APPENDIX A

POPULATION MODELING

Population Model Overview

WinEquus is a program to simulate the population dynamics and management of wild horses created by Stephen H. Jenkins of the Department of Biology, University of Nevada at Reno. For further information about this model, you may contact Stephen H. Jenkins at the Department of Biology/314, University of Nevada, Reno, Nevada 89557.

The following data was summarized from the information provided within the WinEquus program, and will provide background about the use of the model, the management options that may be used, and the types of output that may be generated.

The population model for wild horses was designed to help wild horse and burro specialists evaluate various management strategies that might be considered for a particular area. The model uses data on average survival probabilities and foaling rates of horses to project population growth for up to 20 years. The model accounts for year-to-year variation in these demographic parameters by using a randomization process to select survival probabilities and foaling rates for each age class from a distribution of values based on these averages. This aspect of population dynamics is called environmental stochasticity, and reflects the fact that future environmental conditions that may affect a wild horse population's demographics cannot be established in advance. Therefore, each trial with the model will give a different pattern of population growth. Some trials may include mostly "good" years, when the population grows rapidly; other trials may include a series of several "bad" years in succession. The stochastic approach to population modeling uses repeated trials to project a range of possible population trajectories over a period of years, which is more realistic than predicting a single specific trajectory.

The model incorporates both selective removal and fertility treatment as management strategies. A simulation may include no management, selective removal, fertility treatment, or both removal and fertility treatment. Wild horse and burro specialists can specify many different options for these management strategies such as the schedule of gathers for removal or fertility treatment, the threshold population size which triggers a gather, the target population size following a removal, the ages and sexes of horses to be removed, and the effectiveness of fertility treatment.

To run the program, one must supply an initial age distribution (or have the program calculate one), annual survival probabilities for each age-sex class of horses, foaling rates for each age class of females, and the sex ratio at birth. Sample data are available for all of these parameters. Basic management options must also be specified.

Population Data: Age-Sex Distribution

An important point about the initial age-sex distribution is that it is NOT necessarily the starting population for each of the trials in a simulation. This is because the program assumes that the initial age-sex distribution supplied on this form or calculated from a population size that the user enters is not an exact and complete count of the population. For example, if the user enters an initial population size of 100 based on an aerial survey, this is really an estimate of the population, not a census. Furthermore, it is likely to be an underestimate, because some horses will be missed in the survey. Therefore, the program uses an average sighting probability of approximately 90 percent (Garrott et al. 1991) to "scale-up" the initial population estimate to a starting population size for use in each trial. This is done by a random process, so the starting population sizes are different for all trials. An option does exist to consider the initial population size to be exact and bypass this scaling-up process.

Population Data: Survival Probabilities

A fundamental requirement for a population model such as this is data on annual survival probabilities of each age class. The program contains files of existing sets of survival, or it is possible to enter a new set of data in the table.

In most cases, Wild Horse and Burro Specialists do not have information on survival probabilities for their populations, so the sample data files provided with WinEquus are used and assume that average survival probabilities in the populations are similar. These data are more difficult to get than is often assumed, because they require keeping track of known individuals over time. A "snapshot" of a population, providing information on the age distribution at a single gather, can NOT be used to estimate survival probabilities without assuming a particular growth rate for the population (Jenkins1989). More data from long-term studies of marked horses are needed to develop estimates of survival in various habitats.

Population Data: Foaling Rates

Foaling rates are the proportions of females in each age class that produce a foal at that age. Files are available within the program that contain existing sets of foaling rates, or the user may enter a new set of data in the table. The user may also enter the sex ratio at birth, another necessary parameter for population simulation.

Environmental Stochasticity

For any natural population, mortality and reproduction vary from year-to-year due to unpredictable variation in weather and other environmental factors. This model mimics such environmental stochasticity by using a random process to increase or decrease survival probabilities and foaling rates from average values for each year of a simulation trial. Each trial uses a different sequence of random values, to give different results for population growth. Looking at the range of final population sizes in many such trials will give the user an indication of the range of possible outcomes of population growth in an uncertain environment.

