APPENDIX 7A

DESCRIPTION AND REVIEW OF INVENTORY, GROWTH AND YIELD

Vegetation Typing

The JDSF Vegetation Classification System vegetation type maps used in this analysis are derived from remotely sensed Landsat satellite imagery. A consulting firm under contract to JDSF completed the vegetation typing in the fall of 1996. The vegetation map was used as the basis for the timber inventory update completed in 1997. The vegetation map was created using a combination of field plot summaries, aerial photography, and field verification. Training sites consisted of accurately located forest inventory plots. The coverage was developed using an unsupervised classification process with input from local field staff. The procedures used to create the vegetation map are as follows:

Register and Terrain Correct Images--Two Landsat Thematic Mapper (TM) images were acquired, one from 10 July 1989, and the other from 11 June 1996. These images were both geographically registered using control points derived from easily identifiable features in JDSF's GIS data such as road intersections, rock outcrops, and confluence of streams. The imagery was terrain corrected using a 10-meter digital elevation model created from elevation contours that were derived from USGS 7.5 minute topographic maps. The Root Mean Squared (RMS) error of the registration and terrain correction process was 1.2 pixels (or 36 meters ground distance). The RMS error of the registration between images was 0.2 pixels (or 6 meters ground distance).

Determine Areas of Significant Vegetation Change--One of the sources of information used to create the vegetation map was a summary of vegetation characteristics from existing field plots (established in 1989). To avoid using plot summaries from areas that had experienced significant change, a "vegetation change map" was produced using digital change analysis techniques that examined the difference in vegetation indices between the 1989 TM image and the 1996 TM image. Areas that exhibited substantial increases or decreases in vegetation were identified, and field plots from those areas were excluded from use in the determination of vegetation characteristics.

Conduct Unsupervised Classification--An unsupervised classification of the 1996 TM image was produced for the East and West sides of the forest. The unsupervised image classification (ISODATA), which classifies image pixels into statistically distinct classes, was done independently for the east and west portions of the forest. Twenty-five unique classes were identified in each portion of the forest. The unsupervised classification provided important information on the heterogeneity of the forest, and served as a guide for identification of "training sites" for later stages of preparation of the vegetation map.

Select Training Sites--Based on field investigation, summaries of field plot vegetation characteristics, and 1:12,000 color stereo aerial photography (1993 and 1996 photo dates), representative areas for each vegetation type found in JDSF were identified. Training sites were delineated on the aerial photos. Training sites were first selected for areas that were most homogeneous (based on the unsupervised classification). Areas of increasing heterogeneity required increasing field verification and refinement to identify training sites. A minimum of two training sites was identified for each vegetation type. Field plots from 1989 were updated for growth to represent 1996 conditions.

Conduct Supervised Classification--Based on the identified training sites, the 1996 TM image was classified using a maximum likelihood classifier. The classification was done in a stepwise progression, with the most spectrally unique and easily identifiable vegetation types classified first. Those areas that were classified in the early steps of the process were "masked out" so as to limit the number of classes and variability within the image to be classified. A composite classified image was produced that merged each step of the classification. Six or seven reflectance bands, or ratios and transformations of the TM reflectance bands, were used to reliably separate vegetation classes within each classification step.

Conduct Field Verification--Maps of the vegetation classification were produced and taken to the field for verification. Field review was conducted to verify the correctness and consistency of each vegetation type. Two rounds of field verification and subsequent modification of the vegetation typing were conducted.

Aggregate Vegetation Strata--The final vegetation classification of was aggregated into several levels of aggregation: 1, 2, 5, and 10 acre minimum polygon size. Upon review, it was decided that a 5-acre minimum polygon size would be used, except in areas designated as Group Selection, where a 2.5-acre minimum polygon size would be used. The aggregation into vegetation polygons was done using a "majority filter."

Vegetation Classification Systems

A subset of the JDSF Vegetation Classification System was created by the Forest that resulted in a new combination of vegetation types, size classes and densities to describe Vegetation Management polygons. This was essentially a crosswalk procedure that reclassified the polygons created using the procedure described above. The following tables present the crosswalk from JDSF vegetation type to the Vegetation Management types.

