APPENDIX C
FIRE MANAGEMENT PLAN

Author: Andrew M. Beavers
Fire Ecology and Management Specialist
Center for Environmental Management of Military Lands
Colorado State University, Fort Collins, CO 80523-1490

Date of Draft: 3-18-14

Na Pua Makani Fire Management Sections

Goals and Objectives

The goal of the fire measures outlined below is to mitigate the fire risk posed by construction and operation of the Na pua Makani Wind Farm. To achieve this goal, the following objectives have been defined:

1. Use engineering and maintenance of the wind farm infrastructure to limit fire ignitions from the wind farm infrastructure to an average of less than one per decade.
2. Use industry accepted best management practices to minimize the probability of ignitions during construction.

Background

The Na Pua Makani Wind Farm will introduce additional machinery, electrical infrastructure, and human activity to the project area. Parts of the project area have historically been exposed to very little human presence and this additional activity will potentially slightly increase the fire risk. The following sections are intended to mitigate the additional fire threat posed by construction and operation of the wind farm. Fire mitigation may occur via education; mechanical, chemical, or biological manipulation of the vegetation (hereafter 'fuels'); or construction of barriers to fire such as firebreaks. Fire mitigation should always be commensurate with the threat posed by the activity in question and the values at risk.

Fire Weather Analysis

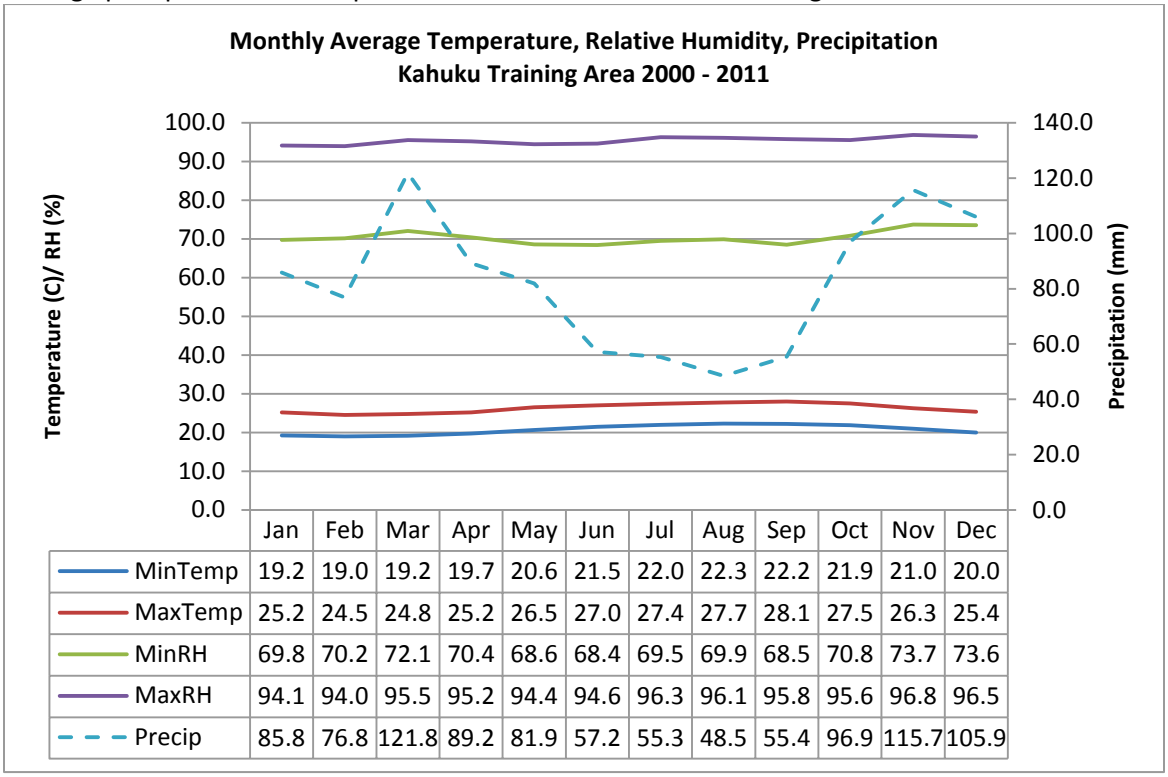
Period of record weather data was collected from the meteorological towers installed for the wind farm project as well as from the Kahuku Training Area Remote Automated Weather Station (RAWS). Wind analyses were run with data from the meteorological towers. These towers do not provide a full suite of weather data, so all other analyses were run using data from the Kahuku Training Area RAWS. Wind monitoring heights at the wind farm towers are higher (10 m) than typically used for fire weather analyses (6.09 m), so a power law correction factor was used to adjust wind speeds for the drag factors associated with interaction with surface features (Masters 2013).

