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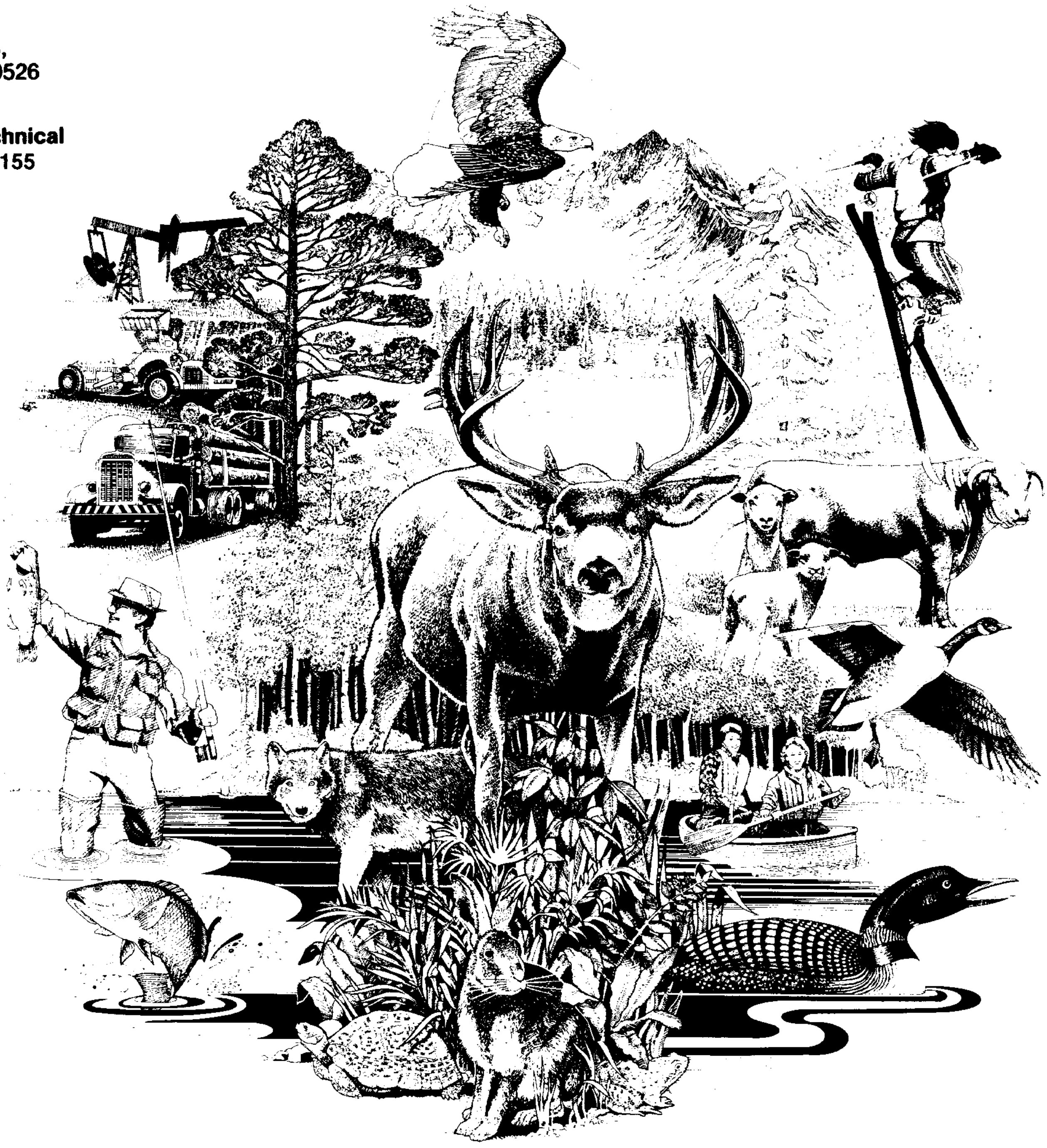
Documentation of the National Forest System Resource Interactions Model

Tony Baltic and John Hof



Abstract

The National Forest System Resource Interactions Model is an upper level linear programming model developed to aid in the analysis of multiresource interactions for the 1989 RPA National Assessment. This report documents the development and structure of this linear programming model, emphasizing its multilevel nature and the data requirements for such an approach. The resolution of data deficiencies, a major problem in applying such a multilevel optimization approach, also is examined.

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Information on resource interactions has been identified in the provisions of the legislation (the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) as amended by the National Forest Management Act of 1976 (NFMA)) as an essential component of national renewable resource assessments. However, estimation of resource interactions is very complex, especially when several resource outputs are involved over a large geographical area, such as the National Forest System (or just one National Forest System Region). After the completion of two national assessments, quantitative information on renewable resource interactions is still very limited. One of the major conclusions of the chapter on Multiple Resource Interactions in the 1979 Assessment (USDA Forest Service 1981) was:

> At the present time, knowledge of these interactions is limited and should be the focus of increased attention from the forestry research community. The accuracy of any modeling efforts to quantify these resource interactions will be limited by the understanding of both the biology and economics of multiresource production.

In the research needs chapter of the same Assessment, it was stated:

> Information on physical responses of forest and range land and the associated waters to management practices is still inadequate and especially so for multiresource interactions. The effort now going into describing and measuring the responses of these resources to management practices must be greatly expanded to provide the information necessary for efficient administration and management of forest and range lands.

In these discussions of resource interactions, investment and environmental impacts are explicitly included as an integral part of the analysis.

This report documents the development and structure of a National Forest System Resource Interactions Model. The model was developed to respond to the legislative provisions and assessment of research needs, and represents the present level of applicable technological development.

STRUCTURE OF THE MODEL

The multilevel resource interactions analysis utilizes upper level linear programming (LP) models to develop technically efficient regional production possibilities. Discrete management alternatives generated by the local (forest) level planning LP models (Johnson et al. 1986a, 1986b, 1986c, 1986d; Kelly et al. 1986; Kent et al. 1985; Robinson et al. 1986) are used in the upper level models as the decision variables for quantifying resource interactions. Regional level results from this analysis may be integrated into a national level renewable resource planning process. Bartlett (1974) and Wong (1980) did much of the early work in developing this approach. Hof and Pickens (1986) developed the details of this approach and tested it in a case study.

Table 1 shows an abbreviated version of the upper level model. In this example, only two forests (subscripted 1 and 2), two alternative management options (superscripted 1 and 2), and two forest outputs produced over two planning time periods (timber 1, timber 2, range 1, range 2) are included. The upper level models developed in this analysis cover five time periods and include as many as 9 forest outputs, 19 forests, and 190 management alternatives.

In table 1, X_1^1 through X_2^2 are 0-1 decision variables representing selection (1) or rejection (0) of the discrete management alternatives developed by the national forests in their lower level planning analyses. The column vectors of outputs associated with each management alternative are collected in the first six rows (accounting rows) of the model and are represented by the A_{ij} matrix of physical product/cost coefficients (for i=1,...6, j=1,...,4). For example X_1^1 represents the selection (X_1^1=1) or rejection (X_1^1=0) of the vector of outputs A_{i1} for i=1,...,4 and cost A_{i1} for i=5,6 associated with management alternative 1 in forest 1. For this study, the costs are adjusted for inflation but are not discounted. The 0-1 constraint rows force the selection of only one alternative for each forest planning unit by constraining the aggregate value of a forest's decision variables to equal ("type" column) a value of 1 ("RHS" column). However, the decision variables in this model are continuous, such that for any X, $0 \leq X \leq 1$. Therefore, the solution may include a partial selection of management alternatives, the combination of which satisfies the 0-1 constraints. For example, the management alternative options available in forest 1, X_1^1 and X_2^1, might solve with values of 0.6 and 0.4, respectively.

Each accounting row is associated with an analogous accounting column. The accounting columns represent the regional production outputs and costs associated with the chosen solution. Thus, columns aggregate the outputs/costs of the alternatives selected in the solution. The aggregate outputs are then transferred to the production constraint rows and constrained to meet specified targets. For example, first period timber output (T1) is constrained to be greater than or equal to ($\geq$ type) K_1 (RHS).

Table 1.--An abbreviated upper level (regional) model structure.

		Decision variables				Accounting columns							
		Forest 1		Forest 2		Outputs				Cost 1	Cost 2	Type	Right-hand side
		X^1_1	X^1_2	X^2_1	X^2_2	T1	T2	R1	R2	C1	C2		(RHS)
Accounting rows	Timber 1	A_{11}	A_{12}	A_{13}	A_{14}	-1						=	0
	Timber 2	A_{21}	A_{22}	A_{23}	A_{24}		-1					=	0
	Range 1	A_{31}	A_{32}	A_{33}	A_{34}			-1				=	0
	Range 2	A_{41}	A_{42}	A_{43}	A_{44}				-1			=	0
	Cost 1	A_{51}	A_{52}	A_{53}	A_{54}					-1		=	0
	Cost 2	A_{61}	A_{62}	A_{63}	A_{64}						-1	=	0
	Objective Function									1	1		MIN
0-1 Decision variable constraints	Forest 1	1	1									=	1
	Forest 2			1	1							=	1
Production constraints (targets)	Timber 1					1						≥	K_1
	Timber 2						1					≥	K_2
	Range 1							1				≥	K_3
	Range 2								1			≥	K_4

Aggregate costs are transferred to the objective function row, and their sum is minimized.

This model is structured to minimize cost of regional forest production subject to constraints that force the selection of only one management alternative (and its corresponding vector of outputs and costs) per forest and that bound (constrain) the aggregate production of forest outputs.

Upper Level Model Algebraic Formulation

The algebraic representation of this model, along with definitions for subscripts and variables is:

minimize: $$\sum_{t=1}^{5} \dot{C}_t \qquad \text{(objective function)}$$

subject to: $$\sum_{j=1}^{n} \sum_{i=1}^{m} P_{ijpt} X_{ij} - T_{pt} = 0 \;\forall\; p, t$$

(Production Accounting Rows-Outputs)

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ijt} X_{ij} - \dot{C}_t = 0 \;\forall\; t$$

(Production Accounting Rows-Costs)

$$\sum_{i=1}^{m} X_{ij} = 1 \;\forall\; j$$

(0-1 Constraint Rows)

$$T_{pt} \underset{<}{\geq} K_{pt} \;\forall\; p, t$$

(Production Constraint Rows)

$$X_{ij} \geq 0 \;\forall\; i, j$$
$$T_{pt} \geq 0 \;\forall\; p, t$$
$$\dot{C}_t \geq 0 \;\forall\; t$$

(Non-negativity Constraints)

Definition of Subscripts

- i Represents a management alternative from a lower level model.
- j Represents a lower level model (forest).
- t Represents the time period.
- p Represents the product outputs from the lower level models considered in each upper level model.
- m Represents the number of management alternatives in a lower level model.
- n Represents the number of lower level models.

Definition of Variables

X_{ij} = Management alternative i from lower level planning unit (forest) j.

P_{ijpt} = Output of product p for time period t from management alternative i of forest j (A-matrix).

C_{ijt} = Cost of management alternative i from forest j and time period t (also part of A-matrix).

T_{pt} = A variable to transfer the aggregate output of product p for time period t from the production accounting rows to the production constraint rows.

C^*_t = A variable to transfer the aggregate cost for time period t from the production accounting rows to the objective function.

K_{pt} = The production target for aggregate output of product p for time period t.

DESCRIPTION OF UPPER LEVEL MODEL FORMULATIONS

This section describes each of the variables represented by the column and row headings in the original LP upper level model formulations and the model parameters (matrix coefficients) in detail. The variables are organized in a coded format to enhance computational efficiency and interpretation of solution outputs.

Decision Variable Columns

The dichotomous (0-1) decision variables are represented by the coding R#/#/#. For example, R1/1/1 represents region 1/forest 1/alternative 1. Table 2 lists the forests, their assigned number, and the number of alternatives per forest by region. The table also identifies certain alternatives -- the No Action, Proposed, and RPA Alternatives -- by number and lists the code name for each forest represented in the 0-1 constraint rows that are analogous to the decision variable columns. The columns labeled DEIS and FEIS indicate the source of this forest production data, i.e., either the draft or final environmental impact statement, respectively.

The No Action, Proposed, and RPA Alternatives were specifically required by the NFMA. The No Action Alternative reflects the most likely condition expected if current management direction would continue unchanged. The RPA Alternative is designed to provide goods and services at levels assigned to a forest to meet its regionally-assigned share of national production goals (RPA targets). The Proposed Alternative is the alternative recommended for implementation as the forest plan. Each alternative in table 2 is fully described in the draft and/or final environmental impact statements (EIS) for each forest planning unit.

The alternatives considered were developed in response to legislation and regulations (NFMA, 36 CFR 219.12(f)), public issues, and management concerns. Each alternative represents a different management emphasis, which still maintains multiple-use constraints and an economic efficiency objective. The benchmark alternatives that maximize present net value PNV represent the optimum economic mix of outputs for a forest. Other benchmark alternatives were developed that established the maximum and minimum single resource output capability of a forest. These alternatives were not included in the resource interactions analysis, because a full set of output capabilities is not indicated for these alternatives. Finally, some additional alternatives were considered in the forest EIS's but then were eliminated from detailed analysis for reasons such as infeasibility of implementation, lack of responsiveness to public issues and/or management concerns, and violations of the NFMA. They were not included in this analysis for the same reasons.

Accounting Rows

The model tracks up to 9 outputs and cost over a 50-year planning horizon using five 10-year periods. Table 3 lists the outputs considered, their coding by planning period, their units of measurement, and the regional models in which each output is tracked. The model outputs were chosen based on a review of the EIS from each forest by region and the "initial data" set described below. Summary tables were utilized that indicated full and partial scheduling, and indicated every output/forest/scheduling combination that is reported in the EIS's. Analysis of the completed tables resulted in the decisions reported in table 3. It was intended that the outputs in table 3 represent the most consistently and fully reported of the range of outputs scheduled by each forest and region, and the outputs included were selected as the most appropriate data available for demonstrating resource interactions.

