January 2012

New Zealand Falcon Monitoring and Risk Assessment, Hurunui Wind Farm

Submitted to:
Meridian Energy Ltd
25 Sir William Pickering Drive
PO Box 2454
Christchurch

Report Number. 0978205297

REPORT

Golder Associates

Summary

A pair of New Zealand falcons has remained resident and successfully nested within the proposed Hurunui Wind Farm envelope for the past two breeding seasons (2009/2010 and 2010/2011). During this period they successfully fledged one female nestling in each year. Monitoring of the falcons occurred over both years to assess their breeding success and falcons were radio tracked over the 2010 winter and subsequent breeding season to assess use of habitats and home range within context of the wind farm envelope. Data collected during monitoring the falcons' movement patterns was used in a collision risk model (CRM) to estimate the rate at which collisions with turbines might occur once the wind farm is built.

Potential adverse effects to falcon breeding success associated with construction disturbance will be avoided with the implementation of a Falcon Construction Management Plan providing for the transfer of any eggs or chicks to a captive rearing institution and their subsequent release at a site approved by the Hurunui District Council and the Department of Conservation.

No adverse effects due to disturbance during operation of the Hurunui Wind Farm are expected.

Potential effects to falcons associated with habitat loss are considered negligible because most of the vegetative habitats where the falcons nest and which they favour are located deep in gullies, well away from construction zones. Rock outcrops are potential habitat for nesting falcons, although the resident birds also nest on the ground. An analysis of the removal of rock outcrops due to construction of the wind farm identified the removal of a single rock outcrop on a ridge on 'E Road'. As the falcons are expected to continue to nest in more sheltered gullies and are not restricted to using rock outcrops as nest sites, it is considered that the loss of a single rock outcrop would have negligible effect on falcon habitat at the proposed wind farm.

The home-ranges of both adult and juvenile falcons were centred within and overlapped the area where the turbines are proposed to be built and all of the birds monitored were observed spending some time flying at a height that would place them at risk of collision with the turbines. As a result, detailed data on the movements and behaviour of the falcons at Hurunui was collected to provide estimates of collision mortality using CRM. CRM estimates that on average the time between potential collisions for the resident adult falcons could be approximately 4 to 5 years and every 50 years for juveniles during a three month pre-dispersal period, after which they are expected to disperse from the wind farm. The collision modelling results reflect the location of the nest within the wind farm and the consequential high levels of activity within the wind farm. If the outcomes of the collision risk modelling are reflected in realised mortality, Golder considers that a local adverse effect is possible.

Based on the results of the monitoring and modelling we suggest that some or all of the following options could be used to ensure that any negative impacts to falcons as a result of the Hurunui Wind Farm are avoided, remedied or mitigated so that no net loss is achieved

Avoidance Options

- For any nest located within 500 m of direct line of sight of construction activities, translocation of eggs/chicks to an approved captive rearing institution and subsequent release of juveniles.
- Restriction of construction activities to beyond 200 m of any active nest not within direct line of sight of those activities.
- Use of power pole designs that prevent direct contact with un-insulated live wires by falcons.

Mitigation Options

- Contribute funding to a programme that supports falcon conservation at a level that establishes an additional pair of falcons at an approved site approved by the Department of Conservation and the Hurunui District Council.
- Insulate power poles and transformer boxes currently in use in the region.
- Fund research into how to resolve the electrocution issue nationwide.

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1.0 INTRODUCTION

Meridian Energy Limited (Meridian) has applied for resource consent to build, maintain and operate a wind farm in North Canterbury between Omihi and Greta Valley (Figure 1) (the Hurunui Wind Farm). The proposed wind farm consists of up to 33 turbines with 80 m hub heights and 101 m rotor diameters.

The New Zealand falcon (the falcon) is a nationally threatened species that is known to be present in the project region (Robertson et al. 2007). Three forms of the falcon have been described based on their habitat association and geographic distribution within New Zealand (Fox 1977). Of the three forms, the 'eastern falcon' is generally found in open habitats along the length of the South Island east of the Main Divide and nests principally on the ground or on rock outcrops (Fox 1977). The eastern falcon is classified as Nationally Vulnerable in the Department of Conservation's Threat Classification System (Miskelly et al. 2008). The eastern falcon is the only form present in the Canterbury region encompassing the Hurunui Wind Farm.

Although the effects on falcons within an operational wind farm in New Zealand have never been comprehensively determined, evidence suggests that they might be able to co-exist (Boffa Miskell 2009, 2011). However, because wind farm effects can be site-specific and raptors have been recorded as susceptible to collision with turbines at some wind farms overseas, it is thought that falcons could potentially be at risk where they co-exist with wind farms (Powlesland 2009).

The potential effects of wind farm construction and operation on falcons can be broadly described in four categories (Seaton 2007b):

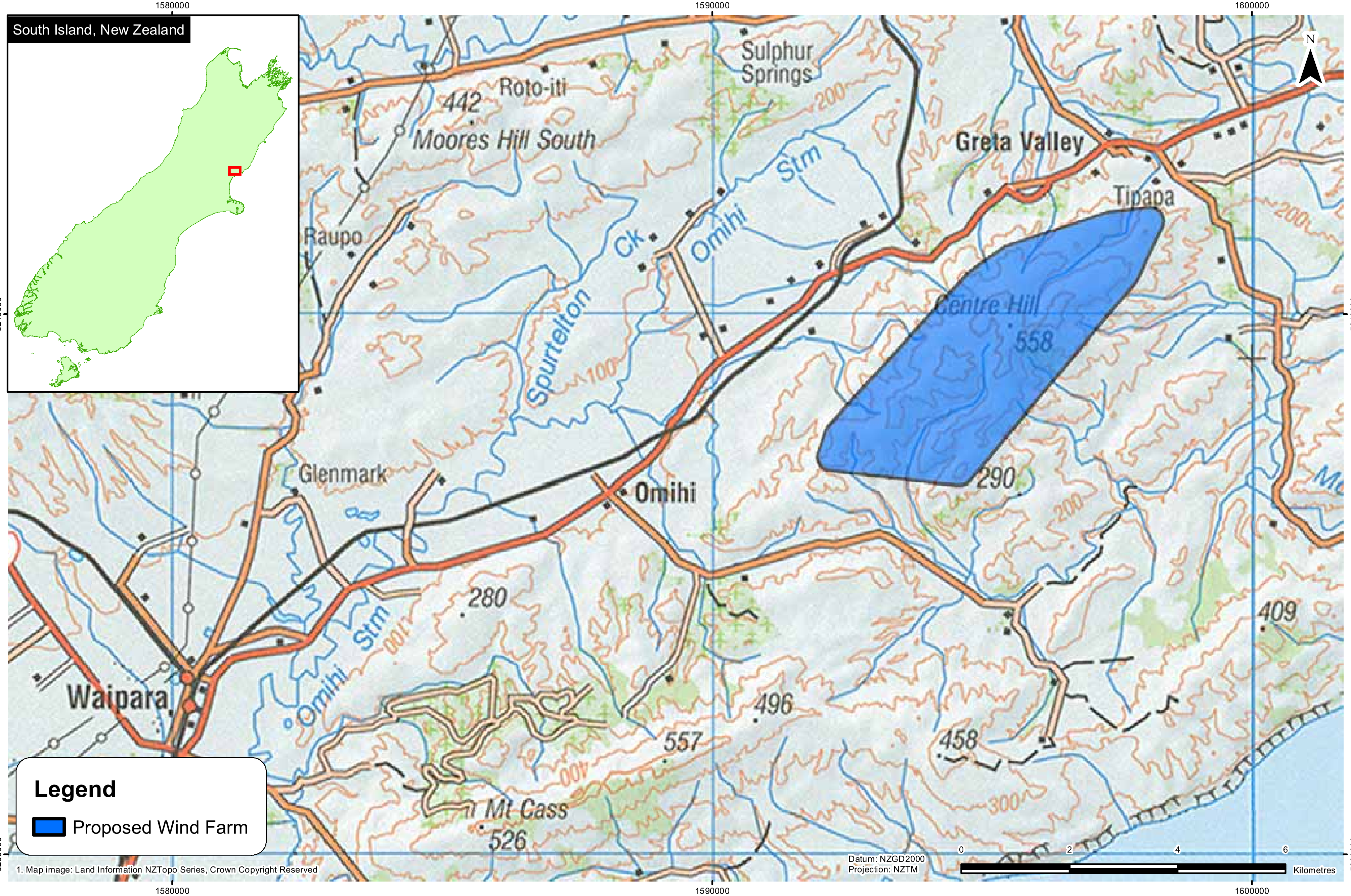
- **Disturbance/Displacement:** where individuals are disturbed from their usual activities (e.g., nesting) or avoid using an area due to wind farm construction and/or operation.
- **Habitat Loss:** where habitat required for the survival of a species is removed or modified.
- **Electrocution:** where birds land on transformer boxes or bridge transmission lines that have not been insulated and suffer electrocution as a result; and
- **Collision Mortality:** where individuals suffer mortality from striking turbine blades.

1.1 Report Outline

This report[1] outlines:

- The falcon nest surveys undertaken at the Hurunui Wind Farm (Phase 1 investigation);
- Onsite investigations undertaken to understand the behaviour, home range and habitat use of falcons over the proposed wind farm envelope (Phase 2 investigation);
- The risk of collision to falcons posed by the Hurunui Wind Farm, as estimated by collision risk modelling (CRM) (Phase 3 investigation); and
- Potential avoidance, remediation and mitigation strategies to address potential disturbance effects and collision risk.

[1] This report is subject to the limitations outlined in Appendix A.



1. Map image: Land Information NZTopo Series, Crown Copyright Reserved

TITLE SITE LOCATION: HURUNUI WIND FARM

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2.0 PROJECT LOCALITY AND ECOLOGICAL CONTEXT

The proposed wind farm is approximately 66 km north of Christchurch near the Greta Village, adjacent to State Highway 1 (as shown in Figure 1 above) and is approximately 13 km from the east coast, being separated from it by a series of north/south-oriented ridges. The development area is predominately situated around Centre Hill (558 masl[2]) and is topographically characterised by steeply ridged hills and incised valleys. The proposed wind farm lies in the Motunau Ecological District which is characterised by coastal hills and valleys draining eastwards into the Motunau Plain. The project site comprises six landowners who collectively manage over 3,454 ha of land, mainly for cattle and sheep grazing. A detailed vegetation description is provided in the Project Hurunui Ecological Assessment report (Boffa Miskell, 2010a) which identifies 12 vegetation community types in the wind farm footprint and adjacent land. Pasture and mixed pasture/silver tussock associations comprise about 66 % of the vegetation present in the wind farm envelope (Boffa Miskell, 2010a). This vegetation type is characterised by introduced grasses and herbaceous species which comprise most of the vegetation communities on the lower elevations within the project area. On higher elevations and steeper slopes silver tussock grassland communities are present and mix with pasture. Silver tussock grassland communities are heavily grazed and indigenous plant diversity is low. About 21 % of the vegetation within the wind farm envelope comprises grey shrubland-pasture and silver tussock communities which are characterised by open shrubland, typically comprising matagouri and other shrubs over pasture and silver tussock. This land cover forms the core use habitats within the falcons' home ranges in the wind farm. Other habitat features important for falcons include rock outcrops which are common on steeper slopes and provide prominent perching habitat for foraging falcons as well as potentially providing overhead cover and substrates for nests.

3.0 METHODS

3.1 Introduction

The study comprised three phases as follows:

Phase 1: Breeding surveys to assess whether falcons were nesting within the wind farm envelope and the spatial relationship of any nests to the proposed turbines.

Phase 2: Radio-tracking the adult pair of falcons during autumn/winter 2010 to assess:

- the extent to which falcons are using the proposed wind farm envelope;
- the falcons' habitat use patterns; and
- at what heights the falcons might fly through the potential risk zone.

This phase was extended to include radio tracking the adult male during the 2010/2011 breeding season and the juvenile female falcon during the post-fledging period to consider seasonal variation. The adult female falcon was not radio tracked during the 2010/2011 nesting season because her winter home range was centred within the wind farm and would likely remain so over the summer breeding season.

Phase 3: Collision risk was estimated using CRM based on the data collected in Phase 2.

Methods associated with these three phases are described in the following sections.

[2] Metres above sea level

3.2 Phase 1 - Breeding Surveys

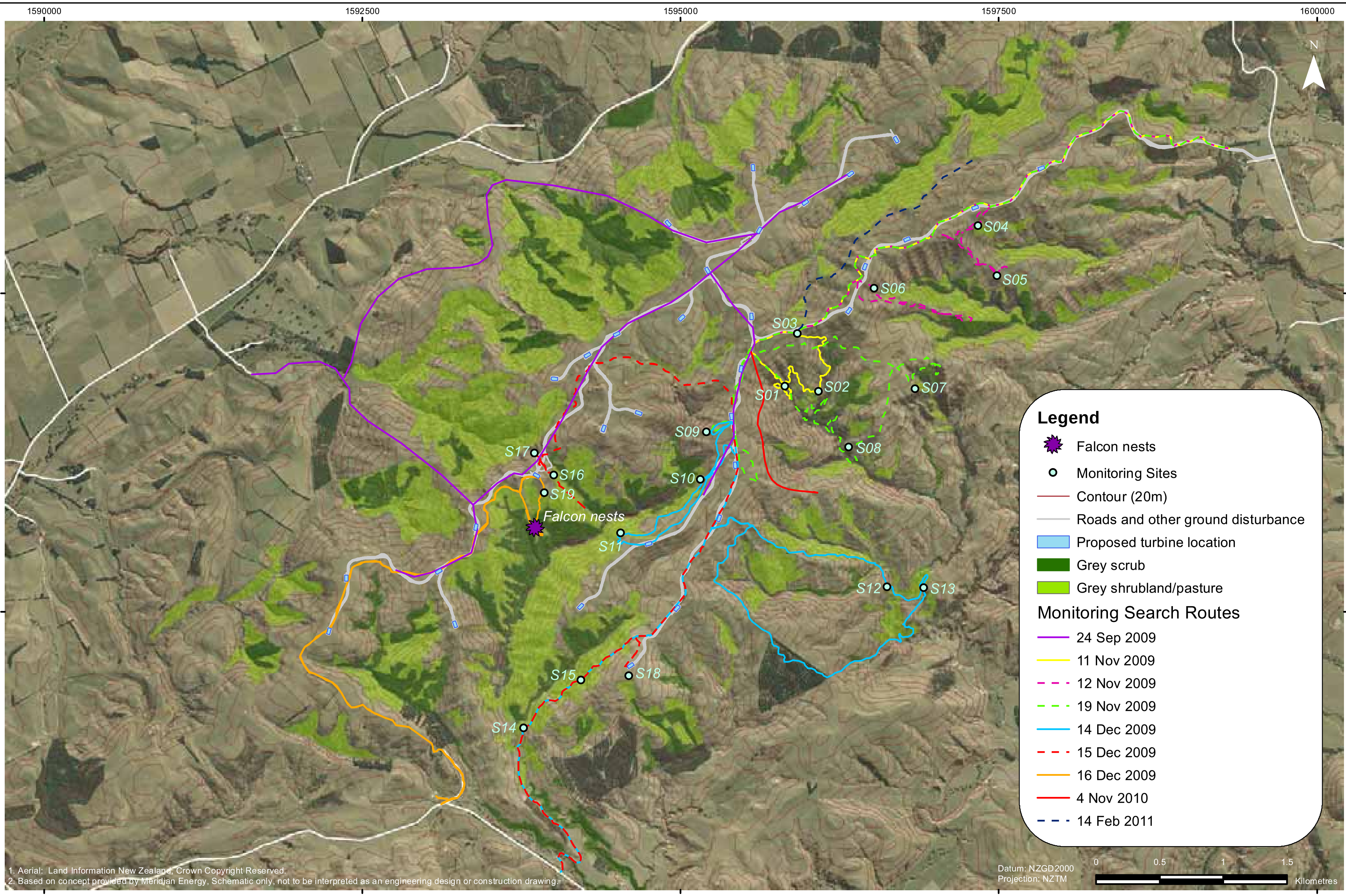
Falcons are most conspicuous during the September to March breeding season (peaking between November and February) when they are very vocal and their activity is focused on their nest site (Fox 1977; Seaton 2007a). Contrasting with the breeding season, at other times of the year falcon activity patterns are more dispersed and they are less vocal, rendering them easily overlooked. Survey effort in this study was therefore timed to occur during the peak of the breeding season when detectability and use of the proposed wind farm was expected to be highest. Surveys were not conducted in inclement weather conditions when falcon activity is reduced and detection rates are low. Prior to formal surveys commencing, aerial photos of the study area were examined to identify potential nesting habitat, e.g., incised valleys, rocky outcrops, pine forest and native vegetation. Following this, the site was visited on 3 August 2009 to confirm findings and provide a focus for formal surveys.

