Appendix D
Service Analysis of Golden Eagle Fatality Predictions from the Alta East ECP

D.1 Background

The Service uses explicit models in a Bayesian statistical inference framework to estimate eagle fatalities at a wind facility while accounting for uncertainty. The analysis presented below follows the Service's Eagle Conservation Plan Guidance version 2 (ECP Guidance, USFWS 2013); a more detailed background on the Service's model and modeling framework are presented in Appendix D of the Technical Appendices of the ECP Guidance. The basic Service fatality prediction model is based on the assumption that there is a predictable relationship between pre-construction eagle exposure (λ) and subsequent annual fatalities resulting from collisions with wind turbines (F), such that:

$$F = \varepsilon \lambda C$$

Where C is the probability of a collision given a minute of eagle flight within the hazardous area (see Service definition in ECP Guidance Technical Appendices), and ε is the expansion factor, a constant that describes the total area and time within a project footprint that is potentially hazardous to eagles; this is used to expand the estimated fatality rate into the annual number of predicted fatalities. One advantage of using a Bayesian modeling framework is the ability to incorporate known information directly into the model fitting by defining an appropriate prior probability distribution (or simply "prior"). The Service has defined prior distributions for both eagle exposure and collision probability based on the best available data. The exposure prior is updated with the pre-construction eagle use data collected at the site (which will overwhelm any influence of the prior with adequate sampling) and the collision probability will be updated with post-construction fatality if the project becomes operational. The expansion term represents the hazardous area (dependent on turbine number and size).

D.1.1 Alta East

We calculated eagle risk at Alta East under three scenarios. It should be noted that all scenarios assume that the observers detected 100% of eagle flight minutes below 200-m within an 800-m radius plot for each count.

- Model Scenario 1 was calculated for 51 turbines. This approximates Alternative 2 – Issue permit for Applicant's ECP Model.
- Model Scenario 2 was calculated for 47 turbines. This approximates Alternative 4 – Issue permit for Applicant's ECP with curtailment of four ridgeline turbines when eagles are observed. For purposes of modeling this scenario we used the extremely conservative assumption that the project would operate with four fewer turbines throughout the year.
- Model Scenario 3 was calculated for 97 turbines. In our environmental assessment, we included as an "alternative considered but eliminated from detailed study" of "Issue Permit for Reduced Project North, 97 Wind Turbine Generators." The Bureau identified the Reduced Project North Alternative – 97 Wind Turbine Generators as the preferred

alternative in its final environmental impact statement, but issued its record of decision for only 51 turbines. Because the record of decision authorizes only the 51 turbines, and not 97 turbines, we eliminated the 97 turbine alternative from further study in our environmental assessment because it was not authorized by the Bureau. However, we include it in our modeling scenarios to demonstrate the difference in results between a 97-turbine project and a 51-turbine project.

D.1.2 EXPOSURE

The Service defines a prior for eagle exposure (Gamma (0.97, 2.76)) based on the exposure rates across a range of sites (USFWS 2012). The prior is then updated with the eagle flight minutes observed and the total area and time covered by observation surveys to get the posterior distribution for exposure that is then used in the fatality model (USFWS 2013). In this case,

$$\textbf{\textit{Posterior } } \boldsymbol{\lambda} \sim \textbf{\textit{Gamma}}\mathbf{(0.97 + 17, 2.76 + 574.03), therefore}$$

$$\textbf{\textit{Posterior } } \boldsymbol{\lambda} \sim \textbf{\textit{Gamma}}\mathbf{(17.97, 576.79)}$$

Observation surveys recorded 17 eagle minutes over 574.03 hr-km2 of observations (this is the product of the area and time observed). Note, unless strata are specified, exposure rate is assumed to be uniform across the space and time of the project footprint. In this case the observation data were not collected in such a way that allow for spatial or temporal stratification, therefore the model is assuming the data represent the range of exposure throughout a typical year.

D.1.3 COLLISION

The Service defines the collision probability as *Beta* (2.31, 396.69) based on information from projects presented in Whitfield (2009).

$$\textbf{\textit{Prior C}} \sim \textbf{\textit{Beta}}\mathbf{(2.31, 396.69)}$$

D.1.4 EXPANSION

This is the product of the total hazardous area ($A = \pi r^2$), where r is the turbine rotor radius and A is summed across all turbines) and daylight hours.

