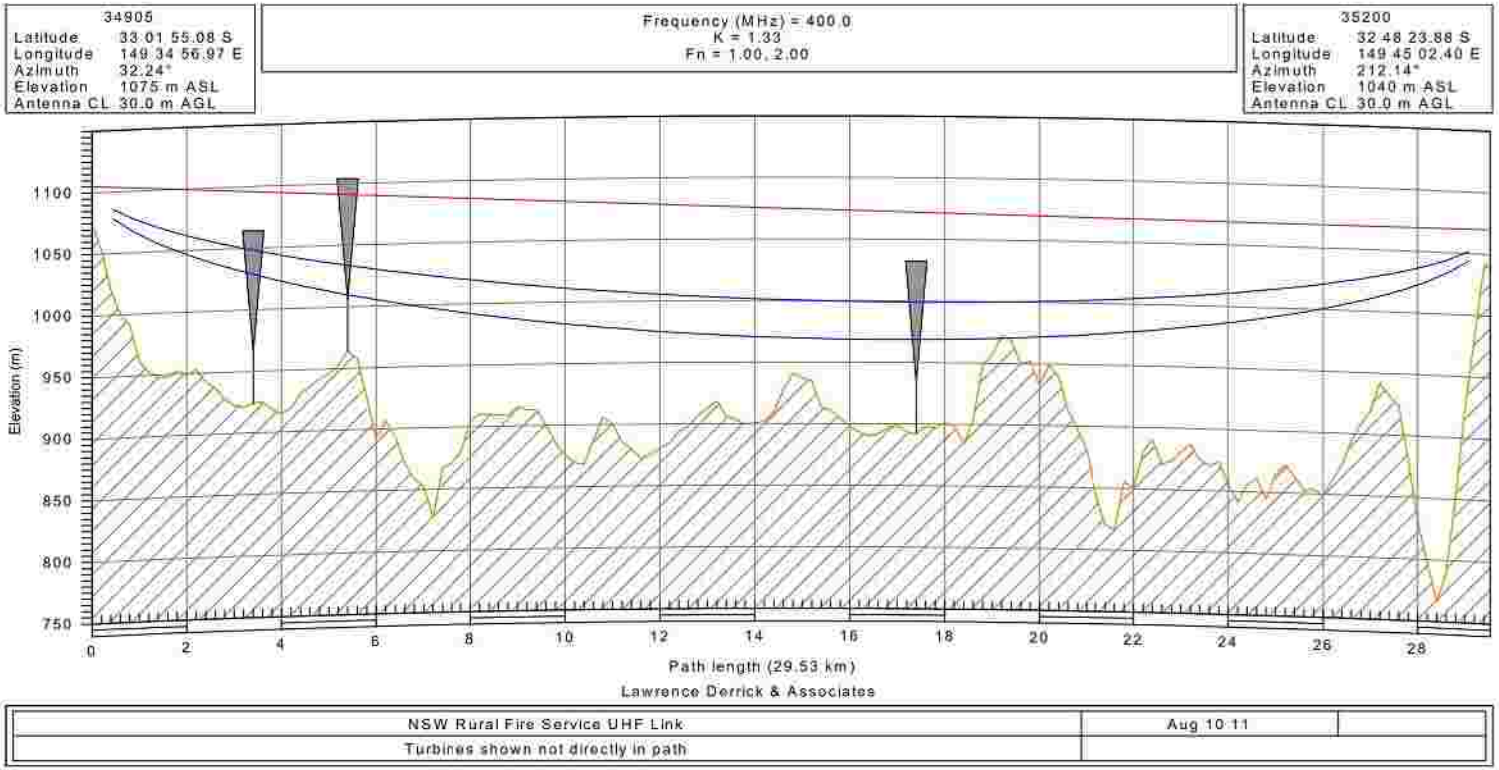
For the omnidirectional case $g_1(0) = g_1(\theta)$ & $g_2(0) = g_2(\theta)$
It can also be assumed that S_1 will approx equal D_p