The 50-year planning horizon covers either the years from 1981 to 2030 or 1986-2035, depending upon when a region began its planning process. The planning horizon is noted in the "initial data" recording matrix for each forest (described below). Dispersed recreation outputs include wilderness recreation visitor days (RVD) and wildlife and fish user days (WFUD) and are recorded as projected use. If capacity is reported and use is unavailable, capacity is recorded. Region 1 is the only region where total dispersed recreation (REC) was sufficiently disaggregated to record motorized (RECM) and nonmotorized (RECNM) dispersed recreation separately.

Wildlife habitat improvements (HAB) are defined as projects undertaken directly for the benefit of wildlife (individual forests may target any one or combination of game, nongame, and endangered species). This output is reported in acres or acre equivalents and is recorded as acres (# ACRES). Either elk (ELK) or deer (DEER) is recorded as the management indicator species (MIS) in the data set. The MIS are considered representative of the species that inhabit the planning area of a forest and lower level forest planning focuses on these species in order to maintain viable populations of all existing native vertebrates. These wildlife outputs are recorded as potential (capacity) or projected populations (#ELK or #DEER). If both a winter and summer range population is reported, the larger of the two is recorded.

Table 2.--Decision variable coding.

Coding Example: R1/8/5=Region 1/Helena NF/Proposed Alternative

Region #	Forest	Forest code name	Forest #	# of alts.	No action alt. #	Proposed alt. #	RPA alt. #	DEIS	FEIS
1	Beaverhead	BEAVERHD	1	12	1	7	2	x	
1	Bitterroot	BITTERRT	2	10	6	4	1	x	
1	Clearwater	CLEARWTR	3	12	1	5	3	x	
1	Custer	CUSTER	4	17	5	9	2	x	
1	Deerlodge	DEERLDGE	5	14	1	12	3	x	
1	Flathead	FLATHEAD	6	19	7	11	2	x	
1	Gallatin	GALLATIN	7	11	1	7	4	x	
1	Helena	HELENA	8	11	1	5	2	x	
1	Idaho Panhandle	IDAHOPAN	9	13	8	11	1	x	
1	Lewis & Clark	LEWISCLK	10	17	1	12	2	x	
1	Lolo	LOLO	11	9	1	4	8	x	
1	Nezperce	NEZPERCE	12	30	1	6	4	x	
1	Kootenai	KOOTENAI	13	15	9	10	4	x	
2	Arapaho & Roosevelt	ARAPAHO	1	7	2	1	1		x
2	Bighorn	BIGHORN	2	8	2	1	3		x
2	Black Hills	BLACKHLS	3	10	6	1	10		x
2	Grand Mesa, Uncompahgre, Gunnison	GRANDMSA	4	9	2	1	3		x
2	Medicine Bow	MEDICINE	5	10	2	1	3		x
2	Nebraska	NEBRASKA	6	8	5	6	7		x
2	Pike & San Isabel	PIKE	7	5	2	1	3		x
2	Rio Grande	RIOGRDE	8	9	2	1	3		x
2	Routt	ROUTT	9	6	2	1	3		x
2	San Juan	SAN JUAN	10	10	6	8	5		x
2	Shoshone	SHOSHONE	11	6	1	4	6	x	
2	White River	WHITERVR	12	6	2	1	3		x
3	Apache-Sitgreaves	APACHE	1	6	6	1	5	x	
3	Carson	CARSON	2	7	2	1	3	x	
3	Cibola	CIBOLA	3	7	2	1	3		x
3	Coconino	COCONINO	4	8	2	1	3	x	
3	Coronado	CORONADO	5	6	2	1	3	x	
3	Gila	GILA	6	8	2	1	3	x	
3	Kaibab	KAIBAB	7	7	2	1	3	x	
3	Lincoln	LINCOLN	8	6	2	1	3	x	
3	Prescott	PRESCOTT	9	7	2	1	3	x	
3	Santa Fe	SANTA FE	10	7	3	1	2	x	
3	Tonto	TONTO	11	9	4	9	3		x
4	Ashley	ASHLEY	1	9	1	2	5	x	
4	Caribou	CARIBOU	2	15	1	10	7		x
4	Challis	CHALLIS	3	11	1	11	2	x	
4	Dixie	DIXIE	4	8	1	2	7	x	
4	Fishlake	FISHLAKE	5	11	8	11	5	x	
4	Humboldt	HUMBOLDT	6	11	6	9	5	x	
4	Manti-LaSal	MANTI	7	8	1	8	4	x	
4	Payette	PAYETTE	8	12	1	10	6	x	
4	Salmon	SALMON	9	12	1	12	4	x	
4	Sawtooth	SAWTOOTH	10	12	1	2	5	x	
4	Targhee	TARGHEE	11	8	4	3	2		x
4	Toiyabe	TOIYABE	12	9	1	6	4	x	
4	Wasatch-Cache	WASATCH	13	8	1	8	2		x
4	Bridger-Teton	BRIDGER	14	10	4	10	3	x	
5	Angeles	ANGELES	1	9	2	1	3	x	
5	Cleveland	CLEVE	2	7	2	1	3		x
5	Eldorado	ELDORADO	3	9	2	1	1	x	
5	Inyo	INYO	4	6	2	1	3	x	

(Continued)

Table 2.--(continued).

Coding Example: R1/8/5=Region 1/Helena NF/Proposed Alternative

Region #	Forest	Forest code name	Forest #	# of alts.	No action alt. #	Proposed alt. #	RPA alt. #	DEIS	FEIS
5	Lassen	LASSEN	6	9	2	1	3	x	
5	Los Padres	LOS PADR	7	10	2	1	7	x	
5	Mendocino	MENDOCINO	8	8	2	1	3	x	
5	Plumas	PLUMAS	10	6	2	1	3	x	
5	San Bernardino	SAN BERN	11	6	2	1	3	x	
5	Sequoia	SEQUOIA	12	10	2	1	3	x	
5	Shasta-Trinity	SHASTA	13	7	2	1	3	x	
5	Sierra	SIERRA	14	10	2	1	3	x	
5	Six Rivers	SIX RIV	15	8	2	1	3	x	
5	Stanislaus	STANISLA	16	8	3	1	4	x	
5	Tahoe	TAHOE	17	11	2	1	3	x	
8	Alabama	ALABAMA	1	6	1	6	5	x	
8	Chattahoochee Oconee	CHATOCON	2	6	3	6	2		x
8	Cherokee	CHEROKEE	3	6	1	6	2	x	
8	Croatan-Uwharrie	CROATUWH	4	10	1	5	2	x	
8	Daniel Boone	DANBOONE	5	12	1	10	2	x	
8	Florida	FLORIDA	6	9	2	7	1	x	
8	Francis Marion	FRANCISM	7	8	1	5	2		x
8	George Washington	GEOWASH	8	8	1	8	7	x	
8	Jefferson	JEFFERSN	9	11	2	1	10		x
8	Kisatchie	KISATCH	10	11	1	4	3		x
8	Mississippi	MISSIPPI	11	8	2	5	6		x
8	Nantahala-Pisgah	NANPISG	12	10	1	7	2	x	
8	Ouachita	OUACHITA	13	10	1	4	2	x	
8	Ozark-St. Francis	OZARKSTF	14	8	8	4	7	x	
8	Sumter	SUMTER	15	11	1	10	2		x
8	Texas	TEXAS	16	12	5	10	3	x	
9	Allegheny	ALEGHENY	1	7	2	4	2	x	
9	Chequamegon	CHEQUAM	2	11	1	7	8	x	
9	Chippewa	CHIPPEWA	3	8	2	3	3	x	
9	Green Mountain	GREEN MT	4	6	1	4	2	x	
9	Hiawatha	HIAWATHA	5	7	5	7	4	x	
9	Hoosier	HOOSIER	6	8	1	4	4		x
9	Huron-Manistee	HURON	7	9	3	7	7	x	
9	Mark Twain	MARK TWN	8	7	7	5	5	x	
9	Monongahela	MONONGA	9	5	1	5	4	x	
9	Nicolet	NICOLET	10	9	1	5	2	x	
9	Ottawa	OTTAWA	11	10	2	7	6	x	
9	Shawnee	SHAWNEE	12	10	2	4	8	x	
9	Superior	SUPERIOR	13	8	1	6	5	x	
9	Wayne	WAYNE	14	7	1	3	5	x	
9	White Mountain	WHITE MT	15	5	1	5	2	x	

Table 3.–Forest outputs.

Output	Accounting rows code (by period 1-5)	Accounting columns code (by period 1-5)	Measurement units (aver. annual)	Forest region reporting
Dispersed motorized recreation	RECM1 RECM2 RECM3 RECM4 RECM5	RECM1P RECM2P RECM3P RECM4P RECM5P	MRVD	1

(Continued)

Table 3.--(continued)

Output	Accounting rows code (by period 1-5)	Accounting columns code (by period 1-5)	Measurement units (aver. annual)	Forest region reporting
Dispersed nonmotorized recreation	RECNM1 RECNM2 RECNM3 RECNM4 RECNM5	RECNM1P RECNM2P RECNM3P RECNM4P RECNM5P	MRVD	1
Total dispersed recreation	REC1 REC2 REC3 REC4 REC5	REC1P REC2P REC3P REC4P REC5P	MRVD	2,3,4,5,8,9
Wildlife habitat improvement	HAB1 HAB2 HAB3 HAB4 HAB5	HAB1P HAB2P HAB3P HAB4P HAB5P	# ACRES	1,2,3,4,5,8,9
Elk	ELK1 ELK2 ELK3 ELK4 ELK5	ELK1P ELK2P ELK3P ELK4P ELK5P	# ELK	1,2,3,4
Deer	DEER1 DEER2 DEER3 DEER4 DEER5	DEER1P DEER2P DEER3P DEER4P DEER5P	# DEER	5,8
Fish	FISH1 FISH2 FISH3 FISH4 FISH5	FISH1P FISH2P FISH3P FISH4P FISH5P	MFISH or MLBS	1,5
Range	RNG1 RNG2 RNG3 RNG4 RNG5	RNG1P RNG2P RNG3P RNG4P RNG5P	MAUM	1,2,3,4,5,8,9
Timber	TMBR1 TMBR2 TMBR3 TMBR4 TMBR5	TMBR1P TMBR2P TMBR3P TMBR4P TMBR5P	MMCF	1,2,3,4,5,8,9
Water Yield	WTR1 WTR2 WTR3 WTR4 WTR5	WTR1P WTR2P WTR3P WTR4P WTR5P	MACFT	1,2,3,4,5,8
Sediment Yield	SDMT1 SDMT2 SDMT3 SDMT4 SDMT5	SDMT1P SDMT2P SDMT3P SDMT4P SDMT5P	MTONS	1,2,3,4,5,8
Cost	COST1 COST2 COST3 COST4 COST5	COST1P COST2P COST3P COST4P COST5P	MM1978$ or MM1982$	1,2,3,4,5,8,9

Fish (FISH) are recorded either by potential population (MFISH) or weight (MLBS), the metric being consistent for any single region. Fish are reported in several different categories; non-wilderness fish in streams, fish in streams, catchable trout in streams, anadromous, etc. These are aggregated into one category, i.e., fish, for the purposes of this analysis. Range (RNG) is reported as projected or permitted grazing use and these are recorded in thousands of animal unit months (MAUM). If capacity is reported and use data is unavailable, capacity is recorded.

The timber output (TMBR) recorded includes allowable sale plus any additional products such as fuelwood, posts and poles, or biomass. Allowable sale is the quantity of timber that may be sold from the area of suitable land covered by the forest plan for a time period specified in the plan. If allowable sale is not reported, programmed sales offered is used. Programmed sales offered is allowable sale plus an unregulated volume. Timber is recorded in millions of cubic feet (MMCF).

Water (WTR) is recorded as total projected yield in thousands of acre feet (MACFT) and sediment (SDMT) is recorded as total projected yield in thousands of tons (MTONS).

Costs (COST) recorded include operating and maintenance and capital investment costs (these come from appropriated funds), timber purchaser road credits (for roads built by timber purchasers), and forest fire fighting funds. The costs recorded exclude allocated and cooperator funds. Allocated funds are federal funds appropriated for an agency or program outside the Forest Service but applied to Forest Service projects (for example, land acquisitions using Land and Water Conservation funds). Cooperator funds cover non-federal costs such as State Fish and Game expenditures for projects on Forest Service lands. All of the outputs and costs are recorded by period on an average annual basis.

Production Coefficients (A-Matrix)

The column vectors of physical production and cost coefficients quantify the mix of outputs and cost associated with particular management alternatives and forests. The individual outputs and cost from each column vector are collected in the accounting rows. These column and row vectors represent the A-matrix of technological coefficients in the upper level LP models. These coefficients were extracted either directly or indirectly from the schedules of outputs reported, by alternative, in the EIS of each national forest.

Indirect methods of data collection were required because not all of the model outputs in table 3 were fully scheduled in the EIS's. In such cases, the missing data were either obtained from a forest or regional planning team (from other forest planning records or the teams best estimate) or were estimated using the data available with regression, interpolation, or other techniques (discussed in the section on methodologies for dealing with data deficiencies). Many output measurement units were not consistent with those in table 3. Factors for conversions to common units either were obtained from the forests or regions, or were estimated based on extrapolations from the data available.

In some cases, the data available were insufficient to warrant any estimations, and the affected alternatives were eliminated from the analysis. The most frequently eliminated alternatives were benchmark alternatives which displayed the most data omissions. The objective was to minimize the amount of estimated data, but at the same time preserve a wide range of alternatives.

The remainder of this section examines, in detail, the initial data recording procedure, and the methodologies for dealing with data deficiencies. To conserve space and avoid redundancy, it will not cover every deficiency or every alternative output vector in the entire set considered. A comprehensive illustration using the Bridger-Teton National Forest in Region 4 is presented. In addition, examples of other distinct methodologies used in the direct recording and estimation of production data are reviewed.[2]

Initial Data Recording

Production coefficients by forest were recorded manually in a matrix format. Table 4 shows the matrix format and the initial nonhomogenous recording of data for the Bridger-Teton National Forest.[3] In this particular EIS, the primary and benchmark alternatives were scheduled (except for cost) in separate (but similar) tables, and two separate schedules for costs (primary and benchmark) also were reported. Most forest EIS's have schedules of resource activity outputs and costs similar to those for the Bridger-Teton. However, some EIS's display separate output schedules for each alternative; and there were many cases where the data recording relied on singular output schedules reported in the resource descriptions or environmental consequences sections of the EIS. There also were instances where data necessary for the direct derivation or estimation of production coefficients were found within the text.

