

Appendix G.

**Kahuku Wind Power Wildlife Monitoring Report
and Fatality Estimates for Waterbirds and Bats
(October 2007 – April 2009)**

By

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1.0 INTRODUCTION

Firstwind (formerly UPC Hawaii Wind Partners, LLC) has proposed to develop a 30 mega-watt wind power facility near the town of Kahuku on the island of Oahu, Hawaii. Kahuku Wind Power is situated one mile from the James Campbell Wildlife Refuge which harbors a significant portion of Hawaii's endangered waterbirds (Fig. 1). Avian and bat surveys were conducted to assess the risk of the proposed wind facility to Federal or state-listed threatened or endangered species that may be found on site or may transit through the site. When the project is completed, Kahuku Wind Power will consist of 12 turbines and one permanent meteorological (met) tower.

The goals of the study were to:

- 1) quantify the level of bird and bat activity on site using visual surveys and Anabat detectors (for bats) with emphasis on characterizing the flight patterns and activity of threatened and endangered species within these groups;
- 2) conduct waterbird surveys at nearby wetlands to characterize flight activity and diurnal or seasonal variations in abundance or activity (if any) and
- 3) estimate fatality rates of threatened and endangered species due to operation of turbines and met towers

2.0 METHODS

2.1 Quantifying Bird Activity

Point count stations (Stations B to K, Fig. 1) were selected to provide maximum survey coverage of the project area. Ten point count stations were established on the site and used during the survey period from October 2007 to December 2008 (Fig. 1). Four to eight point count stations were surveyed during each session and sessions were conducted in the morning (0600 – 1000 h), afternoon (1000 – 1400 h) and evening (1400 – 1800 h). Each point count lasted 20 minutes per station. Two observers using 10 x 50 binoculars with a 6.5 degree field of vision were present at each point count and all passerines, owls (Strigiformes) and doves (Columbiformes) within a 200 m radius of the count location were recorded. Bird species aurally detected within 200 m radius were also recorded. Waterbirds and seabirds, which are larger and more visible were recorded to within a 400 m radius of the count station. Data recorded include time of day, bird species, size of flock, flight direction, flight altitude, distance between bird/s and observer, habitat, location (on site or off site) and sex and age of bird where possible. Weather conditions were also documented. Wind speed and wind direction were recorded with a Kestrel 4500 (Nielsen Kellerman, USA), % cloud cover and visibility were estimated visually and precipitation was categorically documented.

Three additional point count stations were established from June - December 2008 along roads running along wetlands at the north-east of the project site (Stations 77, 78 and 79; Fig. 1). These additional point counts were established to describe the flight activity of endangered Hawaiian waterbirds that may not be adequately surveyed at the established on-site point count locations. Survey methods at these point count stations followed the protocol described above. However, due to the greater number of endangered waterbirds in the surveyed wetlands, point counts were confined to a radius of 200 m for all bird species. In addition, bird flight paths that crossed the road moving from the wetlands to the uplands or from vice versa were also recorded. This behavior was quantified and used as a measure the likelihood of waterbirds flying over the upland Kahuku Wind Power site.

Predominant flight directions were determined for all point counts on site and at the surveyed wetlands. The distribution of flight direction was tested using a Chi-Square Goodness-of-Fit to

determine if flight paths were random or directional in nature. Flight activity at each point count station on site at Kahuku Wind Power was tested using a one-way ANOVA with replicates to determine if some stations had higher flight activity than other stations. The data was log-transformed to normalize the data before running the analyses. Post-hoc Tukey's pairwise comparisons were conducted to determine which point count stations had higher rates of flight activity. All analyses were conducted using the statistical software SYSTAT (version 12, Systat Software, Inc.).

2.2 Quantifying bat activity

Nocturnal visual surveys and acoustic monitoring using bat detectors were used to quantify bat activity at the Kahuku Wind Power facility. Nocturnal visual surveys were conducted twice a month from October 2007 to December 2008. Four to eight point counts were surveyed for 20 minutes during each field session using the avian point count stations on the project site. Night vision goggles (Kerif ITT PVS-7 F5001 Series) and infra-red spotlights (Brinkmann Q-beam Max Million III) were used to detect bats to a distance of 30 m.

Three to five Anabat detectors (Titley Electronics, NSW, Australia) were deployed at any one time at various locations at the Kahuku Wind Power site from April 2008 to April 2009 (Fig. 2). Anabat detectors record any ultrasonic sounds emitted up to a radius of approximately 30 m from the device. These sounds are subsequently downloaded and analyzed by examining the sonograms of recorded sound files to confirm the presence of bats by identifying their echolocation (ultrasonic) calls. Anabat detectors were moved to new locations if they did not detect any calls for at least a month. Bat activity was quantified by the number of call sequences recorded (regardless of number of bat calls) and the number of bat passes (a sequence with three or more calls) per detector night. A bat call is one frequency modulated sweep, while a call sequence consists of a continuous recording of one or more bat calls. A call sequence with three or more calls qualifies as a bat pass (Kunz et al. 2007).

2.3 Calculating Fatality Estimates for Koloa Maoli-like Ducks

The koloa maoli-like ducks (or Hawaiian duck hybrids) are not endangered, but are hybrids of the endangered koloa maoli (*Anas wyvilliana* or Hawaiian duck) and the mallard (*Anas platyrhynchos*) and are a waterbird species of interest as they are likely to exhibit similar behaviors to the endangered koloa maoli.

Fatality estimates closely follow the model by Day and Cooper (2008) with modifications. The model includes movement rates (average passage rates over the site), horizontal interaction probabilities (probability of a bird encountering a turbine), exposure indices (the number of birds actually encountering a turbine within a given time frame), and fatality probability (the likelihood of fatality upon striking a structure). Different avoidance rates (probability of flying around the airspace of a structure rather than entering it) were also applied. Fatality estimates were divided into three parts; fatality at heights of the rotor swept zone (RSZ, 32 – 128 m), fatality from colliding with the tubular towers below the RSZ (< 32 m), and fatality upon collision with the met tower.

2.3.1. Passage rates

The average passage rate (flocks/hr/ha) of koloa maoli-like ducks was determined from koloa maoli-like duck flight activity rates at all point count stations on site. As koloa maoli-like ducks are large and visible, a 400 m radius was assumed for each point count. A uniform passage rate was assumed over the entire site encompassing the locations of all turbines and met towers. This enabled one hectare (ha) plots to be centered on each turbine and the passage rate of koloa maoli-like ducks in and around the airspace of each turbine to be calculated.

2.3.2 Calculating Horizontal Interaction Probabilities

The horizontal interaction probability for the RSZ was calculated on the assumption that the volume of the RSZ was a solid sphere with a radius of 47 m (the length of the turbine blades) (Fig. 3). The interaction probability for one RSZ (i.e., probability of encountering one RSZ of a turbine) is the proportion of the volume of one RSZ over the volume of a 1 ha plot from a height of 32 m to 128 m centered on each turbine (Fig. 3).

The interaction probability of one tubular tower (i.e., probability of encountering the tubular tower of the turbine below the RSZ) is the proportion of the volume of the tubular tower over the volume of a 1 ha plot from ground level to 32 m centered on each turbine (Fig. 3).

The interaction probability of one met tower is the proportion of the volume of the tower (80 m high) over the volume of a 1 ha plot centered on the tower at a height less than 80 m. The volume of the met tower consists of the volume of the lattice structure modeled as a solid structure (Fig. 4). The model also over-estimates the volume of the met tower by assuming a straight line taper from the base to the top, rather than a curve.

2.3.3 Exposure indices

Exposure indices estimate the likelihood of collision of a bird when it is in the airspace of the structure and the likelihood of fatality upon collision.

2.3.4 Fatality Probability Factors

Fatality probability factors within the RSZ (i.e., probability of striking a blade on frontal approach and probability of fatality if striking blade) are derived from the model developed by Day and Cooper (2008) for the Clipper C-96 turbine. Similarly, the fatality probability factors for the tubular towers of the turbines and met towers (probability of striking a tower if in airspace and probability of fatality if striking the tower) are also derived from same model (Day and Cooper 2008).