For Alta East Model Scenario 1, ε is

$$\varepsilon = (51 \times (\pi \times 0.0515^2)) \times 4448.48 = 1890.37$$

The units for ε are hr·km2.

D.1.5 ESTIMATING FATALITIES

Table D-1. Site Data for all model scenarios*

Input		
Location	Latitude	Longitude
	35.109809	-118.225093
	Value	Notes
Number of Turbines*	51, 47, 97	2.85 MW
Turbine Rotor Radius (km)	0.0515	103-m diameter
Count Duration (hr)	0.5	30-min counts
Eagle Minutes	17	
Number of Counts	571	
Count Area (km2)	18.84	800-m circular plot
	Mean	SD
Exposure Prior	0.352	0.357
Exposure Posterior	0.031	0.007

*All inputs were the same for all model scenarios except for the number of turbines; 51, 47, and 97 for Model Scenarios 1, 2, and 3 respectively.

So the fatality estimate is a product of

$$\textit{Fatalities} = \textit{Posterior}\ \lambda \times \textit{Prior}\ C \times \varepsilon$$

We calculate predicted fatalities using simulation runs that draw from the exposure and collision distributions and insert the drawn values into the model. This results in a distribution of predicted fatalities:

Model Scenario 1: 51 Turbines

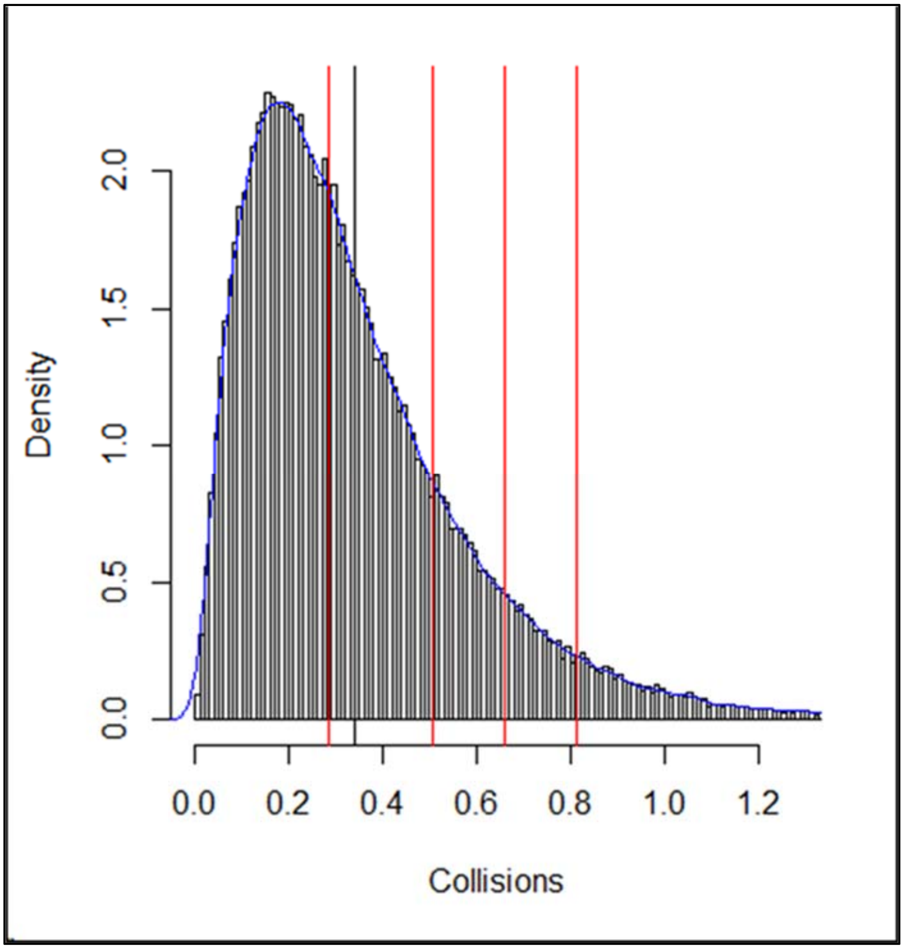

Figure D-1. Annual predicted fatalities for Alta East for Model Scenario 1 (51 turbines). The probability distribution of the collision probability prior, a Beta distribution with a mean of 0.341 and a standard deviation of 0.244. Moving from left to right, the red lines indicate the 50th, 80th, 90th and 95th confidence intervals for annual predicted golden eagle collision rates.