How variable are annual survival probabilities and foaling rates for wild horses? The longest study reporting such data was done at Pryor Mountain, Montana by Garrott and Taylor (1990). Based on 11 years of data at this site, survival probability of foals and adults combined was greater than 98 percent in 6 years, between 90 and 98 percent in 3 years, 87 percent in 1-year, and only 49 percent in 1-year of severe winter weather. These values clearly are not normally distributed, but can be approximated by a logistic distribution. This pattern of low mortality in most years, but markedly higher mortality in occasional years of bad weather, was also reported by Berger (1986) for a site in northwestern Nevada. Therefore, environmental stochasticity in this model is simulated by drawing random values from logistic distributions. If desired, different values can be entered to change the scaling factors for environmental stochasticity.

Because year-to-year variation in weather is likely to affect foals and adults similarly, this model makes foal and adult survival perfectly correlated. This means that when survival probability of foals is high, so is survival probability of adults, and vice versa. By contrast, the correlation between survival probabilities and foaling rates can be adjusted to any value between -1 and +1. The default correlation is 0 based on the Pryor Mountain data and the assumption that most mortality occurs in winter and winter weather is not highly correlated with foaling-season weather.

The model includes another form of random variation, called demographic stochasticity. This means that mortality and reproduction are random processes even in a constant environment; i.e., a foaling rate of 40 percent means that each female has a 40 percent chance of having a foal. Because of demographic stochasticity, even if scaling factors for both survival probabilities and foaling rates were set equal to 0, different runs of the simulation would produce different results. However, variation in population growth due to demographic stochasticity will be small except at low population sizes.

Gathering Schedule

There are three choices for the gather schedule: gather at a regular interval, gather at a minimum interval (the default), or gather in specific years. Gathering at a minimum interval means that gathers will be conducted no more frequently than a prescribed interval (e.g., 3 years), but will not be conducted if the time interval has passed unless the population is above a threshold size that triggers a gather.

Gather interval

This is the number of years between gathers.

Gather for fertility treatment regardless of population size?

If this option is selected (the default), then gathers occur according to the gathering schedule specified regardless of whether or not the population exceeds a threshold population size. One effect of this is that a minimum-interval schedule really functions as a regular interval.

Continue gather after reduction to treat females?

Continuing a gather after a reduction to treat females (with fertility control management options) means that, if a gather for a removal has been triggered because the population has exceeded a threshold population size, then horses will continue to be processed even after enough have been removed to reduce the population to the target population size. As additional horses are processed, females, to be released back, will be treated with an immunocontraceptive according to the information specified in the Contraceptive Parameters form.

Threshold for gather

The threshold population size for triggering a gather is the actual population size in a particular year estimated by the program. This is NOT the same as the number of horses counted in an aerial census, but closer to an estimate of population size taking into account the fact that an aerial census typically underestimates population size.

Target population size

This is the goal for the population size following a gather and removal. Horses will be removed until this target is reached, although it may not be possible to achieve this goal, depending on the removal parameters (percentages of each age-sex class to be removed) and gathering efficiency.

Are foals included in Appropriate Management Level (AML)?

In most districts, foals are counted as part of the AML.

Gathering efficiency

Typically, some horses will successfully resist being gathered, either by hiding in habitats where they cannot be seen or moved by a helicopter, or following escape routes that make it dangerous or uneconomical for them to be herded from the air. These horses are not available for removals or fertility treatment. The default gathering efficiency is 80 percent, meaning that the program assumes that 20 percent of the population will successfully resist being gathered. This value may be changed.

Note that the program assumes that horses of all age-sex classes are equally likely to be able to be gathered. This is an unrealistic assumption because bachelor males, for example, may be more likely to successfully avoid being gathered than females or foals or band stallions.

Sanctuary-bound horses

Age-selective removals typically target younger age classes such as 0 to 5-year-olds or 0 to 9-year-olds because these horses are more easily adopted. However, it may not be possible to reduce the population to a target size by restricting removals to these younger age classes, especially if age-selective removals have been conducted in the past. In this case, an option is available to remove older animals as well, who may be destined for permanent residence in a long term holding facility rather than for adoption. The minimum age of these long term holding facility horses is specified for this element. When older age classes as well as younger age classes are identified for removal on the Removal Parameters form, horses of these older age classes are selected along with younger age class horses as the population is reduced to the target value. If a minimum age for long-term holding facility horses is specified, then older animals are only removed if the population cannot be reduced to the target population size by removing the younger ones.

Percent Effectiveness of fertility control

These percentages represent the percentage of treated females that are in fact sterile for 1-year, 2 years, etc. (i.e., the efficacy or effectiveness of fertility treatment). The default values are 90 percent efficacy for 1-year. However, the user may specify the effectiveness year-by-year, for up to 5 years.