During the 2009/2010 breeding season, surveys were undertaken over seven days between 24 September 2009 and 16 December 2009. The surveys focused on areas of potential nest habitat, but also included observations on the general landscape within and surrounding the proposed wind farm envelope. Once the location of suitable nesting habitat had been defined, subsequent targeted surveys focused on these habitats. Surveys during the 2010/2011 breeding season were targeted on suitable areas of nesting habitat and unsuitable habitats were excluded, thereby reducing the overall 2010/2011 survey time to two days (4 November 2010 and 14 February 2011).

Surveys comprised a combination of observing from fixed survey points and intuitive, meander ‘roaming’ searches by an experienced ecologist familiar with the species and its behaviour. Fixed survey points were located to provide the observer with maximal views of basins, spurs, prominent rock features and patches of native vegetation. Observations from these points occurred for up to four hours depending on the quality and complexity of the visible habitat. Roaming surveys allowed the observer to use professional judgment to target survey effort towards habitats where falcon nest sites were more likely to be located. The method also facilitated observation of the general landscape and wind farm footprint for flying or perched falcons.

During the breeding season the males in particular are very territorial and frequently broadcast their distinctive ‘kek kek kek’ call when flying over their territory, usually calling when approaching the nest area or when attacking potential predators such as harriers. From late courtship to shortly before the nestlings fledge female falcons rarely venture more than 200 m from the nest site (L Barea, personal observation) and spend much of their time soliciting food from the male with a characteristic whining call. Older and recently-fledged nestlings also solicit food by whining, which can often be heard from several hundred meters away. The detection of the whine call is therefore diagnostic of a reproductive pair. During the surveys observers were therefore especially vigilant for auditory cues such as the territorial ‘kek kek kek’ or whining calls.

In addition to field surveys, interviews were held with local land owners regarding any observations of falcon behaviour they might have made onsite. General avifauna surveys were also carried out by Boffa Miskell staff over eight weeks, starting in late November 2009 (Boffa Miskell 2010b). These included fixed point count surveys spread over the entire wind farm envelope, 5-minute bird counts in areas of bush and roaming surveys to establish general bird abundances. During these surveys any observations of falcons were noted and reported to the falcon survey team to provide confirmation of the results of the more intensive, targeted falcon surveys described above. The survey routes are shown in Figure 2.



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3.3 Phase 2 - Home-Range, Habitat Use and Flight Height

3.3.1 Field set-up

In order to assess the movements of the falcons with respect to the wind farm layout, both adult falcons were tracked using radio telemetry during the 2010 autumn/winter period. To account for seasonal variation and potential differences in behaviour between adult and juvenile falcons, the adult male and juvenile female falcon were radio tracked during the 2010/2011 summer period. The adult female falcon was not radio tracked during the 2010/2011 summer period because her autumn/winter home range was entirely within the wind farm and would likely remain so over the summer nesting period given that, as noted above, nesting females rarely move more than a few hundred meters from the nest during this period (L Barea personal observation).

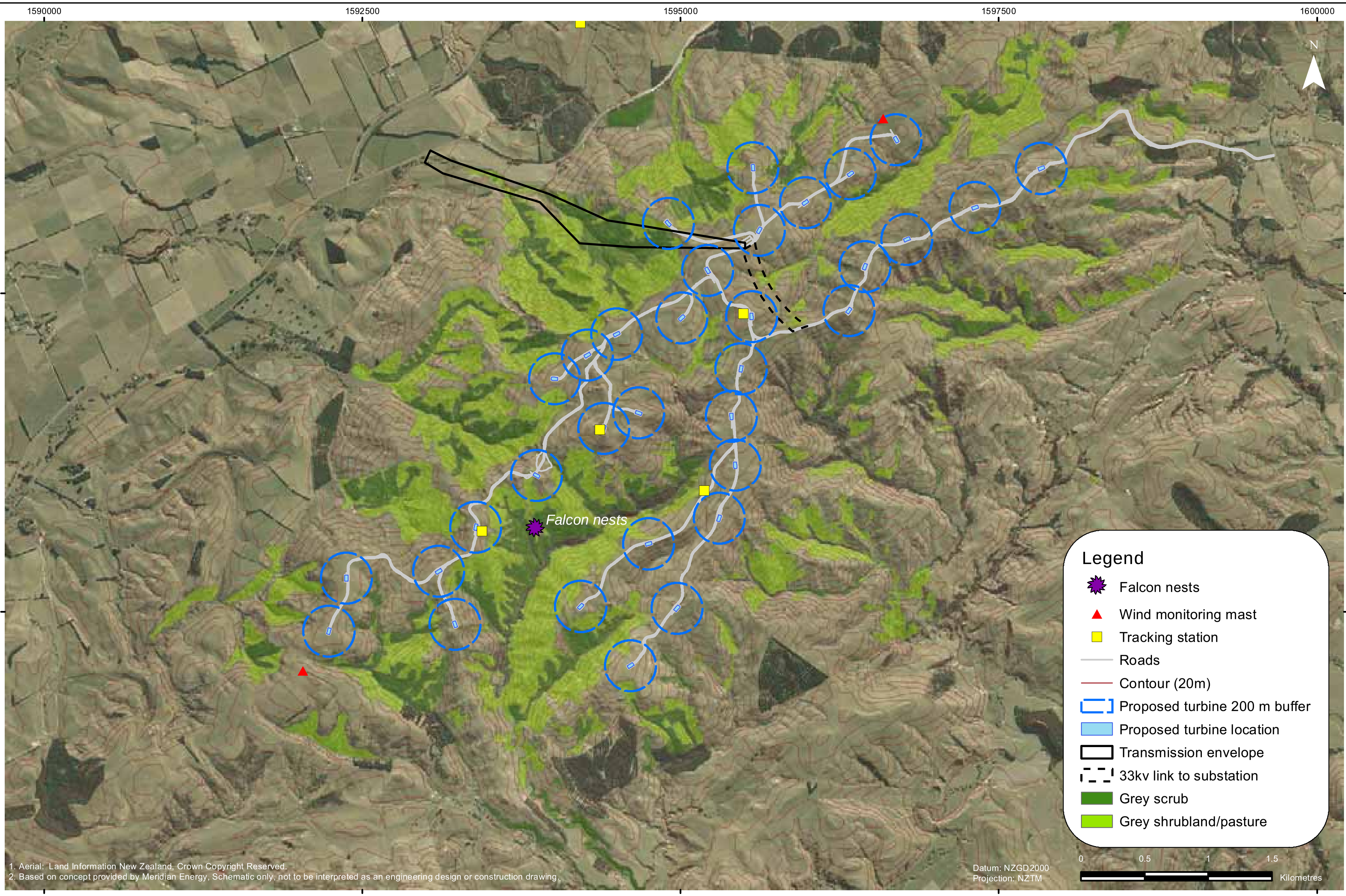
Falcons were trapped using Balchatri traps or noose hats (Bloom 1987) and transmitters attached using backpack harnesses. The transmitters fitted had an approximate 12 month transmitting life and an inbuilt mortality signal that was triggered if the unit remained stationary for more than 24 hours. Trapping and radio tracking was conducted under Department of Conservation permits 0285 and CA-27062-FAU.

Four fixed tracking stations were established at high points that provided optimal 360 degree line-of-sight radio reception allowing data collection by triangulation (Kenward 2001; Figure 3). Triangulation was chosen as the method for data collection because it has been shown to be effective in other studies (Barea 1995; Seaton 2007a), including Meridian's Central Wind project (Golder Associates & Boffa Miskell 2009). Each station was recorded with pink flagging tape and a GPS so that it could be accurately relocated at a later date. These stations were used for all subsequent radio tracking, unless on a given day no signal could be detected over a half hour period, in which case a temporary tracking station was established and recorded by GPS at a location nearby where reception was improved.

3.3.2 Timing of monitoring/sampling protocol

Because the area over which a falcon ranges can potentially vary between seasons, the radio tracking methodology was designed to sample falcon movements across key seasons, including the summer breeding season for the male. Accordingly, radio tracking was undertaken during the post breeding autumn/winter (March–July 2010) and summer (December to March 2011, i.e., during the summer breeding season). The adult male was tracked during both tracking periods, the adult female during the first tracking period and the fledgling female during the second tracking period. During the period the adult female was tracked her home range was almost entirely within the wind farm envelope. Nesting female falcons spend most of their time in a very small area around the nest during the breeding season (L Barea personal observation). Consequently, it was considered that additional tracking of the adult female's movements during the 2010/2011 breeding season would not substantially add to the understanding of potential effects because any variation in home range would likely result in a reduction, rather than an increase, in use of the wind farm and therefore reduced associated risk. Consequently, a precautionary approach was taken by basing the annual collision risk of the adult female on the data collected during the autumn/winter period and the female was not tracked during summer.

Sampling effort comprised tracking each adult bird for 10 days within the tracking period, with radio fixes recorded every 10 minutes over an eight hour day, varied so that the range of daylight hours was sampled. This level of effort was based on a similar study undertaken for Meridian's Central Wind project near Taihape (Golder Associates & Boffa Miskell 2009). In that study, an analysis of increasing home range size against the number of radio fixes indicated that home ranges reached an asymptote after ten days, i.e., the home range of an individual was fully described in this period. In order to ensure that ten days' tracking was also appropriate in this study, cumulative area use plots using Biotas 2.0 – Ecological Software Solutions™, were similarly generated to check appropriate asymptotes had been reached.



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LOCATION OF RADIO TRACKING STATIONS DURING FALCON HOME RANGE MONITORING: HURUNUI WIND FARM

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During the first tracking period the first bird tracked was randomly chosen with the flip of a coin on the first day of each month's tracking. After that the individuals were tracked on alternate days with the same bird tracked for eight hours each day. In this manner each bird was tracked for two full eight hour days per month with one of those days starting shortly after day break and the other finishing shortly before nightfall to allow for potential variation across the day. At the beginning of each tracking day the members of the three person tracking team synchronised their watches so that fixes were taken at the same time. During the second tracking period the adult male and juvenile female falcon were tracked on separate field trips for eight hours each day with the male being tracked for five consecutive days in December, 2010 and five consecutive days in January, 20011. The juvenile was tracked for two days per month between January 2011 and March 2011.

3.3.3 Flight height

The risk of colliding with turbine blades exists when falcons fly at heights that place them within the rotor swept area (RSA). The turbine specifications for the proposed Hurunui wind farm include a hub height of 80 m and a maximum height from ground to extended blade tip of 130.5 m. The RSA is between 29.5 and 130.5 m (measured vertically). Consequently, falcons may be at risk from collision when flying through the RSA.

To assess the amount of time falcons spend flying within the proposed RSA, field ecologists undertaking the radio tracking study were also vigilant to observe and record falcon behaviour, including flight heights. Data were recorded onto standardised field sheets and included the upper and lower estimates of flight height relative to the RSA and the topographic feature the bird was observed flying over, e.g., ridge, slope or valley floor. To reduce variability/bias between observers group training in height estimation using features of known height was undertaken at the start of both tracking periods and observers were encouraged to question their own and each other's estimations on a regular basis. To maximise the number of observations of flight height for each individual, two additional observers tasked with collecting behavioural data in a targeted manner were positioned on a prominent ridge above the nest site during the second period of radio tracking the male falcon. This was reduced to one observer during the period the juvenile was tracked due to the bird's small home range.

3.3.4 Home range

Field data were transcribed into Excel spreadsheets and filtered to extract data that enabled an analysis of each falcon for each study period. The location of each falcon at the time of each 10 minute fix was estimated using LOAS 4.0 (Ecological Software Solutions™) following the same process used for Meridian's Central Wind project (Golder Associates and Boffa Miskell 2009). LOAS 4.0 converts the bearings obtained by radio triangulation into locations by finding the most likely estimate for a falcon's location given the average of the co-ordinate points for the observed set of bearings.

The locations for individual falcons were pooled across the study period to reflect the respective season for the analysis. These data were then analysed in Biotas 2.0 to produce home ranges with a kernel estimator (Worton 1989) using least squares cross validation Seaman and Powell (1996). 95 %, 75 % and 50 % kernels were produced for each falcon. The kernel method considers the variation in the data rather than evaluating each point in isolation from others, thus providing unbiased estimates of the probability of occurrence of different areas (i.e., kernel contours) within a home range. This is important when examining home ranges in the spatial context of features on interest, e.g., habitat types or proximity to turbines. An additional utility of Biotas 2.0 is that outputs are optionally generated as shape files and can be imported directly into GIS software. These contours were mapped in GIS over a habitat layer depicting previously mapped vegetation classes (Boffa Miskell 2010) and relative use of different habitats compared with their availability. The use of differing parts of the home range in the context of the spatial layout of turbines was also analysed in GIS.