2.3.5 Avoidance Rates

Low mortality of waterbirds has been documented at wind turbines situated coastally (as is the proposed Kahuku Wind Power project), despite the presence of high numbers of waterbirds in the vicinity (e.g., Kingsley and Whittam 2007). Studies at wind energy facilities proximally located to wetlands and coastal areas have shown that waterbirds and shorebirds are among the birds most wary of turbines and that these birds readily "learn" to avoid the turbines over time (Koford et al. 2004, Jain 2005, Carothers 2008). Thus avoidance rates of 90%, 95% and 99% were applied to this project to provide a range of reasonable and prudent fatality estimates.

2.4 Calculating Fatality Estimates for Bats

Extensive monitoring of bat activity at pre-existing wind farms has shown a strong positive relationship between the total number of bat passes per night for each detector on site with estimated fatalities per turbine per year (Kunz et al. 2007). Essentially, the number of bat fatalities per turbine per year is almost equivalent to the number of bat calls per night for each detector on site (see Table 1). However, the data on echolocation passes reported in these studies did not distinguish among species. Moreover, echolocation calls were recorded at different altitudes at some sites and only at ground level at others. In addition, echolocation call data were collected after the wind energy facilities were constructed. Thus, it is unclear whether preconstruction bat pass data, as in the case of Kahuku Wind Power, would have shown a different pattern. Furthermore, the relationship between preconstruction call rates and fatality rates may not exist or may not be as strong if modifications to forested habitats (thereby creating linear landscapes) or the turbines themselves attract bats (Kunz et al. 2007).

Thus, bat fatality estimates per turbine at Kahuku Wind Power was calculated using the following assumptions:

- 1) the change in landscape or construction of turbines does not attract bats to the area,
- 2) post-construction bat activity remains the same as pre-construction bat activity, and
- 3) the number of bat fatalities per turbine per year is equivalent to the number of bat passes per night for each detector on site (as shown by Kunz et al. 2007)

If the level of bat activity recorded at the Kahuku Wind Power site is low, the estimated take of bats per turbine will be based on the number of call sequences per detector night, rather than the number of bat passes (Assumption 3). This will provide a more conservative fatality estimate.

Potential for bats to collide with met tower is considered negligible because these objects are stationary and should be readily detected by the bats. Of 64 wind turbines at Mountaineer Wind Energy Center in the Appalachian plateau in West Virginia, bat fatalities were recorded only at operating turbines and not at a non-operational turbine during the study period (Kerns et al. 2005). This supports the expectation that the presence of stationary structures such as met tower and cranes should not result in bat fatalities.

3.0 RESULTS

3.1 Diurnal Point Count Surveys

3.1.1 On-site Surveys

Avian point count surveys were conducted for 64.9 hours between October 2007 and December 2008. Point count surveys were conducted by First Wind from October 2007 to May 2008, and by SWCA from June 2008 to December 2008. Twenty three bird species (and 6 introduced mammal species) were observed during the diurnal point count surveys (Table 2). For ESA "related" listed species, only koloa maoli-like ducks (*Anas* sp) apply, and were seen on three occasions at the northern portion of the Kahuku Wind Power site.

Native resident and migratory birds protected under the Migratory Bird Treaty Act (MBTA) include the greater frigate bird (*Fregata minor*), Pacific golden plover (*Pluvialis fulva*) and ruddy turnstone (*Arenaria interpres*). Migratory shorebirds arrived at Kahuku Wind Power in September and departed in May. Data so far indicates that Pacific golden plover are more frequently observed in flight (0.57 flocks/hr/point count) than the ruddy turnstone (0.02 flocks/hr/point count) at Kahuku Wind Power. The great frigate bird is resident year round in Hawaii and flies over the site occasionally (0.17 flocks/hr/point count, Table 2).

Most flight activity at Kahuku Wind Power was dominated by introduced bird species. Common myna (*Acridotheres tristis*), red-vented bulbuls (*Pycnonotus cafer*), cattle egret (*Bubulcus ibis*), Japanese white-eye (*Zosterops japonicus*), finch species, zebra dove (*Geopelia striata*) and spotted dove (*Streptopelia chinensis*) accounted for 85% of the bird activity observed at Kahuku Wind Power. Seventy-five percent of all flights observed (3rd quartile) were less than 15 m altitude (Fig. 5, see box plot). Ninety three percent of all flights observed were below the RSZ; only 3.4% of all flocks flew within the RSZ and 0.05% above the RSZ. The species most frequently observed flying within the RSZ were cattle egrets (Table 3). The only native species flying within the RSZ were the great frigate bird and koloa maoli-like ducks. Figure 5 also illustrates flight directions (of all bird species combined) at the different point count stations within the Kahuku Wind Power site. Predominant flight directions (> 20% of observed flights) were present for seven of ten point count stations (Table 4) and were mostly perpendicular to the proposed turbine rows (Fig. 5). Bird activity (flights/hr) varied with point count location (range 13.71 – 30.60 flight/hr) but statistical analyses indicate that only point count station D had significantly higher bird activity than one other station (Station J).

3.1.2 Adjacent Wetland Bird Surveys

Observations of endangered Hawaiian waterbirds were conducted at wetlands closest to the project site. The wetlands comprised mostly of active and abandoned shrimp ponds and were surveyed by SWCA biologists between June and December 2008. Hawaiian stilt (*Himantopus mexicanus knudseni*) and Hawaiian coot (*Fulica alai*) were observed in flight at the adjacent wetlands as well as koloa maoli-like ducks. No Hawaiian moorhen (*Gallinula chloropus sandvicensis*) were observed.

Compared to the flight activity of koloa maoli-like ducks observed in the adjacent wetlands (0.33 flocks/hr/ha, see below), the activity of koloa maoli-like ducks over the Kahuku Wind Power site is low (0.05 flocks/hr/ha). The average flock size for koloa maoli-like ducks as observed in adjacent wetlands was 2.0 birds per flock (range 1 – 9). Only 2.7 % of the observed flight altitudes were within the RSZ; the remainder below the RSZ (Fig. 6). Koloa maoli-like ducks freely moved between the wetlands and uplands. Thirty-three % (n = 45) of all observed flocks (n = 147) in flight were from the wetlands to the uplands or from the uplands to the wetlands. Flight direction was predominantly from the north and west ($X^2=51.1$, $df=7$, $p=0.000$). Most ducks were observed flying between recently harvested cornfields (located below Kahuku Wind Power) and the wetlands. This provides confirmation that koloa maoli-like ducks will occasionally transit past the Kahuku Wind Power site. Flight activity in the adjacent wetlands is highest in the mornings and the evenings and low in the afternoon ($X^2=69.9$, $df=2$, $p=0.000$).

No other state endangered or other ESA-listed or candidate species have been observed at Kahuku Wind Power since the initial surveys began in October 2007. Hawaiian stilt were often seen flying within the adjacent wetlands, but only observed once flying from uplands to wetland (1.3%, 1 of 76 flocks, Fig. 7). This supports the lack of observations of Hawaiian stilt flying over Kahuku Wind Power. The average flock size of Hawaiian stilt was 1.5 birds per flock and predominant flight direction was also from the north and west ($X^2=81.9$, $df=7$, $p=0.000$). As most flights were short between nearby ponds, 75 % of the observed flight altitudes were below 5 m. However, for the few longer-distance flights (100 m or more), the maximum flight height was 30 m, just below the turbine's RSZ. Flight activity in the adjacent wetlands was highest in the mornings and lower in the afternoons and evenings ($X^2=21.3$, $df=2$, $p=0.000$).

Of 31 observations of Hawaiian coot, only one individual was seen in flight between ponds in the adjacent wetlands. No Hawaiian coots were observed flying upland from the wetlands or vice versa. These observations together indicate that Hawaiian coot are highly unlikely to be flying over Kahuku Wind Power at any time and support the absence of observations of Hawaiian coot in flight over Kahuku Wind Power during the 15-month long observations on site.