then

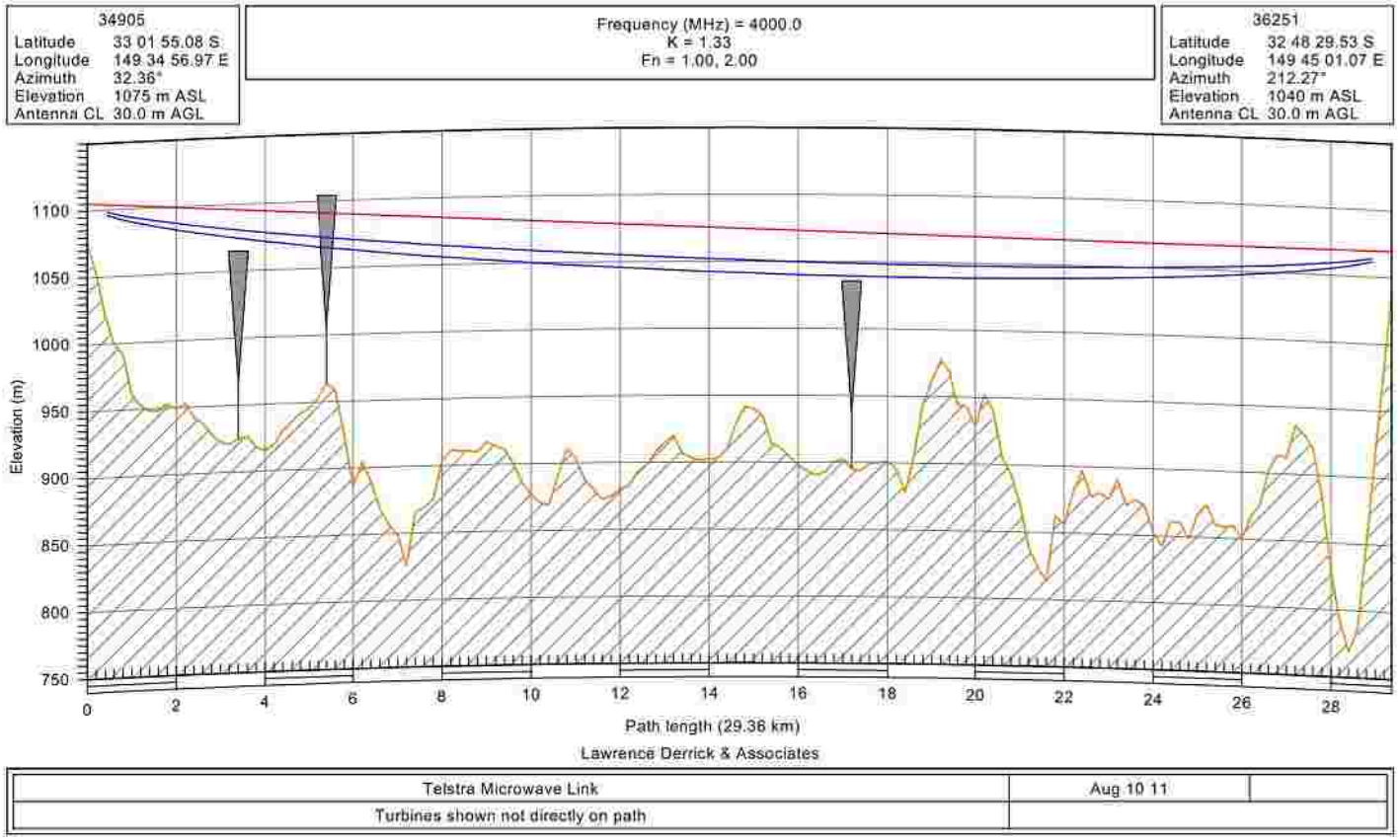
$$r_{ci} = \frac{l_i}{l_d} = \frac{4\pi S_2^{\,2}}{\sigma}$$