Maximum and minimum temperature and maximum and minimum relative humidity are nearly constant throughout the year (Figure 1). Average nighttime humidity recovery is very good, as demonstrated by maximum relative humidity levels in excess of 90%. This indicates that most fires will either go out or become inactive at night. Average minimum relative humidity is very high as well, with monthly average minimum relative humidity never dropping below 65%. This usually translates into dead fuel moisture that remains quite high the majority of the time, minimizing the potential for fire spread. However, in this case high wind speeds increase the drying effect of the air and therefore decrease fine fuel moisture measurements. Wind speeds are very high throughout the year and wind

direction is overwhelmingly dominated by the easterly trade winds (Figure 2). It is the effect of these high winds that results in lower than expected 1 hour fuel moisture measurements (Table 1).

Precipitation is concentrated in the winter months with a drier, though still quite moist, period from June through September. Even during this period, average rains are > 4 cm per month. Live herbaceous moisture is high (> 120%) virtually without exception (Table 1) indicating that fire behavior will generally be dampened by the presence of live fuels.

Figure 1. Monthly average minimum and maximum temperature and relative humidity and monthly average precipitation for the period of record of the Kahuku Training Area RAWS.

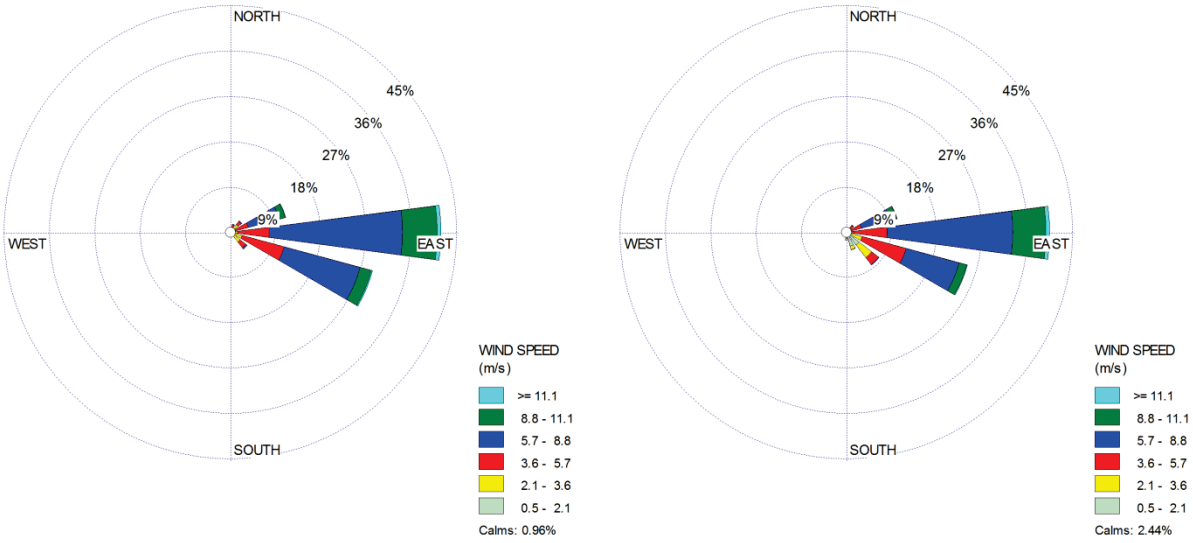


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MinTemp	19.2	19.0	19.2	19.7	20.6	21.5	22.0	22.3	22.2	21.9	21.0	20.0
MaxTemp	25.2	24.5	24.8	25.2	26.5	27.0	27.4	27.7	28.1	27.5	26.3	25.4
MinRH	69.8	70.2	72.1	70.4	68.6	68.4	69.5	69.9	68.5	70.8	73.7	73.6
MaxRH	94.1	94.0	95.5	95.2	94.4	94.6	96.3	96.1	95.8	95.6	96.8	96.5
Precip	85.8	76.8	121.8	89.2	81.9	57.2	55.3	48.5	55.4	96.9	115.7	105.9

Table 1. Percentile weather data for the period of record of the Kahuku Training Area RAWS.