Hawaiian moorhen were not observed at adjacent wetlands either in flight or on the ground, although they were likely present. This is not surprising considering the species secretive and highly sedentary behavior (USFWS 2005). These factors indicate that Hawaiian moorhen are highly unlikely to be flying over Kahuku Wind Power at any time and also support the absence of observations of Hawaiian moorhen in flight over Kahuku Wind Power during the 15-month long observations on site. Due to the lack of wetlands at Kahuku Wind Power, waterbirds are not expected to be present (either resident or vagrant) on the grounds of Kahuku Wind Power (SWCA 2008).

3.2 Nocturnal Surveys

3.2.1 Visual Surveys

Eighteen hr of nocturnal visual surveys were conducted at Kahuku Wind Power between October 2007 and December 2008. Nocturnal surveys were conducted by First Wind from October 2007 to May 2008, and SWCA from June 2008 to December 2008. No bats were observed during the entire observation period. Only one incidental visual sighting of the Hawaiian hoary bat was recorded in July 2008, during a radar survey for seabirds.

3.2.2 Acoustic Monitoring

Eleven sites at Kahuku Wind Power were acoustically sampled from April 2008 to April 2009 (Figure 2). A total of 1285 detector nights were sampled between April 2008 and April 2009 (Table 6). Hawaiian hoary bat call sequences were recorded on 20 occasions from three locations (Anabat A in late November, D, and E) from April 2008 to April 2009 (Table 6). The limited data suggest that bat activity may increase from June to September and are lowest or absent from December to February. The peak activity is within the period bat numbers are expected to increase in the lowlands because of migration from higher altitudes (Menard 2001). The period of low bat activity coincides with bat migration from lowlands to higher altitudes (Menard 2001). However, due to the very small sample sizes, it is not possible to draw any conclusive patterns herein, and bats may be present on-site year round. Anabat detectors on the site estimate an average hoary bat activity rate of 0.01 bat passes/detector/night or 0.016 call sequences/detector per night. The detection rates at Kahuku Wind Power are 40-fold lower than detection rates at Hakalau National Wildlife Refuge (0.66 passes/detector/night, Bornaccorso, USGS unpublished report). Bat activity at Kahuku Wind Power is also less than half that at the Kaheawa Wind Pastures, which has an activity rate of 0.04 bat call sequences/detector/night (First Wind 2008).

3.3 Estimated Fatality Rates of Koloa Maoli-like Ducks

Three flocks of koloa maoli-like ducks were observed during the 15month avian survey resulting in an average passage rate of 0.001flocks/hr/ha over the project site (Table 7). Incidental sightings include observations of a flock of koloa maoli-like ducks in May 2007, June and December 2008. Using flight altitudes observed in the adjacent wetlands, we estimate that 2.7% of all flights occurring over Kahuku Wind Power occur within the RSZ with the remaining below the RSZ (Table 8).

The estimated fatality rate for koloa maoli-like ducks entering the RSZ ranges between 0.0002and 0.002 koloa maoli-like ducks/RSZ/year assuming 99% and 90% collision avoidance rate respectively (Table 9). Fatality rates due to koloa maoli-like ducks striking the tubular towers of the turbines are even lower at 0.0001 and 0.001 koloa maoli-like ducks /tower/year, assuming a 99% and 90% avoidance rate respectively. Combined, the estimated fatality rate for koloa maoli-like ducks at a turbine at Kahuku Wind Power is between 0.0003 and 0.003 birds/turbine/year or 0.004 to 0.038 birds for twelve turbines per year combined.

Fatality rates due to koloa maoli-like ducks striking the met towers of the turbines are 0.00005 to 0.0005 birds /tower/year, assuming a 99% and 90% avoidance rate respectively).(Table 10).

The total fatality at all turbines and met towers on the site is estimated between 0.004 0.038 koloa maoli-like ducks/year (9% and 90% avoidance rate respectively) (Table 11). This result is not unexpected due to the low passage rates observed on site. Studies of wind energy facilities located in proximity to wetlands and coastal areas have shown that waterbirds and shorebirds are among the birds most wary of turbines and that these birds readily learn to avoid the turbines over time (Carothers 2008). Avoidance behavior has also been documented by nēnē at the existing operating facility on Maui (Kaheawa Wind Power 2008). Thus, the estimated take at 95% avoidance (95% of the birds that approach the turbine successfully avoid it) is used as the basis of the take estimates. The fatality rate at 95% avoidance for koloa maoli-like ducks was estimated at 0.02 birds/year for all 12 turbines and one permanent met tower on site.

3.4 Estimated fatality rates of Hawaiian hoary bat

Based on substantial sampling effort (1285 detector nights between April 2008 and April 2009) the estimated take/turbine/year at Kahuku Wind Power with a bat activity of 0.016 bat call sequences/detector/night is 0.016 bats/turbine/year. This results in a total take of 0.19 bats/year for all twelve turbines on the site.

4.0 CONCLUSION

Kahuku Wind Power avifauna is comprised primarily of introduced birds. Native birds were occasionally observed transiting the site; however no resident native avifauna was recorded. Of the waterbirds, only the koloa maoli-like ducks were observed transiting the site and are at risk of colliding with the turbines. However the estimated fatality rate was small, approximating two ducks every 100 years. No endangered waterbirds were observed flying over the site and the lack of observations is supported by the flight patterns of these species in the adjacent wetlands.

Hawaiian Hoary bats are present at Kahuku Wind Power, but activity rates were very low compared to other sites. The estimated fatality of Hawaiian hoary bats is approximately 2 bats every ten years.

Table 1 Fatality and bat activity indices at 5 wind-energy facilities on the mainland United States (from Kunz et al. 2007).

Study area	Inclusive dates of study*	Bat mortality (no./turbine/yr)	Bat activity (no./detector/night)	Total detector nights	Source
Mountaineer, WV	31 Aug-11 Sep 2004	38	38.2	33	E.B. Arnett, Bat Conservation International, unpubl. Data
Buffalo Mountain, TN	1 Sep 2000-30 Sep 2003	20.8	23.7	149	Fieldler 2004
Top of Iowa, IA	15 Mar-15 Dec 2003, 2004	10.2	34.9	42	Jain 2005
Buffalo Ridge, MN	15 Mar-15 Nov 2001, 2002	2.2	2.1	216	Johnson et al. 2004
Footee Creek Rim, WY	1 Nov 1998-31 Dec 2000	1.3	2.2	39	Gruver 2002

* Sample periods and duration of sampling varied among studies, with no fatality assessments conducted or bat activity monitored in winter months.

Table 2. Bird and mammal species observed at Kahuku Wind Power site from October 2007 to December 2008 by First Wind and SWCA.

Common Name	Scientific Name	Bird Activity (flocks/hr/point count)	% of Observed Flight Activity	Rank
Birds				
Common myna	<i>Acridotheres tristis</i>	6.37	20.59	1
Red-vented Bulbul	<i>Pycnonotus cafer</i>	5.50	17.80	2
Cattle Egret	<i>Bubulcus ibis</i>	5.36	17.35	3
Finches and/or white-eyes	-	3.85	12.46	4
Spotted dove	<i>Streptopelia chinensis</i>	2.74	8.87	5
Zebra Dove	<i>Geopelia striata</i>	2.56	8.28	6
Red-crested Cardinal	<i>Paroaria coronata</i>	0.92	2.99	7
Japanese white-eye	<i>Zosterops japonicus</i>	0.89	2.89	8
House finch	<i>Carpodacus mexicanus</i>	0.62	1.99	9
Pacific golden plover	<i>Pluvialis fulva</i>	0.57	1.84	10
Northern Cardinal	<i>Cardinalis cardinalis</i>	0.40	1.30	11
House sparrow	<i>Passer domesticus</i>	0.35	1.15	12
Great frigate bird	<i>Fregata minor</i>	0.17	0.55	13
White-rumped shama	<i>Copsychus malabaricus</i>	0.12	0.40	14
Red-whiskered bulbul	<i>Pycnonotus jocosus</i>	0.11	0.35	15
Common Waxbill	<i>Estrilda astrild</i>	0.09	0.30	16
Nutmeg mannakin	<i>Lonchura punctulata</i>	0.06	0.20	17
Koloa maoli-like ducks	<i>Anas</i> sp.	0.05	0.15	18
Java sparrow	<i>Padda oryzivora</i>	0.05	0.15	18
Chestnut munia	<i>Lonchura malacca</i>	0.03	0.10	20
Ring-necked pheasant	<i>Phasianus colchicus</i>	0.03	0.10	20
African silverbill	<i>Lonchura cantans</i>	0.02	0.05	22
Ruddy turnstone	<i>Arenaria interpres</i>	0.02	0.05	22
Unidentified owl	-	0.02	0.05	22
Mammals				
Domestic cattle	<i>Bos taurus</i>			
Horse	<i>Equus caballus</i>			
Dog	<i>Canis lupus familiaris</i>			
Cat	<i>Felis catus</i>			
Small Indian mongoose	<i>Herpestes javanicus</i>			
Feral pig	<i>Sus scrofa</i>			