Note that in the data recording matrix (table 4), the rows represent outputs by period and the columns represent planning alternatives. The number that heads each column is the coding number for that alternative in the decision variable code (for example, the proposed alternative from the Bridger-Teton would be identified by the decision variable code R4/14/10--see table 2). The number directly under the column heading number is the identification given to each alternative in the EIS itself. Alternative 11 and 12 are the maximum PNV benchmark alternatives and are identified by adding the prefix "BM-" to the number assigned in the EIS. Finally, the RPA, No Action, and Proposed Alternatives are identified in the recording process.

The data in the initial recording either were copied or derived directly from the schedules of outputs in the EIS. For example, wildlife habitat improvement (HAB) and range (RNG) data for the Bridger-Teton NF were taken directly from the schedules in

[2]Complete information about all of the technological coefficients in the A-matrix for each regional model is documented in notes maintained in research unit RM-4851 at the Rocky Mountain Forest and Range Experiment Station.

[3]The schedules of outputs in the Bridger-Teton National Forest Draft Environmental Impact Statement (EIS), from which these data were obtained, are on pages II-28 through II-44 and B-III-5 through B-III-26.

Table 4.–Bridger-Teton National Forest production coefficients -- initial data recording (nonhomogenous).

			Alternatives											
			1	2	3	4	5	6	7	8	9	10	11	12
Period	Units	Output	1	2	3	4	5	6	7	8	9	10	BM-2	BM-3
					RPA	No Action						Proposed	Max PNV	
													Mkt. outputs	All outputs
		REC												
1986 1995	MRVD's		1795.7	1797.3	1915.8	1853.1	1854.8	1880.4	1812.6	1814.9	1835.1	1848.8	1787.6	1850.5
1996 2005			2546.1	2546.5	2620.9	2526.4	2528.2	2563.5	2463.5	2467.1	2497.1	2513.9	2540.1	2516.2
2006 2015			3214.7	3214.2	3241.5	3117.3	3119.1	3161.9	3035.6	3035.9	3075.5	3098.5	3218.4	3101.1
2016 2025			4035.8	4034.6	4017.8	3859.2	3860.7	3914.5	3753.8	3755.9	3806.2	3831.0	4041.2	3834.4
2026 2035			4744.8	4743.4	4681.3	4489.1	4490.6	4553.1	4362.3	4362.0	4423.0	4453.6	4752.0	4457.2
		HAB												
1	#ACRES		0	0	301	672	672	330	682	2299	672	1008	0	2866
2			0	0	301	672	672	331	682	2299	672	1008	0	2866
3			0	0	301	672	684	331	694	2299	678	1020	0	2883
4			0	0	301	672	713	331	697	2371	749	1117	268	2889
5			0	0	426	966	966	466	996	2608	966	1406	268	3126
		ELK												
1	#ELK													
2														
3														
4														
5			13000	13500	18500	17800	17500	20000	21000	21500	21000	21500		
		RNG												
1	MAUM		263.3	263.3	257.8	255.2	255.2	255.9	255.2	261.9	255.2	255.2	238.9	255.2
2			273.1	273.1	260.2	257.5	257.5	258.3	257.5	262.8	257.5	257.5	239.1	257.5
3			282.5	282.5	261.7	258.9	258.9	259.8	258.9	263.3	258.9	258.9	239.2	258.9
4			291.7	291.7	263.4	260.4	260.5	261.5	260.5	264.0	260.4	260.5	239.2	260.4
5			300.7	300.7	266.9	263.8	264.0	264.9	264.0	265.5	263.9	264.0	239.9	263.9
		TMBR												
1	MMCF													
2														
3														
4														
5														
		WTR												
1	MACFT		5740.3	5735.5	5733.6	5730.6	5730.6	5728.4	5730.3	5726.1	5728.0	5728.9	5743.7	5728.2
2			5771.4	5756.0	5749.0	5739.6	5740.0	5733.2	5738.9	5726.1	5733.6	5735.3	5782.4	5732.6
3			5792.1	5768.9	5757.3	5746.1	5743.3	5735.9	5743.4	5726.1	5739.2	5740.5	5806.2	5735.9
4			5793.1	5771.2	5757.2	5749.7	5745.3	5735.9	5743.5	5726.1	5740.8	5743.1	5807.0	5737.8
5			5783.7	5771.4	5756.3	5750.7	5744.2	5735.8	5745.4	5726.1	5740.7	5744.0	5799.9	5740.5
		SDMT												
1	MTONS													
2														
3														
4														
5														

(Continued)

Table 4.--(continued).

			Alternatives											
			1	2	3	4	5	6	7	8	9	10	11	12
Period	Units	Output	1	2	3 RPA	4 No Action	5	6	7	8	9	10 Proposed	BM-2 Max PNV Mkt. outputs	BM-3 Max PNV All outputs
		COST												
1	MM1978$		7.90	6.60	6.16	5.27	5.23	4.53	5.95	3.16	4.52	4.95	8.10	4.77
2			8.79	7.96	6.17	4.88	4.92	4.73	6.01	3.19	5.15	5.56	9.35	5.30
3			9.02	7.37	6.45	5.74	5.03	4.93	6.14	3.23	5.33	6.01	9.21	5.63
4			8.01	7.52	6.76	5.61	4.95	5.12	6.30	3.28	5.51	6.18	8.99	6.02
5			7.22	7.54	6.74	5.69	5.02	5.41	7.12	3.38	5.89	6.48	7.97	6.62

the EIS, while dispersed recreation (REC) and water yield (WTR) data are fully reported in the EIS tables, but in a disaggregated state. Table II-17 on page II-125 of the Bridger-Teton EIS disaggregates total recreation and indicates that dispersed recreation includes wildlife and fish user days (WFUD) but not wilderness recreation. Thus, dispersed and wilderness recreation are summed to derive the total dispersed recreation recorded in table 4. The water yield reported in the EIS is not total yield but the increase over "natural yield." However, the natural level is implicitly revealed in this table (see water meeting quality goals, alternative 8). Therefore, total water yield is derived directly from the schedule by adding water yield increases to this natural level. Cost also is fully scheduled in the EIS, but in 1982 dollars. It is a straightforward procedure to convert these costs to 1978 dollars. The reported cost is simply multiplied by the appropriate price deflator 150.42/207.38. The only other data that could be recorded directly from the EIS was the partial reporting for elk (ELK). This data came from a bar graph on page II-130 of the EIS.

This initial record of production coefficients is referred to as the nonhomogenous data set, because it is not only incomplete with respect to the outputs to be modeled (table 3) but also incommensurate between forests.

Methodologies for Dealing with Data Deficiencies

After the initial recording of production coefficients, data deficiencies and inconsistencies could be identified. For example, inconsistencies in the reporting of elk, timber, sediment and cost were noted for the Bridger-Teton National Forest as follows. Elk was not reported in periods 1 through 4 for the primary alternatives and not at all for the benchmarks. Timber was made up of three separately reported components; allowable sale, fuelwood, and other products. Allowable sale was fully reported in millions of cubic feet (MMCF) for all alternatives. Other products and fuelwood also were fully reported for all the alternatives, but were reported in board feet (BF), and a BF to CF conversion ratio was not given. Sediment yield was not reported. However, a natural sediment rate of 195,000 tons/yr was reported (page IV-65 of the EIS) and it was indicated in the text that the yield over natural was scheduled in other forest records. Finally, the inclusion or exclusion of allocated funds in the cost figures could not be ascertained from the EIS, although costs were otherwise fully reported and could be directly recorded. In such cases, it was assumed that allocated funds were not included and reported costs were matriculated in the initial recording process. However, if the forest planning team was contacted to obtain other data, they were also asked about allocated funds. Therefore, the disposition of allocated funds was always noted in this process of defining deficiencies.

The next step in completing the recording of a forest's production data set involved contacting the forest planning team to see if any of the missing data was available from other planning records, or if the team could provide their best estimates. In the case of the Bridger-Teton National Forest, the planning team was able to provide the following data: first period elk for primary alternatives, BF to CF conversion ratios for both fuelwood and other products (posts and poles), and the schedule of sediment yield over natural for the primary alternatives. The Forest planning team also indicated that allocated funds were insignificant.

These additional data obtained from a forest either were transferred directly to the data recording matrix or were transferred after appropriate manipulations. For example, only the elk data provided by the Bridger-Teton could be directly recorded. BF to CF conversion ratios supplied by the forest were applied to the timber outputs reported in BF before all timber outputs could be aggregated and recorded and sediment yields over natural were added to the natural yield reported to obtain the total yield to be recorded.

Finally, estimation strategies were formulated and implemented for data deficiencies still existing after forest contact and the subsequent transformation and recording of data provided by the forest planning team. For the Bridger-Teton, these data gaps included elk in periods 2, 3, and 4 for the primary alternatives,

Table 5.–Bridger-Teton National Forest production coefficients -- complete data recording (homogenous).

			Alternatives									
			1	2	3	4	5	6	7	8	9	10
Period	Units	Output	1	2	3 RPA	4 No action	5	6	7	8	9	10 Proposed
		REC										
1	MRVD		1795.7	1797.3	1915.8	1853.1	1854.8	1880.4	1812.6	1814.9	1835.1	1848.8
2			2546.1	2546.5	2620.9	2526.4	2528.2	2563.5	2463.5	2467.1	2497.1	2513.9
3			3214.7	3214.2	3241.5	3117.3	3119.1	3161.9	3035.6	3035.9	3075.5	3098.5
4			4035.8	4043.6	4017.8	3859.2	3860.7	3914.5	3753.8	3755.9	3806.2	3831.0
5			4744.8	4743.4	4681.3	4489.1	4490.6	4553.1	4362.3	4362.0	4423.0	4453.6
		HAB										
1	#ACRES		0	0	301	672	672	330	682	2299	672	1008
2			0	0	301	672	672	331	682	2299	672	1008
3			0	0	301	672	684	331	694	2299	678	1020
4			0	0	301	672	713	331	697	2371	749	1117
5			0	0	426	966	966	466	996	2608	966	1406
		ELK										
1	#ELK		17800	17800	17800	17800	17800	17800	17800	17800	17800	17800
2			16500	16725	17975	17800	17725	18350	18600	18725	18600	18725
3			15400	15650	18150	17800	17650	18900	19400	19650	19400	19650
4			14200	14575	18325	17800	17575	19450	20200	20575	20200	20575
5			13000	13500	18500	17800	17500	20000	21000	21500	21000	21500
		RNG										
1	MAUM		263.3	263.3	257.8	255.2	255.2	255.9	255.2	261.9	255.2	255.2
2			273.1	273.1	260.2	257.5	257.5	258.3	257.5	262.8	257.5	257.5
3			282.5	282.5	261.7	258.9	258.9	259.8	258.9	263.3	258.9	258.9
4			291.7	291.7	263.4	260.4	260.5	261.5	260.5	264.0	260.4	260.5
5			300.7	300.7	266.9	263.8	264.0	264.9	264.0	265.5	263.9	264.0
		TMBR										
1	MMCF		43.22	28.70	22.73	13.37	13.37	6.88	12.12	0	5.58	8.54
2			53.91	34.28	24.30	13.37	14.70	7.93	14.17	0	12.06	11.44
3			55.60	35.58	24.54	20.89	15.44	7.93	14.17	0	12.06	15.06
4			44.55	36.50	24.38	20.75	15.30	7.91	14.41	0	11.94	15.06
5			35.59	36.52	24.54	20.89	15.44	8.17	20.39	0	12.60	15.06
		WTR										
1	MACFT		5740.3	5735.5	5733.6	5730.6	5730.6	5728.4	5730.3	5726.1	5728.0	5728.9
2			5771.4	5756.0	5749.0	5739.6	5740.0	5733.2	5738.9	5726.1	5733.6	5735.3
3			5792.1	5768.9	5757.3	5746.1	5745.3	5735.9	5743.4	5726.1	5739.2	5740.5
4			5793.1	5771.2	5757.2	5749.7	5745.3	5735.9	5743.5	5726.1	5740.8	5743.1
5			5783.7	5771.4	5756.3	5750.7	5744.2	5735.8	5745.4	5726.1	5740.7	5744.0
		SDMT										
1	MTONS		212.83	212.83	202.24	201.80	201.80	198.63	198.33	197.02	198.50	198.05
2			213.02	213.02	203.15	201.50	201.50	198.25	198.53	197.10	198.07	198.42
3			213.62	213.62	202.41	201.43	201.43	198.22	198.38	196.90	197.96	198.31
4			215.55	215.55	202.65	201.01	201.01	198.46	198.64	197.16	198.11	198.57
5			214.73	214.73	202.23	200.38	200.38	198.03	198.18	196.92	197.92	198.12
		COST										
1	MM1978$		7.90	6.60	6.16	5.27	5.23	4.53	5.95	3.16	4.52	4.95
2			8.79	7.96	6.17	4.88	4.92	4.73	6.01	3.19	5.15	5.56
3			9.02	7.37	6.45	5.74	5.03	4.93	6.14	3.23	5.33	6.01
4			8.01	7.52	6.76	5.61	4.95	5.12	6.30	3.28	5.51	6.18
5			7.22	7.54	6.74	5.69	5.02	5.41	7.12	3.38	5.89	6.48

the full schedule of elk for the benchmark alternatives, and the full schedule of sediment yield for the benchmarks. A straightforward interpolation between period 1 and 5 data provided the estimates for elk under the primary alternatives. There was no acceptable method available for estimating the full schedules of elk or sediment yield in the benchmark alternatives. Therefore, a judgment was made to eliminate the benchmark alternatives from the analysis because of insufficient data.

Table 5 represents the completed homogenous data matrix for the Bridger-Teton National Forest. The complete production data set for a forest is referred to as the homogenous set since the recorded production data are analogous for all forests in a region, and, therefore, suitable for interactions analysis. Appendix 1 shows the entire procedure for recording the homogenous set of production coefficients for the Bridger-Teton National Forest as it is documented in the study notes. This documentation format, used for each forest planning unit in the National Forest System, encompasses the following: the initial data available from the forest EIS, identification of data deficiencies, data obtained from forest contact, disposition of data provided by the forest, identification of deficiencies remaining after forest contact, techniques used to estimate missing data, and any elimination of alternative output vectors. Table 6 is a summary of the disposition of the entire set of production coefficients in the Region 4 model by forest and output.