TABLE VI-5.3F JDSF VEGETATION CROSSWALK TO VEGETATION MANAGEMENT	
JDSF Vegetation Types	**Vegetation Management**
Redwood	Redwood/Douglas-fir
Redwood/Douglas-Fir	Redwood/Douglas-fir
Douglas-Fir/Redwood	Douglas-fir/Redwood
Mixed Conifer	Douglas-fir/Redwood
Hardwood/Redwood	Mixed Hardwood/Conifer
Alder	Mixed Hardwood/Conifer
Closed-Cone Pine/Cypress	Pine
Pygmy Forest	Pygmy
Mixed Hardwood/Conifer	Mixed Hardwood/Conifer
Grass/Bare Ground	Non Timber
Brush	Non Timber

TABLE VI-5.3G JDSF SIZE CLASS CROSSWALK TO VEGETATION MANAGEMENT SIZE CLASS		
JDSF Size Class	**DBH Range**	**Vegetation Management**
1	<1"	<18”
2	1"-6"	<18”
2O	Size 2 (>75%) under 4, 5 or 6	<18”
3	6"-11"	<18”
4	11"-18"	<18”
4M	Size 4 over 2 or 3	<18”
5	18"-24"	18”+
5M	Size 5 over 2, 3 or 4	18”+
6	>24"	18”+
6M	Size 6 over 2, 3, 4 or 5	18”+

TABLE VI-5.3H JDSF DENSITY CROSSWALK TO VEGETATION MANAGEMENT DENSITY		
JDSF Density	**Percent Cover**	**Vegetation Management Density**
S	10-24.9	S
P	25-39.9	S
M	40-59.9	M
D	60-79.9	D
E	80-100	D

Timber Inventory

Intensive Forest Inventory (IFI): Estimates of timber volumes and other vegetation characteristics are derived primarily from a system of plots referred to as the JDSF Intensive Forest Inventory (IFI). This system of plots was established in 1989. The IFI is based on a stratified random sampling design. The IFI plots were located on randomly selected points of a 10-chain grid. The plots were installed as 3-plot clusters or single plots, with each plot being comprised of 3 nested fixed radius plots. Trees 11 inches and greater were measured on the largest plot ($1/5^{th}$ acre). Trees 7 inches to 10.9 inches were measured on the intermediate plot ($1/20^{th}$ acre). Trees 6.9 inches and smaller were tallied by 2-inch classes on a $1/100^{th}$ acre regeneration plot. Tree measurements included species, diameter breast height and live crown ratio. A subset of trees was also measured for total height, defect, and 10-year radial increment.

As discussed above, a new vegetation strata map was produced for this project in 1996. Some of the existing plots were located in areas that were harvested some time between 1989 and 1996, and therefore no longer represented the new conditions. These plots were removed from the inventory system. In addition, some of the 1989 IFI plots could not be reliably located relative to the new vegetation strata map, and were also removed from the inventory system. This resulted in a number of vegetation strata being under-represented from the perspective of growth and yield modeling or reliable timber volume estimates.

To fix this problem, an additional 130 clusters (390 plots) were installed in early 1997. These supplementary sample plots conformed to the same design as the IFI plots installed in 1989. The 390 supplementary plots from 1997 along with the 1,506 surviving 1989 plots provided sufficient data to compute volume and to project growth and yield estimates. The 1,506 unharvested 1989 plots were updated to account for growth from 1989–1997 using the FREIGHTS growth and yield simulator.

The Forest was divided into two inventory blocks, separated along the western edge of Chamberlain Creek planning watershed to account for significant differences in stocking between the west end and the east end of the Forest. The east inventory block consists of the eastern WWAA and a relatively small area in the headwaters of Two Log Creek in the eastern portion of the southern WWAA. The west inventory block consists of the northern WWAA, the western WWAA, and most of the southern WWAA.

Continuous Forest Inventory: The original continuous forest inventory (CFI) system consisted of 141 rectangular one-half acre permanent plots distributed on a square 3/4-mile systematic grid across the forest (sixty chains between plot centers). The plots were first established and the first measurements were obtained in 1959. Since then, the plots have been re-measured in 1964, 1969, 1974, 1984, 1989, and 1999.