Table 3. Species composition of birds flying within the RSZ

Bird species	% of species composition within RSZ	Rank
Cattle egret	63.8	1
Common myna	11	2
Great frigate bird	8.7	3
House finch	4.7	4
Red-vented bulbul	4.7	4
Koloa maoli-like ducks	0.8	6
House sparrow	0.8	6
Pacific golden plover	0.8	6
Red-crested cardinal	0.8	6
Spotted dove	0.8	6
Zebra dove	0.8	6

Table 4. Flight activity and predominant flight directions at Kahuku Wind Power point count stations

Stations	Average flight activity (flights/hr)	Predominant flight direction (>20%)	Chi-Square test
B	20.85 (n= 197)	NE	$X^2=30.4$, df=7, p=0.000
C	29.14 (n= 285)	E	$X^2=58.1$, df=7, p=0.000
D	44.57 (n= 432)	E	$X^2=89.3$, df=7, p=0.000
E	17.77 (n= 78)	NE, W	$X^2=16.6$, df=7, p=0.020
F	22.20 (n= 200)	N, E	$X^2=66.2$, df=7, p=0.000
G	26.85 (n= 234)	-	$X^2=6.0$, df=7, p=0.540
H	20.10 (n= 206)	-	$X^2=9.3$, df=7, p=0.232
I	16.71 (n = 85)	W	$X^2=26.3$, df=7, p=0.000
J	13.71 (n= 64)	E	$X^2= 9$, df=7, p=0.253
K	30.60 (n= 131)	E	$X^2=18.7$, df=7, p=0.009

 statistically significant

Table 5. Analysis of flight activity at point count stations by time of day.

Analysis of Variance					
Source	Type III SS	df	Mean Squares	F-ratio	p-value
Point count stations	2.915	9	0.324	2.642	0.007
Error	22.188	181	0.123		

 statistically significant

Table 6. Bat activity at Kahuku Wind Power

Year	Month	Nights per Anabat Detector					Total nights	No. of calls sequences	No. of bat passes (> 2 bat calls)
		A	B	C	D	E			
2008	April	21	21	21	21	21	105	1	1
2008	May	27	1	27	27	27	109	1	0
2008	June	30	0	30	20	30	110	4	1
2008	July	31	0	31	31	31	124	3	3
2008	Aug	31	26	31	31	31	150	3	2
2008	Sept	30	30	30	30	30	150	5	3
2008	Oct	31	6	9	19	31	96	1	1
2008	Nov	30	17	30	11	13	101	1	1
2008	Dec	26	23	31	17		97	0	0
2009	Jan			31			31	0	0
2009	Feb		2	28	2	2	34	0	0
2009	Mar		30	27	31	31	119	1	1
2009	April		2	-	27	30	59	0	0
Total						1285	20	13	

Table 7. Koloa maoli-like duck passage rates over Kahuku Wind Power

		400m radius point counts
A	Total point counts	167
B	No. of birds observed	8
C	Birds per point count B/A	0.048
D	Birds per hour C*3	0.144
E	Area sampled (ha) 0.4*0.4*3.14	50.265
F	Passage rate (birds/hr/ha) D/E	0.003
G	Total project area (ha)	233.8
H	Passage rate (birds/hr/site) F*G	0.668
I	Passage per day over site	8.021

Table 8. Fatality estimate of koloa maoli-like ducks within rotor swept zone

Variable		
Movement rate		
A	mean movement rate (birds/hr/ha)	0.002859071
B	daily movement rate (birds/day/ha) A*12	0.03430885
C	fatality domain (days)	365
D	annual movement rate (birds/year) B*C	12.52273025
E	proportion birds flying within rotor swept zone (>30m and < 128m)	0.027210884
F	annual movement rate within rotor swept zone (>30m and <128 m) D*E	0.340754565
Horizontal interaction probability		
G	Volume occupied by rotor swept zone (m3)	463011.84
H	Vol of 1 ha area from minimum to maximum rotor height (>32 to <128m) (m3)	960000
I	Horizontal interaction probability G/H	0.482304
Exposure index		
J	daily exposure index (birds/rotor swept zone/day) B*E*I	0.000450267
K	annual exposure index (birds/rotor swept zone/yr) F*I	0.16434729
Fatality probability		
L	Probability of striking a blade on frontal approach	0.156
M	Probability of fatality if striking blade	0.95
N	Probability of fatality if an interaction on frontal approach L*M	0.1482
Fatality index		
O	Annual fatality rate with 90% exhibiting collision avoidance (birds/turbine/yr) K*N*0.1	0.002435627
P	Annual fatality rate with 95% exhibiting collision avoidance (birds/turbine/yr) K*N*0.05	0.001217813
Q	Annual fatality rate with 99% exhibiting collision avoidance (birds/turbine/yr) K*N*0.01	0.000243563

Table 9. Fatality estimate of koloa maoli-like ducks striking tubular towers

Variable		
Movement rate		
A	mean movement rate (birds/hr/ha)	0.002859071
B	daily movement rate (birds/day/ha) $A*12$	0.03430885
C	fatality domain (days)	365
D	annual movement rate (birds/year/ha) $B*C$	12.52273025
E	proportion birds below rotor swept zone (>32m)	0.972789116
F	annual movement rate below rotor swept zone (>30m) $D*E$	12.18197569
Horizontal interaction probability		
G	Volume occupied by tubular tower (m^3)	486.3232
H	Vol of 1 ha area below blade height (<32m) (m^3)	320000
I	Horizontal interaction probability G/H	0.00151976
Exposure index		
J	daily exposure index (birds/tubular tower/day) $B*E*I$	5.07224E-05
K	annual exposure index (birds/tubular tower/yr) $F*I$	0.018513679
Fatality probability		
L	Probability of striking a tubular tower if in airspace	1
M	Probability of fatality if striking tubular tower	0.95
N	Probability of fatality upon interaction $L*M$	0.95
Fatality index		
O	Annual fatality rate with 90% exhibiting collision avoidance (birds/tower/yr) $K*N*0.1$	0.0017588
P	Annual fatality rate with 95% exhibiting collision avoidance (birds/tower/yr) $K*N*0.05$	0.0008794
Q	Annual fatality rate with 99% exhibiting collision avoidance (birds/tower/yr) $K*N*0.01$	0.0001758800