$= 4x\ \pi\ x\ 300^2/1000$
=1130 or 30.5dB at 300 metres

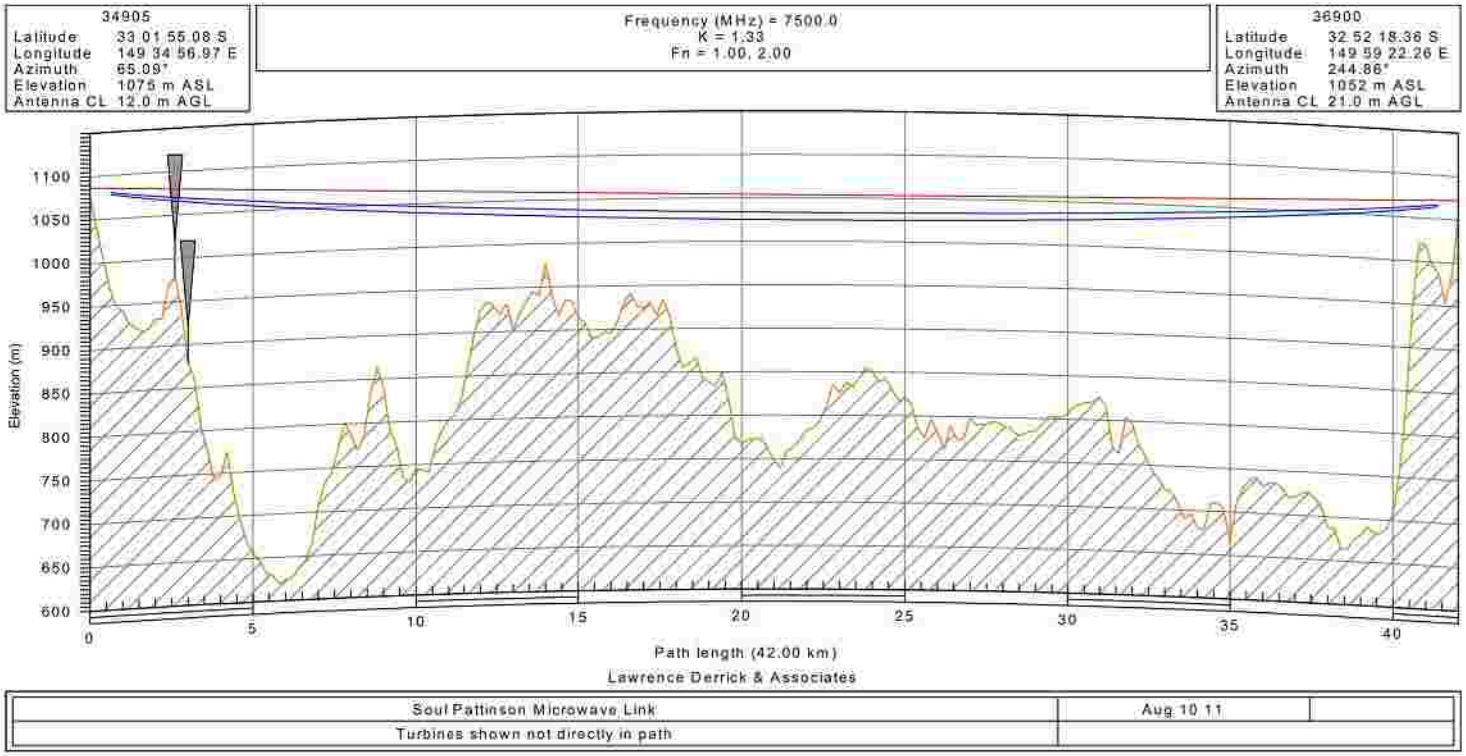
ATTACHMENT 9 – NSW RFS LINK PATH PROFILE SITE 34905 to 36200