Table D-2. Annual Predicted Fatalities for Model Scenario 1

	Mean	SD	CI50	CI80	CI90	CI95
51 Turbines	0.341	0.244	0.284	0.504	0.660	0.814

Model Scenario 2: 47 Turbines

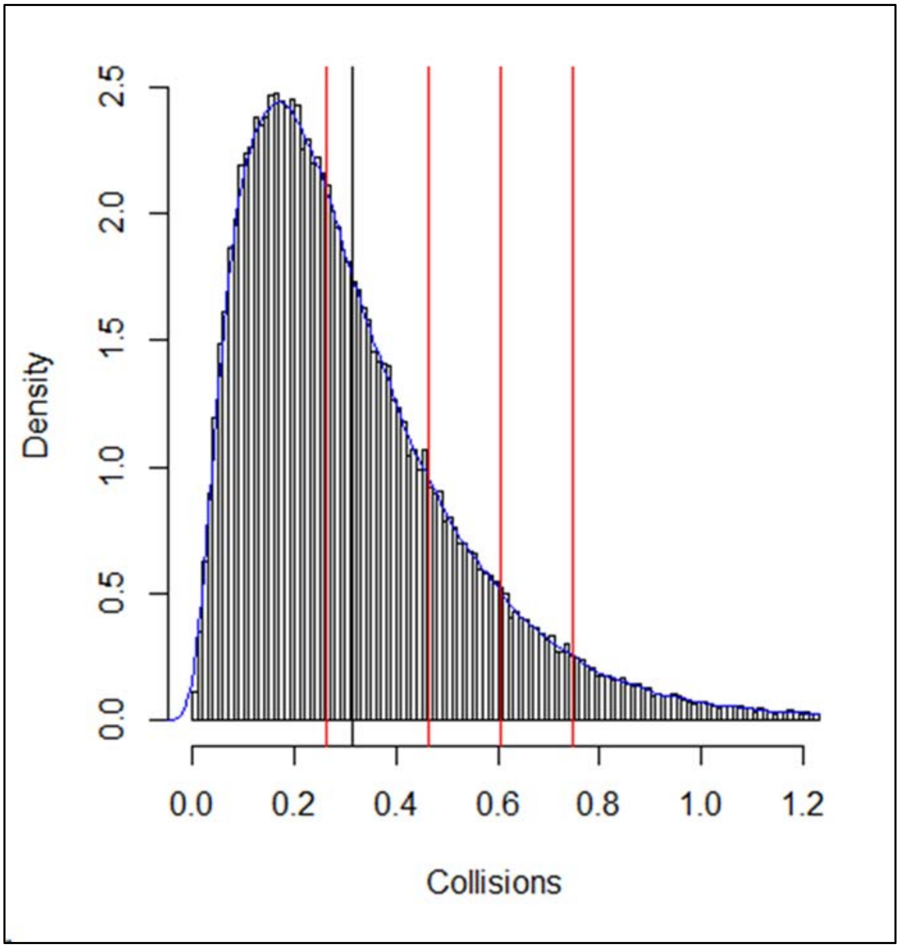

Figure D-2. Annual predicted fatalities for Alta East for Model Scenario 2 (47 turbines). The probability distribution of the collision probability prior, a Beta distribution with a mean of 0.315 and a standard deviation of 0.224. Moving from left to right, the red lines indicate the 50th, 80th, 90th and 95th confidence intervals for annual predicted golden eagle collision rates.

