Title: Linear Programming Model for Timber Harvest Scheduling

Course:
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Abstract: Here we outline the reasons for using linear programming to economically evaluate timber harvest schedules. The methodology is applied to an actual operational setting. Sensitivity analysis is discussed with regard to capital investment and NPV return.

LINEAR PROGRAMMING MODEL FOR TIMBER HARVEST SCHEDULING

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EMP-P9208

HARVEST SCHEDULING MODEL
HARVEST PLANNING SYSTEM
Engineering Management 535

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INTRODUCTION

A Timber company wishes to plan its harvests for the next fifteen years. It has projected the inflation rate, the rate of increase in log values, and the rate of inflation of its costs. The approximate demands for raw logs (including the demands of its own mills) are also known.

The company owns acreage of forest and can also purchase cutting rights on other lands and pre-harvested logs. One type of forest is recognized, and the distribution of the types of logs that it will yield after harvest has been estimated.

The current volume of wood on each timber stand is known. Applying the distribution (see Appendix A, Table 101) to the current volumes and log values give the present worth (or total log value) of each stand.

Harvest schedules have been typically set at the beginning of each year. During the year there is very little deviation from the plan. Road-building and other lengthy preparations ensure that outside stumpage purchases and log purchases must combine to bridge the gap between actual demand and planned harvests.

Decision makers have noticed that the information available when they realize flaws in their planning was available when the harvest plan was set (Rubitschun, 1992). Too many variables to consider simultaneously, too many limiting factors, and too many years that are affected by each year's plan are the reasons cited for the poor planning (Rubitschun, 1992). These are also the reasons the problem is well suited to linear programming techniques.

The objective is to maximize the net present value of the company's harvesting division. Harvesting a forest (whether owned outright, or ownership of cutting rights) introduces several costs. These include logging costs, transportation costs, and roading costs (to build roads to the site).

If the company owns the land, a reforestation cost is also incurred. This reforestation cost is outside the scope of the model, which is limited to standing timber harvests and log purchases to satisfy log requirements for the planning horizon (fifteen years).

LITERATURE SEARCH

The idea of using linear programming for forest harvest scheduling is not a new one. References to the practice date back to the late 1950's (Clutter, et al., p. 273). Application models such as Timber RAM, FORPLAN, and MAX-MILLION have been used throughout the Southeast and the Pacific Northwest (Clutter, et al., p. 274).

MODEL

$$\text{MAX } Z = \sum_{i=1}^{15} \sum_{j=i}^{i+3} \sum_{k=1}^{\#\text{ of log types}} -c_i F_i - s_i P_i - h_{ij} H_{ij} - l_{ik} L_{ik} + m_i M_i,$$

$F_i, P_i, H_{ij}, L_{ik}, M_i$ decision variables

WHERE

c_i = the present value of the cost to harvest one acre in year i.

F_i = the acreage harvested in year i.

s_i = the present value of the down payment cost of an MBF of outside stumpage in year i.

P_i = the volume in MBF (thousand board feet) of outside stumpage purchased in year i.

h_{ij} = the present value of the cost in year j of the remaining balance per MBF on stumpage purchased in year i, given that the stumpage is harvested in year j.

H_{ij} = the volume in MBF of outside stumpage to be purchased in year i and harvested in year j.

l_{ik} = the present value of the cost of an MBF of log type k in year i.

L_{ik} = the volume in MBF of log type k purchased in year i.

m_{ik} = the price charged to customers per MBF of log type k in year i

M_{ik} = the volume in MBF to be sold of log type k in year i.

S.T.

$$\sum_{i=1}^{15} F_i \leq T_T$$

$$F_i \leq T_i$$

$$\sum_{j=i}^{i+3} H_{ij} \leq G_i$$

$$\sum_{k=1}^{\#\text{ of log types}} L_{ik} \leq O_i$$

FOR

i = the time period, typically a year

j = the maximum allowable wait between the purchase and harvest of outside stumpage.

k = the number of log types

T_T = the overall limit on fee land harvests for the entire planning horizon

T_i = the limit on fee land harvests for year i

G_i = the limit on stumpage harvests for year i

O_i = the limit on log purchases for year i

$$F_i \geq 0 \quad \text{for all } i$$
$$P_i \geq 0 \quad \text{for all } i$$
$$H_{ij} \geq 0 \quad \text{for all } i \text{ and } j$$
$$L_{ik} \geq 0 \quad \text{for all } i \text{ and } k$$
$$M_i \geq 0 \quad \text{for all } i$$

APPROACH

Several factors contributed to making it necessary to formulate the problem as given above. The coefficients in the objective function are all in present dollars per unit. That is, the objective function is discounted back to the present using the given discount rate in Table 5 (see Appendix A). Much of the research was a search for a practical application of stochastic coefficients to a linear programming problem. This search was discontinued for two reasons:

(1) Stochastic Linear Programming lends itself to discrete probability distributions (Qi, p. 183). This is so each possible outcome can be enumerated in terms of the objective function. For this application this is not practical as the size of the problem becomes immense (Beale, Dantzig, and Watson, p. 103).

(2) In LP, the objective function is assumed to be linear. This is not the case since the discount rate for year i+1 is clearly not statistically independent from the discount rate in year i.