The original one-half acre CFI plots were fixed area rectangular plots, 2 chains by 2.5 chains. In addition to the main plot there were three subplots: a one-quarter acre subplot was put in at the time of the first measurement to measure tree heights in order to establish a height-diameter relationship. This subplot was only put in during the first measurement of the plots in 1959. Subsequent re-measurements did not measure heights, but rather relied on this relationship to estimate heights. A 1/25-acre subplot was used to measure trees 3.0 inches to 10.9 inches DBH. Finally, 40 one-thousandth-acre subplots were used to record conifer reproduction less than 3.0 inches DBH.

General data measured at each CFI plot includes aspect, slope, age class (young growth/old growth), and whether the stand has been harvested in the past. Data measured on individual trees include species, DBH to the nearest 1/10-inch, merchantability class, crown class, vigor class, defect indicators, and regeneration status of the tree (re-measured, ingrowth, logged). Heights were measured on approximately half of the trees at the time of the first measurement in 1959. These data were used to estimate a height–diameter relationship that was used on subsequent re-measurements.

This original inventory design was used for five re-measurement occasions, in 1959, 1964, 1969, 1974, and 1984. The design changed in 1989, when a new plot system was established, consisting of 308 permanent plots and 2,054 temporary plots. Starting in 1989, permanent plots were circular one-fifth acre plots rather than rectangular one-half acre plots. Of the 308 permanent plots, 140 were located at the plot centers of the original CFI plots. The remaining 168 permanent plots were established using the stratified random sample design of the 1989 inventory.

The 1989 permanent plots consisted of a one-fifth acre (52.7 feet radius) main plot on which all trees greater than 11.0 inches DBH were measured. All trees 7.0 inches DBH and larger were recorded on a one-twentieth acre subplot. Finally all trees 1/10 of an inch or greater DBH were measured on a one-hundredth acre subplot.

Summary of Vegetation and Inventory

Table VI-5.3I is a summary of the 1997 IFI inventory. Information is presented for the east and west side of the Forest. This table includes a JDSF vegetation type identified as GSEL that was used to classify timber stands recently harvested under the group selection silviculture method. Due to the complex structural mosaic created by group selection areas, this type was kept as a separate category.

TABLE VI-5.3I
TIMBER INVENTORY VOLUMES AND VEGETATION TYPES ON THE EAST AND WEST ENDS OF JDSF

	JDSF Vegetation Type	Vegetation Management	Site Class	Acres	Conifer Volume (mbf/ac)	Hardwood Vol (mbf/ac)	All Species Vol (mbf/ac)	Conifer Total (mbf)	Hardwoods Total (mbf)	All Species Total (mbf)
E	BR	NON-TIMBER	3	22.96	10	6	16	229.6	138	367
E	BR	NON-TIMBER	4	7.08	9	5	14	63.72	35	99
E	BR	NON-TIMBER	8	33.1	8	5	13	264.8	166	430
E	DR5DM	DR18+D	2	479.03	26	2	28	12,454.78	958	13413
E	DR5DM	DR18+D	3	777.71	25	2	27	19,442.75	1555	20998
E	DR5DM	DR18+D	4	364.77	23	2	25	8,389.71	730	9119
E	DR5EM	DR18+D	2	191.64	28	2	30	5,365.92	383	5749
E	DR5EM	DR18+D	3	169.56	27	1	28	4,578.12	170	4748
E	DR5EM	DR18+D	4	216.01	27	1	28	5,832.27	216	6048
E	DR5PM	DR18+S	3	288.04	8	3	11	2,304.32	864	3168
E	DR5PM	DR18+S	4	545.05	8	2	10	4,360.4	1090	5450
E	DR6DM	DR18+D	3	54.48	47	6	53	2,560.56	327	2887
E	DR6DM	DR18+D	4	85.6	46	6	52	3,937.6	514	4451
E	GRBG	NON-TIMBER	2	32.95	0	0	0	0	0	0
E	GRBG	NON-TIMBER	3	26.88	0	0	0	0	0	0
E	GRBG	NON-TIMBER	4	5.3	0	0	0	0	0	0
E	HC3E	HC<18D	2	123.67	14	6	20	1,731.38	742	2473
E	HC3E	HC<18D	3	1,056.93	14	5	19	14,797.02	5285	20082
E	HC3E	HC<18D	4	523.74	14	5	19	7,332.36	2619	9951
E	HR3E	MC<18D	2	269.91	10	3	13	2,699.1	810	3509
E	HR3E	MC<18D	3	1,186.86	9	3	12	10,681.74	3561	14242
E	HR3E	MC<18D	4	1,447.74	9	3	12	13,029.66	4343	17373
E	MC5DM	DR18+D	2	4.91	19	5	24	93.29	25	118
E	MC5DM	DR18+D	3	49.33	19	5	24	937.27	247	1184
E	MC5DM	DR18+D	4	31.71	19	5	24	602.49	159	761
E	R5MM	RD18+M	2	13.76	6	3	9	82.56	41	124
E	R5MM	RD18+M	3	92.97	6	3	9	557.82	279	837
E	R5MM	RD18+M	4	68.49	6	3	9	410.94	205	616
E	R6DM	RD18+D	2	164.35	33	3	36	5423.55	493	5917
E	R6DM	RD18+D	3	398.78	32	3	35	12,760.96	1196	13957