Removal Parameters

This allows the user to determine the percentages of horses in each sex and age class to be removed during a gather. The program uses these percentages to determine the probabilities of removing each horse that is processed during a gather. If the percentage for an age-sex class is 100 percent, then all horses of that age-sex class that are processed will be removed until the target population size is reached. If the percentage for an age-sex class is 0 percent, then all horses of that age-sex class will be released. If the percentage for an age-sex class is greater than 0 percent but less than 100 percent, then the proportion of horses of that age-sex class removed will be approximately equal to the specified percentage.

Contraception Parameters

This allows the user to specify the percentage of released females of each age class that will be treated with an immunocontraceptive. The default values are 100 percent of each age class, but any or all of these may be changed.

Most Typical Trial

This is the trial that is most similar to each of the other trials in a simulation.

Population Size Table

The default is both sexes and all age classes, but summary results may also be chosen for a subset of the population. The table identifies some key numbers such as the lowest minimum in all trials, the median minimum, and the highest minimum. Thinking about the distribution of minima for example, half of the trials have a minimum less than the median of the minima and half have a minimum greater than the median of the minima. If the user was concerned about applying a management strategy that kept the population above some level, because the population might be at risk of losing genetic diversity if it were below this level, then one might look at the 10th percentile of the minima, and argue that there was only a 10 percent probability that the population would fall below this size in x years, given the assumptions about population data, environmental stochasticity, and management that were used in the simulation.

Gather Table

The default is both sexes and all age classes, but summary results may be for a subset of the population. The table shows key values from the distribution of the minimum total number of horses gathered, removed, and (if one elected to display data for both sexes or just for females) treated with a contraceptive across all trials. This output is probably the most important representation of the results of the program in terms of assessing the effects of your management strategy because it shows not only expected average results but also extreme results that might be possible. For example, only 10 percent of the trials would have entailed gathering fewer animals than shown in the row of the table labeled "10th percentile," while 10 percent of the trials would have entailed gathering more than shown in the row labeled "90th percentile." In other words, 80 percent of the time one could expect to gather a number of horses between these two values, given the assumptions about survival probabilities, foaling rates, initial age-sex distribution, and management options made for a particular simulation.

Growth Rate

This table shows the distribution of the average population growth rate. The direct effects of removals are not counted in computing average annual growth rates, although a selective removal may change the average foaling rate or survival rate of individuals in the population (e.g., because the age structure of the population includes a higher percentage of older animals), which may indirectly affect the population growth rate. Fertility control clearly should be reflected in a reduction of population growth rate.

Population Modeling, South Steens Herd Management Area (HMA)

To complete the population modeling for the South Steens HMA, version 1.40 of the WinEquus program, created April 2, 2002, was utilized.

Objectives of Population Modeling

Review of the data output for each of the simulations provided many useful comparisons of the possible outcomes for each alternative. The creator of the modeling program, Stephen Jenkins stresses that it is important to think about the range of possible outcomes, not just focus on one average or typical trial. Some of the questions that need to be answered through the modeling include:

- Do any of the Alternatives "crash" the population?
- What effect does fertility control have on population growth rate?
- What effects do the different alternatives have on the average population size?

Population Data, Criteria, and Parameters utilized for Population Modeling

Initial age structure for the 2004 herd was from the 1998 release data collected during the 1998 gather. A simulation, using the 1998 release population as the initial age structure, was then conducted for the years 1999 to 2004 under the "no management" management option, to represent what the population would be comprised of in 2004. The most typical trial obtained from this simulation was saved and used to represent the 2004 age structure of the herd and rescaled to an initial population of 586, which represents the estimated population in 2004.

The following table displays the initial age structure for the 2004 wild horse population utilized in the population model for the proposed action and alternatives.

Initial Age Structure – 2004

Age Class	South Steens Initial Age Structure 2004	
	Females	Males
Foals	47	60
1	21	34
2	49	43
3	37	45
4	24	29
5	7	4
6	1	3
7	2	5
8	2	1
9	5	4
10-14	40	33
15-19	28	30
20+	16	16
Total	279	307

All simulations used the survival probabilities and foaling rates supplied with the WinEquus population model for the Granite Range HMA. Survival and foaling rate data were extracted from "Wild Horses of the Great Basin," by J. Berger (1986, University of Chicago Press, Chicago, IL, xxi + 326 pp.). They are based on Joel Berger's 6-year study in the Granite Range HMA in northwestern Nevada.