To conserve space and still provide sufficient documentation as to the range of methodologies employed in this study, a format similar to Appendix 1 is utilized to present examples from other forests and regions. These examples cover the distinct methodologies that were utilized for the direct derivation and/or indirect estimation of dispersed recreation, wildlife habitat improvement, elk, deer, fish, range, timber, water yield, sediment yield, and cost in Appendix 2.

The general approach taken for handling data deficiencies when simple unit conversions, interpolations, and extrapolations were not feasible, was to apply simple linear regression to use some explanatory variable to predict the missing forest production data (mainly sediment and water yields). A straight-line linear model in two variables is expressed as y=a+bx, where y is the dependent variable, x is the independent variable, a is the y-intercept, and b is the slope. Such a line can be fitted to a sample of known data points (x,y), and the resulting equation is used to estimate an unknown dependent variable, y, given a known predictor variable, x. For example, assume that sediment yield for a particular forest is only partially scheduled. Further assume that road construction bears a direct linear relationship to the amount of total sediment yield on the forest and that this output is fully scheduled. The available sediment data and the analagous portion of road construction data were then used to fit a linear equation. This equation was then used in conjunction with the remaining road construction data to predict the unscheduled sediment yields. It would be useful to know the strength of the relationship between sediment yield and road construction in this problem. If the relationship is very weak or nonexistent, we would want to explore other approaches to the problem of estimating the unscheduled sediment yield data. The correlation coefficient (r) was used for this purpose.

Road construction, the independent variable generally used in the estimation of sediment yield, is assumed not to have carryover effects on the sediment yields in succeeding decades --assuming most roads will be closed and stabilized, the carryover effect on sediment yield is significantly diminished within 5 to 7 years. Conversely, timber harvesting, the activity with the greatest effect on water yield, is assumed to have long-term effects. In this study, a percentage of allowable sale is carried over from preceding to succeeding decades to account for this effect. The carryover is based on an assumed percentage carryover of water yield from the initial harvest through the 1st, 2nd, 3rd, and 4th decades of 75%, 66%, 50%, and 33%, respectively. These carryover percentage estimates resulted from discussions with several forest system hydrologists and are based on their professional judgments. The allowable sale data carried over are called allowable sale equivalents, because they are added to the current year's allowable sale for purposes of predicting current water yield. Thus, allowable sale equivalents encompass the carryover of water yield still being generated from prior years' harvest activities. Appendix 2 presents specific examples of these calculations, as well as the more straightforward calculations for outputs other than water yield and sediment yield.

Not all of the forest planning units had completed their EIS's by the time the models in this study became functional. Thus, the Boise NF in Region 4 and the Klamath and Modoc NFs in Region 5 are not included in their respective regional models, and Region 6 is not yet included in the analysis, because most of its forests' EIS's are unavailable. Furthermore, most of the production data available came from draft environmental impact statements (DEIS), the initial planning document submitted for public review and subject to revision before the final environmental impact statements (FEIS) were prepared. Table 2 includes two columns indicating the source of production data for each forest planning unit, the DEIS or FEIS. Finally, there are 16 forest planning units whose FEIS's are now available but whose study data came from their DEIS's, again because the models were operational before these FEIS's became available. Table 7 lists these forests by region.

0-1 Decision Variable Constraints

The 0-1 constraint rows are represented by the code names for each forest (from table 2). The management alternatives from each forest are represented in their respective 0-1 rows by assigning each a coefficient of 1 in this row. Then only one alternative (or combination of alternatives equaling one) can be selected to be in the solution by assigning a RHS value of 1 to each 0-1 equality constraint row.

Accounting Columns

The accounting columns aggregate the output production (cost) from the management alternatives selected to be in solution, and represent the total produced (spent) as a column in the matrix. The activity level of these columns is the amount of

Table 6.–Disposition of production coefficients in Region 4 Model.

Initial # alts.		Forest[3]	Output	Fully sched-uled		Partially sched-uled		Unsched-uled		Conver-sion factor needed		Data provided by Forest		Data estimated interpola-tion		Data estimated regres-sion		Data estimated other		Alterna-tives elimi-nated	
P[1]	BM[2]			P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM
9	2	Ashley																		0	1
			REC	X			X														
			HAB	X			X														
			ELK	X			X														
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT	X	X																
			COST	X			X			X	X										
13	2	Caribou																		0	0
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X					X	X										
			WTR	X	X																
			SDMT	X					X								X				
			COST	X	X																
11	2	Challis																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X					X				X								
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT					X	X			X					X				
			COST	X	X					X	X										
8	2	Dixie																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X					X												
			RNG	X	X																
			TMBR	X	X					X	X					X	X				
			WTR	X	X																
			SDMT					X	X	X		X				X					
			COST	X	X					X	X										
		Fishlake																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X					X			X									
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SMDT			X			X			X			X						
			COST	X	X					X	X										
9	2	Humboldt																		0	0
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X					X	X										
			WTR	X	X																
			SDMT			X	X					X	X					X	X		
			COST	X	X					X	X		X								

(Continued)

Table 6.--(continued).

Initial # alts.		Forest[3]	Output	Fully sched-uled		Partially sched-uled		Unsched-uled		Conver-sion factor needed		Data provided by Forest		Data estimated interpola-tion		Data estimated regres-sion		Data estimated other		Alterna-tives elimi-nated	
P[1]	BM[2]			P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM	P	BM
8	3	Manti-LaSal																		0	3
			REC	X			X							X							
			HAB			X			X				X								
			ELK	X			X							X							
			RNG	X			X							X							
			TMBR	X			X							X							
			WTR			X	X						X	X							
			SDMT			X			X						X	X					
			COST			X	X						X	X							
10	2	Payette																		0	0
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT					X	X			X	X								
			COST	X	X					X	X										
12	2	Salmon																		0	2
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X									
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT			X			X			X						X			
			COST	X	X					X	X										
12	2	Sawtooth																		0	2
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X									
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT			X			X			X						X			
			COST	X	X					X	X										
8	0	Targhee																		0	0
			REC	X																	
			HAB	X																	
			ELK					X				X									
			RNG	X																	
			TMBR	X						X		X									
			WTR	X																	
			SDMT					X										X			
			COST	X																	
9	2	Toiyabe																		0	2
			REC	X	X																
			HAB	X	X																
			ELK					X	X			X	X								
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT					X	X			X	X					X	X		
			COST	X	X																

(Continued)

Table 6.--(continued).

Initial # alts. P[1]	Initial # alts. BM[2]	Forest[3]	Output	Fully scheduled P	Fully scheduled BM	Partially scheduled P	Partially scheduled BM	Unscheduled P	Unscheduled BM	Conversion factor needed P	Conversion factor needed BM	Data provided by Forest P	Data provided by Forest BM	Data estimated interpolation P	Data estimated interpolation BM	Data estimated regression P	Data estimated regression BM	Data estimated other P	Data estimated other BM	Alternatives eliminated P	Alternatives eliminated BM
8	2	Wasatch-Cache																		0	2
			REC	X	X																
			HAB	X	X																
			ELK	X	X																
			RNG	X	X																
			TMBR	X	X																
			WTR	X	X																
			SDMT			X			X			X						X			
			COST	X	X																
10	2	Bridger-Teton																		0	2
			REC	X	X																
			HAB	X	X																
			ELK			X			X			X		X							
			RNG	X	X																
			TMBR	X	X					X	X	X	X								
			WTR	X	X																
			SDMT			X	X					X									
			COST	X	X					X	X										

[1]P = Primary alternatives (alternatives considered in detail).

[2]BM = Benchmark alternatives (Max. PNV).

[3]Uinta National Forest did not schedule any outputs -- forest indicated unavailable.

production (expenditure) associated with the row. This aggregation is achieved by assigning a subtraction operator (-) and unity coefficient (1) to the appropriate column and cell and setting equality type rows with RHS values of zero. Table 3 lists the code for the forest product outputs represented by the accounting columns.

Objective Function Row

The costs collected in the accounting columns are transferred to the objective function row. The objective function row forces the LP algorithm to minimize the costs of producing the required output levels. To achieve this transfer and minimization of costs, the coefficients in this row must be positive and unitary (1). The code for the objective function row is "MINOBJ".

Table 7.--Forests whose FEIS's are available but not in model.

Region	Forest
1	Flathead
2	Shoshone
3	Coronado, Gila, Lincoln
4	Ashley, Dixie, Manti LaSal, Uinta[1]
8	Cherokee, Ouachita, Texas, Florida
9	Chequamegon, Green Mountain, Nicolet, Ottawa, Shawnee

[1]The Uinta National Forest FEIS was available at the time the Region 4 model was built but there are no scheduled production data in this FEIS, nor are any available from other planning records.

Production Constraint Rows

The outputs (except cost) collected in the accounting columns are transferred to the production constraint rows. These rows constrain the outputs in solution to meet specified targets. The production constraints are assigned by means of adding "bounds" data to the LP problem input data. A specified target value (RHS) is assigned each output along with coding that designates the values as either a lower bound (LO, meaning $\geq$ type) or upper bound (UP, meaning $\leq$ type) constraint on physical production.

Data Storage

After the homogenous data sets were completed for each forest in a region, the next step involved storing this regional forest production data in a data file on the Sperry Univac 1100 computer system at the Fort Collins Computer Center (FCCC).

Table 8.–Data file with production data and computer code formulation of LP problem for Region 4.

1.	NAME		RPAR4			
2.	ROWS					
3.	E	REC1				
4.	E	REC2				
5.	E	REC3				
6.	E	REC4				
7.	E	REC5				
8.	E	HAB1				
9.	E	HAB2				
10.	E	HAB3				
11.	E	HAB4				
12.	E	HAB5				
13.	E	ELK1				
14.	E	ELK2				
15.	E	ELK3				
16.	E	ELK4				
17.	E	ELK5				
18.	E	RNG1				
19.	E	RNG2				
20.	E	RNG3				
21.	E	RNG4				
22.	E	RNG5				
23.	E	TMBR1				
24.	E	TMBR2				
25.	E	TMBR3				
26.	E	TMBR4				
27.	E	TMBR5				
28.	E	WTR1				
29.	E	WTR2				
30.	E	WTR3				
31.	E	WTR4				
32.	E	WTR5				
33.	E	SDMT1				
34.	E	SDMT2				
35.	E	SDMT3				
36.	E	SDMT4				
37.	E	SDMT5				
38.	E	COST1				
39.	E	COST2				
40.	E	COST3				
41.	E	COST4				
42.	E	COST5				
43.	N	MINOBJ				
44.	E	ASHLEY				
45.	E	CARIBOU				
46.	E	CHALLIS				
47.	E	DIXIE				
48.	E	FISHLAKE				
49.	E	HUMBOLDT				
50.	E	MANTI				
51.	E	PAYETTE				
52.	E	SALMON				
53.	E	SAWTOOTH				
54.	E	TARGHEE				
55.	E	TOIYABE				
56.	E	WASATCH				
57.	E	BRIDGER				
58.	COLUMNS					
59.	R4/1/1	REC1	992.	REC2	1141.	
60.	R4/1/1	REC3	1287.	REC4	1434.	
61.	R4/1/1	REC5	1579.	HAB1	925.	
62.	R4/1/1	HAB2	925.	HAB3	925.	
63.	R4/1/1	HAB4	925.	HAB5	925.	
64.	R4/1/1	ELK1	5800.	ELK2	5900.	

(Continued)

Table 8.–(continued).

65.	R4/1/1	ELK3	5800.	ELK4	5700.
66.	R4/1/1	ELK5	5500.	RNG1	77.
67.	R4/1/1	RNG2	80.	RNG3	82.
68.	R4/1/1	RNG4	83.	RNG5	84.
69.	R4/1/1	TMBR1	13.8	TMBR2	12.
70.	R4/1/1	TMBR3	11.7	TMBR4	10.5
71.	R4/1/1	TMBR5	8.6	WTR1	960.
72.	R4/1/1	WTR2	972.	WTR3	982.
73.	R4/1/1	WTR4	989.	WTR5	993.
74.	R4/1/1	SDMT1	32.	SDMT2	33.
75.	R4/1/1	SDMT3	35.	SDMT4	38.
76.	R4/1/1	SDMT5	36.	COST1	4.91
77.	R4/1/1	COST2	5.73	COST3	6.78
78.	R4/1/1	COST4	6.71	COST5	6.93
79.	R4/1/1	ASHLEY	1.		
.					
.					
.					
3061.	R4/14/9	BRIDGER	1.		
3062.	R4/14/10	REC1	1843.8	REC2	2513.9
3063.	R4/14/10	REC3	3098.5	REC4	3831.0
3064.	R4/14/10	REC5	4453.6	HAB1	1008.
3065.	R4/14/10	HAB2	1000.	HAB3	1020.
3066.	R4/14/10	HAB4	1117.	HAB5	1406.
3067.	R4/14/10	ELK1	1781.0	ELK2	18725.
3068.	R4/14/10	ELK3	19650.	ELK4	20575.
3069.	R4/14/10	ELK5	21550.	RNG1	225.2
3070.	R4/14/10	RNG2	257.5	RNG3	258.9
3071.	R4/14/10	RNG4	260.5	RNG5	264.0
3072.	R4/14/10	TMBR1	8.54	TMBR2	11.44
3073.	R4/14/10	TMBR3	15.06	TMBR4	15.06
3074.	R4/14/10	TMBR5	15.06	WTR1	5728.9
3075.	R4/14/10	WTR2	5735.3	WTR3	5740.5
3076.	R4/14/10	WTR4	5743.1	WTR5	5744.0
3077.	R4/14/10	SDMT1	198.05	SDMT2	198.42
3078.	R4/14/10	SDMT3	198.31	SDMT4	198.57
3079.	R4/14/10	SDMT5	198.12	COST1	4.95
3080.	R4/14/10	COST2	5.56	COST3	6.01
3081.	R4/14/10	COST4	6.18	COST5	6.48
3082.	R4/14/10	BRIDGER	1.		
3083.	REC1P	REC1	-1.		
3084.	REC2P	REC2	-1.		
3085.	REC3P	REC3	-1.		
3086.	REC4P	REC4	-1.		
3087.	REC5P	REC5	-1.		
3088.	HAB1P	HAB1	-1.		
3089.	HAB2P	HAB2	-1.		
3090.	HAB3P	HAB3	-1.		
3091.	HAB4P	HAB4	-1.		
3092.	HAB5P	HAB5	-1.		
3093.	ELK1P	ELK1	-1.		
3094.	ELK2P	ELK2	-1.		
3095.	ELK3P	ELK3	-1.		
3096.	ELK4P	ELK4	-1.		
3097.	ELK5P	ELK5	-1.		
3098.	RNG1P	RNG1	-1.		
3099.	RNG2P	RNG2	-1.		
3100.	RNG3P	RNG3	-1.		
3101.	RNG4P	RNG4	-1.		
3102.	RNG5P	RNG5	-1.		
3103.	TMBR1P	TMBR1	-1.		
3104.	TMBR2P	TMBR2	-1.		
3105.	TMBR3P	TMBR3	-1.		
3016.	TMBR4P	TMBR4	-1.		