The minimum convex polygon (MCP) method is another commonly used technique and was also used in the analysis. Kernel estimators provide estimations of home ranges that are finer grained and more closely aligned to where individuals are recorded than those produced using a MCP. Consequently, kernel home ranges were considered to be more appropriate for assessing habitat-use patterns. The MCP home ranges provide a broader representation of where falcons could potentially be found and hence were used to conservatively describe the extent of the area an individual could potentially use with respect to collision risk.

3.3.5 Habitat use

An analysis of autumn/winter habitat use was undertaken for falcons based on vegetation in their 75 % kernel contour home range because this level of analysis provided the closest spatial context with the wind farm layout and it was the habitats within the wind farm that were of interest. The 2010/2011 summer analysis for the adult male was based on the 95 % kernel because the home range had shifted from the previous winter and the summer 95 % kernel provided a more appropriate spatial context with the wind farm.

The analysis reflects Johnson's (1980) third order habitat selection. Johnson's third order habitat selection level refers to the hierarchical process of an animal's selection and use of habitats within its home range, i.e., after the second order process of home range selection within a landscape has occurred, and as such it reflects selection of important components within the home range.

Habitat availability within the kernels was quantified using GIS and a vegetation layer supplied by Boffa Miskell (2010). The habitat use of each falcon was sampled from within their respective home range based on a 200 m circular buffer placed around each falcon location to reflect uncertainty associated with the radio triangulation. Within each circular buffer the proportion of different vegetation types was calculated in GIS and the values averaged across all buffers for use in the overall analysis. This approach recognises that variation in the proportion of vegetation types within a defined area associated with a falcon's location reflect the selection of that location by the falcon. While this is a coarser approach to one where the position of an animal relative to its habitat is known explicitly, it retains biological relevance while considering spatial uncertainty in the falcon's locations.

3.4 Phase 3 - Collision Risk

3.4.1 Collision risk modelling

Collision risk models have been used to estimate potential mortality arising from collisions with turbines at wind farms and can be useful when limited information is available to inform potential risk (Madders and Whitfield 2006; Strickland et al. 2011). In situations where there is insufficient empirical data available to inform risk, collision models may be the only practical means for its estimation (Strickland et al. 2011). Collision modelling has been used in New Zealand to assess the potential level of migratory shorebird collisions for the Taharoa Wind Farm (Fuller et al. 2009) and for migratory shorebirds and bush birds for the Hauāuru mā raki Wind Farm. The results from collision risk models and have also been used to inform management plans as part of mitigation packages overseas (e.g., Kaheawa Wind Power 2006).

Collision modelling is an improvement over qualitative or subjective methods of assessment, e.g., making general inferential statements about collision potential based on observed flight activity or abundance, because it involves an objective approach to using available data to estimate a general level of potential effect. It is important to recognise that the method produces relatively coarse estimates that should be considered at a high level, rather than as precise estimates. In New Zealand collision risk modelling results have been used to initially consider the appropriateness of a wind farm at a site given the magnitude of estimated effect and then to objectively provide a quantitative basis for the development of mitigation and biodiversity offsets. This is probably the most appropriate use of the method.

Collision risk modelling for the falcons at the Hurunui Wind Farm was carried out using the results of the radio tracking and behavioural monitoring. This analysis was based on the model developed by Scottish Natural Heritage (the Band model) and outlined in Band et al. (2007).

3.4.2 The Band Model

The Band model is routinely used to assess avian collision risk at wind farms in the United Kingdom (Madders and Whitfield 2006), and the collision modelling approach is in line with international practice for the assessment of the risk to birds at wind farms (e.g., Strickland et al. 2011). The Band model estimates the probability that a bird of a given body length, wingspan and flight speed flying through a RSA is struck by the turbine blades of given dimensions and operational parameters, e.g., rotation speed. The model is described with case study examples in Band et al. (2007). The model is implemented in Microsoft Excel as a two stage process, i.e., the probability a bird flying through the RSA collides with the rotor (Stage 1) x number of birds or proportion of time birds spend flying at rotor height (Stage 2).

The model has been mathematically validated by Chamberlain et al. (2005) who provides a cautionary note on the model's sensitivity to the rate at which birds may avoid turbines. The sensitivity of collision models to avoidance rates is further discussed in Chamberlain et al. (2006). It is worth noting that avoidance rates are relevant to all collision risk assessments, including commonly used qualitative or subjective assessments of collision risk which necessarily must consider that most birds avoid turbines.

3.4.3 Model inputs and modelling process

Key inputs into the Band model include a combination of turbine design parameters, statistics describing the size and shape of the species and data on how much time the birds spend at rotor height within the wind farm. In the CRM at Hurunui, turbine design and operational parameters were provided by Meridian, while parameters relating to New Zealand falcon morphology were obtained from the literature (Marchant & Higgins 1993). An overview of the model process and the inputs are provided in Appendices B and C.

The model used in this analysis is a version of the Band model developed by Golder Associates and implemented in the Monte Carlo simulation software, GoldSim V 10.5. Although the GoldSim model provides for a probabilistic analysis that accounts for variation in the data, a deterministic analysis (i.e., inputs were observed values without measures of variation) was conducted after considering sample size and the ability to adequately create a statistical distribution. To better represent variation, the model was run deterministically for each day an individual falcon was radio tracked and the results averaged to allow for the calculation of a standard deviation. As such, the sample data for each model run was the data collected over a single radio tracking day.

3.4.4 Avoidance rate

Although avoidance rates have been estimated for several species of bird of prey (see Whitfield and Madders 2006), the rate at which New Zealand falcons might avoid turbines is currently unknown. Empirically-derived avoidance rates for a range of bird of prey species are consistently high, with values typically falling between 98% and 100% (Whitfield and Madders 2006). In this study, avoidance was modelled using values reported in Whitfield and Madders (2006) for the related similar sized and behaviourally similar (L Barea personal observation) prairie falcon (*Falco mexicanus*). Madders and Whitfield (2006) report a range of avoidance rates for prairie falcons as between 99.5 % to 100 %. Because this range is only based on two studies and there are no established avoidance rates for the New Zealand falcon, CRM at Hurunui adopted a conservative approach by using the lower value of that range in the models, i.e., 99.5 %. Until avoidance for falcons in New Zealand is better understood, this approach is considered appropriate because it has some empirical basis.

4.0 RESULTS

4.1 Phase 1 – Breeding Surveys

4.1.1 Habitat assessment

During the nesting surveys, potential falcon nesting habitat was located in the grey scrub in the deeply incised valleys surrounding Centre Hill. Although approximately 28 % of the project area comprises grey scrub habitat (Boffa Miskell 2010a) not all of this area is suitable for falcon nesting. For example, in many areas the scrub is too dense, which leads to the spatial distribution of suitable nesting habitat being patchy. Although suitable nesting habitat is present, identifying the precise location where falcons select nest sites is not possible, because such selection is contingent on a wide variety of factors, many of which are unknown.

Notwithstanding this, from observations of nesting falcons in similar habitats, they are less likely to nest outside of the scrub habitats and nest sites are more likely to be located within sheltered gullies rather than on exposed ridge tops where the turbines (and nearly all access roads) would be located.

4.1.2 Nest site locations

One pair of breeding falcons was located nesting onsite during the 2009/2010 and 2010/2011 breeding seasons. In December of the 2009/2010 season both adults were trapped and banded, allowing confirmation in the second season that the same pair were nesting in the same gully. Both nests were located in grey scrub habitat within the south west portion of the proposed site (Figure 4), approximately 465 m south-east of proposed turbine D4, and 410 m south west of turbine D5. The distance between the two nest sites was approximately 50 m (Figure 4a), indicating a high degree of site fidelity and that the birds are likely to continue to nest in this gully. There are seven turbines within approximately 1 km of these nests.

The nest in 2009/2010 comprised a scrape on the ground under a small *Coprosma crassifolia* bush on the northeast facing slope of the spur (Figure 4b). The nest was on the same side of the spur in 2010/2011 but had been relocated approximately 50 m further up the valley and was located on the top of a small (1 m high) rock stack partially sheltered by scrubby vegetation (Figure 4c). In the vicinity of both nests were several prostrate kowhai (*Sophora prostrata*) plants and small rocky outcrops under which fledglings sheltered once they had left the nest.

4.1.3 Productivity

During the 2009/2010 breeding season a female nestling aged approximately 30 days was observed in the nest gully on 16 December 2009. The site was again visited on 21 December 2009 and when the nest scrape was located it was found to contain one unhatched egg, indicating an initial clutch size of at least two. By this time the nestling had successfully fledged from the nest and was observed flying in the nest gully. It is not possible to say how many eggs were laid or hatched due to the time at which the nest attempt was located, but clutch initiation, hatching and fledging dates can be estimated by back-calculating from the known age of the nestling (Table 1).

In 2010/2011 the nest was located on 4 November, 2010 and found to contain three eggs. The nest was revisited on 6 December, 2010 and found to contain a single nestling estimated to have hatched approximately 18 days earlier. No sign of the other two eggs or nestlings was present and it remains unknown whether the eggs hatched or were subject to predation.

4.2 Phase 2 - Home-Range, Habitat Use and Flight Height

4.2.1 Radio tracking effort

Falcons were radio tracked across two study periods reflecting the autumn/winter period and summer breeding seasons. The adult male and female were both tracked between March and July 2010 and the adult male and a juvenile female that successfully fledged during the 2010/2011 breeding season was tracked over the 2010/2011 summer.

Both the adult male and female falcons were trapped on 21 December 2009 and numbered and colour bands and a radio transmitter attached (Male H-22276; Female S-80365). Radio transmitters (Kiwitrack Ltd.) weighed approximately 15 g, included a mortality sensor and were attached using a woven cotton back pack type harnesses incorporating a weak link.

Figure 4: Photos of (a) the nest gully facing due west with both nest sites indicated, (b) the 2009/2010 nest scrape and (c) the 2010/2011 nest scrape.

Table 1: Nesting chronology and summary of falcon productivity at the proposed Hurunui wind farm during the 2009/2010 and 2010/2011 breeding seasons.

Nest attempt	Approximate date	Number and sex observed
2009/2010 breeding season		
Laid	16 October 2009	at least two eggs*
Hatched	16 November 2009	1 Female nestling
Fledged	20 December 2009	1 Female fledgling
2010/2011 breeding season		
Laid	20 October 2010	3 eggs observed November 4
Hatched	19 November 2010	1 nestling observed December 6
Fledged	23 December 2010	1 Female fledgling

*based on unhatched egg present 21 December.

Attempts to trap the female fledgling on 12 January 2010 were unsuccessful because the bird did not approach the trap. Further attempts to trap the juvenile on 1 and 2 February 2010 were unsuccessful because the bird could not be located. No reports of a young bird were made by the radio-tracking team after this and it seems likely that if the bird survived, it moved offsite. However, it should be noted that several feral cats - including a brood of kittens, indicating that cats breed in the area - were observed during site visits to monitor the falcons (including in the nest gully), so it is possible that this bird could have suffered predation. Further, if the juvenile had become independent of its parents it might have died through starvation, as is a risk for many young birds that have left the natal area (for example all three female fledglings radio-tracked at Project Central Wind died from starvation within six months of fledging the nest - Golder Associates & Boffa Miskell 2009).

The adult male was re-trapped on 5 November 2010 so that a new transmitter could be attached before the battery on the old unit was depleted. The female that fledged the nest during the 2010/2011 breeding season was trapped and fitted with a transmitter on 12 January 2011 so that the risk to this age group during the pre-dispersal period could be investigated. This bird was not banded.

Table 2 shows the distribution of radio tracking effort across the two study periods along with the number of useable fixes obtained per month. After removal of fixes associated with flying falcons and those where field ecologists had noted poor radio reception, 404 and 402 locations were obtained for the adult male and adult female respectively for the autumn/winter tracking period, and 356 and 262 for the adult male and juvenile female during the summer period. These were then analysed in Biotas 2.0 Alpha (Ecological Software Solutions™) to describe monthly and overall home ranges for each individual.

Table 2: Sampling effort for the adult male, adult female and juvenile female falcon's radio tracked at the proposed Hurunui Wind Farm in 2010 and 2011. Note: the adult male was tracked for an additional day on May 20 to increase sample size for that month.

Month	Sampling Dates			Number of Useable Fixes		
	Adult Male[1]	Adult Female	Juvenile Female	Adult Male	Adult Female	Juvenile Female
Autumn/winter 2010	Day of month	Day of month	Day of month	# fixes useable	# fixes useable	# fixes useable
March	19, 21	18, 20	-	91	80	-
April	21, 23	20, 22	-	88	86	-
May	17, 19, 20	18, 20	-	76	84	-
June	14, 16	15, 17	-	72	73	-
July	13, 15	12, 14	-	77	79	-

Month	Sampling Dates			Number of Useable Fixes		
Summer 2010/2011						
December	6, 7, 8, 9, 10		-	188	-	-
January	16, 17, 18, 19, 20		24, 25	168	-	79
February	-	-	14, 15	-	-	91
March	-	-	16, 17	-	-	92

[1]**Note**: The adult male was tracked for an additional day on 20 May 2010 to increase sample size for that month.

Figure 5 illustrates that after 10 days of sampling the home range of both adult birds during the autumn/winter 2010 sampling period stabilised (after obtaining about 260 locations for each bird). During this period of tracking the size of the male's range increased in a stepwise manner to temporarily stabilise and then increase further (by about 8 %) before levelling off. The female's home range initially stabilised after about 80 locations and then increased in response to short-term sorties outside of the initial home range before levelling off again.

During the 2010/2011 summer tracking period the home range of the adult male was stable for the most of the sample time. After about 260 locations the home range increased in size and re-stabilised at 300 locations. Overall, this illustrates that ten days of tracking was sufficient to adequately describe the movements of the adult falcons in each of the study periods, generating representative home ranges and informing how much time they spend in the vicinity of the proposed turbines.

The pre dispersal home range of the juvenile female did not stabilise but continued a trend of increasing size with time. This is an expected pattern for a juvenile falcon at this period of its development towards independence and dispersal from its natal home range and the results of this study should be interpreted in that context, i.e., the bird is expected to leave the wind farm area prior to the following breeding season.