Percentile	Temperature (°C)	RH (%)	Windspeed (m/s)	1 hr. Moist. (%)	Live Herb. Moist. (%)
97	28	56	10.3	7	131
90	28	61	8.9	8	162
80	27	65	8.0	9	180
50	26	74	6.3	10	231

Figure 2. Daytime (0700 – 1800, left) and nighttime (1800 – 0700, right) wind roses for the period of record of the Na Pua Makani Wind Farm meteorological towers. Wind speeds have been adjusted for surface drag from 10 m to 6.09 m.



Fuels

Fuels within the project area include a variety of grass, grass/shrub, and shrub fuel matrices as well as small patches of timber. The substation, construction staging area, operations and maintenance building and storage yard, and two of the nine Phase I wind turbines are located in the midst of existing agricultural fields, which are generally unburnable as currently utilized. The remaining seven turbines are located within grass, grass/shrub, and timber fuels. All of the wind farm infrastructure will be on concrete or gravel pads.

Even in the timber and shrub fuels, grasses comprise a substantial portion of the surface fuels which tend to be primarily responsible for the forward spread of a fire. The grasses are mostly guinea grass (*Megathyrsus maximus*) and California grass (*Urochloa mutica*). These grasses can be highly flammable when cured. There are some pockets of ironwood (*Casuarina equisetifolia*) and eucalyptus (*Eucalyptus spp.*) which both are capable of contributing to fire control problems under dry conditions. However, the climatic conditions necessary to produce problematic fire behavior in these vegetation types are rare on this part of Oahu due to the previously noted substantial precipitation and high relative humidity throughout the year.

Fire History

The Kahuku Training Area abuts the proposed project area to the west and covers 3,680 ha. Military training there has resulted in a total of 10 wildfire ignitions since 2000. The largest of these fires grew to 1.4 ha and the average fire size was 0.46 ha. However, military training is far more ignition-prone than wind turbine construction or operation and access in Kahuku Training Area for firefighters is far more difficult than it will be within the proposed project area. As a result, fires at Kahuku Training area have additional time to grow prior to any suppression action relative to what is predicted for the project area.

Outside of Kahuku Training Area, but within five kilometers of the project area on the east side of the Koolau Mountains ridgeline, there have been a total of 104 recorded fires since 2001. These have averaged 0.42 ha in size. The largest three fires were 10.1, 4, and 3.2 ha.

Values at Risk

There is a community of homes to the north of the project area, due north of the proposed substation. The closest homes are 450 m away from the nearest possible ignition source.

A United States Fish and Wildlife Service data layer depicting federally listed species density indicates that approximately half of the proposed project area lies in the 'little or no' federally listed species zone. The other half lies in the 'low concentration' of federally listed species zone. The shortest distance between a possible ignition source within the project area and the 'medium concentration' of federally listed species zone is 1.5 km. The shortest distance between a possible ignition source within the project area and the 'high concentration' of federally listed species zone is 2.6 km.

Fire Risk Analysis

Fire behavior within the project area is mitigated by the moist conditions. Using weather data from the Kahuku RAWS, an analysis of potential fire behavior under 50th, 80th, and 97th percentile weather conditions found minimal fire activity (Table 2). Even under 97th percentile conditions, probability of ignition is extremely low at 43%; weather at this extreme normally produces ignition probabilities in excess of 90%. These conclusions are corroborated in the fire history by the relatively few fires in the area (on average 10 per year in an area of roughly 50 km^2) and their small size (<1 ha on average).

Table 2. Fire behavior outputs from BehavePlus (Andrews and Chase 1989) under 50th, 80th, and 97th percentile weather conditions for fuels found within the project area. Fuel model identifiers (in parentheses) are per Scott and Burgan 2005.

Fuels		Fire Behavior (Rate of Spread (km/hr))/Flame Length (m)/Probability of Ignition (%))		
Fuel Model	Vegetation Represented	50th Percentile Weather	80th Percentile Weather	97th Percentile Weather
High load, coarse humid climate grass (GR8)	Heavy grass fuels	0.024/0.24/31	0.036/0.30/36	0.048/0.34/43
Moderate load, humid climate timber-shrub (TU2)	Christmas Berry shrublands and broadleaf forest	0.150/0.82/31	0.217/0.98/36	0.314/1.19/43
Long-needle litter (TL8)	Ironwood forest	0.066/0.73/31	0.087/0.82/36	0.115/0.94/43

The likelihood of a wildfire ignition during construction or operation of the project is very low. Sparks from welding and other construction activities are the most likely source. Once operating, all electrical lines will be below ground making an ignition from transmission lines impossible. There are very rare instances in which a wind turbine may catch fire, but these cases are exceptional, in part because there is a very large financial incentive for the operator to avoid this scenario.