Survival probabilities and foaling rates utilized in the population model for the proposed action and alternatives are displayed in the following table.

Survival Probabilities and Foaling Rates

Age Class	Survival Probabilities		Foaling Rates
	Females	Males	
Foals	.917	.917	--
1	.969	.969	--
2	.951	.951	.35
3	.951	.951	.40
4	.951	.951	.65
5	.951	.951	.75
6	.951	.951	.85
7	.951	.951	.90
8	.951	.951	.90
9	.951	.951	.90
10-14	.951	.951	.85
15-19	.951	.951	.70
20	.951	.951	.70

The following table displays the removal criteria utilized in the population model for the proposed action and Alternative I.

Removal Criteria

Age	Percentages for Removals	
	Females	Males
Foal	100%	100%
1	100%	100%
2	90%	100%
3	90%	100%
4	90%	90%
5	80%	90%
6	50%	50%
7	50%	50%
8	50%	50%
9	50%	50%
10-14	50%	50%
15-19	50%	50%
20+	50%	50%

Population Modeling Criteria

The following summarizes the population modeling criteria that are common to the proposed action and Alternative I:

- Starting Year: 2004
- Initial gather year: 2004
- Gather interval: minimum interval of 5 years
- Sex ratio at birth: 57 percent male
- Percent of the population that can be gathered: 90 percent
- Minimum age for long-term holding facility horses: 6 years old
- Foals are included in the AML
- Simulations were run for 4 years with 100 trials each

The following summarizes the population modeling criteria for Alternative II, No Action:

- Starting Year: 2004
- Sex ratio at birth: 57 percent male
- Simulations were run for 4 years with 100 trials each

The following table displays the population modeling parameters utilized in the model for the proposed action and Alternative I:

Population Modeling Parameters

Modeling Parameter	Proposed Action	Alternative I
Management by removal and fertility control	Yes	--
Management by removal only	--	Yes
Threshold Population Size for Gathers	304	304
Target Population Size Following Gathers	159	159
Gather for fertility control regardless of population size	Yes	--
Gathers continue after removals to treat additional females	No	--
Effectiveness of Fertility Control: year 1	94%	--
Effectiveness of Fertility Control: year 2	82%	--

Population Modeling Results

Population size in 5 years

Out of 100 trials in each simulation, the model tabulated minimum, average and maximum population sizes. The model was run from 2004 to 2008 to determine what the potential effects would be on population size for the proposed action and alternatives. These numbers are useful to make relative comparisons of the different alternatives, and potential outcomes under different management options. The data displayed within the tables is broken down into different levels.

The lowest trial, highest trial, and several in between are displayed for each simulation completed. According to the creator of the modeling program, this output is probably the most important representation of the results of the program in terms of assessing the effects of proposed management, because it shows not only expected average results but also extreme results that might be possible.

Population Sizes in 5 years - Minimum

Alternative	Proposed Action	I	II
Lowest Trial	135	132	539
10th Percentile	170	184	598
25th Percentile	198	196	616
Median Trial	**216**	**212**	**635**
75th Percentile	231	230	664
90th Percentile	248	243	701
Highest Trial	276	337	842

This table shows that in 5 years and 100 trials for each alternative, the lowest number of 0-20+ year old horses ever obtained was 132 under Alternative I. Half of the trials were greater than the median and half were less than the median. Additional interpretation may be made by comparing the various percentile points. For example, for the proposed action, only 10 percent of the trials resulted in fewer than 170 wild horses as the minimum population, and 10 percent of the trials resulted in a minimum population larger than 248 wild horses. In other words, 80 percent of the time, one could expect a minimum population between these two values for the proposed action, given the assumptions about survival probabilities, foaling rates, initial age-sex distribution, and management options made for this simulation.

Alternative I (lower AML of 159 head without fertility control) reflects the lowest minimum population of all alternatives. The population size for the proposed action is very close to, but slightly larger than Alternative I. Alternative II, No Action, reflects the highest minimum population levels of all of the trials.

None of the results obtained for any of the alternatives indicate that a crash of the population would occur if the alternative were implemented. The level to which the population is gathered appears to be more of an influence to the population size than fertility control. The No Action Alternative results in the highest minimum population.