Table D-3. Annual Predicted Fatalities for Model Scenario 2

	Mean	SD	CI50	CI80	CI90	CI95
47 Turbines	0.315	0.224	0.261	0.464	0.606	0.746

Model Scenario 3: 97 Turbines

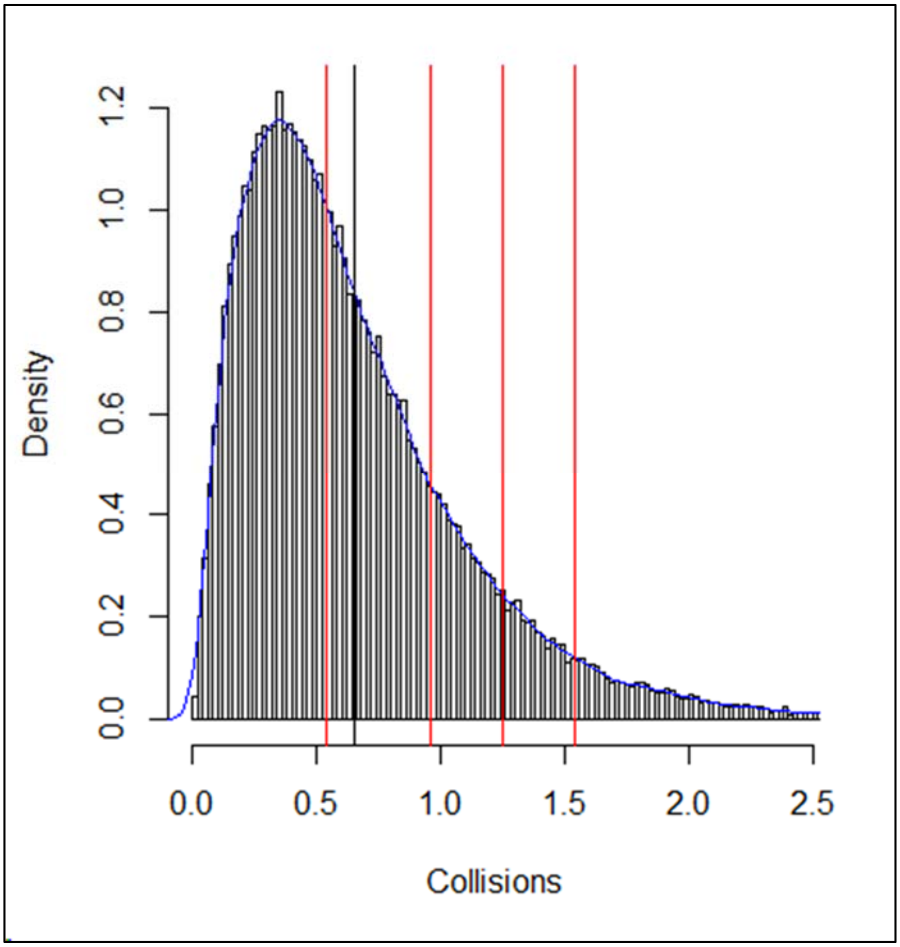

Figure D-3. Annual predicted fatalities for Alta East for Model Scenario 3 (97 turbines). The probability distribution of the collision probability prior, a Beta distribution with a mean of 0.649 and a standard deviation of 0.461. Moving from left to right, the red lines indicate the 50th, 80th, 90th and 95th confidence intervals for annual predicted golden eagle collision rates.

Table D-4. Annual Predicted Fatalities for Model Scenario 2

	Mean	SD	CI50	CI80	CI90	CI95
97 Turbines	0.649	0.461	0.540	0.960	1.252	1.539

D.2 Discussion

All of the model scenarios have the same inputs except for the number of turbines. We modeled different scenarios based on different turbine numbers because these represent different alternatives considered in our environmental analysis and to demonstrate the difference in annual predicted golden eagle collision rates for these different alternatives. Our results indicate that there is a negligible decrease in predicted collision rate at the 80^{th} confidence interval from 51-turbines to 47-turbines and an approximately 2-fold increase in predicted collision rate at the 80^{th} confidence interval from 51- and 47-turbines to 97-turbines.