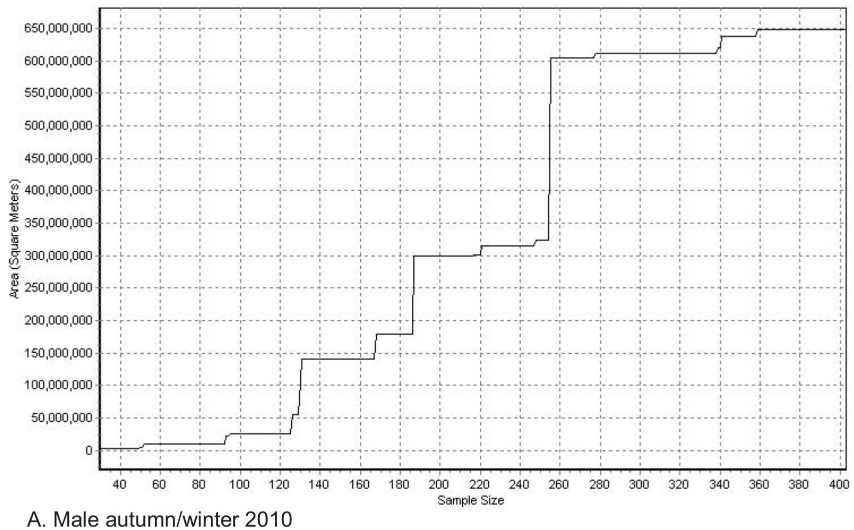
4.2.2 Home range

The home ranges of all three falcons tracked are illustrated in Figures 6, 7, 8 and 9 and the area of each kernel home range provided in Table 3.

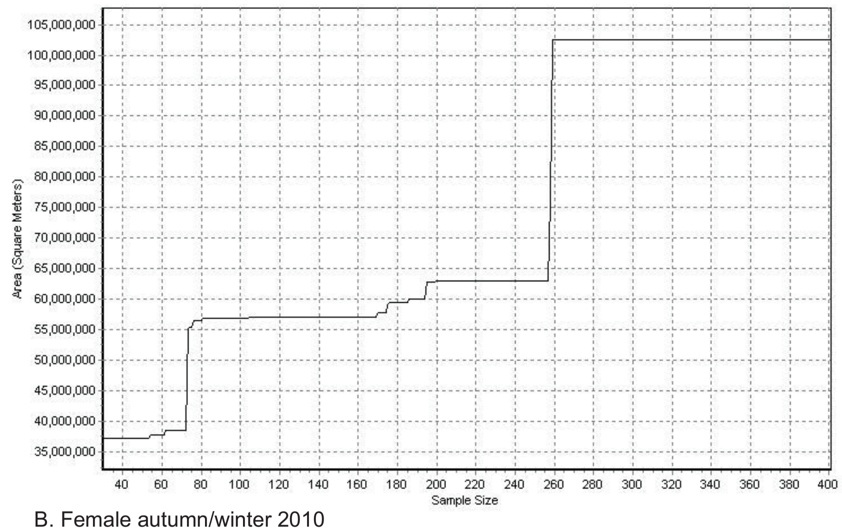
Table 3: Kernel home range sizes (hectares/square kilometres) for the adult male, adult female and juvenile female falcons tracked at the proposed Hurunui Wind Farm.

Kernel probability (%)	Home range size ha (km^2)			
	Adult male (autumn/winter 2010)	Adult male (summer 2010/2011)	Adult female (autumn/winter 2010)	Juvenile female (summer 2010/2011)
95	1447 (14.47)	1660 (16.60)	710 (7.10)	132 (1.32)
75	435 (4.35)	568 (5.68)	209 (2.09)	37 (0.37)
50	119 (1.19)	280 (2.80)	67 (0.67)	13 (0.13)

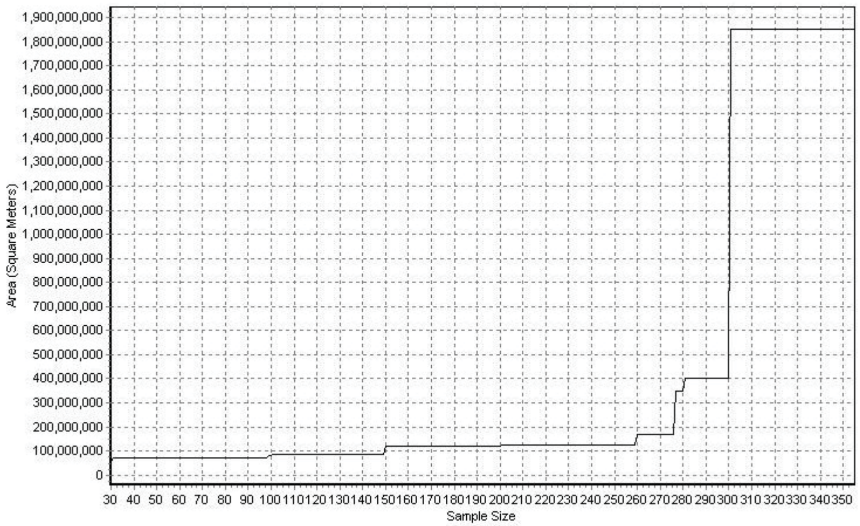
The larger home range size for the male falcon is consistent with studies on New Zealand falcons radio tracked in Kaingaroa Forest (Seaton 2007a) and at Meridian's Central Wind project (Golder Associates & Boffa Miskell 2009). The core use area of both falcons' home range was centered within the wind farm envelope (Figures 6–8) and the nest site was located within the core use area of the male's home range, but was less associated with the core use area of the female's range, reflecting the increased proportion of time she spent in the gullies east of the nest (Figure 7). Nevertheless, almost all of her home range was contained within the wind farm.



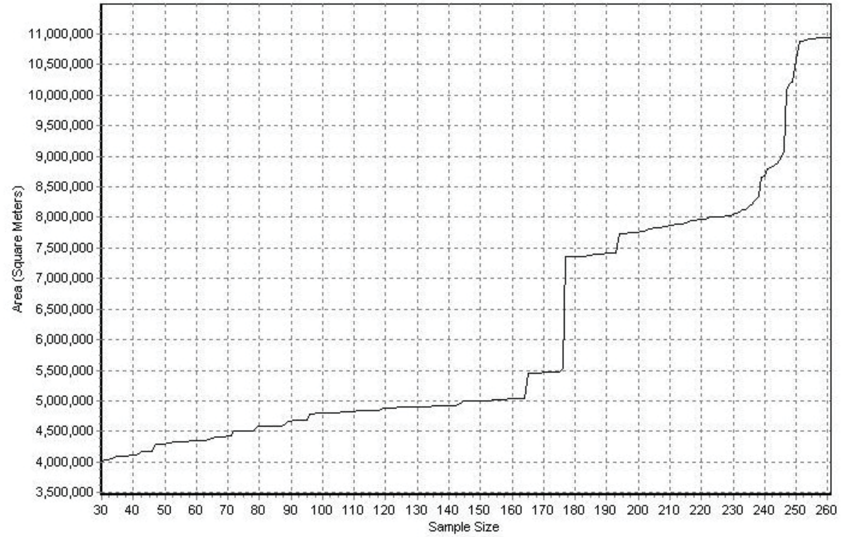
A. Male autumn/winter 2010



B. Female autumn/winter 2010



C. Male summer 2010/2011



D. Juvenile female summer 2010/2011

Schematic only, not to be interpreted as an engineering design or construction drawing

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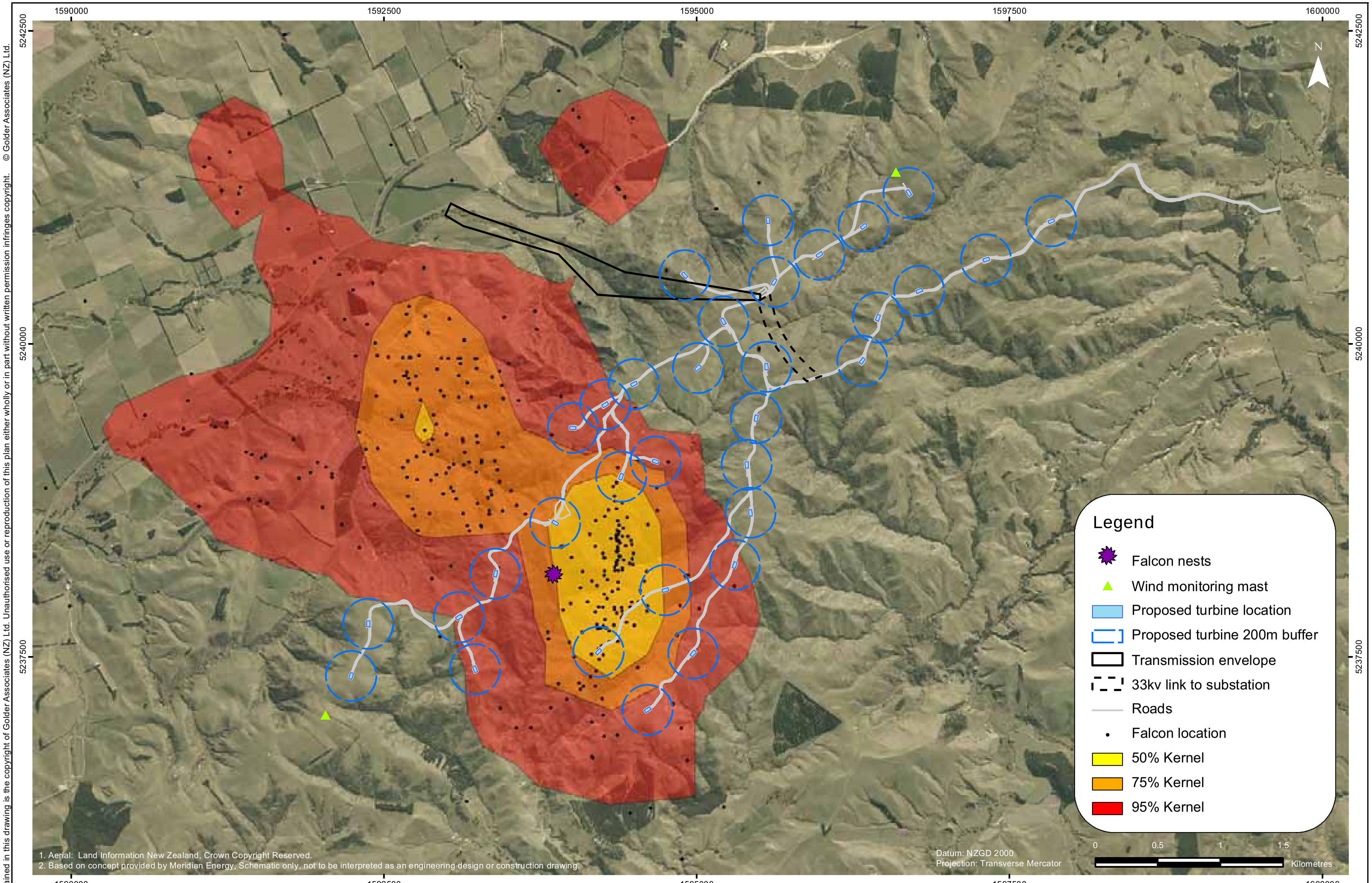

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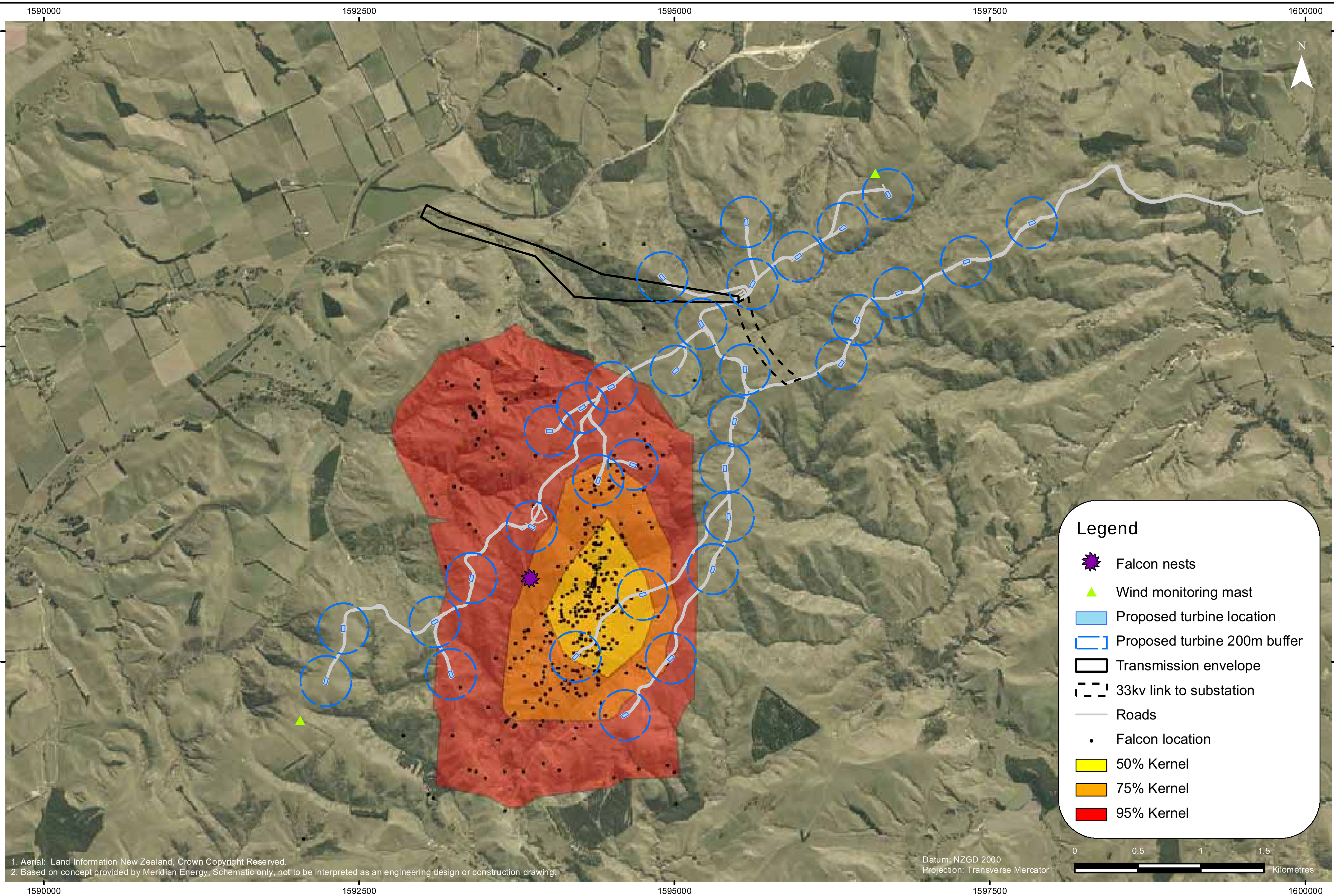