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E	R6DM	RD18+D	4	169.44	32	3	35	5,422.08	508	5930
E	R6MM	RD18+D	2	6.84	26	2	28	177.84	14	192
E	R6MM	RD18+D	3	93.81	25	2	27	2,345.25	188	2533
E	R6MM	RD18+D	4	252.91	25	2	27	6,322.75	506	6829
E	RD2M	RD<18M	3	8.57	27	0	27	231.39	0	231
E	RD5PM	RD18+S	2	106.11	17	3	20	1,803.87	318	2122
E	RD5PM	RD18+S	3	159.21	16	3	19	2,547.36	478	3025
E	RD5PM	RD18+S	4	43.43	16	3	19	694.88	130	825
E	RD6E	RD18+D	2	45.6	42	2	44	1,915.2	91	2006
E	RD6E	RD18+D	3	104.82	42	2	44	4,402.44	210	4612
E	RD6E	RD18+D	4	24.68	42	2	44	1,036.56	49	1086
E	RD6EM	RD18+D	2	41.98	23	4	27	965.54	168	1133
E	RD6EM	RD18+D	3	743.48	23	4	27	17,100.04	2974	20074
E	RD6EM	RD18+D	4	720.8	22	3	25	15,857.6	2162	18020
E	RD6MM	RD18+M	2	173.75	15	4	19	2,606.25	695	3301
E	RD6MM	RD18+M	3	474	14	4	18	6636	1896	8532
E	RD6MM	RD18+M	4	664.95	13	3	16	8,644.35	1995	10639
E	RD6PM	RD18+P	2	429.63	24	3	27	10,311.12	1289	11600
E	RD6PM	RD18+P	3	1443.78	23	2	25	33,206.94	2888	36094
E	RD6PM	RD18+P	4	1161.45	23	2	25	26,713.35	2323	29036
W	AL	HC	2	13.07	20	6	26	261.4	78	340
W	AL	HC	3	6.66	19	6	25	126.54	40	166
W	AL	HC	8	37.64	19	6	25	715.16	226	941
W	CPC5E	PINE18+D	3	359.12	36	0	36	12,928.32	0	12928
W	CPC5E	PINE18+D	8	262.96	34	0	34	8,940.64	0	8941
W	DR5DM	DR18+D	2	2164.94	61	2	63	132,061.3	4330	136391
W	DR5DM	DR18+D	3	926.52	59	2	61	54,664.68	1853	56518
W	DR5DM	DR18+D	4	343.63	56	2	58	19,243.28	687	19931
W	DR5EM	DR18+D	2	673.97	46	1	47	31,002.62	674	31677
W	DR5EM	DR18+D	3	104.69	44	0	44	4,606.36	0	4606
W	DR5EM	DR18+D	4	75.99	42	0	42	3,191.58	0	3192
W	GRBG	NON-TIMBER	2	93.69	0	0	0	0	0	0