(Continued)

Table 8.--(continued).

3107.	TMBR5P	TMBR5	-1.		
3108.	WTR1P	WTR1	-1.		
3109.	WTR2P	WTR2	-1.		
3110.	WTR3P	WTR3	-1.		
3111.	WTR4P	WTR4	-1.		
3112.	WTR5P	WTR5	-1.		
3113.	SDMT1P	SDMT1	-1.		
3114.	SDMT2P	SDMT2	-1.		
3115.	SDMT3P	SDMT3	-1.		
3116.	SDMT4P	SDMT4	-1.		
3117.	SDMT5P	SDMT5	-1.		
3118.	COST1P	COST1	-1.	MINOBJ	1.
3119.	COST2P	COST2	-1.	MINOBJ	1.
3120.	COST3P	COST3	-1.	MINOBJ	1.
3121.	COST4P	COST4	-1.	MINOBJ	1.
3122.	COST5P	COST5	-1.	MINOBJ	1.
3123. RHS					
3124.	RHS1	REC1	0.	REC2	0.
3125.	RHS1	REC3	0.	REC4	0.
3126.	RHS1	REC5	0.	HAB1	0.
3127.	RHS1	HAB2	0.	HAB3	0.
3128.	RHS1	HAB4	0.	HAB5	0.
3129.	RHS1	ELK1	0.	ELK2	0.
3130.	RHS1	ELK3	0.	ELK4	0.
3131.	RHS1	ELK5	0.	RNG1	0.
3132.	RHS1	RNG2	0.	RNG3	0.
3133.	RHS1	RNG4	0.	RNG5	0.
3134.	RHS1	TMBR1	0.	TMBR2	0.
3135.	RHS1	TMBR3	0.	TMBR4	0.
3136.	RHS1	TMBR5.	0.	WTR1	0.
3137.	RHS1	WTR2	0.	WTR3	0.
3138.	RHS1	WTR4	0.	WTR5	0.
3139.	RHS1	SDMT1	0.	SDMT2	0.
3140.	RHS1	SDMT3	0.	SDMT4	0.
3141.	RHS1	SDMT5	0.	COST1	0.
3142.	RHS1	COST2	0.	COST3	0.
3143.	RHS1	COST4	0.	COST5	0.
3144.	RHS1	ASHLEY	1.	CARIBOU	1.
3145.	RHS1	CHALLIS	1.	DIXIE	1.
3146.	RHS1	FISHLAKE	1.	HUMBOLDT	1.
3147.	RHS1	MANTI	1.	PAYETTE	1.
3148.	RHS1	SALMON	1.	SAWTOOTH	1.
3149.	RHS1	TARGHEE	1.	TOIYABE	1.
3150.	RHS1	WASATCH	1.	BRIDGER	1.
3151. BOUNDS					
3152.	LO BOUNDS1		REC1P	17230.73	
3153.	LO BOUNDS1		REC2P	17230.73	
3154.	LO BOUNDS1		REC3P	17230.73	
3155.	LO BOUNDS1		REC4P	17230.73	
3156.	LO BOUNDS1		REC5P	17230.73	
3157.	LO BOUNDS1		HAB1P	18737.	
3158.	LO BOUNDS1		HAB2P	18737.	
3159.	LO BOUNDS1		HAB3P	18737.	
3160.	LO BOUNDS1		HAB4P	18737.	
3161.	LO BOUNDS1		HAB5P	18737.	
3162.	LO BOUNDS1		ELK1P	78817.	
3163.	LO BOUNDS1		ELK2P	78817.	
3164.	LO BOUNDS1		ELK3P	78817.	
3165.	LO BOUNDS1		ELK4P	78817.	
3166.	LO BOUNDS1		ELK5P	78817.	
3167.	LO BOUNDS1		RNG1P	2045.92	
3168.	LO BOUNDS1		RNG2P	2045.92	
3169.	LO BOUNDS1		RNG3P	2045.92	
3170.	LO BOUNDS1		RNG4P	2045.92	

(Continued)

Table 8.--(continued).

3171.	LO BOUNDS1	RNG5P	2045.92
3172.	LO BOUNDS1	TMBR1P	102.99
3173.	LO BOUNDS1	TMBR2P	102.99
3174.	LO BOUNDS1	TMBR3P	102.99
3175.	LO BOUNDS1	TMBR4P	102.99
3176.	LO BOUNDS1	TMBR5P	102.99
3177.	LO BOUNDS1	WTR1P	23381.64
3178.	LO BOUNDS1	WTR2P	23381.64
3179.	LO BOUNDS1	WTR3P	23381.64
3180.	LO BOUNDS1	WTR4P	23381.64
3181.	LO BOUNDS1	WTR5P	23381.64
3182. ENDATA			

These data files were not used simply for data storage, but constituted a computer code formulation of the upper level LP. This required a specified data image format specified by the Functional Mathematical Programming System (FMPS) in the Sperry Univac 1100 computer system.

Table 8 shows a data file with a computer code formulation for Region 4. Note that the LP problem data are organized into 4 chapters--rows, columns, right hand sides (RHS), and bounds. The rows chapter defines the rows that will be used in the LP and specifies the type of constraint. The Es indicate row type equality, while the N indicates a nonconstraining row to be used as the objective function. The columns chapter serves two functions. The first function is to define the columns in the matrix, and the second function is to enter the technical coefficients into the matrix (this portion of table 8 is truncated to save space). The coefficients are entered into the file directly from the homogenous recording matrixes. The accounting variables are also entered in this input chapter. Note that the costs are linked to the objective function here. The RHS chapter specifies the right hand side values of the accounting and 0-1 constraint rows. Finally, the bounds chapter assigns target levels for each output. Note that technical coefficients with a value of zero need not be entered in the appropriate chapter.

Table 9 illustrates an initial coded matrix for the LP problem of interest in this analysis (this example utilizes Region 4 data truncated to the first two alternatives for the first forest and the last two alternatives for the last (14th) forest to save space). The A's in the A-matrix represent the production coefficients. Note that no bounds are designated for costs, because they serve as the objective function. Also note that sediment yield is constrained by upper bounds, while all other outputs have lower bounds. The remainder of the matrix has either zero (represented by blanks) or unitary coefficients (with a negative operator in the case of the accounting columns) as described previously.

DESCRIPTION OF SOLUTION OUTPUT

The LP problem is formulated so the solution results in the selection of one alternative (or the partial selection of several alternatives, the combination of which satisfies the 0-1 constraints), and its (their) associated vector of outputs and cost, from each forest planning unit. This selection typically depends

Table 9.--Illustration of an initially coded LP problem matrix.

	R4/1/1	R4/1/2	•••	R4/14/9	R4/14/10	REC1P	REC2P	REC3P	REC4P	REC5P	HAB1P	HAB2P	HAB3P	HAB4P	HAB5P	ELK1P	ELK2P	ELK3P	ELK4P	ELK5P	RNG1P	RNG2P	RNG3P	RNG4P	RNG5P	TMBR1P	TMBR2P	TMBR3P	TMBR4P	TMBR5P	WTR1P	WTR2P	WTR3P	WTR4P	WTR5P	SDMT1P	SDMT2P	SDMT3P	SDMT4P	SDMT5P	COST1P	COST2P	COST3P	COST4P	COST5P	RHS
LOWER BOUND						L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L											
UPPER BOUND																																				U	U	U	U	U						
REC1	A	A		A	A	-1																																								0
REC2	A	A		A	A		-1																																							0
REC3	A	A		A	A			-1																																						0
REC4	A	A		A	A				-1																																					0
REC5	A	A		A	A					-1																																				0
HAB1	A	A		A	A						-1																																			0
HAB2	A	A		A	A							-1																																		0
HAB3	A	A		A	A								-1																																	0
HAB4	A	A		A	A									-1																																0
HAB5	A	A		A	A										-1																															0
ELK1	A	A		A	A											-1																														0
ELK2	A	A		A	A												-1																													0
ELK3	A	A		A	A													-1																												0
ELK4	A	A		A	A														-1																											0
ELK5	A	A		A	A															-1																										0
RNG1	A	A		A	A																-1																									0
RNG2	A	A		A	A																	-1																								0
RNG3	A	A		A	A																		-1																							0
RNG4	A	A		A	A																			-1																						0
RNG5	A	A		A	A																				-1																					0
TMBR1	A	A		A	A																					-1																				0
TMBR2	A	A		A	A																						-1																			0
TMBR3	A	A		A	A																							-1																		0
TMBR4	A	A		A	A																								-1																	0
TMBR5	A	A		A	A																									-1																0
WTR1	A	A		A	A																										-1															0
WTR2	A	A		A	A																											-1														0
WTR3	A	A		A	A																												-1													0
WTR4	A	A		A	A																													-1												0
WTR5	A	A		A	A																														-1											0
SDMT1	A	A		A	A																															-1										0
SDMT2	A	A		A	A																																-1									0
SDMT3	A	A		A	A																																	-1								0
SDMT4	A	A		A	A																																		-1							0
SDMT5	A	A		A	A																																			-1						0
COST1	A	A		A	A																																				-1					0
COST2	A	A		A	A																																					-1				0
COST3	A	A		A	A																																						-1			0
COST4	A	A		A	A																																							-1		0
COST5	A	A		A	A																																								-1	0
MINOBJ																																									1	1	1	1	1	N
ASHLEY	1	1																																												1
BRIDGER-TETON				1	1																																									1

upon which combination of alternatives minimizes aggregate costs subject to constraints on the aggregate production of outputs. If it is not possible to satisfy all of the constraints, there is no feasible solution to the problem, and it must be reformulated by restating the constraints. A solution is feasible if all constraints can be satisfied, and is optimal when it has the most favorable value of the objective function (the minimum cost in typical cases).

The LP solution output emanates from the FMPS software, and follows the format documented for that LP solution package. The principal solution information of interest would typically be the value of the variables in solution, and the output shadow prices. In this format, a "column activity" displays the value of the variables selected to be in the solution. The decision variables that are rejected (not in the solution) have a value of zero. The column labeled "reduced cost" in the solution output represents the shadow price of the specified variables. The shadow price for a product measures the marginal contribution of that output to the value of the objective function, that is, the rate at which the objective function (minimum cost) could be decreased by decreasing the constraint on the output by one unit (increasing the constraint in the case of sediment output) while holding all other variable constraints constant. However, there is a limited range within which a constraint on a particular variable can be changed before the solution will result in a different basis--implying that it may have a greater effect on the objective function than is indicated by the shadow price. The relative ranges for this kind of parametric change for all of the variables can be determined using the FMPS algorithm.

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APPENDIX 1

Study Notes Documenting Homogenous Data Set for Bridger-Teton National Forest

I. Nonhomogenous Data Set and Deficiencies
  A. Alternatives
    1. 10 primary and 2 benchmark.
  B. REC
    1. Dispersed recreation fully scheduled for primary and benchmark alternatives-tables II-1 and B-III-2.
      a. includes WFUD's - table II-17, page II-125.
      b. excludes wilderness RVD's - table II-17, page II-125.
    2. Wilderness recreation fully scheduled for primary and benchmark alternatives-tables II-1 and B-III-2.
    3. Total dispersed recreation = dispersed + wilderness
  C. HAB
    1. Fully scheduled for all primary and benchmark alternatives - tables II-1 and B-III-2.
  D. ELK
    1. Reported only for 5th period of primary alternatives - bargraph on page II-130.
  E. RNG
    1. Fully scheduled for all primary and benchmark alternatives - tables II-1 and B-III-2.
  F. TMBR
    1. Allowable sale fully scheduled for primary and benchmark alternatives in CF - tables II-1 and B-III-2.
    2. Fuelwood and other products fully scheduled for primary and benchmark alternatives in BF - tables II-1 and B-III-2.
      a. BF to CF conversion ratios not reported.
  G. WTR
    1. Total water yield not reported.
    2. Water yield meeting quality goals fully scheduled for primary and benchmark alternatives - tables II-1 and B-III-2.
    3. Increased water yield over natural fully scheduled for primary and benchmark alternatives - tables II-1 and B-III-2.
    4. It is implicit in table II-1 (see page II-37) that natural yield is 5726.1 MAcFt/yr and that total water yield is equal to water meeting quality goals.
    5. Can either use water meeting quality goals or add increase over natural to natural yield.
      a. for example, using period #1 of alternative #1.
        1) water meeting quality goals = 5740.30 MAcFt or
        2) increase over natural = 14.2 MAcFt so 14.2 MAcFt + 5726.1 MAcFt = 5740.30 MAcFt
  H. SDMT
    1. Sediment yield not reported.
    2. Natural sediment rate reported = 195,000 tons/yr - page IV-65.
    3. Text indicated sediment yield scheduled in other planning records.
  I. COST
    1. Costs fully scheduled for primary and benchmark alternatives in 82$ - tables II-1-B and B-III-2B.
    2. Allocated funds not mentioned in EIS.
    3. Convert 82$ to 78$.
      a. use implicit price deflator (1972=100).
      b. for example, for period #1 of alternative #1.
        1) 1982=207.38 and 1978=150.42
        2) so deflator is $\frac{150.42}{207.38}$
        3) and 10.89 MM1982$ x $\frac{150.42}{207.38}$ = 7.90 MM1978$