ATTACHMENT 10 – TELSTRA LINK PATH PROFILE SITE 34905 to SITE 36251



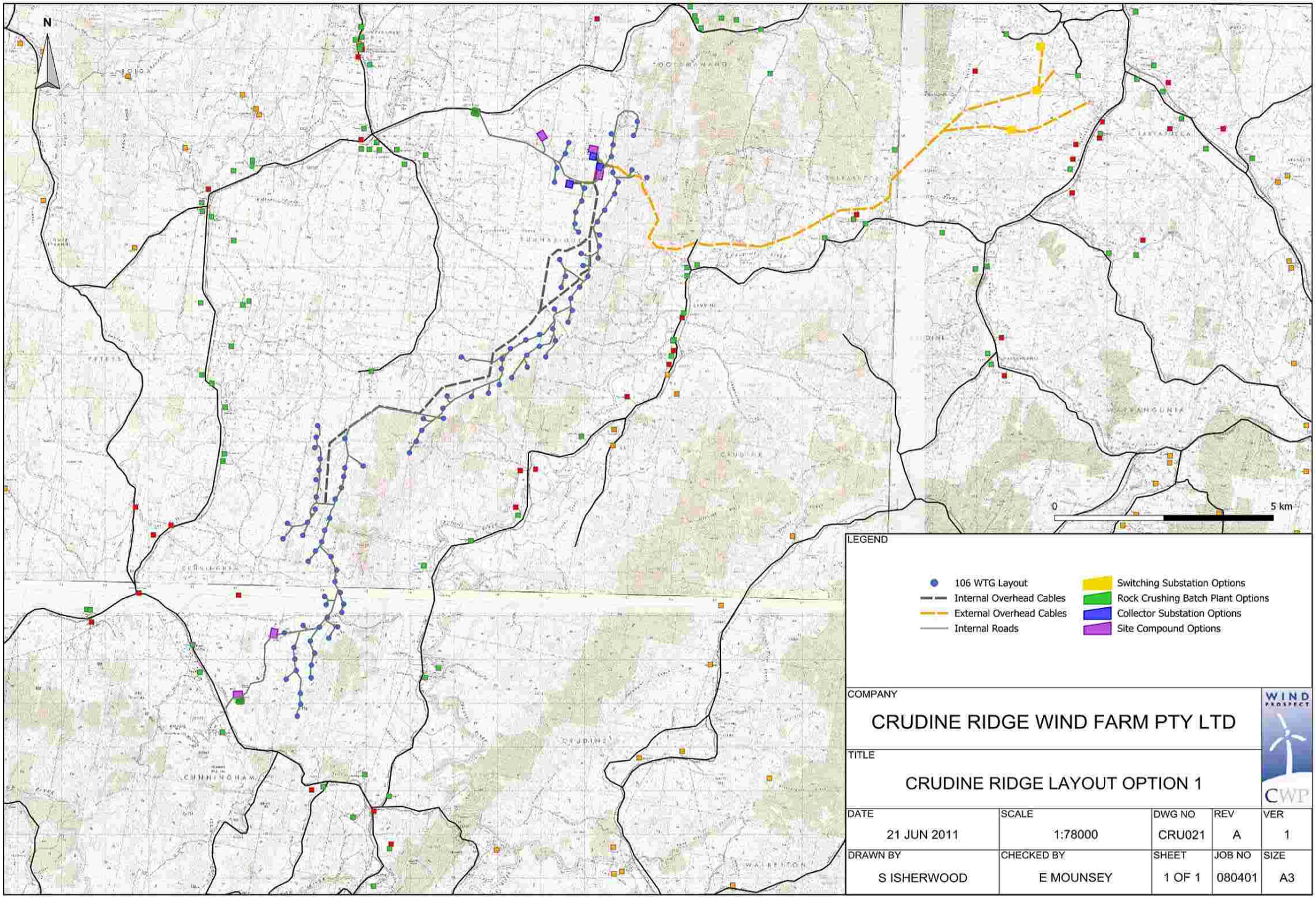
ATTACHMENT 11 – SOUL PATTINSON LINK PATH PROFILE SITE 34905 to SITE 36900