Should a fire start, even under 97th percentile conditions it is exceedingly unlikely that it would harm any resources at risk. Despite their relative proximity, homes in the area are at very little risk due to the

highly consistent wind direction which would blow any fire westward, away from the homes to the north (see Figure 2). Rates of spread on the flanks of the fire would be a fraction of those enumerated in Table 2, which lists the rate of spread at the head of the fire (the fastest spreading portion of the fire). The 'medium density' federally listed species zone that lies downwind from the project area is 1.5 km away from the closest proposed turbine pad. Under 97th percentile conditions, it would take over 4.5 hours for a fire to reach the edge of this zone. However, 97th percentile conditions rarely persist for more than two or three hours resulting in even longer travel times to these sensitive resources. Based on an assumption of an elliptical fire shape with a length 4 times the width (very likely a substantial over-estimation of the distance traveled), the largest fire recorded fire in the Kahuku area would have traveled 717 meters indicating that the resources in the area are at little to no risk.

Considering the low probability of an ignition source from construction or operation activities, the low probability of ignition should a firebrand (spark, cigarette, etc.) come into contact with the fuels (Table 2), the low probability of conditions conducive to rapid fire spread (Table 2), and the lack of persistence of such weather conditions over a period of more than a few hours, the overall likelihood of a fire impacting any resource in the area is very small. Probabilities such as these are multiplicative, such that small probabilities compound one another and in a situation such as this, the overall probability becomes very small.

Fire Prevention Requirements

Because the probability of wildfire is so low, no measures beyond normal construction best management practices are required to mitigate the threat. The below measures are specific to fire and shall be practiced throughout the life of the project.

- All heavy equipment and construction vehicles will carry a fire extinguisher as part of their standard equipment. These will allow employees to combat vehicle fires and prevent spread to vegetative fuels.
- Gas powered (non-diesel) vehicles will not be parked in vegetation greater than 10 cm (4 inches) in height. This will prevent catalytic converters from contacting vegetation and igniting a wildfire.
- Smoking will be prohibited on the work site except unvegetated areas and no less than 5 m (~16 ft) from the nearest vegetation or inside a vehicle. Cigarettes smoked in vehicles will be disposed of within the vehicle.
- All internal combustion engines will utilize spark arrestors.
- All welding, grinding, and other spark producing activities will occur no less than 5 m (~16 ft) from the nearest vegetation.
- Exposed aerial welding (e.g. not inside the tower or the nacelle) at more than 15 m (~50 ft) above the ground will be restricted to times when sustained winds are less than 11 m/s (~25 mph) OR when relative humidity is greater than 80%.
- Maintenance of mechanical and electrical systems within the turbine and nacelle will occur regularly, as recommended by the manufacturer, to limit mechanical failures that can result in equipment fires which could then spread to nearby vegetation.

Fuels Management Requirements

Due to the very low probability of ignition and the minimal fire behavior expected should an ignition occur, no special fuels management is justified. Fuels management around the turbine towers and other infrastructure will be carried out per operations procedures identified elsewhere in this EIS. These measures will benefit fire risk mitigation goals by eliminating or reducing vegetation near wind farm infrastructure.

Description of Fire Fighting Resource Availability

The project area falls within the response area of Station 13 of the City and County of Honolulu Fire Department (HFD), Kahuku Fire Department. The department maintains a 24 hour response capability and is staffed and equipped in accordance with HFD protocols. Assuming a rate of travel of 24 kmh (15 mph), response time to the project boundary is estimated to be less than 3 minutes, to the substation less than 5 minutes, and to the furthest turbine location less than 12 minutes.

References

Andrews, P. L. and C. H. Chase. 1989. BEHAVE: fire behavior prediction and fuel modeling system - BURN subsystem, part 2. General Technical Report INT-260, United States Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Masters, G.M. 2013. Renewable and Efficient Electric Power Systems 2nd edition. Wiley. ISBN: 9 78-1-118-14062-8.

Scott, J. H. and R. E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. General Technical Report RMRS-GTR-153, United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.