II. Data Provided by Forest
  A. Forest Contact Persons - Carl Pence, Paul Arnt
    1. Phone # 307-733-2752
    2. Initial contact - 10/28/86
    3. Forest provided data - 11/12/86
  B. ELK
    1. 1st period primary alternatives provided by forest.
      a. 17,800 elk across all primary alternatives.
      b. Periods 2, 3, and 4 of primary alternatives and all periods, benchmarks unavailable.
  C. TMBR
    1. Forest provided BF to CF conversion ratios.
      a. Fuelwood - 4.86
      b. Other products - 1.00
  D. SDMT
    1. Forest provided schedule of increases over natural yield for primary alternatives - Mtons/year.
      a. Alternatives

Period	1	2	3	4	5	6	7	8	9	10
1	17.83	17.83	7.24	6.80	6.80	3.63	3.33	2.02	3.50	3.05
2	18.02	18.02	8.15	6.50	6.50	3.25	3.53	2.10	3.07	3.42
3	18.62	18.62	7.41	6.43	6.43	3.22	3.38	1.90	2.96	3.31
4	20.55	20.55	7.65	6.01	6.01	3.46	3.64	2.16	3.11	3.57
5	19.73	19.73	7.23	5.38	5.38	3.03	3.18	1.92	2.92	3.12

  E. COST
    1. Allocated funds are insignificant.

III. Homogenous Data Set Completed

A. ELK

1. Interpolate using periods 1 and 5 data to estimate data for periods 2, 3, and 4 of the primary alternatives.
   a. For example, using alternative #1.
      1) 1st = 17,800 and 5th = 13,000
      2) so (17,800 - 13,000) / 4 = 1200
      3) and 2nd = 17,800 - 1200 = 16,600
         3rd = 16,600 - 1200 = 15,400
         4th = 15,400 - 1200 = 14,200
         5th = 14,200 - 1200 = 13,000

B. TMBR

1. Convert fuelwood and other products to CF and aggregate all timber outputs to get total timber.
   a. For example, using period #1 of alternative #1.
      1) Other products = 16.5 MMBF and 16.5 MMBF / 1.00 = 16.50 MMCF
      2) Fuelwood = 48.2 MMBF and 48.2 MMBF / 4.86 = 9.92 MMCF
      3) Allowable sale = 16.80 MMCF
      4) Total timber in period #1 of alternative #1 = 43.22 MMCF

C. Alternatives

1. 10 primary alternatives.
   a. Benchmark alternatives BM-1 and BM-2 eliminated from analysis:
      1) Elk and sediment unscheduled and unavailable.
      2) No logical method for estimating elk with data available.

APPENDIX 2

Examples of Distinct Methodologies for Deriving and Estimating Missing Outputs

Examples of Distinct Methodologies for Deriving and Estimating Dispersed Recreation

I. Clearwater NF

A. In Region 1, dispersed recreation was recorded in two categories: motorized and nonmotorized. These categories were aggregated from the Recreation Opportunity Spectrum (ROS) classifications (roaded natural, semiprimitive motorized, semiprimitive nonmotorized, and primitive or wilderness) generally reported in this region.

B. Semiprimitive motorized and semiprimitive nonmotorized dispersed recreation were combined into one semiprimitive category for the Clearwater. The disaggregation of this category was not available.

C. Use a neighboring forest, the Nezperce, to estimate the disaggregation of this category into motorized and nonmotorized components.

1. On the Nezperce, semiprimitive motorized dispersed recreation represents approximately 90% of total semiprimitive dispersed recreation across all alternatives and decades. Use this percentage to estimate the disaggregation of semiprimitive dispersed recreation into motorized and nonmotorized semiprimitive dispersed recreation across all alternatives and decades for the Clearwater.

2. Then aggregate roaded natural and semiprimitive motorized to obtain total motorized dispersed recreation (RECM) and semiprimitive nonmotorized and wilderness to obtain total nonmotorized dispersed recreation (RECNM).

II. Beaverhead NF

A. Semiprimitive nonmotorized, semiprimitive motorized, and roaded natural dispersed recreation were labeled Type 1, Type II, and Type III dispersed recreation, respectively, on this forest.

B. Aggregate Type I and wilderness recreation into the total nonmotorized dispersed component and Type II and Type III into the total motorized dispersed component.

III. Black Hills NF

A. Wilderness RVD's were reported.

B. Dispersed RVD's were reported (table IV-33). The table did not indicate if wilderness RVD's were included in this figure.

1. The Forest indicated that wilderness RVD's were included in the dispersed recreation reported in table IV-33.

IV. Numerous Forests

A. Wildlife and fish user days (WFUD's) were often reported separately in the EIS in addition to the category called dispersed recreation. However, it was not always made explicit as to whether or not WFUD's were included in the dispersed recreation category reported. In such cases, the forest would be contacted to supply that information.

B. Wilderness RVD's were usually reported separately and not included in the dispersed recreation category reported.

1. Wilderness RVD's would then be added to dispersed recreation to obtain total dispersed recreation.

V. George Washington NF

A. Dispersed recreation, wilderness RVD's, and WFUD's were reported separately in tables B-16 of original DEIS and II-IA of supplement.
B. Forest personnel indicated that wilderness RVD's and WFUD's were included in the dispersed recreation figure reported in these tables.

VI. Monongahela NF

A. Total recreation was reported by ROS class. No distinction was made between developed and dispersed recreation (page B-191 to B-194).
B. The Forest indicated semiprimitive motorized and roaded natural contain both developed and dispersed recreation in the following proportions:

Period	Dispersed	Developed
1	67%	33%
2 through 5	68%	32%

C. The Forest indicated rural is all developed and semiprimitive nonmotorized is all dispersed.

Examples of Distinct Methodologies for Deriving and Estimating Wildlife Habitat Improvement

I. Beaverhead NF

A. HAB was reported in dollars but not available in acres.
B. Objectives outlined in proposed plan call for 3,319 acre equivalents of habitat improvements per year.
C. Reported annual cost of habitat improvement for proposed alternative is $14,400.
D. Use cost and acres from proposed alternative and scheduled HAB dollars to estimate acres of habitat improvements for all other alternatives.
   1. 3,319 acres / $14,400 = .23 acre/$
   2. Multiply HAB schedule in $ by .23 to get estimates for scheduled acres.

II. Custer NF

A. HAB was reported only for periods 1, 3, and 5 but not available for periods 2 and 4.
B. Interpolate to estimate for periods 2 and 4 (the average of periods 1 and 3 and 3 and 5 respectively).

III. Numerous Forests

A. HAB was often reported on a 50-year average annual basis and recorded likewise in this study if neither additional data nor a logical method for estimating decadal differences were available.

IV. Prescott NF

A. Wildlife "projects" were reported in $ for the first and fifth periods.
B. The Forest provided cost figure of $40/acre of wildlife habitat improvement. No other data was available.
C. Convert the scheduled $ to acres by dividing by $40/acre and then interpolate between periods 1 and 5 to estimate for periods 2, 3, and 4.

V. Chippewa NF

A. HAB was scheduled only for alternative #3.
B. No other data was available.
C. Wildlife benefits in $ were scheduled for all alternatives.
D. Apply the decadal HAB/wildlife benefits ratio for alternative #3 to the schedule of wildlife benefits for all other alternatives to estimate their HAB.
E. For example, in period 1 of alternative #3, HAB/$ benefits = 4090/2.86 = 1430.07.
   1. Since $ benefits = 2.73 for period 1 of alternative #2, then 2.73 x 1430.07 = 3904 acres of wildlife habitat improvements for this alternative and period.

Examples of Distinct Methodologies for Deriving and Estimating Elk.

I. Grand Mesa, Uncompahgre, & Gunnison NF

A. Total big game potential for deer and elk was scheduled.
B. The current percentage split of 74% and 26% respectively was reported.
C. The forest indicated the same proportional split exists across all alternatives and decades.

II. Shoshone NF

A. Elk was not reported. No other data were available from the forest.
B. Forage reserved for wildlife was scheduled as cattle animal unit months (CAUM) in table IV-9, pg. IV-29.
C. Current populations (1983) for big game species are reported (elk, deer, sheep, moose, antelope, goat) in table II-13, pg. III-36.
D. CAUM equivalents for elk, deer, and sheep were reported.
E. Use the schedule of CAUM's, current wildlife populations, and CAUM equivalents to estimate elk.
F. Current wildlife populations and % of total are:

Animal	1983 Population	% Of Total Big Game
Elk	15,700	45
Deer	13,450	38
Sheep	3,890	11
Moose	855	2
Antelope	1,210	3
Goat	100	1
Total	35,205	100%

G. CAUM equivalents are: 2 elk, 4 deer, and 5 sheep.
   1. Assume the same CAUM equivalents for moose and antelope as for elk and deer, respectively.

H. Assuming constant 1983 percentage composition of big game species across all periods for all alternatives, use reserved forage schedule and CAUM equivalents to estimate the schedule of elk populations.

I. For example, for period 1 of alternative A, reserved CAUM's = 39,400.
   1. If x = total big game, then

   $$39{,}400 = X\left(\frac{.45}{2} + \frac{.38}{4} + \frac{.11}{5} + \frac{.02}{2} + \frac{.03}{4} + \frac{.01}{5}\right)$$

   where the numerators are the % of total big game species for elk, deer, sheep, moose, antelope, and goat, respectively, and the denominators are CAUM equivalents for those same respective game species.
   2. Thus, X=108,990 animals and reserved forage can accommodate .45(108,990) = 49,045 elk.
   3. However, since 1983 elk populations are close to the objective for period 1 (15,075 elk), use the ratio of 1983 CAUM equivalents to the CAUM forage reserve in period 1 of the no action alternative across all periods and alternatives to estimate elk populations.
   4. Thus, $\frac{15{,}700}{2} + \frac{13{,}450}{4} + \frac{3890}{5} + \frac{855}{2} + \frac{1210}{4} + \frac{100}{5} = 12{,}740.5$ CAUM equivalents for 1983.
   5. Then 12,740.5 (CAUM equivalents) / 39,400 (CAUM capacity) = 32%.
   6. Apply this ratio across all periods and alternatives.
   7. Thus, for period 1, alternative A, .32 x 49,045 = 15,695 elk.

III. Coconino NF
   A. Elk was not reported.
   B. The forest provided elk numbers for periods 1 and 5 across all alternatives.
   C. Interpolate to estimate for periods 2, 3, and 4.

IV. Gila NF
   A. Elk was not reported and not available.
   B. The forest provided estimations, based on habitat components, for the first and fifth periods.
      1. The forest indicated the second period for alternatives with increasing elk would be 7000 animals (except for alternative B), then interpolate from there.
      2. The forest indicated that for alternatives with decreasing elk, periods 3 and 4 are the same as period 5. Interpolate to get period 2.

V. Lincoln NF
   A. Elk was not reported.
   B. The forest indicated that elk was recently reintroduced on the forest.
      1. The forest will try to maintain a viable population of approximately 350 animals.
   C. The percent increase in habitat for indicator species (includes elk) was reported for the planning horizon by alternative in table 58, page 139.
   D. Use table 58 and initial viable population of 350 animals to estimate the schedule for elk.
   E. For an example, alternatives B and C are utilized.
      1. There is no increase in habitat in alternative B, so elk population is estimated to remain at 350 animals over all periods.
      2. There is a 10% increase in habitat in alternative C, so the elk population is estimated at 385 animals (350 + .10 x 350) over all periods.

Examples of Distinct Methodologies for Estimating Deer

I. Tahoe NF
   A. The low and high range for deer was reported by alternative.
   B. The forest indicated that these figures represented first and fifth period populations respectively. Periods 2, 3, and 4 were not available.
   C. Interpolate between periods 1 and 5 to estimate deer populations for periods 2, 3, and 4.

II. Florida NF
   A. Deer was not scheduled. Current population, optimum population, and minimum population was reported.
   B. A Deer habitat capability index was scheduled for alternatives 2 and 10 and provided by the forest.
      1. The forest also provided the following information. When the index = 100, deer population is 12,200. A maximum index number of 130 is equivalent to an optimum deer population of 24,400. A minimum index number of 75 is equivalent to a minimum deer population of 6,250.
   C. Use the habitat capability index (Y) and reforestation and thinning acres (X) for alternatives 2 and 10 to calculate a regression equation.
      1. For Y=mX+b
         m=24.9
         b=81.53
         r=.59
         and Y=24.9X + 81.53
   D. Use the regression equation above with reforestation and thinning acres from all other alternatives (as independent variable, X) to estimate a fully scheduled habitat capability index.
   E. Then use the estimated capability index along with the data equating current, optimum, and minimum deer populations to specified index numbers to estimate the full schedule of deer populations.
   F. For example, for alternative 1, the habitat capability index numbers estimated using the regression equation are:

Period	Index #
1	92
2	97
3	102
4	97
5	94

1. Since 100-75 = 25 index points and 12,200 - 6250 = 5950 deer, there are 238 deer/index point below 100 (5980 / 25 = 238).
2. Similarly, since 130-100 = 30 index points and 24,400 - 12,200 = 12,200 deer, there are 407 deer/index point above 100 (12,200 / 30 = 407).
3. Then, the final calculations in the estimation of deer numbers are:

Period			# Deer
1	12,200-[(100-92)x238]	=	10,296
2	12,200-[(100-97)x238]	=	11,486
3	12,200+[(102-100)x407]	=	13,014
4	12,200+[(100-97)x238]	=	11,486
5	12,200+[(100-94)x238]	=	10,712

Examples of Distinct Methodologies for Deriving or Estimating Fish

I. Idaho Panhandle NF
   A. Fish was reported for periods 1, 2, and 5 but not available for periods 3 and 4.
   B. Calculate a regression equation for each alternative using available fish data (periods 1, 2, and 5) and the analagous sediment yields.
   C. Estimate missing fish data using these equations and sediment from periods 3 and 4 as the independent variable x.
   D. For example, for alternative 1, the regression is Y = -1.8276X + 3099.03 and r = -.99.
      1. Applying sediment yields to this regression, fish is estimated for periods 3 and 4 as follows:

Period			Mfish
3	-1.8276(261.7)+3099.03	=	2621
4	-1.8276(196.6)+3099.03	=	2740

II. Custer NF
   A. Fish was reported for the first, third, and fifth periods but not available for the second and third period.
   B. Interpolate to estimate fish in second and third periods.