ATTACHMENT 12

WIND FARM SITE LAYOUT INCLUDING POWER LINE ROUTES

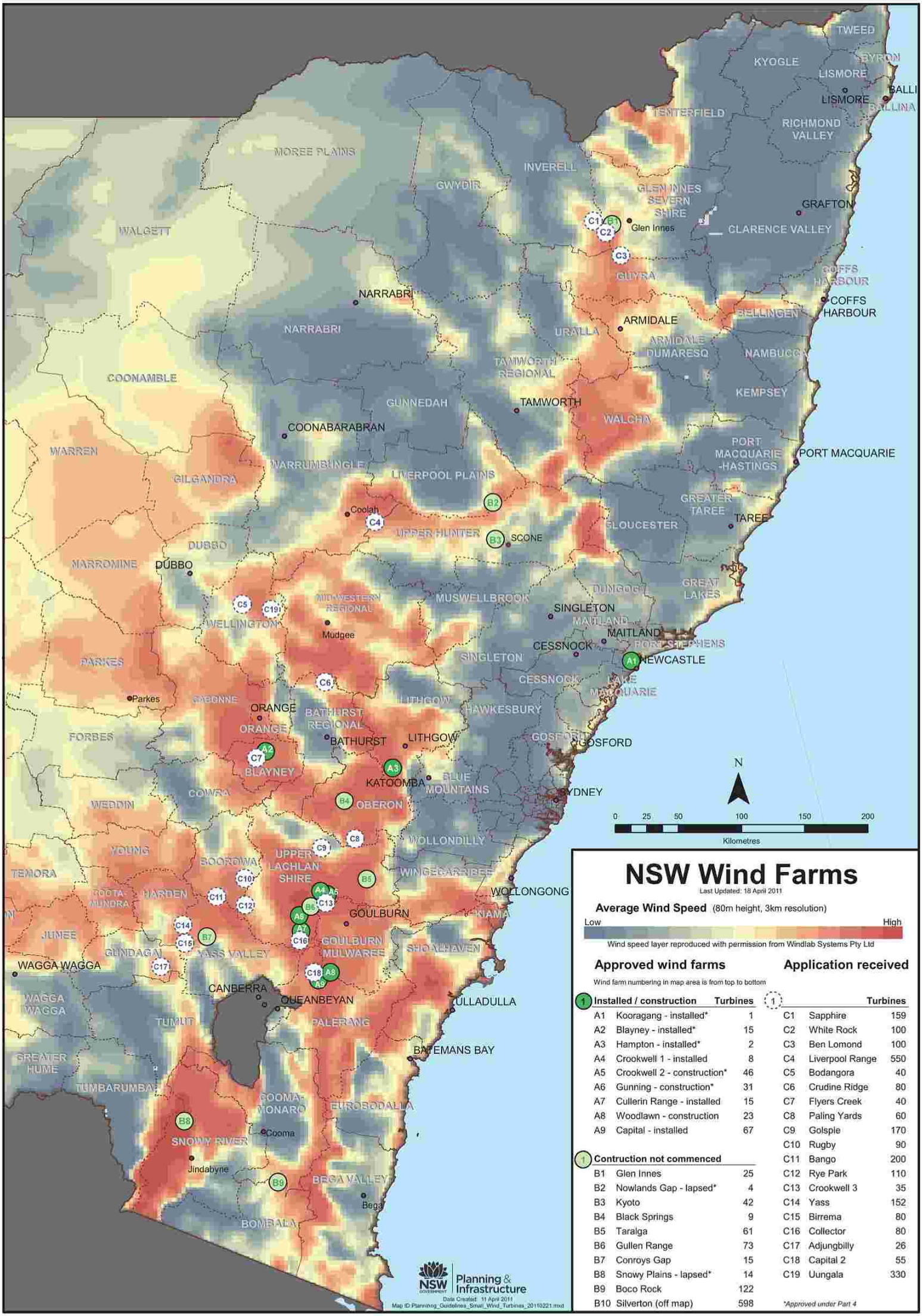
Map shown on following Page


N
0
5 km
LEGEND
106 WTG Layout
Internal Overhead Cables
External Overhead Cables
Internal Roads
Switching Substation Options
Rock Crushing Batch Plant Options
Collector Substation Options
Site Compound Options
COMPANY
CRUDINE RIDGE WIND FARM PTY LTD
TITLE
CRUDINE RIDGE LAYOUT OPTION 1
WIND PROSPECT
CWP
DATE
21 JUN 2011
SCALE
1:78000
DWG NO
CRU021
REV
A
VER
1
DRAWN BY
S ISHERWOOD
CHECKED BY
E MOUNSEY
SHEET
1 OF 1
JOB NO
080401
SIZE
A3

ATTACHMENT 13

MAP OF WIND FARMS IN NSW INCLUDING THOSE ADJACENT TO CRUDINE RIDGE WIND FARM

Map shown on following page



NSW Wind Farms

Last Updated: 18 April 2011

Average Wind Speed (80m height, 3km resolution)

Low — High

Wind speed layer reproduced with permission from Windlab Systems Pty Ltd

Approved wind farms

Wind farm numbering in map area is from top to bottom

	Installed / construction	Turbines
A1	Kooragang - installed*	1
A2	Blayney - installed*	15
A3	Hampton - installed*	2
A4	Crookwell 1 - installed	8
A5	Crookwell 2 - construction*	46
A6	Gunning - construction*	31
A7	Cullerin Range - installed	15
A8	Woodlawn - construction	23
A9	Capital - installed	67

	Contruction not commenced	
B1	Glen Innes	25
B2	Nowlands Gap - lapsed*	4
B3	Kyoto	42
B4	Black Springs	9
B5	Taralga	61
B6	Gullen Range	73
B7	Conroys Gap	15
B8	Snowy Plains - lapsed*	14
B9	Boco Rock	122
B10	Silverton (off map)	598

Application received

		Turbines
C1	Sapphire	159
C2	White Rock	100
C3	Ben Lomond	100
C4	Liverpool Range	550
C5	Bodangora	40
C6	Crudine Ridge	80
C7	Flyers Creek	40
C8	Paling Yards	60
C9	Golspie	170
C10	Rugby	90
C11	Bango	200
C12	Rye Park	110
C13	Crookwell 3	35
C14	Yass	152
C15	Birrema	80
C16	Collector	80
C17	Adjungbilly	26
C18	Capital 2	55
C19	Uungala	330

*Approved under Part 4

NSW GOVERNMENT Planning & Infrastructure

Date Created: 11 April 2011

Map ID Planning_Guidelines_Small_Wind_Turbines_20110221.mxd