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	JDSF Vegetation Type	Vegetation Management	Site Class	Acres	Conifer Volume (mbf/ac)	Hardwood Vol (mbf/ac)	All Species Vol (mbf/ac)	Conifer Total (mbf)	Hardwoods Total (mbf)	All Species Total (mbf)
W	GRBG	NON-TIMBER	3	38.46	0	0	0	0	0	0
W	GRBG	NON-TIMBER	8	17.21	0	0	0	0	0	0
W	GSEL	GSEL	1	7.98	65	0	65	518.7	0	519
W	GSEL	GSEL	2	1,285.99	62	0	62	79,731.38	0	79731
W	GSEL	GSEL	3	75.53	60	0	60	4,531.8	0	4532
W	HC3E	HC<18D	2	95.97	39	5	44	3,742.83	480	4223
W	HC3E	HC<18D	3	59.76	39	5	44	2,330.64	299	2629
W	HC3E	HC<18D	4	17.05	38	5	43	647.9	85	733
W	HR3E	MC<18D	2	461.23	42	6	48	19,371.66	2767	22139
W	HR3E	MC<18D	3	124.22	40	6	46	4,968.8	745	5714
W	HR3E	MC<18D	4	324.65	39	5	44	1,2661.35	1623	14285
W	MC5DM	DR18+D	2	37.45	50	0	50	1,872.5	0	1873
W	MC5DM	DR18+D	3	113.97	48	0	48	5,470.56	0	5471
W	PYGMY	PYGMY	8	612.67	1	0	1	612.67	0	613
W	R6DM	RD18+D	1	25.08	66	2	68	1,655.28	50	1705
W	R6DM	RD18+D	2	2,055.62	64	2	66	131,559.7	4111	135671
W	R6DM	RD18+D	3	1,023.77	62	2	64	63,473.74	2048	65521
W	R6DM	RD18+D	4	79.07	60	1	61	4,744.2	79	4823
W	R6MM	RD18+M	1	22.62	69	3	72	1,560.78	68	1629
W	R6MM	RD18+M	2	2,362.49	66	2	68	155,924.3	4725	160649
W	R6MM	RD18+M	3	478.44	64	2	66	30,620.16	957	31577
W	R6MM	RD18+M	4	137.65	62	2	64	8,534.3	275	8810
W	RD1	RD<18	2	94.15	0	0	0	0	0	0
W	RD1	RD<18	3	16.35	0	0	0	0	0	0
W	RD2EO	RD<18D	2	26.76	27	1	28	722.52	27	749
W	RD2EO	RD<18D	3	33.83	27	1	28	913.41	34	947
W	RD2M	RD<18M	2	1,523.82	17	0	17	25,904.94	0	25905
W	RD2M	RD<18M	3	99.57	17	0	17	1,692.69	0	1693
W	RD3P	RD<18S	2	598.21	5	0	5	2,991.05	0	2991
W	RD3P	RD<18S	3	4.65	5	0	5	23.25	0	23
W	RD5PM	RD18+S	2	1,462.15	49	2	51	71,645.35	2924	74570
W	RD5PM	RD18+S	3	139.44	47	1	48	6,553.68	139	6693