III. Numerous Forests
   A. Forests often reported several categories of fish separately.
   B. These categories were simply aggregated to obtain total fish potential.

Examples of Distinct Methodologies for Estimating Range

I. Helena NF
   A. Range was reported for all periods except the fourth, which was not available.
   B. Estimate the fourth period by interpolation.

II. Regions 8 and 9
   A. If range was not mentioned in the EIS's, it was recorded as -0- across all periods and alternatives.
   B. Several forest EIS's indicated range was insignificant and it was not reported.
      1. Range was recorded at -0- across all periods and alternatives in these cases.

Examples of Distinct Methodologies for Deriving and Estimating Timber

I. Custer NF
   A. Timber was reported for periods 1, 3, and 5 but unavailable for periods 2 and 4.
   B. Estimate for periods 2 and 4 by interpolation.

II. Numerous Forests
   A. Other forest timber outputs such as fuelwood, posts and poles, and biomass were often reported in addition to allowable sale, base harvest or net merchantable.
      1. These were simply aggregated, after any necessary conversion to common reporting units, to derive a total timber production schedule.

III. Cibola NF
   A. Fuelwood was reported in BF but the conversion ratio (to CF) was not available.
   B. Sawtimber and other products were reported in BF and CF.
      1. The conversion for these timber outputs is approximately 3.66:1 based on conversion calculations from a sampling of the reported data.
      2. Use this ratio as the estimate for fuelwood volume.

IV. Caribou NF
   A. Fuelwood was reported in cords but the ratio to convert to CF was not available.
   B. Use the conversion ratio from Manti-LaSal, 1 cord = 84 CF.

V. Inyo NF
   A. Fuelwood was reported in cords but the conversion ratio was not available.
   B. The cords to CF conversion ratio for fuelwood in the Pacific Coast Region is reported as 86.7 CF/cord in "An Analysis of the Timber Situation in the United States 1952-2030" (USDA, Forest Service, 1982).
   C. This conversion ratio was used for Regions 5 and 6 unless otherwise provided by forests.

VI. Stanislaus NF

A. Biomass was reported in tons.

B. The forest suggested using the same conversion as on the Lassen, 25LB/CF or 80 CF/ton.

VII. Francis Marion NF

A. Fuelwood was reported by alternative as 50 year totals. A schedule was not available.

B. The forest indicated that a good fuelwood schedule estimate would be to proportion fuelwood totals with the allowable sale schedule.

VIII. Wayne NF

A. Total harvest was reported in BF but a conversion to CF was not available.

B. Use the conversion for LTSY which was reported at 3.54 MMCF/yr = 20.7 MMBF/year or 5.85:1.

Examples of Distinct Methodologies for Deriving and Estimating Water Yield

I. Clearwater NF

A. Water yield was not reported.

B. Estimate water yield using a regression equation with allowable sale and water yield data from a neighboring forest, the Nezperce.

1. Use alternatives D, E, and G from the Nezperce since these display a range in allowable sale closest to that of the Clearwater.
2. Transform the allowable sale data to allowable sale equivalents to account for carryover effects.

C. For example, the equivalents for alternative G1 are:

Period	Allowable sale	Allowable sale equivalents
1	21.7	97.1
2	27.2	257.7
3	33.9	472.3
4	42.4	682.1
5	53.0	891.9

1. Using coefficients developed from the 75%, 66%, 50%, and 33% water yield carryover effects, the above equivalents were calculated as follows:
   4.375 x 21.7 = 97.1
   4.375 x 27.2 + 7.095 x 21.7 = 257.7
   4.375 x 33.9 + 7.095 x 27.2 + 5.88 x 21.7 = 472.3
   4.375 x 42.4 + 7.095 x 33.9 + 5.88 x 27.2 + 4.325 x 21.7 = 682.1
   4.375 x 53.0 + 7.095 x 42.4 + 5.88 x 33.9 + 4.235 x 27.2 + 1.815 x 21.7 = 891.9
2. The regression equation using this Nezperce data is Y = .047 X + 41.79.

D. Estimate increase in water yields for the Clearwater using this regression equation.

E. For example, the allowable sale equivalents for alternative A from the Clearwater are:

Period	Allowable sale	Allowable sale equivalents
1	36.9	161.4
2	44.3	455.6
3	53.1	763.6
4	63.8	1072.6
5	76.5	1354.2

1. Then solve the regression Y = .047 X + 41.79 where X is the independent variables (allowable sale equivalents) and Y is the dependent variable (increase in water yield).

Period	m	X	+	b	=	Y (increased) (yield)
1	.047	(161.4)	+	41.79	=	49.4
2	.047	(455.6)	+	41.79	=	63.2
3	.047	(763.3)	+	41.79	=	77.7
4	.047	(1072.6)	+	41.79	=	92.2
5	.047	(1354.2)	+	41.79	=	105.4

F. Add the increase to base water yield to get total water yield.

G. First estimate the base water yield for the Clearwater.

1. The Nezperce forest area = 2,218,040 acres.
2. The Clearwater forest area = 1,837,116 acres.
3. Thus, the Clearwater equals 82.83% (1,837,116 / 2,218,040) of the Nezperce.
4. The Nezperce base water yield = 3600 MAcFt.
5. The estimated base water yield for the Clearwater is thus 2981.88 MAcFt (.8283 x 3600 MAcFt).

H. Total water yield for alternative A from the Clearwater can now be estimated as follows:

Period	Increased yield	+	Base	=	Total yield (MAcFt)
1	49.4	+	2981.88	=	3031.3
2	63.2	+	2981.88	=	3045.1
3	77.7	+	2981.88	=	3059.6
4	92.2	+	2981.88	=	3074.1
5	105.4	+	2981.88	=	3087.3

II. Custer NF

A. Average annual water yield over a 75-year planning horizon was reported.

B. Base water yield is 1070MAcFt (minimum level benchmark yield).

C. Estimate decadal average annual increase in water yield over base by using allowable sale and planning period average annual yield.

D. For example, increase in water yield for alternative 2 is estimated as follows:

1. Planning period acreage annual yield = 1100 MAcFt or 30 MAcFt above base.
2. The total 50-year increase over basic is 1500 MAcFt (50 yrs. x 30 MAcFt/yr).

3. Convert allowable sale to equivalents.

Period	Allowable sale (total period)	Allowable sale equivalents (total period)
1	6	26.25
2	13	99.45
3	19	210.64
4	22	332.91
5	25	443.13
	50-yr. totals =	1112.38

4. Calculate water yield per equivalent, 1500 MAcFt / 1112.38 = 1.34846 MAcFt/equivalent.
5. Calculate average annual increased yield by period.

Allowable sale equivalents x Yield/Equivalent = Increase

Period	(Aver. annual)				(Aver. annual)
1	2.6	x	1.35	=	3.5
2	9.9	x	1.35	=	13.4
3	21.1	x	1.35	=	28.5
4	33.3	x	1.35	=	45.0
5	44.3	x	1.35	=	59.8

E. Calculate the estimate for total water yield.

Period	Increased yield	+	Base	=	Total yield
1	3.5	+	1070	=	1073.5
2	13.4	+	1070	=	1083.4
3	28.5	+	1070	=	1098.5
4	45.0	+	1070	=	1115.0
5	59.8	+	1070	=	1129.8

III. Numerous Forests

A. Water yield was often reported as an increase over a base or natural yield. The increase was simply added to the base yield to get total yield.
   1. If a base or natural yield was not reported, it was estimated by comparison with a neighboring or similar forest whose base yield was reported.
   2. Proration by total forest acreage was used to estimate the base yields.
B. The total water yield meeting quality goals reported by many forests was often equal to total water yield. This was either indicated in the EIS or by the forests.

IV. Helena NF

A. Water yield was not reported and not available.
B. The forest provided the natural yield, 415,000 AcFt/yr.
C. The forest indicated 1 MMBF of timber harvest produces an additional 21 acre feet of water per year.
D. The forest indicated that water yield will recover to pre-harvest levels by the end of the 2nd decade after harvest.
   1. Therefore, the carryover percentages for approximating water yield increases from timber harvest will be 75% and 33% for the 1st and 2nd decades, respectively (instead of the 75%, 66%, 50%, and 30% split used for other forests).
E. Use allowable sale data (in BF), base yield (415 MAcFt/yr.), harvest yield (21 AcFt/yr.), and carryover (75% and 33% to succeeding decades) to estimate scheduled water yield.
F. For example, the estimate of total water yield for alternative A is calculated as follows.
   1. The coefficients for calculating total allowable sale equivalents are derived in the same manner as these for the four decade carryover coefficients described earlier.
   2. These coefficients are:

Period	Allowable sale equivalents per year
1	3.375
2	5.61
3	1.815

   3. The allowable sale equivalents (MMBF) for alternative A are:

Period	Allowable sale	Allowable sale equivalents
1	16.7	56.4
2	20.9	164.2
3	21.2	219.1
4	21.2	228.4
5	21.2	229.0

   4. Then total additional yield is calculated as follows:

Period	Yield/MMBF (AcFt)	x	Allowable sale equivalents	=	Add. yield (AcFt)
1	21	x	56.4	=	1184.4
2	21	x	164.2	=	3448.2
3	21	x	219.1	=	4601.1
4	21	x	228.4	=	4796.4
5	21	x	229.0	=	4809.0

   5. Total yield is calculated by simply adding the additional yield to base yield.

Period	Additional yield	+	Base yield	=	Total yield
1	1.18	+	415	=	416.18
2	3.45	+	415	=	418.45
3	4.60	+	415	=	419.6
4	4.80	+	415	=	419.8
5	4.81	+	415	=	419.81

Examples of Distinct Methodologies for Deriving and Estimating Sediment Yield

I. Beaverhead NF

A. Sediment was reported in periods 1, 3, and 5 only for the primary alternatives.

B. Sediment does not appear to have any positive linear relationship with road construction.

C. However, it does appear that sediment increases at a proportional rate. Period 3 is close to the median between periods 1 and 5 over all alternatives.

1. Interpolate to estimate periods 2 and 4.

II. Idaho Panhandle

A. Sediment yield was not reported and not available.

B. Use a neighboring forest, the Clearwater, to estimate sediment yield.

C. Estimate base sediment yield using total forest acreage.

1. Area of Clearwater = 1,837,116 acres.
2. Area of Idaho Panhandle = 2,500,000 acres.
3. Base sediment yield on Clearwater = 57.4 MTons/yr.
4. Estimated base yield for Idaho Panhandle is

$\frac{2{,}500{,}000}{1{,}837{,}116} \times 57.4 = 78.1$ MTons/year.

D. Use increase in sediment yield and road construction data from the Clearwater to calculate a regression equation.

1. Then use road construction from Idaho Panhandle as independent variable in this regression to estimate increase in sediment yield on Idaho Panhandle.
2. The Clearwater regression has a low correlation coefficient, r = .28.
3. Try fitting regressions by decade across all Clearwater alternatives. These r values range from .76 to .97 (5 equations).
4. Use decadal regressions with analogous road construction data from Idaho Panhandle to estimate increases in sediment yield.
5. Then add these increases to the estimated base yield (78.1 MTons/year) to get total yields.

E. For example, the regression equations for alternative 1 are:

Period		
1	Y = .9842 X -9.9234	r = .97
2	Y = 1.008 X -3.7335	r = .76
3	Y = 1.2799 X -4.409	r = .97
4	Y = 1.1647 X +4.3735	r = .96
5	Y = 1.142 X +23.602	r = .80

1. Then, solve for increased sediment yield (Y) given road construction miles (X) and add to base yield (78.1 MTons/yr) to get total sediment yield.

Period	Road construction (x)	Increased yield	+ Base	= Total
1	310	295.2	78.1	373.3
2	227	225.1	78.1	303.2
3	163	204.2	78.1	282.3
4	98	118.5	78.1	196.6
5	79	113.8	78.1	191.9

III. Kootenai NF

A. Sediment was not reported. The forest could only provide yield for the no action alternative.

B. Calculate a regression using the no action sediment yield and timber output in BF.

1. The correlation with road construction and timber output in CF was not as good.
2. The regression equation is Y = 4545 X + 43.54, r = .52.

C. Use this regression equation with timber output in BF from all other alternatives as independent variable to estimate sediment yields.

IV. Deerlodge NF

A. Sediment yield was not reported and not available.

B. Calculate a regression equation using the scheduled sediment yield and road construction from the Helena NF.

1. Y = .1652 X + 1.3373, r = .77.

C. Use this regression with road construction from the Deerlodge as the independent variable to estimate sediment yield.

V. Custer NF

A. Sediment yield was not reported and not available.

B. The forest provided a base yield of 2,647 MTONS/yr.

C. No strong linear relationship between road construction and sediment yield on neighboring forests existed.

D. The forest recommended using the ratio between base sediment yield and base water yield to estimate sediment yield.

1. Calculate the base sediment/water yield ratios.

$\frac{2647 \text{ MTons}}{1070 \text{ MAcFt}} = 2.47$ Tons/AcFt.

2. Then multiply the scheduled water yield by this ratio to estimate the schedule for sediment yield.
3. For example, the sediment yield for alternative 1 is estimated as follows:

Period	Water yield	x	Ratio	=	Sediment yield
1	1072.8		2.47		2649.8
2	1077.3		2.47		2660.9
3	1081.1		2.47		2670.3
4	1083.8		2.47		2677.0
5	1085.0		2.47		2680.0

VI. Pike and San Isabel NF

A. Sediment yield was not reported and not available.

B. Use 50-year average road construction and 50-year average increase in sediment over base from each alternative on the Arapaho and Roosevelt NF in a regression equation to estimate the sediment yield on the Pike and San Isabel.

1. Road construction data from the Roosevelt was only available on 50-year average basis.
2. The regression equations is: $Y = .1943 X + 64.9$ and $r = .89$.

C. Estimate base level sediment yield on Pike.

1. Area of Arapaho and Roosevelt = 1,471,963 acres.
2. Area of Pike = 2,751,736 acres.
3. The base level yield on the Roosevelt = 647.84 M Tons/yr.
4. The estimated base level yield on the Pike is:

$$\frac{2,751,736}{1,471,963} \times 647.84 = 1211.09 \text{ MTons/yr.}$$

D. Add the increase in yield estimated using the regression to the estimated base yield to get total sediment yield.

1. Use average annual road construction by decade from the Pike as the independent variable, X, for estimating increase in sediment yield.