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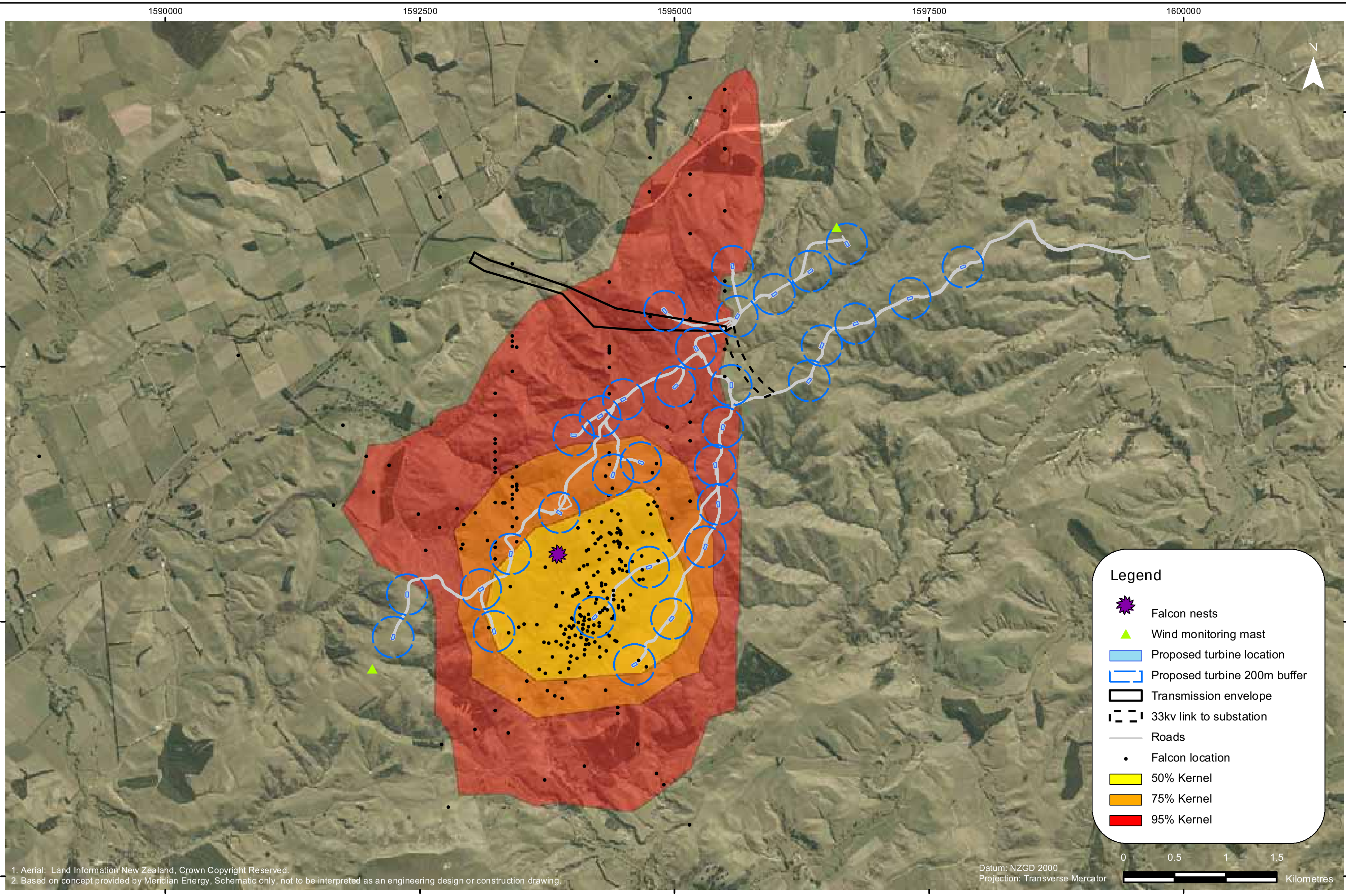

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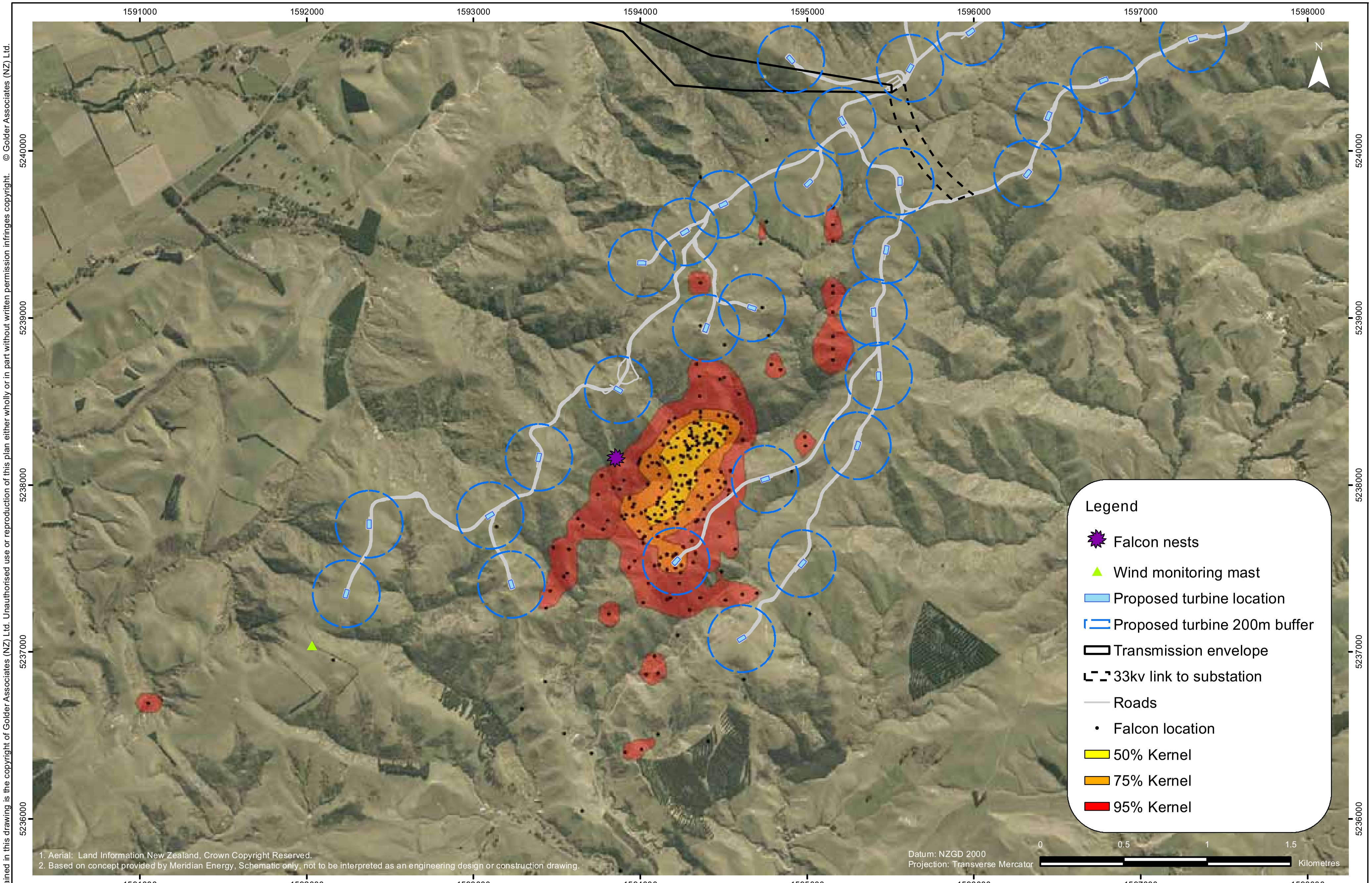

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TITLE JUVENILE FALCON KERNEL ANALYSIS - JANUARY-MARCH 2011: HURUNUI WIND FARM

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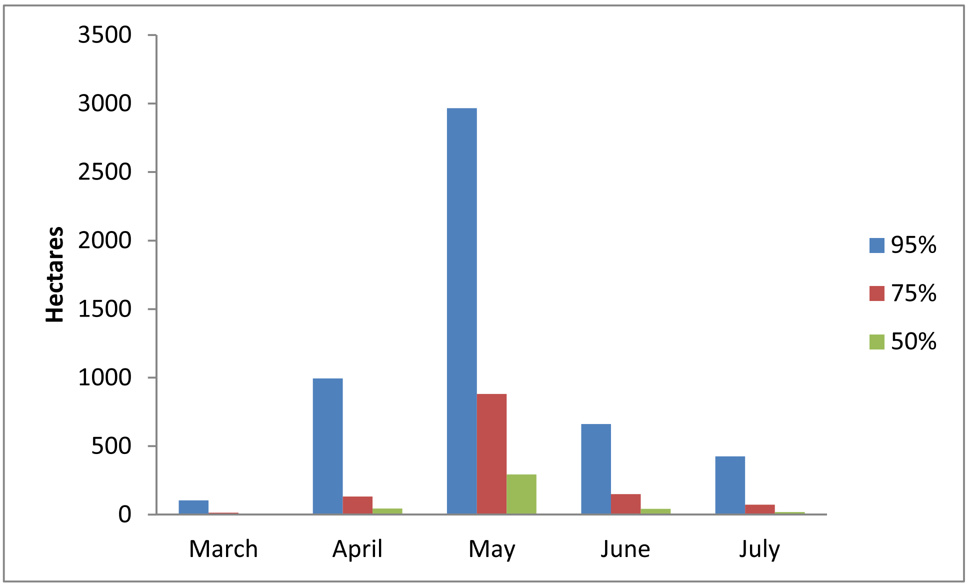
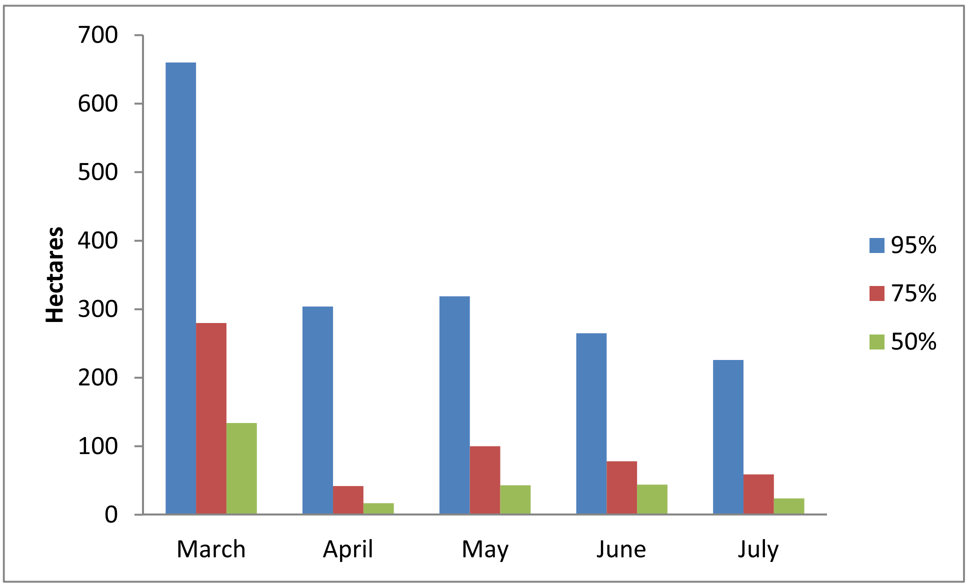
4.2.2.1 Adult male and female falcon autumn/winter 2010 kernel home ranges

During autumn and winter the adult male's home range was about twice the size of the adult female's home range for all three kernel contour levels analysed (Table 3). This was the case in every month except March, when, for an unknown reason, the female's home range was larger than that of the males. The male's 95 % kernel home range increased from a March low of 105 ha to May peak of 2966 ha before decreasing to 661 ha and 425 ha for June and July respectively (Figure 10). The mean (± 1 standard error) 95 % kernel for the male across all months was 1030 ha (± 505 ha). On a monthly basis the female's 95 % kernel home range declined from a peak in March of 660 ha to stabilise between 226 ha and 310 ha, respectively, for the remaining months. The values for the 75 % and 50 % kernel home ranges showed a similar temporal trend. The degree of overlap in home range between the sexes was approximately 50 % at all kernel levels, indicating that male and female falcons do not hold exclusive home ranges.



(a)



(b)

Figure 10: Monthly kernel home range sizes (95, 75 and 50 % kernels) for the adult male(a) and adult female (b) falcons radio tracked during the autumn/winter 2010 period.

4.2.2.2 *Adult male and juvenile female summer 2011 home ranges*

Monthly analyses were not carried out during the second tracking phase because the tracking occurred over a shorter timeframe and was aimed at intensively sampling the breeding season and post fledging periods for the male and juvenile falcons respectively.

During the summer monitoring period the male's home range was consistently larger than during the previous autumn/winter at all kernel levels analysed (Table 3). During both tracking periods the male's home range was centered on the nest site and surrounding gully systems. However, the shape of the home ranges for both periods differed. During the 2010 autumn/winter period the male's 95 % and 75 % kernels extended out to the west of the wind farm (Figure 6). During the summer 2011 tracking period, the falcon shifted the extremity of his home range to the north and in doing so increased the number of turbines potentially interacted with from 15 to 24, a 28 % increase (Figure 8). The reason for this change is unknown but may be related to a change in foraging behaviour associated with an increased demand for provisioning food for his mate and nestlings.

The juvenile female's home range was considerably smaller than the male's summer home range and the adult female's winter home range. The centre of the bird's kernels were south and east of the nest site and reflected general movement patterns in that direction. The observed smaller home range is expected for a juvenile falcon that is still dependant on its parents for food, rendering the need to forage widely absent. However, the general movement patterns towards the south/east displayed by the bird and the fact that the home range did not stabilise (Figure 9) suggest that the bird may eventually disperse towards that direction.

4.2.3 Potential to interact with turbines

Table 4 shows the number of 200 m buffered turbines intersecting the three kernel levels analysed for each falcon and study period. Based on this analysis, all birds studied have the potential to interact with some turbines. This is not unexpected given the location of the nest, its central focus within their respective home ranges and their spatial context with the wind farm. The adult male's home range contained the most turbines based on the summer home range kernels presented in this report. The adult male's and the adult female's 95 % and 75 % autumn/winter kernels intercepted similar numbers of turbines each. The female's 50 % kernel intercepted half as many turbines as the males. The juvenile falcon's home range was the smallest and accordingly contained the fewest number of turbines at all kernel levels relative to the adults.

Table 4: The number of 200 m turbine buffers intersecting the home range kernels of the falcons studied during the autumn/winter 2010 and summer 2010/2011 tracking periods. Percent of total (sample size = 33) turbines are shown in parentheses.