Table 10. Fatality estimate of koloa maoli-like ducks at met tower

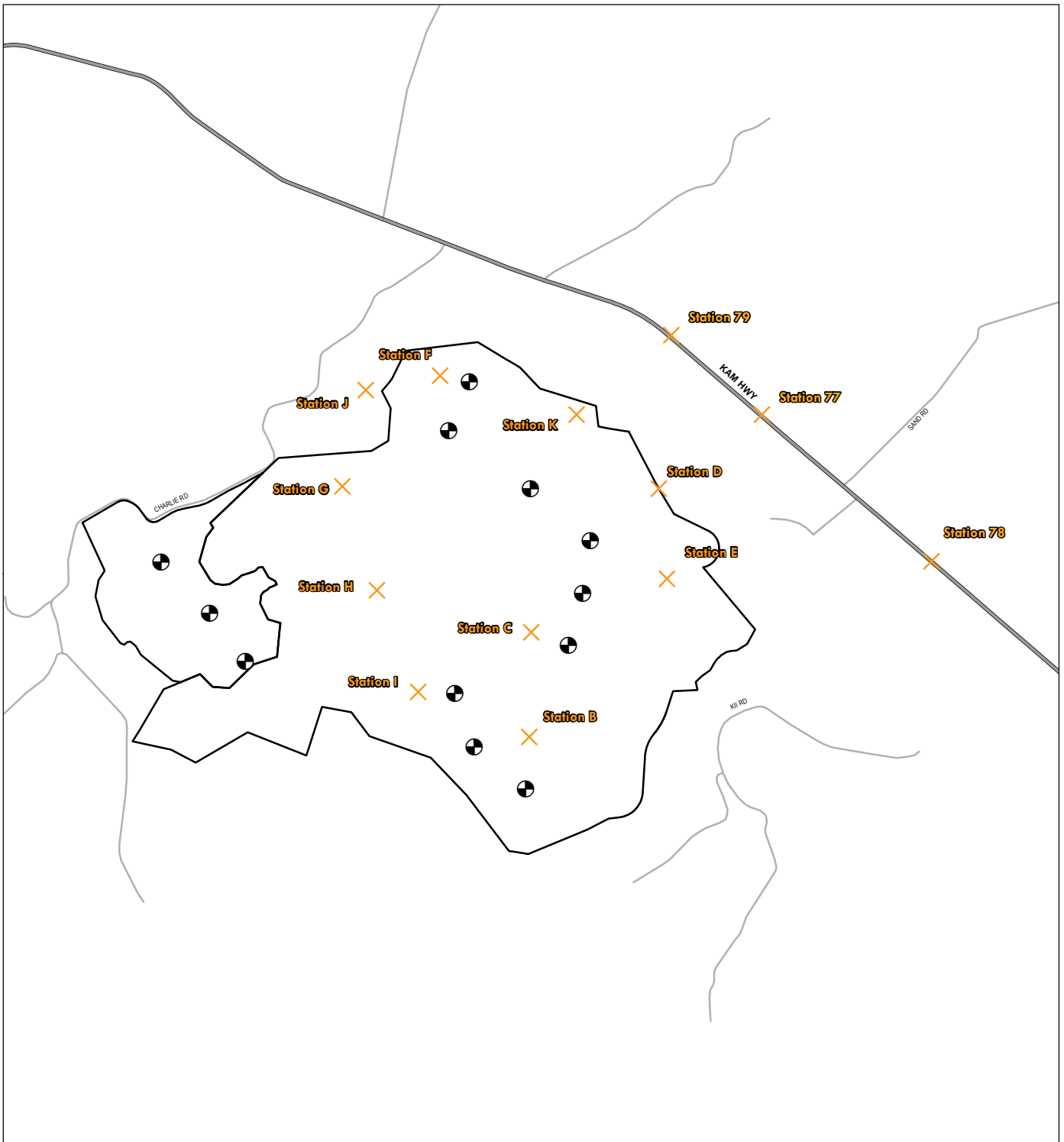
	Variable	
	Movement rate	
A	mean movement rate (birds/hr/ha)	0.002859071
B	daily movement rate (birds/day/ha) A*12	0.03430885
C	fatality domain (days)	365
D	annual movement rate (birds/year) B*C	12.52273025
E	proportion birds below meteorological tower (<60m)	1
F	annual movement rate below meteorological tower (<60m) D*E	12.52273025
	Horizontal interaction probability	
G	Volume occupied by meteorological tower (m3)	420.1840223
H	Vol of 1 ha area meteorological tower (<80m) (m3)	800000
I	Horizontal interaction probability G/H	5.25E-04
	Exposure index	
J	daily exposure index (birds/tower/day) B*E*I	1.80E-05
K	annual exposure index (birds/tower/yr) F*I	6.58E-03
	Fatality probability	
L	Probability of striking a met tower if in airspace	1
M	Probability of fatality if striking tubular tower	1
N	Probability of fatality upon interaction L*M	1
	Fatality index	
O	Annual fatality rate with 90% exhibiting collision avoidance (birds/tubular tower/yr) M*P*0.05	0.000657731
P	Annual fatality rate with 95% exhibiting collision avoidance (birds/tubular tower/yr) M*P*0.05	0.000328866
Q	Annual fatality rate with 99% exhibiting collision avoidance (birds/tubular tower/yr) M*P*0.01	0.0000657731

Table 11. Predicted annual fatality rate of koloa maoli-like ducks at Kahuku Wind Power.

	Turbines (x12)	Met tower	Total fatality
Annual fatality rate with 90% exhibiting collision avoidance (birds/yr)	0.050	0.00066	0.051
Annual fatality rate with 95% exhibiting collision avoidance (birds/yr)	0.025	0.00033	0.025
Annual fatality rate with 99% exhibiting collision avoidance (birds/yr)	0.005	0.00007	0.005

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Legend




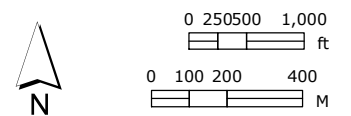
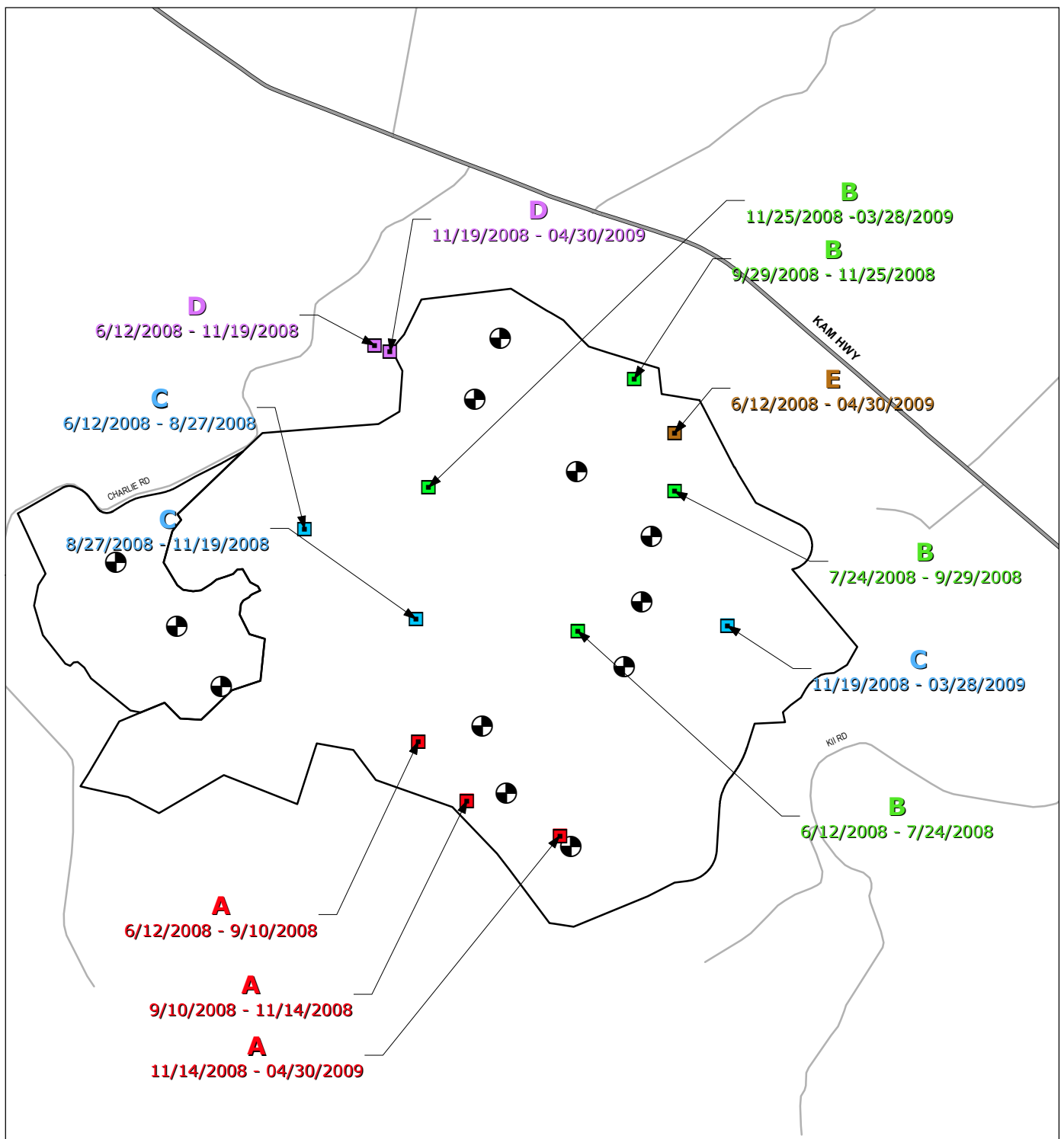
-  Turbine/Tower Locations
-  Point Count Locations
-  Project Parcel