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W	RD6DM	RD18+D	2	28.34	86	0	86	2,437.24	0	2437
W	RD6DM	RD18+D	3	76.05	85	0	85	6,464.25	0	6464
W	RD6DM	RD18+D	4	22	84	0	84	1,848	0	1848
W	RD6E	RD18+D	2	296.38	49	0	49	14,522.62	0	14523
W	RD6E	RD18+D	3	126.16	48	0	48	6,055.68	0	6056
W	RD6E	RD18+D	4	15.53	47	0	47	729.91	0	730
W	RD6EM	RD18+D	2	2,420.24	70	1	71	169,416.8	2420	171837
W	RD6EM	RD18+D	3	1,131.56	68	1	69	76,946.08	1132	78078
W	RD6EM	RD18+D	4	39.93	66	1	67	2,635.38	40	2675
W	RD6MM	RD18+M	2	800.36	33	2	35	26,411.88	1601	28013
W	RD6MM	RD18+M	3	223.8	32	2	34	7161.6	448	7609
W	RD6MM	RD18+M	4	231.42	31	2	33	7,174.02	463	7637
W	RD6PM	RD18+S	1	119.6	55	1	56	6,578	120	6698
W	RD6PM	RD18+S	2	6,449.97	53	1	54	341,848.4	6450	348298
W	RD6PM	RD18+S	3	2,397.05	51	1	52	122,249.6	2397	124647
W	RD6PM	RD18+S	4	152.37	50	1	51	7,618.5	152	7771
				48,652				2,002,685	90577.72	2093263.22

Forest Growth and Yield

The Draft Forest Management Plan relies on growth and yield projections completed by CDF and presented in the Option "A" document submitted with Timber Harvesting Plans. The following procedures were used. Forest growth projections are based on the 1997 timber inventory that is grown and harvested over time. Projections are completed for land type polygons that based on vegetation strata and management considerations. The resulting growth projection represents the expected future conditions that will result from applying one silvicultural prescription to a particular land type over time. The set of all possible growth trajectories for all silvicultural prescriptions for each land type becomes the pool of candidate prescriptions. The forest-planning model assigns one prescription from this pool to each land type, thus creating a management alternative for the Forest. 17,101 different growth projections were created in the growth projection stage of the analysis.

In order to analyze the effects of successive generations of stands on the same site, it is necessary to project forest development out for a sufficiently long time to capture conditions likely to result from a given management direction applied consistently over time. The projection period used analysis was 120 years.

The growth, harvest, and yield models have been integrated into a single computer simulator that makes it feasible to examine large numbers of complex management scenarios. This simulator is referred to as FREIGHTS (Forest Resource Inventory, Growth, and Harvest Tracking System). Dr. Bruce Krumland of Landring, Inc developed the CATS model used within FREIGHTS to project timber growth and yield for the JDSF's stands. This model is similar to the CRYPTOS computer model developed earlier by Krumland and Wensel.

FREIGHTS grows each inventory plot individually from the start of one growth period to the beginning of the next successive growth period. Individual plot simulation results are then merged into an average stand condition. A growth period of one decade was used. Growth and yield information is normally reported for the "average" condition of each period, normally the mid-point of that period, just after any harvests or plantings. Some yields are reported for the beginning of the period. All plots are then aggregated to arrive at periodic stand statistics. This procedure avoids the risk of bias associated with plot aggregation. All harvests and regeneration are assumed to take place at the midpoints of projection periods.

CDF found that initial growth simulations with the FREIGHTS model with default calibration coefficients resulted in over estimation of growth when long-term projections under conservative silvicultural prescriptions with few harvest entries were modeled. This assessment was made based on JDSF foresters' local experience and published yield tables (Lindquist and Palley 1963). The FREIGHTS growth model was calibrated to a lower growth rate using a stand density index (SDI) approach (Stage 1983). It was based on the observation that when stand density approached a given percentage of maximum stand density as defined by Reineke (1933), mortality will occur, thereby reducing stand density and growth rate. Inducing mortality at 80 percent of the maximum stand density index produced long-term growth trajectories that corresponded to local evidence and the reviewed literature.

The SDI and maximum SDI were calculated for each land type for each growth period based on basal area weighted by species (Daniel, Helms and Baker 1979). If the SDI exceeded 80 percent of the maximum SDI, mortality was simulated as thinning from below in the smallest crown ratios until SDI of the stand was 80 percent of the maximum SDI.

The resulting growth trajectories proved to closely match observed growth rates on the Forest under the proposed management as well as evidence in the reviewed literature (Lindquist and Palley 1963).

As part of the analysis for this project, Jim Lindquist and Jerry Allen completed an independent review of the growth and yield information. Dale Thornburgh evaluated late successional forest development under alternatives B, C1, D, and E. The findings from these reviews have been incorporated into the impacts analysis section of the Timber Section.