	Male autumn/winter 2010			**Female autumn/winter 2010**			**Male summer 2010/2011**			**Juvenile summer 2010/2011**		
Kernel Size %	**95**	**75**	**50**	**95**	**75**	**50**	**95**	**75**	**50**	**95**	**75**	**50**
# turbines in kernel (% of total)	15 (45)	8 (24)	4 (12)	14 (42)	7 (21)	2 (6)	24 (73)	13 (39)	9 (27)	8 (24)	1 (3)	0 (0)

4.2.4 Potential to interact with transmission lines and meteorological masts

None of the falcon home ranges intercepted the two proposed meteorological masts (Figures 6–9) and, although the spatial extent of their home ranges in the future is unknown, the risk of collision with meteorological masts may be low. The only home range to intercept the proposed transmission lines was that of the male falcon during summer (Figure 8), although his winter home range was adjacent to the proposed lines (Figure 6). During this period the falcon may have flown over the transmission envelope when moving between his main home range and the cluster of locations to the north (see Figure 6). If the home ranges of falcons at the site include the location of transmission lines and meteorological masts, there would be a level of risk of collision with the structures. However, given the small area occupied by masts and transmission lines relative to the spatial scale at which falcons use the landscape, the risk is expected to be low.

4.2.5 Habitat-use

4.2.5.1 Adult male and female falcon, autumn/winter 2010

The habitats present within the each falcon's 75 % kernel are shown in Figure 11 and quantified in Table 5. During this period, the use of all habitats was similar to their availability, suggesting that none are strongly selected for or against, with the possible exception of grey shrubland/pasture and pasture/silver tussock. There was some evidence for selection of grey shrubland/pasture habitats because its proportional use was greater than its availability and the 95 % confidence interval (Figure 12) for use does not overlap availability. Pasture/silver tussock habitats were used more than any other habitat but at rates slightly lower than its availability, providing some, but weak, evidence that this habitat was selected against (Figure 12). The high use of pasture/silver tussock, but lower use relative to its availability might simply reflect its high abundance in the area and that it is not limiting. A similar pattern is suggested for the female falcon (Figure 12) although. due to the smaller size of her home range, exotic forest was absent and therefore unavailable as a habitat.

Table 5: Habitat available (hectares/percentage) in the 75 % kernel home range for the adult male, adult female during autumn/winter 2010 and the 95 % kernel for the adult male during summer 2010/2011 at the proposed Hurunui Wind Farm.

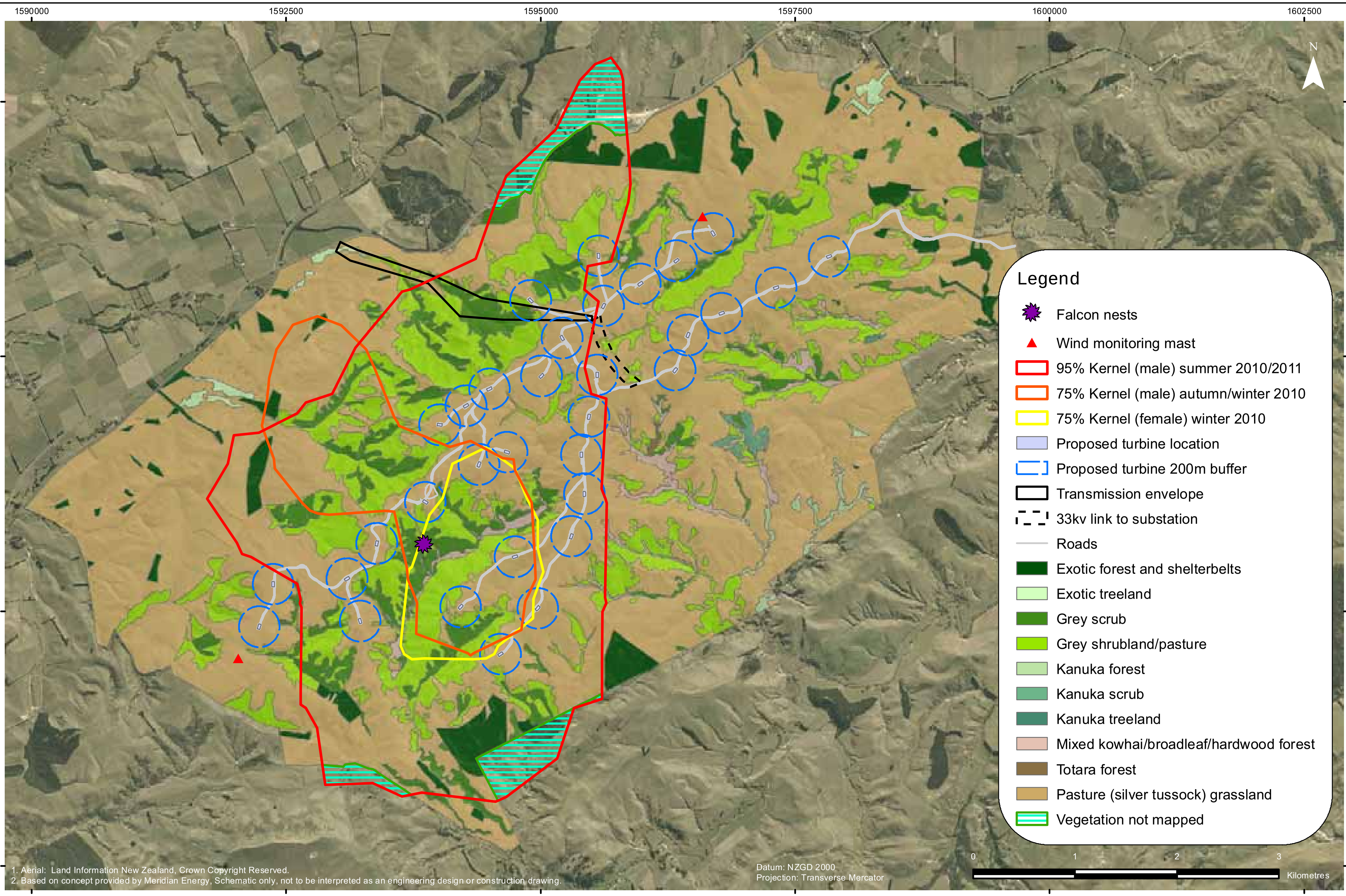
Habitat Type	Adult Female (autumn/winter 2010)	Adult Male (autumn/winter 2010)	Adult Male (summer 2010/2011)[1]
Exotic forest and shelterbelts	- / -	4.6 / 1.1	63.8 / 4.1
Grey scrub	34.1 / 16.3	62.0 / 14.3	186.0 / 11.9
Grey shrubland/pasture	85.8 / 41.1	156.1 / 35.9	454.0 / 29.1
Mixed Kowhai/broadleaf/hardwood forest	9.2 / 4.4	8.0 / 1.8	14.0 / 0.9
Pasture (silver tussock) grassland	79.6 / 38.1	204.0 / 46.9	844.0 / 54.0

[1] **Note**: 98 ha of vegetation near periphery of the male's summer home range was unmapped.

4.2.5.2 Adult male summer, 2010/2011

The habitats present within the falcons' 95 % kernel are shown in Figure 11 and quantified in Table 5. The male's 95 % kernel extended beyond the limit of vegetation mapped for the project by 98 ha and this area was excluded from the habitat analysis. This is not considered to affect the results of habitat use analysis because the area of unmapped vegetation is small (about 6 % of the bird's home range) and is located away from the wind farm footprint (Figure 11).

During the summer breeding season the home range for the adult male falcon differed from that in the previous autumn/winter period. Despite the shift in home range to the north, the broad level habitat use patterns remained similar between the two periods. However, the relative use of grey shrubland/pasture increased relative to its availability, and the highly non-overlapping 95 % confidence interval suggests selection for this habitat type (Figure 12). Conversely, pasture/silver tussock habitats were used substantially less frequently than their availability within the home range. The highly non overlapping 95% confidence interval between use and availability of this habitat type suggests that it may be selected against relative to its availability. Thus, although the pattern was similar to the autumn/winter period, the preference of grey shrubland/pasture and apparent avoidance of pasture/silver tussock appeared stronger than during the previous autumn/winter period.



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TITLE

HABITATS WITHIN MALE AND FEMALE FALCON'S AUTUMN/WINTER 2010 75% KERNEL AND THE MALE'S 2010/2011 SUMMER 95% KERNEL

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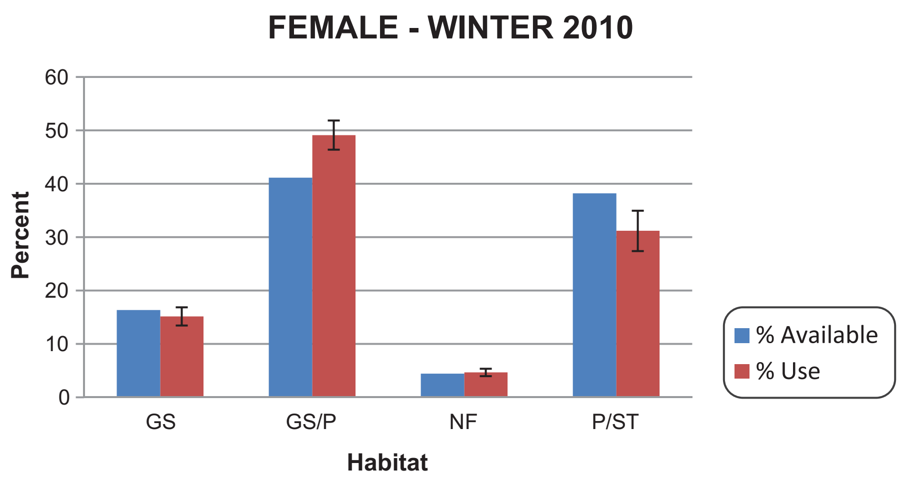
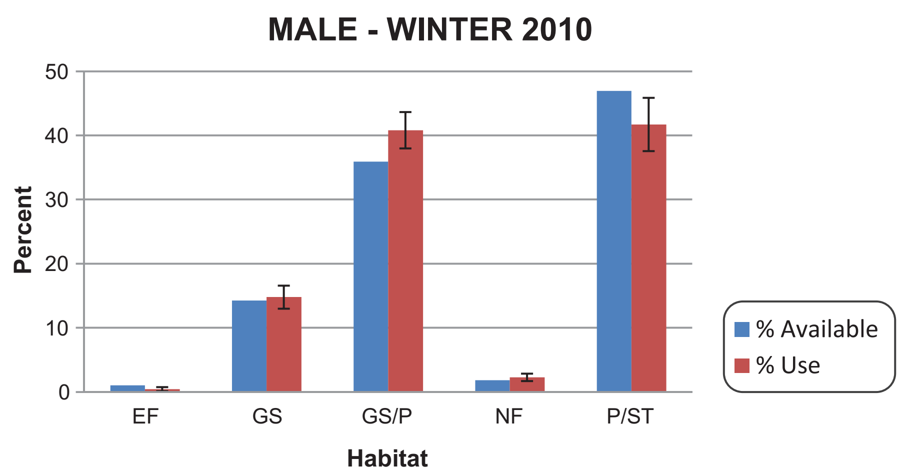
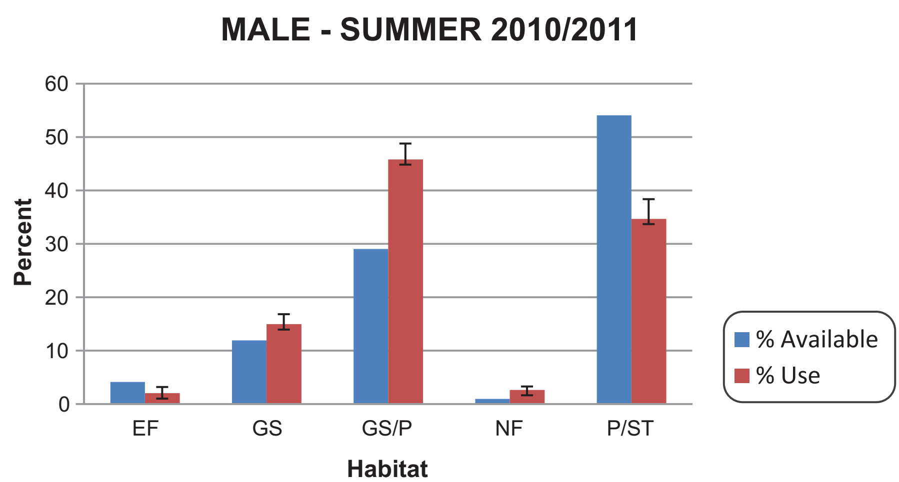


Adult female (autumn/winter 2010)



Adult male (autumn/winter 2010)



Adult male (summer 2010/2011)

Legend

GS = Grey Scrub GS/P = Grey Shrubland/Pasture
EF = Exotic Forest NF = native Forest P/ST = Pasture Silver Tussock

Error bars = 95% confidence intervals

TITLE PROPORTION OF HABITAT AVAILABLE AND USED IN THE 75% KERNEL BY THE ADULT MALE AND FEMALE FALCON DURING AUTUMN/WINTER 2010, AND 95% KERNEL FOR THE ADULT MALE DURING SUMMER 2010/2011 AT THE PROPOSED HURUNUI WIND FARM

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Although not explicitly measured in this study, small bird abundance appeared to be very high in grey scrub and grey scrub/pasture habitats. Hares were also frequently observed in this habitat type. It is possible that the abundance of these food sources influenced the selection of this habitat type by both falcons and may have accounted for increased selection by the male during the summer breeding period. Food availability can be an important driver of nest site selection but habitat structure is also important (Martin 1987; 1993). For raptors, habitat structure is important in terms of providing perches from which to launch hunting forays and as a substrate for nest placement, given that nest site availability can be limiting for raptors (Newton 1997). However, both food availability and habitat structure can interact synergistically (Zanette et al. 2003) and may explain the observed habitat selection patterns in this study. Thus, the stronger habitat use patterns during summer compared to autumn/winter for the male may reflect the relative abundance of prey in grey/shrubland/pasture relative to pasture/silver tussock, and the increased demands of providing food for nestlings and the adult female during the breeding season.

It is important to consider that the habitat selection patterns of both falcons are not independent of each other because they interact as a breeding pair with overlapping home ranges centred on their nest site. Additionally, their habitat use is also influenced by where they choose to nest and the habitats available in its proximity. Thus, habitat selection patterns in future years are expected to be influenced by the habitat available near the selected nest site. This means that, if the falcons choose to nest elsewhere in the wind farm, or outside of it, their habitat use patterns could be different from that observed in this study.

4.2.6 Flight height

The field ecologists recorded 215 estimates of flight height during the course of the entire study. Because the sex and age of falcons could not always be determined accurately, the data were pooled to maximise the sample size for analysis, and these statistics are assumed to be representative of all falcons flying at the proposed Hurunui site. Of the 215 observed flights, 47 occurred over the floor of gullies and were dropped from further analysis because they did not reflect the spatial context of the turbines or the RSA. The remaining 168 observations were of flights over ridge tops and ridge side slopes and were used in the analysis because they better reflect the potential to fly within the RSA.