Figure 1
Station Locations





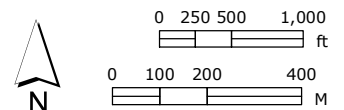
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Anabat Sensors

- A
- B
- C
- D
- E

Project Parcel

Figure 2
Anabat Sensor Locations and Dates of Deployment



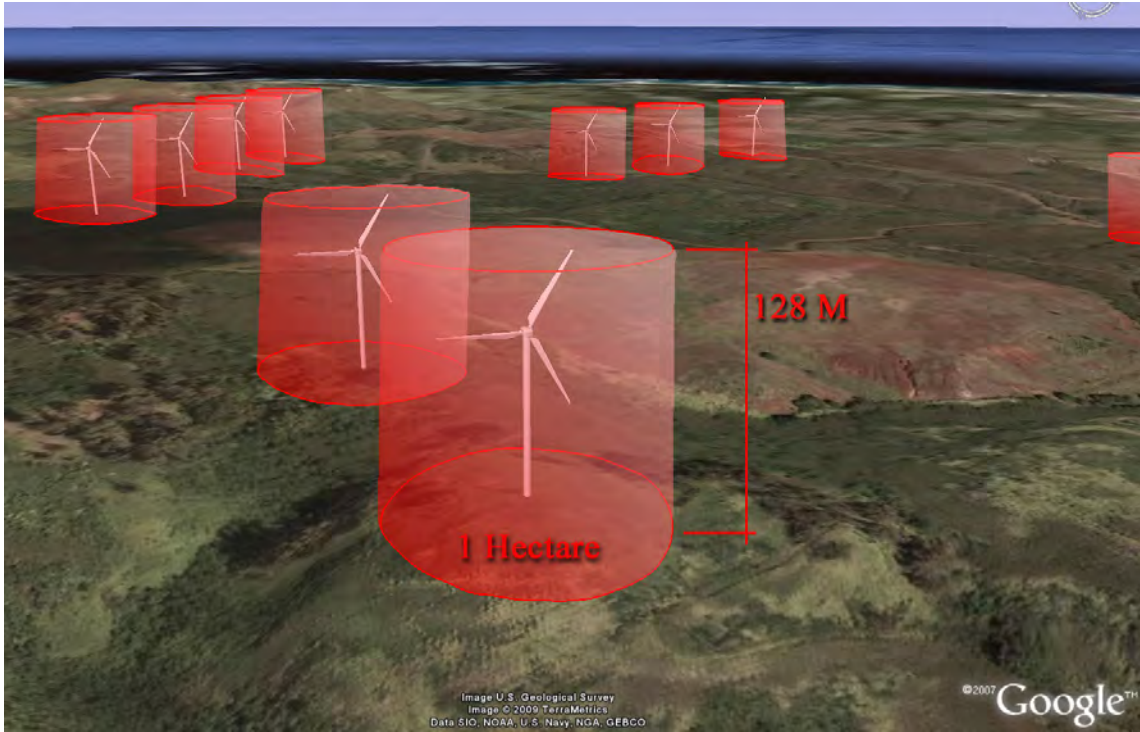
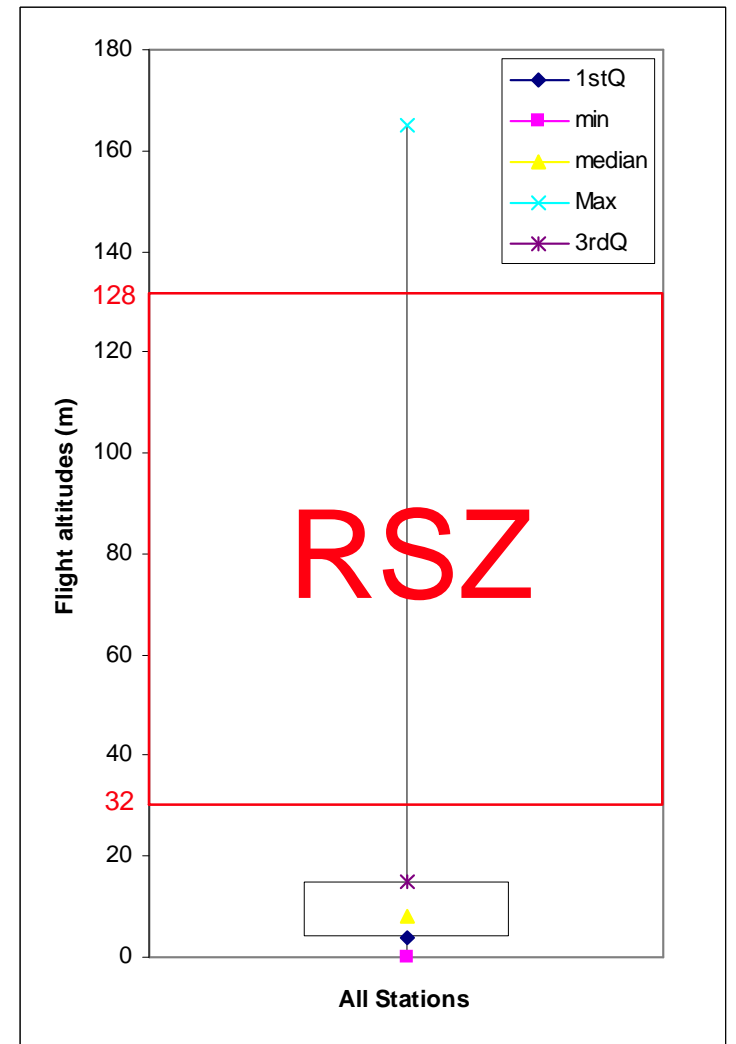
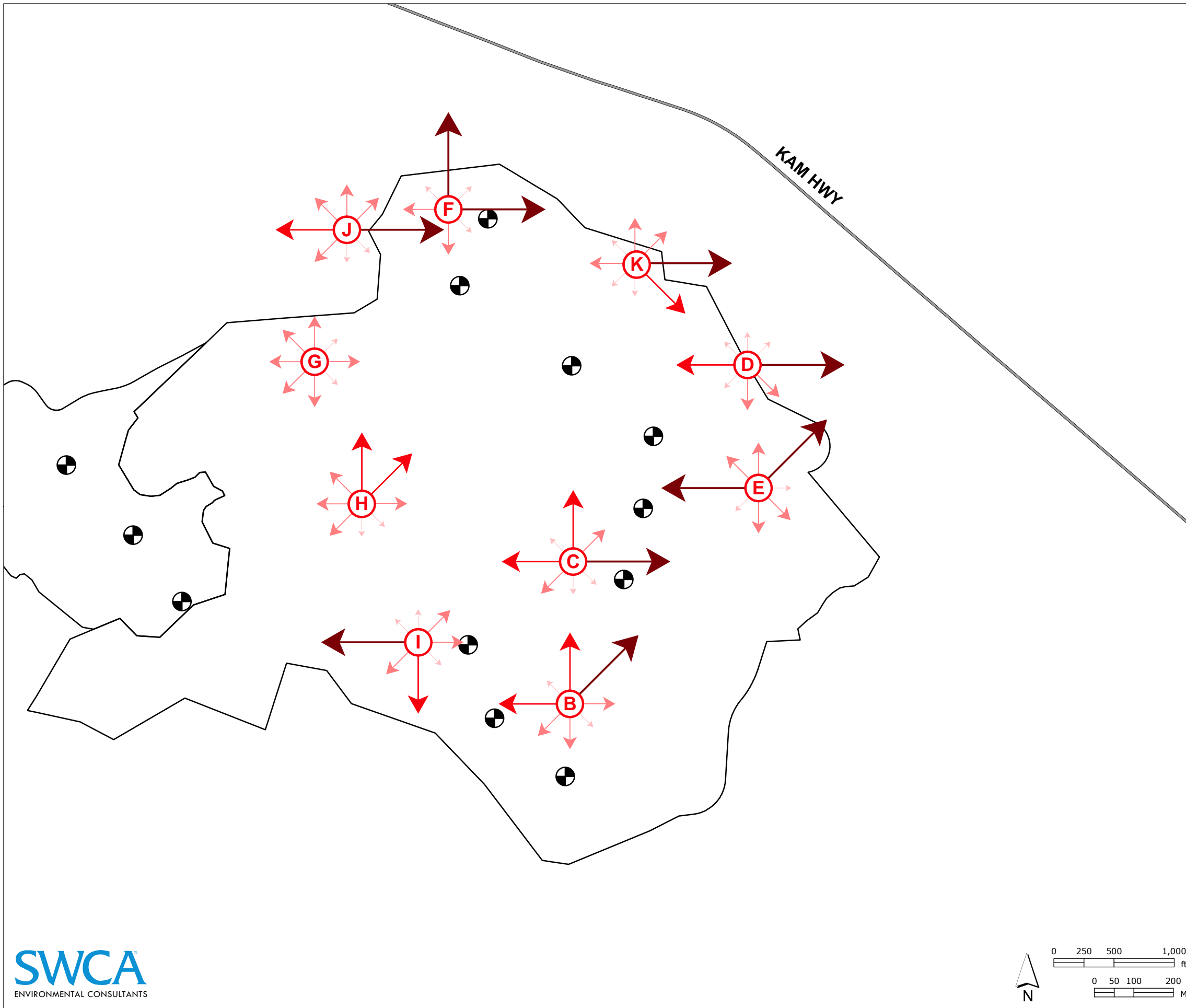