R Code with Data Inputs for Bayesian Eagle Risk Analysis:

Following is the collision fatality model code for Model Scenario 1 (51 Turbines). The only input variable we changed in Model Scenarios 2 and 3 was the number of turbines (“nTurbine”), to 47 and 97 turbines, respectively.

```
### Draft USFWS Collision Fatality Model Code version 4.1 CMData.R
# Source the required function files
source("/Eagles/R/DayLen.R")
source("/Eagles/R/RVSmry.R")
source("/Eagles/R/FatalFcns.R")
## Define seasonal strata and calculate daylight hours
#"Alta East Lat/long" lat=35.109809, long=-118.225093
SeasonType<-"Annual"
LatLng<-c(35.109809,-118.225093)
DayLtHr<-DayLen(LatLng[2],LatLng[1],Type=SeasonType)
colnames(DayLtHr)[1]<-"Season"
DayLtHr$AveDayLen<-with(DayLtHr,DayLtHr/Days)
print(DayLtHr)
### Alta East Wind Project Data ###
cProject<-"Alta East"
Name<-"JAR"
nTurbine<-c(51) #number of turbines
HazRadKm<-c(51.5/1000) #radius of hazardous area around each turbine (km)
HzKM2<-sum(nTurbine*pi*HazRadKm^2) #hazardous area around each turbine (km)
CntHr<-c(30/60)  # count duration (in hours)
## Create the "ExpSvy" data frame
## this includes the Eagle Minutes observed, number of counts conducted,
## the area observed at each observation point, and the Daylight hours
## the data are entered into the data frame manually
ExpSvy<-data.frame(row.names=c("Alta East Annual"),
EMin=c(17),
nCnt=c(571),
CntKM2=c(pi*(800/1000)^2),
DayLtHr=c(4448.48)
 )
##  Indicate whether strata should be totaled
##  If you do not have strata, this should be FALSE
AddTot<-FALSE #Add strata for total (TRUE) or not (FALSE)

### Draft USFWS Collision Fatality Model Code version 4.1 (23 Apr 2013) CollisionModelv4.R
## Analysis Inputs ##
UCI<-c(0.5,0.8,0.9,0.95)
require(rv)
nSim<-100000
setnsims(nSim)
### Survey Inputs ###
nSvy<-nrow(ExpSvy)
```

```
cSvy<-(rownames(ExpSvy))
SmpHrKM2<-with(ExpSvy,nCnt*CntHr*CntKM2)
ExpFac<-ExpSvy$DayLtHr*HzKM2
# Calculate the fatalities and store as a temporary object.
 tmp<-with(ExpSvy,mapply(simFatal,EMin=EMin,SmpHrKM2=SmpHrKM2,ExpFac=ExpFac,
  SIMPLIFY=FALSE
 ))
# R code to get the survey specific simulations in an rv vector.
Fatalities<-rvnorm(nSvy)
Exp<-data.frame(Mean=rep(NA,nSvy),SD=NA,row.names=cSvy)
for(i in 1:nSvy){
Fatalities[i]<-tmp[[i]]
Exp[i,]<-attr(tmp[[i]],"Exp")
}
rm(tmp)
names(Fatalities)<-cSvy
# Summarize the results, including a total if needed.
nSvy<-length(Fatalities)
if(is.null(nSvy))nSvy<-1
FatalStats<-RVSmry(cSvy,Fatalities,probs=UCI)
if(AddTot){
FatalStats<-rbind(
FatalStats,
RVSmry("Total",sum(Fatalities),probs=UCI)
)
}
# Look at the results
cat(cProject,"\n")
cat(paste(Name,", ",date(),"\n",sep=""))
#Number of Turbines
print(nTurbine)
#Hazardous Area Per Turbine (km^2)
#print(HzKM2PT)
print(ExpSvy)
#Exposure rate
print(Exp,digits=3)
#Annual Collision Fatalities
print(FatalStats,digits=2)
# Plots
nPlot<-nSvy+as.integer(AddTot)
nCol<-floor(sqrt(nPlot))
nRow<-ceiling(nPlot/nCol)
xlim<-range(rvrange(Fatalities))
par(mfrow=c(nRow,nCol))
for(iPlot in 1:nSvy){
plotFatal(Fatalities[iPlot],probs=UCI,
```

```
#  xlim=xlim,add=FALSE,  # uncomment this line to put the graphs for all of the strata on the
same scale
main=cSvy[iPlot])
}
if(AddTot)plotFatal(sum(Fatalities),main="Total")
```