Table 6 shows the number of flights and mean percent intercepting the RSA for each study date and for the overall study. The mean percent of flights estimated to intercept the RSA on a sample period basis ranged between 29.0 % and 66.7 %, with an overall mean value of 44 %.

Table 6: Number and percent and overall mean (± 1 standard deviation) of flights observed over ridges and ridge side slopes estimated to pass through the Rotor Swept Area (29.5 m – 30.5 m). The total number of flights observed for each date are shown in parentheses.

Sample Date	# at RSA (sample size)	Mean % flights at RSA
March – July 2010	4 (14)	29.0
6 - 10 December 2010	23 (47)	48.9
16 - 20 January 2011	8 (26)	30.8
24 - 25 January 2011	13 (38)	34.2
14 - 15 February 2011	14 (21)	66.7
16 - 17 March 2011	12 (22)	54.6
		Mean (± SD) = 44.0 (± 15)

4.3 Collision Risk Analysis (Phase 3 Investigation)

The results of the CRM are shown in Table 7. It is important to consider the results in the context of the modelled periods. The analysis assumes that the home ranges for each falcon reflects those in the future. If the falcons choose to nest elsewhere, or environmental factors change and their home ranges also change, then the collision estimates would likely differ.

The analysis suggests that the annual risk is greatest for the adult female, followed by that for the male during the summer period. The adult male appears less at risk during the autumn/winter period than during the summer monitoring period, probably because he spent more time away from the wind farm during autumn/winter (Figure 6). The juvenile appears least at risk over the three month modelling period, reflecting the fact that this period was pre-dispersal, after which juveniles are expected to leave the wind farm area.

Table 7: Mean (± standard deviation) number of estimated collisions per modelled period and number of years between potential collisions for the falcons radio tracked at the proposed Hurunui Wind Farm.

Individual/ tracking period	Modelled period	Mean # Collisions	Average # years between potential collisions
Adult female autumn/winter 2010	1 year	0.24 (0.22)	4
Adult male autumn/winter 2010	6 months	0.06 (0.05)	14
Adult male summer 2010/2011	6 months	0.20 (0.20)	5
Juvenile female summer 2010/2011	3 months	0.02 (0.01)	50

The mean period between potential annual collisions for the adult female is similar to that for the adult male over the six month summer period his data were collected. The adult male appears about three times more likely to collide over the summer period than over autumn/winter, based on the data collected during those periods. Because the period between potential collisions for the adult male in summer is shorter than that for the autumn/winter period, the results for the summer period essentially override those of the autumn/winter period. As such, the model estimates the adult female and male falcons may collide with a turbine within four and five years, respectively, after the turbines become operational.

The results for the juvenile suggest that based on the sampled spatial patterns period between potential collisions may be 50 years. As such, over the consent life of the wind farm the modelling estimates that dispersing juveniles are minimally at risk, but that between five male and seven female adult falcons might collide, if they continue to nest in their current general location. This assumes that individuals are immediately replaced upon collision. It is important to consider that these results are estimates that may differ if falcon behaviour differs from that assessed in this study or if their ability to avoid turbines is different than that modelled.

It is important to also consider that these results reflect the data collected and may vary if the falcons move their nest location or alter their use of space in future years. Monitoring winter and spring/summer was employed to overcome this to some degree. However, although falcons can nest in the same or a similar location every year (as was the case during the monitoring period), it is difficult to predict where falcons will nest in the future as they often change their nest location (Seaton 2007a, L Barea personal observation). Consequently, it is important to consider the results of the model as a guide, rather than an absolute prediction accounting for all scenarios. The 200 m buffer placed around each turbine and used to assess the level of potential turbine interaction as a CRM input is a conservative approach that likely overestimates the potential to interact with turbines, and this should be considered in the interpretation of the results.

Overall, in the absence of empirical data on falcons within operational wind farms in New Zealand, this model provides an objectively derived guide from which to scale potential mitigation. Notably, because the results are based on quantitative data collected in the field at the proposed project location, combined with a modelling process that takes into account the specific characteristics of the proposal, they improve on conclusions and mitigation approaches based on qualitative assessments.

5.0 DISCUSSION

5.1 Potential Effects of the Hurunui Wind Farm

5.1.1 Disturbance and displacement

To date breeding by falcons has only been monitored at one operational wind farm in New Zealand, Meridian's White Hill Wind Farm. Post-construction monitoring of falcons at White Hill has concentrated on locating falcon nest sites and establishing whether falcons continue to breed during operation of the wind farm (Boffa Miskell 2009). Notwithstanding the disappearance of one of the two pairs during the 2009/2010 breeding season at White Hill (Boffa Miskell 2011), no negative impacts to breeding have been confirmed to be related to the operation of the wind farm (nest failure has been the result of introduced mammals predating the nest contents) and falcons are regularly seen flying within the wind farm footprint. These results indicate that falcons resident within a wind farm prior to its construction are not necessarily displaced, but can continue to attempt to breed once the wind farm is operational.

However, disturbance to nesting falcons during the construction of a wind farm has not yet been monitored in New Zealand. The effect of large machinery on falcon breeding success within an industrial pine plantation has, however, been monitored (Seaton et. al 2009), and this may provide some guidance on this issue. Seaton et al. (2009) found that large machinery operating close to a nest could have an impact on breeding success. This suggests that if construction activity at a wind farm is undertaken close to (within 200 m) an active falcon nest, breeding success may be reduced. To avoid this effect in a forestry context, Seaton et al. (2009) recommended that activity should be restricted within 200 m of an active falcon nest. Both nest sites located during this study were more than 200 m from any proposed turbine location or road. Therefore if they remain in this area their breeding success may not be impacted by either the operation or the construction of the Hurunui Wind Farm. However, during setting up the radio tracking in December 2010, the falcon's behaviour over several hours suggested they were concerned about the presence of observers when observers were situated on or near the road between turbines D4 and D5, and in direct view of the nest. Turbines D4 and D5 are located approximately 465 m and 410 m from the nest, respectively. This suggests that this pair of falcons may be sensitive to disturbance if construction occurs within direct line of sight of about 500 m of the nest site, although it is possible that they were reacting to their nest site being checked and/or the presence of observers setting up the study. Consequently, and also because the falcons may choose to nest in other locations in the future, avoidance measures are recommended (see Section 6.0 below).

5.1.2 Habitat loss

5.1.2.1 Vegetation

Due to the relatively small project footprint of the Hurunui wind farm proposal, habitat loss is unlikely to have a negative effect on falcons; either by reducing prey availability or by reducing the amount of nesting habitat available. Because falcon habitat preferences at this site are very broad the loss of a portion of any particular habitat type is unlikely to negatively impact them. The increased selection for grey shrubland/pasture recorded for the male in the breeding season may be explained by changes in foraging behaviour associated with providing food for his mate and chicks. Because most falcon nesting habitat is located in gullies away from construction areas, the small losses of this habitat proposed along the ridges as part of this proposal is unlikely to affect the presence and breeding of falcons at the site.

5.1.2.2 Rock outcrops

Falcons use a range of substrates for nest sites (Fox 1977, Barea 1997, Seaton et al. 2010), including rock outcrops such as that used by the study pair during the second monitored breeding season. Consequently, the removal of rock outcrops potentially reduces the amount of available nesting habitat. The design process for the Hurunui Wind Farm included holding shaping workshops during which design refinements were made to avoid rock outcrop habitat due to its importance for biodiversity values, including herpetofauna and indigenous flora as well as falcon nesting habitat (Boffa Miskell 2011). All rock outcrops, with the exception of two, were avoided during the design phase. One of these rock outcrops located within a turbine platform (A11) will be avoided during the detailed design phase (Boffa Miskell 2011), and it is recommended that this be reflected in appropriate consent conditions. A rock outcrop on E Road cannot be avoided because alternative road alignments would require significant cuts with greater earthworks and potential visual effects or be technically not feasible (Boffa Miskell 2011). However, because the outcrop is located on a ridge road and the falcons are likely to continue to nest within the more sheltered gullies, it is unlikely that the outcrop would be used for nesting in the future. Additionally, outcrops potentially suitable for nesting are abundant within the landscape and the falcons are not restricted to using them as a nesting substrate. Therefore, the loss of one rock outcrop is not considered to adversely affect the potential of the site to support breeding falcons once the wind farm is constructed.

Overall, it is concluded that the removal of vegetation and a portion of a single rock outcrop as a result of this development will not reduce the suitability of the site for falcon breeding or in general.

5.1.3 Electrocution

The threat of electrocution posed by transmission lines has recently been documented by a project set up to release falcons over vineyards in Marlborough (the Falcons for Grapes Project (Seaton et al. 2011). This project has reported almost 50 % of falcon deaths being the result of electrocution caused by the birds landing on un-insulated power poles and transformer boxes (Fox & Wynn 2010). Research undertaken overseas indicates that very large numbers of birds of prey are killed every year by electrocution and these far outweigh any mortality that could potentially be caused by wind turbines (Winkelman 1995).

Electrocution occurs on low voltage power installations associated with low poles and electrical infrastructure, not the high voltage transmission lines proposed as part of the Hurunui Wind Farm. As such, construction and operation of the Hurunui Wind Farm is not expected to present an electrocution risk to falcons.

5.1.4 Collision mortality

Some birds of prey overseas have been reported as being prone to collision with wind turbines, some disproportionately so (e.g., Orloff & Flannery 1992; Percival 2003). These are mostly the large soaring raptors or species that hover; characteristics that are not primary behaviours of New Zealand falcon. Nevertheless, several small species of raptor that do share some characteristics with the New Zealand falcon, (e.g., peregrine falcons, prairie falcons, sparrowhawks and lesser kestrels) have been noted to collide with wind turbines (Kingsley & Whittam 2005). The extent to which this is the case depends not only on the species behaviour but also topography and wind farm design and as such is very much site-dependant (Anderson et al. 2000; Morrison et al. 2007).

Due to a lack of robust collision monitoring at operational wind farms in New Zealand it is still unknown whether falcons collide with wind turbines, and if they do at what frequency this might occur. Anecdotal evidence from White Hill Wind Farm suggests that falcons are able to live in the vicinity of an operational wind farm (Boffa Miskell 2009), although the recent apparent disappearance of one of the two resident pairs remains unexplained (Boffa Miskell 2011). Because the falcons monitored at White Hill have not been individually marked or tracked, it has not been possible to determine whether the same individuals have persisted in the wind farm, to what extent they are prone to collision, how frequently any collisions may occur or how collision risk may vary between the sexes and between ages. Therefore, risk assessments of the effect of wind farms on falcons in New Zealand have relied on a combination of behavioural data and expert opinion. As a result, much uncertainty remains over the level of this potential effect on this species.

In this study CRM suggests that the average time between potential collisions for each of the resident adult falcons may be 4 to 5 years. The effects on juveniles during their pre dispersal period appear low and if so may be substantially lower than predation rates by introduced mammals. The collision rate for adults is similar to the collision estimate for an adult male falcon at Meridian’s Central Wind project where the average time between collisions was estimated to be 5.8 years (Boffa Miskell and Golder Associates 2009).

5.1.4.1 Long term effects

The overall effect to the long term persistence of breeding falcons at the site and their productivity depends on an individual that collides being replaced by another from the floating non-breeding population and a pair of falcon remaining productive at the site. If one of the resident adults is removed by collision and is not replaced by another falcon that subsequently pairs and breeds with the remaining bird, then the presence of nesting falcons at the site will cease, but may resume if falcons re-colonise in the future.

If a falcon that collides is replaced by another falcon that breeds successfully with the remaining bird, then the productivity rate over time will depend of the replacement rate, which is dependent on the number and distribution of falcons in the non-breeding floating population. Currently the size of the non-breeding floating population is unknown, but will be largely related to falcon productivity within the region. Given the type of habitats within the wider region, it is expected that other pairs of breeding falcons are present regionally.

If the results of the modelling hold true, then the future status of nesting falcons at the site may fluctuate between the following scenarios:

- Presence of an active breeding pair via replacement of individuals from the floating population;
- Presence of unpaired individuals;
- Absence of breeding falcons as a breeding species at the site; and
- Fluctuations between the above scenarios.

Re-colonisation in the event of extirpation is plausible because falcons are highly likely present within the region, and monitoring at Meridian's White Hill Wind Farm indicates that falcons can continue to attempt to nest within a proposed wind farm once it becomes operational. Additionally, the construction and operation of the Hurunui Wind Farm is not expected to adversely affect habitat availability and hence nest site quality for falcons.

The results of the CRM analysis reflect in part the location of the falcon's nest within the wind farm and that the area containing the nest is the centre of their home range in both the breeding and non-breeding season. This results in high levels of year round activity within the wind farm. Because the falcons' movements were centred on the nest site during both winter and summer, any changes in the location of nest sites in the future would likely change the collision risk. If the birds chose to nest in the gully systems to the north of Central Hill or in other areas away from the turbines, then collision risk would be expected to be significantly reduced or to be absent. Notwithstanding these possibilities, the effects of collision risk on falcon may be adverse at a local scale, and it is essential that appropriate mitigation is developed. Golder recommends that this is reflected in appropriate consent conditions.

In addition to the risk of collision with turbines, falcons may collide with transmission lines and meteorological masts. Based on the home ranges established in this study, the risk of the resident falcons colliding with meteorological masts is low because the masts would be located outside of the home ranges. However, if the home ranges change or non-resident falcons visit the site, then collisions could occur. Given the small area occupied by masts and transmission lines relative to the spatial scale at which falcons use the landscape, the risk is expected to be low.

6.0 RECOMMENDED MEASURES TO AVOID, REMEDY OR MITIGATE EFFECTS

6.1 Avoidance Strategies

Avoiding adverse effects by modifying the location of some of the turbines in an attempt to reduce collision risk is not recommended because the modelling results are based on data collected from specific individuals over a short period and these, and hence risk, could be different at other times. Consequently, modifying the design of the wind farm would provide little confidence that collision effects would be avoided into the future.

However, potential exists to avoid some non collision related effects as follows:

- Translocation of eggs/chicks when nest is within 500 m direct line of sight of construction activity;

- Restriction of construction activities within 200m of actives nests when not in direct line of sight of those activities; and
- Avoidance of power pole construction which poses a risk of electrocution to falcons.

6.1.1 Avoid electrocution

To avoid increasing the electrocution hazard in the area all new power poles proposed as a result of the wind farm should be of a design that avoids providing perches for falcons where they can suffer electrocution i.e., avoiding a gap between a grounded perch and exposed live wires that can be bridged by a falcon (see Figure 13 for examples of designs to avoid).

Figure 13: Power pole and transformer box designs known to have electrocuted falcons in the Marlborough region: note the transformer in the picture on the right has been retrofitted with a mitigation device to prevent further electrocutions (Fox & Wynn 2010).