Figure 3. Volume of Turbine to Volume of 1 ha Area.

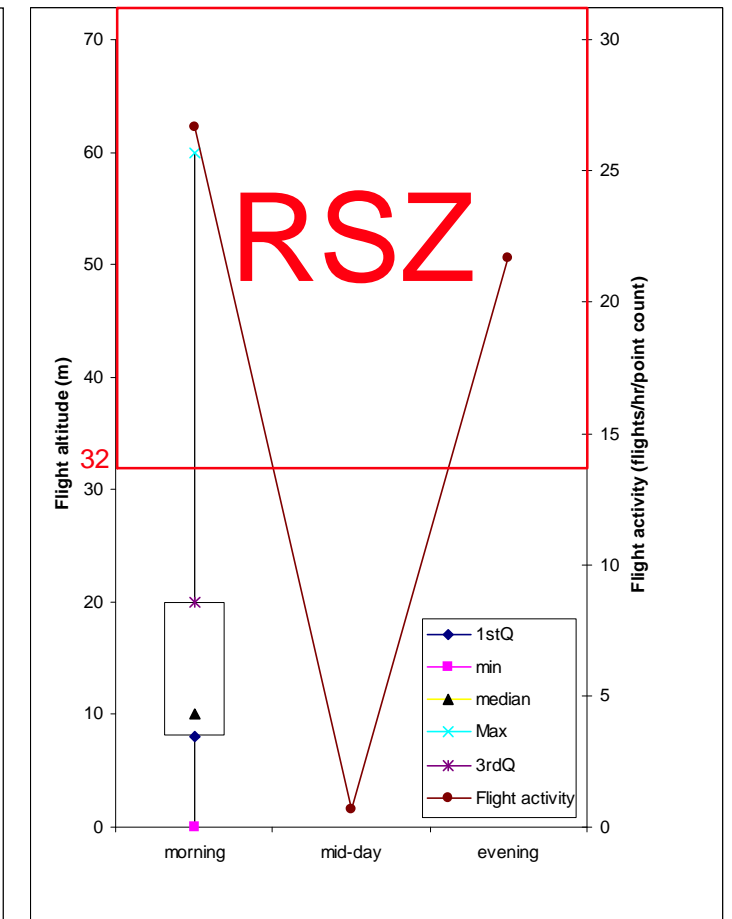
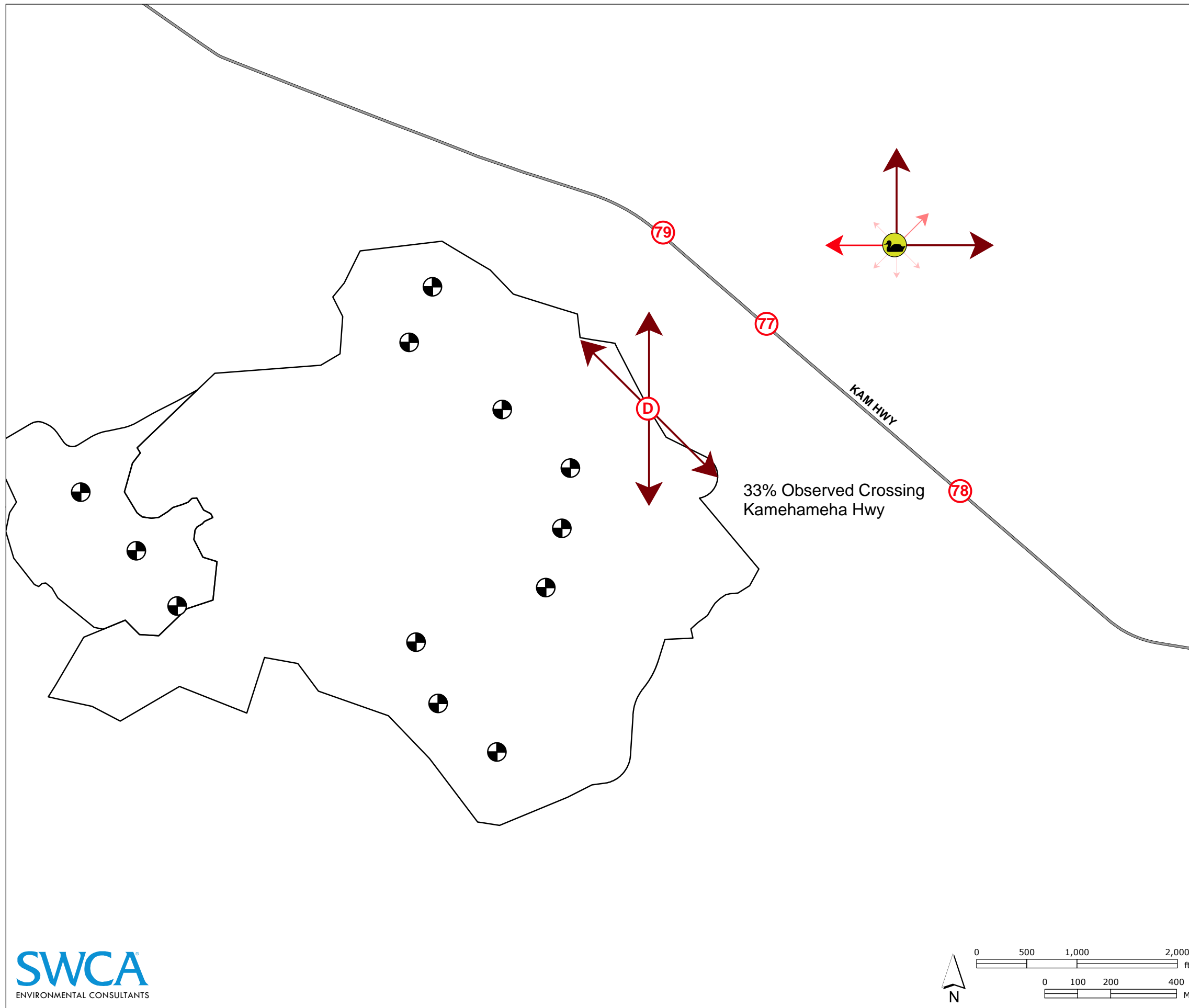