VII. Arapaho and Roosevelt NF

A. The 50-year average increase in sediment yield over baseline was reported for all alternatives.

B. The increase in sediment yield over baseline for period 1 across all alternatives was reported.

C. The baseline yield was not reported. The forest provided this data, 647.84 MTons/yr.

D. Road construction was only available as a 50-year average.

E. Use 50-year average timber harvest in a regression with 50-year average increase in sediment yield to estimate schedule for sediment yield.

1. The Regression equation is $Y = 6.1 X + 62.37$ with $r = .93$.
2. Apply scheduled timber harvest to regression equation, as independent variable X, to estimate schedule of sediment yield increases.
3. Then add increases to base yield to get total yield.

VIII. Bighorn NF

A. Soil loss was reported.

B. Not all soil loss becomes sediment.

C. The forest indicated a 19% sediment delivery ratio would approximate sediment yield.

1. Apply sediment delivery ratio to schedule of soil loss to estimate schedule of sediment yield.

IX. Grand Mesa, Uncompahgre, and Gunnison NF

A. Sediment yield was reported in acre feet over current yield for 1st and 5th periods.

B. The forest indicated 1 AcFt sediment = 1600 Ton.

C. Current sediment yield was not reported.

D. Use White River NF to estimate current yield.

1. Prorate using forest acreage.

E. Convert reported yields to tons.

F. Use a regression with 1st and 5th period sediment yield and timber harvest (there was not a good linear relationship with road construction) to estimate yields for periods 2, 3, and 4.

1. Apply timber harvest in these periods as the independent variable in the regression equation.

X. Numerous Forests

A. Many forests reported soil loss instead of sediment yield, especially in Regions 3 and 4.

1. Most forests provided an estimate for a sediment delivery ratio.
2. If forests couldn't provide this estimate, the delivery ratio from a neighboring or similar forest was used.

XI. Coronado NF

A. Sediment yield was not reported and not available.

B. The DEIS indicates sediment yield will decrease because of watershed improvements.

C. Unsatisfactory watershed acres was scheduled.

D. Use a regression with Cibola NF unsatisfactory watershed acres and soil loss over natural to estimate Coronado soil loss over natural.

1. Use alternatives PA, B, C, D, and F from the Cibola since these alternatives display a range of watershed acres closest to those on the Coronado.
2. The regression is $Y = .271421 X + 2621.73$ with $r = .81$.
3. Apply the schedule of unsatisfactory watershed acres from the Coronado to this regression equation (independent variable X) to estimate soil loss over natural.

E. Estimate natural level soil loss on the Coronado by comparing with Cibola forest acreage and soil loss.

1. The area of the Cibola = 1,889,496 acres.
2. The area of the Coronado = 1,726,514 acres.
3. The Cibola natural level soil loss = 2102.5 MTons/yr.
4. The Coronado soil loss is

$$\frac{1,726,514}{1,889,496} \times 2102.5 = 1921.14 \text{ MTons/yr.}$$

F. Add estimated natural level of soil loss to estimated schedule of soil loss over natural to get schedule of total loss.

G. The forest provided an estimate of 10% for the sediment delivery ratio.

1. Apply this ratio to the schedule of total soil loss to estimate sediment yield.

XII. Coconino NF

A. Sediment yield was not reported and not available.

B. The EIS indicated that sediment should decrease due to watershed improvement projects and road obliteration.

C. Use watershed improvement data to estimate sediment yield.

D. The forest provided a current level of soil loss by vegetation type and total forest and approximated a 5-decade schedule for soil loss based on eventual treatment of all treatable unsatisfactory watershed acres.
   1. The current level of soil loss is 2572.36 MTons/yr.
   2. Period / Soil loss (MTons/yr)

Period	Soil loss (MTons/yr)
1	2492.80
2	2331.20
3	2167.18
4	2038.34
5	2026.00

E. The EIS assigned a level of soil and watershed improvement activities to each alternative.
   1. Level #3 represents low level of watershed treatment, the current level.
   2. Level #4 represents 9-fold increase in watershed improvement over current.
   3. Level #5 represents high level of watershed improvement, about 32% over #4.
   4. Level #6 represents maximum funding for watershed improvement, about 50% over level #5 for periods 1 and 2 and 33% over level #5 for periods 3, 4, and 5.

F. The alternatives were assigned the following levels in the EIS:

1.

PA	A	B	C	D	E	F	Max. PNV
3	3	4 (18% nonforested)	3	5	3	3	3
		3 (82% forested)					

G. Assume that the schedule of soil loss based on treating all unsatisfactory watersheds, that is D.2., equates to level #6.

H. Also assume linear and directly proportional relationships between funding and soil loss reductions from improvements.

I. Then, the level #6 schedule for additional soil loss reductions below the previous periods total soil loss in M Tons is as follows.

Period	Previous period loss	-	Present period loss	=	Level #6 soil loss reduction per period
1	2572.36	-	2492.80	=	79.56
2	2492.80	-	2331.20	=	161.60
3	2331.20	-	2167.18	=	164.02
4	2167.18	-	2038.34	=	128.84
5	2038.34	-	2026.00	=	11.74

J. Based on level #6 being 50% over level #5 funding for periods 1 and 2 and 33% over level #5 for periods 3, 4, and 5, the level #5 reduction in soil loss schedule is as follows.

Period	Soil loss reduction	
1	53.04	(1.50 x = 79.56, so x = 53.04)
2	107.73	etc.
3	123.32	(1.33 x = 164.02, so x = 123.32)
4	96.87	etc.
5	8.83	etc.

K. Based on level #5 being about 32% over level #4, level #4 reduction in soil loss schedule is as follows.

Period	Soil loss reduction	
1	40.18	(1.32 x = 53.04 so x = 40.18)
2	81.61	etc.
3	93.42	
4	72.83	
5	6.69	

L. Based on level #4 being about 9-fold increase over current or level #3, level #3 reduction in soil loss schedule is as follows.

Period	Soil loss reduction	
1	4.46	(9x=40.18 and x = 4.46)
2	9.07	etc.
3	10.38	
4	8.09	
5	.74	

M. Apply the above soil loss reduction schedules to each alternative as indicated in F. to estimate total soil loss schedules (start with period 1 loss reduction from current).
   1. For example, alternative PA was assigned level #3 and the estimation of its soil loss is as follows.

Period	Previous period total soil loss	-	Soil loss reduction	=	Total soil loss
1	2572.36	-	4.46	=	2567.90
2	2567.9	-	9.07	=	2558.83
3	2558.83	-	10.38	=	2548.45
4	2548.45	-	8.09	=	2540.36
5	2540.36	-	.74	=	2539.62

N. Then multiply soil loss schedules by 10%, the sediment delivery ratio stated in the EIS, to estimate sediment yield.

XIII. Salmon NF

A. Sediment yield was reported by decade and alternative as the highest percentage yield over natural for any one year in that decade.

B. The natural level was not reported.
   1. The forest provided a natural level of approximately 22 tons/sq. mi. and 2815.06 sq. mi. on the forest x 22 tons/sq. mi. = 61,931.38 Tons/yr.

C. The forest recommended a method to estimate scheduled sediment yield.
   1. Take 30% of highest percentage over natural reported to estimate the decadal annual average.
   2. Multiply the decadal average percentage over natural by the natural level and add back to natural.

3. Each sediment rate reported by stream type is assumed to be an increase to total forest sediment. For example, in period 1 of alternative 1 the sediment rate in resident only streams is 48%. The sediment rate in anadramous streams is 22%. Thus, .30 x .48 + .30 x .22 = .21 or 21%. Then .21 x 61.9 MTons/yr = 13.0 MTons/yr and 61.9 MTons + 13.0 MTons = 74.9 MTons/yr.

IX. Kisatchie NF

A. Sediment yield was not scheduled and not available.

B. 50-year total sediment yields from certain activities were reported by alternative.

C. The forest recommended a methodology for estimating scheduled sediment yield.

1. Use harvest activities, road construction, site preparation, prescribed fire, and skid trails data reported in the EIS in conjunction with sediment yield coefficients provided by the forest and total 50-year yield reported in the EIS to estimate scheduled sediment yield.

D. Period 1 of alternative A is used here as an example.

1. Estimate yield from harvest activities by multiplying acres accessed (pg IV-38) by a yield coefficient of .149 tons/acre. Thus, 18,150.6 acres/yr x .149 tons/acre = 2704.44 tons/yr.

2. Estimate yield from road construction by multiplying miles/year (pg. IV-38) by a conversion factor of 2.42 to get acres/yr and then multiply this product by a yield coefficient of 16.46 tons/acre to get tons sediment/yr. Thus, 94 mi/yr x 2.42 = 227.48 acres/yr and 227.48 acres/yr x 16.46 tons/acre = 3744.32 tons/yr.

3. The estimation of yield from site preparation proceeds as follows.

Assume site preparation is roughly equal to acres of reforestation (pg. IV-21).

Assume sediment yield (reported as total 50-year yield by alternative on pg. IV-27) is proportional to decadal average annual reforestation (pg. IV-21).

Since 50-year reforestation = 58.4 M Acres, and period 1, alternative A reforestation = 12.2 M Acres then 12.2 / 58.4 = .21 and .21 x 236,557 tons/50-yr = 49,417.7 tons/period 1 or 4.94 MTons/yr.

4. The estimation of yield from prescribed fire proceeds as follows.

Assume sediment/period from prescribed fire (reported as 50-yr total by alternative on pg. IV-29) is proportional to average annual acreage treated by prescribed fire (pg. IV-40).

50-year average annual acres treated = 316,810.

Average annual acres treated in period 5 = 64,870.

50-year sediment yield from prescribed fire acres = 282,481 tons.

Thus, estimated sediment yield in tons/period is

$\frac{64,870}{316,810}$ = 20.48% and .2048 x 282,481 tons

= 57,840.8 tons/period 1 or 5.78 M Tons/year.

5. Estimation of yield from skid trails is considered separately since skid trails were not considered in harvest activities.

50-year total sediment yield from skid trails was reported (pg. IV-25).

Assume yield from skid trails is proportional by period to timber harvest (pg. IV-19).

Since period 1 harvest = 28.5 MMCF,

50-year harvest = 194.1 MMCF, and

50-year sediment yield from skid trails = 3191 tons

then $\frac{28.5}{194.1}$ = 14.68%

and .1468 x 3191 = 468.54 tons/period or .05 MTons/yr.

6. Now aggregate above yields as follows.

harvest activities	=	2.7	MTons/yr
road construction	=	3.74	MTons/yr
site preparation	=	4.94	MTons/yr
prescribed fire	=	5.78	MTons/yr
skid trails	=	.05	MTons/yr
Total	=	17.21	MTons/yr

Examples of Distinct Methodologies for Deriving and Estimating Costs

I. Numerous Forests

A. Costs needed to be reported in common base year 1978 dollars.

B. To convert from 1980 and 1982 dollars, the following conversion factors were obtained from the table of implicit price deflators for gross national product, 1929-83.

1. 1980; $\frac{150.42}{178.42}$ = .8430669207

2. 1982; $\frac{150.42}{207.38}$ = .7253351336

II. Numerous Forests

A. Costs as reported often had to be aggregated or disaggregated to derive the total cost figure of interest in this study, i.e., operation and maintenance + capital investment costs + timber purchases road credits + forest fire fighting funds = total cost.

1. The following costs were subtracted out to the extent they were included in any reporting of forest costs; allocated and cooperator funds.

III. Manti-LaSal NF

A. Cost were reported for 3 periods.

1. The third period covered 3 decades.
2. Decadal averages were not available.

3. Use average for last three decades.

IV. Los Padres NF

A. Forest fire fighting costs (FFF) were not reported for benchmark alternatives.
B. Use average FFF costs from the primary alternatives to apply to the benchmarks.

V. Eldorado NF

A. Total cost reported for benchmark alternatives includes nonfederal costs.
   1. The amount of nonfederal costs were not reported.
B. Nonfederal costs are .5 MM$ for all periods of all primary alternatives.
   1. Assume the same for benchmark alternatives and subtract out of total costs.

VI. Several Forests

A. Some forests indicated that costs reported include negligible amounts of allocated funds which were not disaggregable.
B. Record costs as reported.

VII. Mononagahela NF

A. Costs were reported only for periods 1 and 5 while period 2, 3, and 4 costs were not available.
B. Costs are fully scheduled at 4% discount rate.
C. Use discounting formula to derive costs from schedule of discounted costs.
   1. $V_o = \frac{V_n}{(1+p)}$ represents the formula for present net value (PNV)

   where

   V_o = value of sum of money when placed at interest, or after it has been discounted to its present value (PNV),

   V_n = value of sum of money with interest, p, in n years hence,

   n = # of years of interest bearing periods,

   p = interest rate.

   2. So, $V_n = V_o(1+p)^n = V_o(1.04)^n$.

VIII. Wayne NF

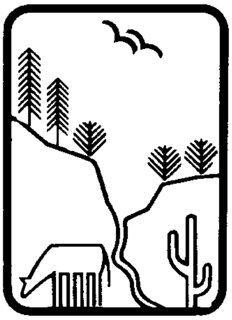
A. Costs were reported only for periods 1 and 5 but not available for periods 2, 3, and 4.
B. Interpolate to estimate periods 2, 3, and 4.

Baltic, Tony; Hof, John. 1988. Documentation of the National Forest System Resource Interactions Model. General Technical Report RM-155. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 30 p.

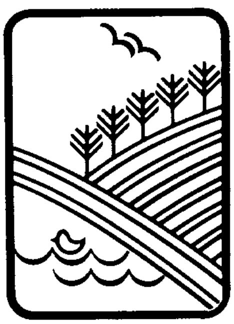
The National Forest System Resource Interactions Model is an upper level linear programming model developed to aid the analysis of multiresource interactions for the 1989 RPA National Assessment. This report documents the development and structure of this linear programming model, emphasizing its multilevel nature and the data requirements for such an approach. A brief description of the solution output that can be derived from the model is also presented. Finally, the resolution of data deficiencies, a major problem in applying such a multilevel optimization approach, is examined.

Keywords: Land management planning, multilevel planning, linear programming, forest economics, modeling

Rocky
Mountains



Southwest



Great
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Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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