6.1.2 Insulate local power poles

As noted above, although not present in the immediate nest gully, power pole designs that pose an electrocution hazard to falcons are common in the local area. Insulation of a number of poles and transformer boxes would therefore reduce this hazard. Insulating the power poles within the adult male and female home ranges would reduce any electrocution risk to birds nesting at Hurunui, while increasing this area would be beneficial to juveniles dispersing from the site.

6.2 Mitigation Options

6.2.1 Support research into electrocution

Although electrocution has been identified as a significant hazard to falcons (and may well be restricting their range nationally) intensive research into this hazard is yet to be undertaken in New Zealand. This includes identifying the mechanics of how falcons (or other birds) are electrocuted and how best to avoid this hazard on a national scale. Placing power lines and transformer boxes underground is the ideal option as it removes the hazard entirely; however this option is not always financially viable thus other options need to be developed. This requires:

- Identifying which power pole and transformer box designs pose the greatest hazard to falcons/other birds;

- Establishing assessment criteria to prioritise which power poles and transformer boxes need insulating in New Zealand; and
- Developing power pole and transformer box designs that avoid the hazard in the first place.

If power poles and transformers could be designed to avoid electrocution they could be replaced with more ‘bird friendly’ designs when they need replacing hence eventually phasing this hazard out. Support of the development and enforcement of national standards that require lines companies to use such ‘bird friendly’ designs would ensure the greatest benefit.

6.2.2 Predator control

Falcons are known to suffer predation by a number of introduced mammalian predators, particularly during the breeding cycle when eggs, nestlings or even adults tending the nest may be predated (Fox 1977, Seaton 2007a). Cats are known to be a particular problem but other predators include pigs, stoats, ferrets, possum, hedgehogs, and magpies. Effective control of these predators at Hurunui could potentially increase the breeding success and survival of adult falcons.

However, predator control is not recommended as a primary action to mitigate the effects of collision mortality because as there is no evidence that predation is limiting their productivity at this site, despite the known presence of introduced predators. Further, the collision modelling results provide uncertainty as to the long term persistence or productivity of nesting falcons at the current site which compromises the utility of this option.

6.2.3 Support falcon conservation

We recommend that all avoidance options are employed but that potentially only one of the mitigation options need be employed if it is on a scale that matches a worst case effect. The worst case effect is that falcons cease to breed at the site and matching that level of effect requires establishing another pair of eastern falcons elsewhere in their range. Adopting this level of effect for mitigation does not mean that this level of effect is actually expected to occur. Instead, it provides a conservative approach to mitigation by ensuring that that the greatest potential effect would be adequately addressed.

Because eastern falcons interact as a population over a very large spatial scale, we do not consider it necessary that this mitigation occur onsite, but that it occurs within the accepted distributional range of eastern falcons, preferably within the Motunau Ecological District. Offsite replacement is also appropriate to avoid placing additional birds at risk and because the impact only involves a single pair of falcons rather than a population.

There are two captive management programmes currently running in New Zealand that specialise in the captive management and conservation of falcons. One is the Wingspan Birds of Prey Trust (Wingspan) (www.wingspan.co.nz) and the other is the Marlborough Falcon Conservation Trust (MFCT) (www.mfct.org.nz). These organisations aim to not only supplement the wild population of falcons but also aim to establish new populations of falcons into areas where they have previously been extirpated. Wingspan has been established for 20 years and currently breeds eastern falcons for release. The MFCT is in a formative stage and plans to breed eastern falcons for release in the future. Contribution of funds to aid conservation efforts would be of direct benefit to the conservation of falcons nationwide.

7.0 SUMMARY OF KEY RESULTS AND CONCLUSIONS

- A breeding pair of falcons has been located within the proposed Hurunui Wind Farm envelope for the past two breeding seasons (2009/2010 & 2010/2011).
- Disturbance of falcon breeding activity is unlikely to be caused by construction or operation of the wind farm if these falcons remain nesting in the current location and construction activities remain out of direct line if sight of the nest. However, if falcons are located nesting within 500 m of any proposed

works that are in direct line of sight of the nest during the construction period, this may result in negative impacts to breeding success in that year and avoidance measures are recommended below.

- Habitat loss and electrocution is not expected to occur, and so will not have an adverse effect on falcons, at the Hurunui Wind Farm.
- The home ranges of both adult and juvenile falcons overlap the area where the turbines are proposed to be built and all individuals were observed spending some time flying at a height that would place them at risk of collision with the turbines.
- As a result, detailed data on the movements and behaviour of the falcons at Hurunui were collected to provide estimates of collision mortality using CRM. CRM estimated that on average the time between potential collisions for the resident adults may be 4 - 5 years and 50 years for non-resident juveniles during a three month pre-dispersal phase.

Based on the results of the monitoring and modelling we suggest that some or all of the following options could be used to ensure that any negative impacts to falcons as a result of the Hurunui Wind Farm are avoided, remedied or mitigated to an acceptable level:

Avoidance Options

- Translocation of eggs/chicks when nest is within 500 m direct line of sight of construction activity.
- Restriction of construction activities within 200 m of actives nests when not in direct line of sight of those activities.
- Use power pole designs that do not provide perches for falcons where they can be electrocuted.

Mitigation Options

- Contribute funding to a programme that supports falcon conservation by releasing captive reared falcons into the wild.
- Fund research into how to resolve the electrocution issue nationwide.

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APPENDIX A

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APPENDIX B

Collision Risk Modelling Process.

The modelling process followed that of the Band (Band et al. 2007) model below. The data were modelled for each observation day and the results averaged to account for variation in the data.

1) The proportion of time where a falcon could potentially interact with a turbine (pt) was calculated by dividing the number of daily locations recorded within a 200 m buffer around each turbine by the total number of locations within the daily home range.

2) Falcons are not at risk of collision during the time they spend perched rather than flying. Consequently, the proportion of time each falcon spent flying on each day it was monitored (ff) was estimated by dividing the number of radio detections recorded as flying by the total number of radio detections for the bird over the same period.

3) Falcons are only at risk when flying at heights that place them within the RSA, in this case between 29.5 and 130.5 meters above the ground. This was calculated as the proportion of observed flights that were estimated to pass through the RSA (pRSA).

4) The proportion of time each falcon was at risk (Rk) was calculated by multiplying together the three proportions above to represent the proportion of time that each falcon spent flying at RSA height within 200m of a turbine, i.e., pt*ff*pRSA.

5) The number of hours during the modelled period of interest (i.e., 1 year, 6 months or 91 days – see Appendix C), during which an individual was at risk (r), was calculated as the product of Rk, the number of days of interest and the number of hours between sunrise and sunset during which the birds were assumed to be potentially active.

6) The volume of the flight risk zone (Vw) was calculated by multiplying the area contained within a 200 m buffer by the number of interaction buffers within the daily home range, i.e., those containing at least 1 falcon location and then multiplying this by the rotor diameter.

7) The volume swept by the number of turbines, i.e., number of interaction buffers (Vr), was calculated by multiplying the number of interaction turbines by $\pi r^2(d)$ where r = rotor radius and d = rotor depth.

8) The time that an individual falcon occupied the volume swept by rotors (b) was calculated by first converting r to seconds (r_s) and multiplying that by the volume of the flight risk zone divided by the volume swept by turbines, i.e., r_s(Vr/Vw).

9) The transit time (t) for a falcon to pass through and completely clear a rotor is a function of flight speed (s), rotor depth(d) and bird length (l) and was calculated as (d+l)/s.

10) The number of rotor transits (r^t) for the modelled period of interest was calculated by multiplying the proportion of time the turbines are expected to be operational (m) (after accounting for operational downtime) by the time that an individual falcon occupied the volume swept by rotors, divided by the transit time i.e., m(b/t).

11) The number of potential collisions for the modelled period of interest (Pc) was calculated as the product of the number of transits and collision probability (c) i.e., the probability that a falcon flying through the rotor is struck, or r^t*c.

12) The number of years elapsing before a single collision is estimated to occur was calculated by dividing 1 by Pc. The results represent the number of years between potential collisions occurring for the modelled period.

APPENDIX C

Collision Risk Modelling Input Parameter Definitions and Values.

A: Collision risk model parameter definitions for all models.

Parameter	Definition	Source
# turbine blades*	Number of turbine blades in rotor	Manufacturer specifications
Bird length (m)*	Length of falcon from bill tip to tail tip	Marchant & Higgins 1993
Wingspan (m)	Wingtip to wingtip in meters	Marchant & Higgins 1993
Rotor Diameter (m)	Diameter of rotor in meters	Manufacturer specifications
Maximum Chord (m)	Maximum width of rotor blade	Manufacturer specifications
Rotation Period (seconds)	Time for rotor to make single rotation	Data supplied by Meridian
Bird Speed (m/sec)	Mean flight speed of NZ falcon	Wingspan Birds of Prey Trust
Blade Pitch	Pitch angle of rotor blade	Data supplied by Meridian
Proportion time within risk zone	Number of locations within 200m buffer/total number of locations in 95% MCP	Calculated in GIS from home range, and falcon location shape files and shape file of proposed turbine locations supplied by Meridian
Proportion of time flying	Number of radio detections where falcon flying/total number radio detections	Radio tracking data for relevant bird and tracking period
Proportion of flights at RSA	Proportion of recorded flight paths intercepting RSA	Visual observation data pooled across all birds
# turbines in home range	Number of 200m turbine buffers intercepting 95% MCP	Calculated in GIS from home range shape files and shape file of proposed turbine locations supplied by Meridian
Area of 95% MCP (m^2)	Area contained within each falcons 95% MCP	Calculated in Biotas home range analysis software
Rotor depth (m)	Depth of rotor-estimate based on max chord	Manufacturer specifications
Turbine downtime (%)	Proportion of time rotors not operating	Supplied by Meridian
Season length (days)	Number of days collision modelled	Number of days in period of interest
Potential hours active/day	Number of days falcon potentially flying	Mean number of hours sunrise to sunset
Rotor radius (m)	Radius of rotor in meters	Manufacturer specifications

B: Collision risk modelling input parameters for all models.

Parameter	Metric
# turbine blades	3
Bird length (m) female/male	0.5/0.4
Wingspan (m) female/male	0.8/0.6
Rotor Diameter (m)	101
Maximum Chord (m)	3.4
Rotation Period (seconds)+	5.7
Bird Speed (m/sec)	11.0
Blade Pitch+	3.5
Rotor depth (m)	3.4
Turbine downtime (%)	13%
Rotor radius (m)	50.5
Proportion of flights at RSA	0.44

C: Collision risk modelling input parameters for the adult female falcon, autumn/winter 2010. Model was run for 12 months assuming 12 hours of potential activity per day.

	Day/Month									
Parameter	**18/3**	**20/3**	**20/4**	**22/4**	**18/5**	**20/5**	**15/6**	**17/6**	**12/7**	**14/7**
Proportion time within risk zone	0.031	0.095	0.169	0.224	0.031	0.118	0.042	0.191	0.333	0.419
Proportion of time flying	0.095	0.075	0.172	0.134	0.080	0.074	0.067	0.107	0.134	0.116
# turbines interacted with	1	4	5	3	1	2	1	1	6	5
Area (m^2) within interaction turbine buffers	125664	502655	628319	376991	125664	251327	125664	125664	753982	628319

D: Collision risk modelling input parameters for the adult male falcon, autumn/winter 2010. Model was run for 6 months assuming 10 hours of potential activity per day.

	Day/Month									
Parameter	**19/3**	**21/3**	**21/4**	**23/4**	**17/5**	**19/5**	**14/6**	**16/6**	**13/7**	**15/7**
Proportion time within risk zone	0.000	0.073	0.105	0.022	0.120	0.067	0.148	0.000	0.243	0.108
Proportion of time flying	0.054	0.169	0.156	0.143	0.206	0.129	0.046	0.032	0.132	0.129
# turbines interacted with	0	2	3	1	3	3	3	0	4	4
Area (m^2) within interaction turbine buffers	0	251327	376991	125664	376991	376991	376991	0	502655	502655

E: Collision risk modelling input parameters for the adult male falcon, summer 2011. Model was run for 6 months assuming 15 hours of potential activity per day.

	Day/Month									
Parameter	**6/12**	**7/12**	**8/12**	**9/12**	**10/12**	**16/1**	**17/1**	**18/1**	**19/1**	**20/1**
Proportion time within risk zone	0.115	0.136	0.436	0.333	0.371	0.105	0.077	0.037	0.056	0.214
Proportion of time flying	0.027	0.139	0.194	0.145	0.140	0.069	0.142	0.115	0.133	0.173
# turbines interacted with	3	2	3	3	3	2	3	1	1	4
Area (m^2) within interaction turbine buffers	376991	251327	376991	376991	376991	251327	376991	125664	125664	502655

F: Collision risk modelling input parameters for the juvenile female falcon, summer 2011. Model was run for 91 days assuming 14 hours of potential activity per day.

	Day/Month					
Parameter	**24/1**	**25/1**	**14/2**	**15/2**	**16/3**	**17/3**
Proportion time within risk zone	0.109	0.070	0.031	0.067	0.152	0.089
Proportion of time flying	0.082	0.075	0.102	0.081	0.047	0.048
# turbines interacted with	2	1	1	3	1	3
Area (m^2) within interaction turbine buffers	251327	125664	125664	376991	125664	376991

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Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australia & New Zealand	+ 61 7 3721 5400
Europe	+ 44 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

AUCKLAND

Tel +64 9 486 8068
Fax +64 9 486 8072

Level 2
Takapuna Business Park
4 Fred Thomas Drive
Takapuna
Auckland 0622

PO Box 33-849
Takapuna 0740

TAURANGA

Tel +64 7 928 5335
Fax +64 7 928 5336

78 Maunganui Road
Tauranga 3116

PO Box 13611
Tauranga Central
Tauranga 3141

HAMILTON

Tel +64 7 928 5335
Fax +64 7 928 5336

Ruakura AgResearch Centre
Room 31 in the Homestead
East Street
Hamilton 3214

PO Box 19-479
Hamilton 3244

NELSON

Tel +64 3 548 1707
Fax +64 3 548 1727

Level 3
295 Trafalgar Street
Nelson 7010

PO Box 1724
Nelson 7040

CHRISTCHURCH

Tel +64 3 377 5696
Fax +64 3 377 9944

Level 1
132 Tuam Street
Christchurch 8011

PO Box 2281
Christchurch 8140

DUNEDIN

Tel +64 3 479 0390
Fax +64 3 474 9642

Level 9A
John Wickliffe House
265 Princes Street
Dunedin 9016

PO Box 1087
Dunedin 9054

ARROWTOWN

Tel +64 3 409 8106
Fax +64 3 409 8106

11 Arrow Lane
Arrowtown 9302

Golder Associates