Legend

Turbine/Tower Locations

Bird Point Count Data Oct 07 - Dec 08

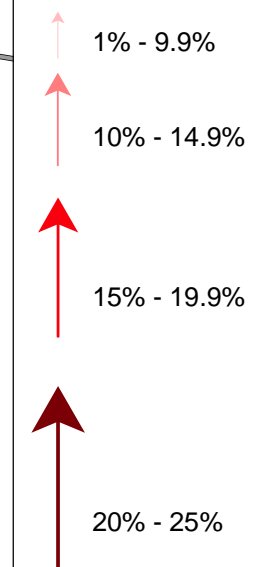
- 1% - 10%
- 10.1% - 15%
- 15.1% - 20%
- 20.1% - 30%

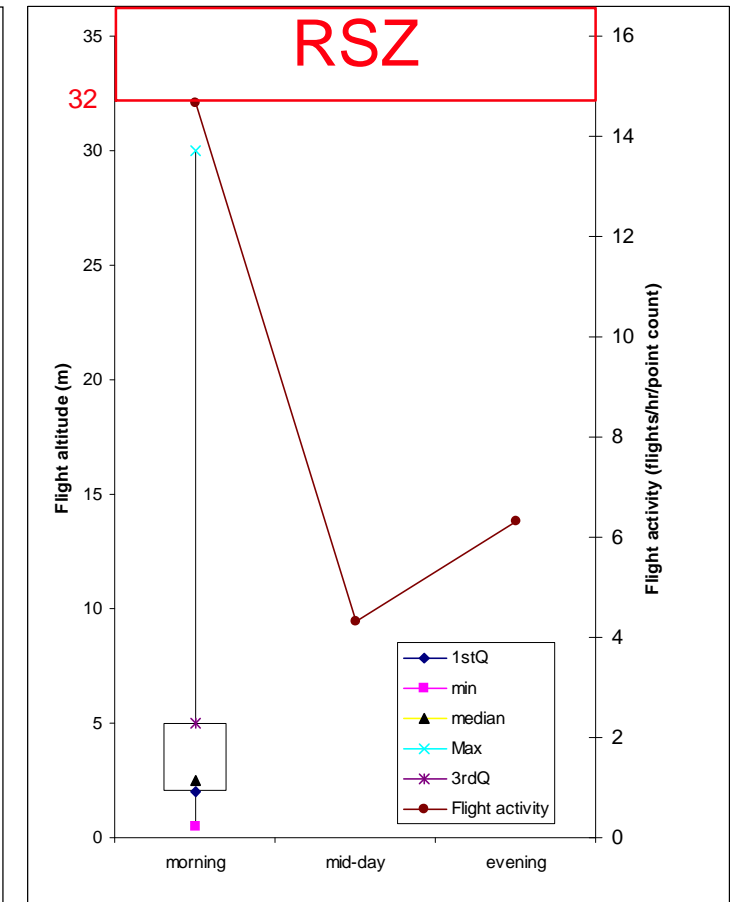
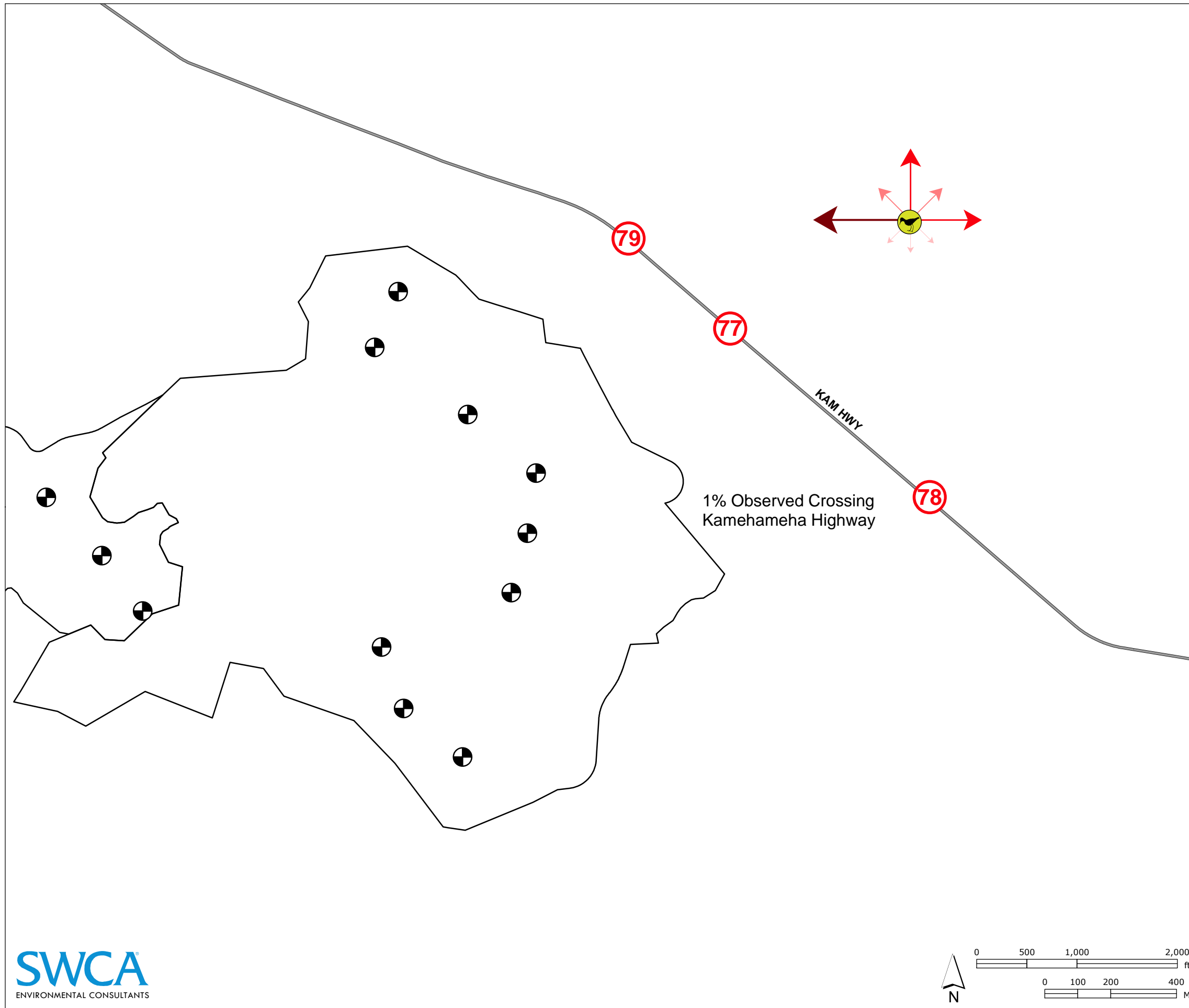


Legend

⊕ Turbine/Tower Locations

Koloa-Maoli Like Duck Percentage by Direction of Travel





Legend

Turbine/Tower Locations
Stilt Occurrences
Percentage by Direction of Travel

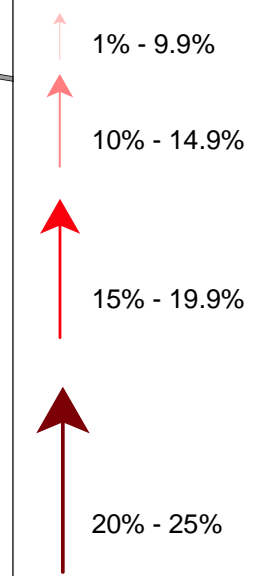


Figure 6
STILT OCCURENCES