The lowest population size ever obtained (132 head) was less than the lower level of the AML range of 159 to 304 wild horses. However, for 90 percent of the time the simulation indicates that the population will be 170 head or more, which is higher than the lower level of the AML range. This occurs due to the assumptions made by the model, which include census accuracy, effectiveness of the gather, and mares that foal following the gather. These are all realistic assumptions and result in simulations that are closer to real world situations rather than making predictions based on finite numbers.

Population Sizes in 5 years - Average

Alternative	Proposed Action	I	II
Lowest Trial	249	265	623
10th Percentile	280	310	769
25th Percentile	303	327	832
Median Trial	**319**	**351**	**904**
75th Percentile	339	374	967
90th Percentile	366	399	1030
Highest Trial	426	516	1198

This table displays the average population sizes obtained for the 100 trials ran for each alternative. The average population size across 5 years ranged from a low of 249 wild horses under the proposed action, to a high of 1198 wild horses under Alternative II, No Action. The proposed action reflects the lowest overall average population size, followed by Alternative I and Alternative II has the highest average population size after 5 years. The difference between the proposed action and Alternative I is a 10 percent increase in average median population size. Both are gathered to the lower level of the AML range but fertility control is not implemented in Alternative I.

Population Sizes in 5 years - Maximum

Alternative	Proposed Action	I	II
Lowest Trial	586	590	686
10th Percentile	600	595	952
25th Percentile	610	611	1065
Median Trial	**630**	**632**	**1166**
75th Percentile	664	656	1320
90th Percentile	710	696	1445
Highest Trial	956	937	1799

This table displays the largest populations that could be expected out of 100 trials for each alternative. The figures for the lowest trial represent what the population is likely to be in 2004. All figures are very similar because under all of the alternatives, the same starting population, and gather efficiency etc., is assumed. The numbers vary due to randomness and assumptions inherent to the modeling program.

Average Growth Rates in 5 years

Average growth rates were obtained by running the model for 100 trials from 2004 to 2008 for the proposed action and each alternative. The following table displays the results obtained from the model:

Average Growth Rate in 4 Years

Alternative	Proposed Action	I	II
Lowest Trial	-6.1%	5.3%	-1.2%
10th Percentile	6.4%	11.0%	10.4%
25th Percentile	10.0%	15.5%	13.1%
Median Trial	**13.6%**	**19.1%**	**16.5%**
75th Percentile	16.0%	21.9%	19.0%
90th Percentile	18.3%	24.2%	20.8%
Highest Trial	22.6%	29.2%	25.0%

As expected, the proposed action which implements fertility control reflects the lowest overall median growth rate. The range of growth rates is a reasonable representation of what could be expected to occur in a wild horse population.

Totals in 5 years – Gathered, Removed, and Treated

The same type of tabular data was obtained from the model for the numbers of wild horses gathered, removed, and treated under each alternative. The data is for one gather only that is proposed take place in 2004, and includes all animals 0-20+ years of age.

Totals in 5 Years -- Gathered

Alternative	Proposed Action	I	II
Lowest Trial	481	480	NA
10th Percentile	493	488	
25th Percentile	500	500	
Median Trial	**515**	**517**	
75th Percentile	541	539	
90th Percentile	582	573	
Highest Trial	782	766	

Totals in 5 Years -- Removed

Alternative	Proposed Action	I	II
Lowest Trial	377	377	NA
10th Percentile	388	386	
25th Percentile	393	394	
Median Trial	**407**	**407**	
75th Percentile	428	424	
90th Percentile	460	452	
Highest Trial	615	604	

Totals in 5 Years -- Treated

Alternative	Proposed Action	I	II
Lowest Trial	27	NA	NA
10th Percentile	29		
25th Percentile	30		
Median Trial	**32**		
75th Percentile	34		
90th Percentile	36		
Highest Trial	49		

The number of horses gathered and removed does not differ greatly between the proposed action and Alternative I because gather criteria is the same for all alternatives.

Population Modeling Summary

To summarize the results obtained by simulating the range of alternatives for the South Steens HMA wild horse gather, the original questions can be addressed.

- Do any of the Alternatives "crash" the population?

  None of the alternatives indicate that a crash is likely to occur to the population. Minimum population levels and growth rates are all within reasonable levels, and adverse impacts to the population are not likely.

- What effect does fertility control have on population growth rate?

  As expected, the proposed action implementing fertility control reflected the lowest overall growth rate.

- What effect do the different alternatives have on the average population size?

  The level to which the population is gathered appears to be more of an influence to population size than fertility control. As expected Alternative II, No Action, results in the highest minimum population.