The runs were made using 8 % as the discount rate in all periods. The timber company has stated its desire to remain in the timber business, despite what the future seems to hold. For this reason, no alternative investments were included in the scope of the model. However, the model sees that 8 % as the alternative investment rate. As seen in the worst case scenario (Appendix C), the model chooses to cut everything it can immediately, leaving only enough to satisfy the lower bounds for future years. In this instance, the timber company would only peripherally be in the timber business beyond the first year.

The converse is also true. In the best case scenario (Appendix D), the model sits and waits for the final year. In fact the model will choose to take negative present values for each of the first fourteen years if the lower bounds on harvests are lifted. This is so it can make a killing in the last year for the overall highest possible present value.

The thought of purposefully losing money for fourteen years for the sake of a year fifteen windfall seems ludicrous, and rightfully so. The model does not see the uncertainty which accompanies the future.

DISCUSSION

Another interesting approach to the problem would be to simulate the variables that are deemed stochastic. This method would yield distributions of output (objective value, decision variable activities, and shadow prices). However, the analysis of such results remains a problem.

There is no guarantee, in fact it's doubtful, that the means of the decision variables would form a feasible solution set. In this context the feasible solution refers to the problem in which all stochastic variables (coefficients, right-hand-sides, bounds) take on their expected values. Further, it is possible that one of the problems defined by a simulation of stochastic values may be infeasible itself.

This again points to the complete enumeration method which is impractical in this instance.

CONCLUSIONS

A crucial concern of the timber company is that they are not taking advantage of all their information. In particular, they see a crisis management style of decision making that is evolving into a policy of "cut today--tomorrow you may not be able to." (Griffith, 1992) This is not in line with their desire to remain in the business they have chosen for themselves.

Indeed, recent crises in the forest industry have increased competition, and put several companies out of business. There seems a promise of a big share of a huge market for the survivors.

The demand for wood is not likely to evaporate (McGair, 1992).

Any multi-stage planning model raises certain questions about the planning horizon. For example, "What happens when you take the results of the 15 year run and plan one year's harvest based on what it said was the optimal harvest schedule for the first year?" Then in the second year, with nothing to lock you in to the original plan, you run the model again. Since your data is better, this seems to make sense. Then you plan your harvests based again on the first year's optimal plan. What happens in the long term?

In the best case scenario, you harvest only what you must, preferring to wait until the last possible moment to cash in (see Appendix E). When you run the model each year, you keep sitting on your hands, in hopes of huge returns someday. "You better learn fast . . . Someday never comes." (John Fogerty)

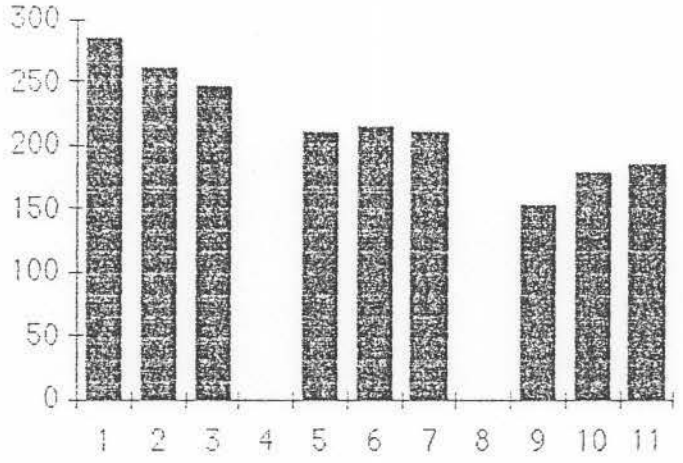
Though no sensitivity analysis was performed with respect to the discount rate, other parameters were tested. It was interesting to see what happened if the optimal plan for the most likely scenario were adopted, and the best case or worst case occurred. Likewise for the other optimal plans.

Runs were made so that each of the nine possibilities could be evaluated (three plans * three outcomes). The results are:

PLAN FOR	OUTCOME	NPV ($000000)
1. Best Case	Best Case	284
2. Most Likely	Best Case	260
3. Worst Case	Best Case	245
5. Best Case	Most Likely	209
6. Most Likely	Most Likely	214
7. Worst Case	Most Likely	210
9. Best Case	Worst Case	152
10. Most Likely	Worst Case	179
11. Worst Case	Worst Case	184

The data from the previous chart is graphed below:

OVERALL NPV BY PLAN AND OUTCOME IN $ MILLION



From this data, it seems a straight forward decision to plan for the most likely case. You've foregone $24 million if the best case happens, but only $5 million if the worst occurs.

This analysis is far from complete, but since the most likely optimal plan involves the least risk, it can be recommended. Further recommendations must include the making of additional runs. The model as formulated lends itself to runs of different planning horizons. It could also be used to model any one given year. In this case the model's primary role would be to allocate the demands for logs to the three types of sources, owned (fee) land harvests, purchased timber rights (stumpage), and log purchases.

This would diminish the model's role in that it would deemphasize the time value of money and the effect of leaving the trees to grow. These two factors influence decision making heavily in the fifteen year model.

APPENDIX A - THE DATABASE

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TABLE 1 HEADER, PURPOSE, AND MODIFICATIONS

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	> COL
HARVEST SCHEDULING MODEL	CL1
Engineering Management 535	CX4
Project Run: Most Likely	CX5
	CX6

*

*

MODEL OUTPUT	P01
To Evaluate Harvest Scheduling	P02
Decisions Under the Assumed	P03
Most Likely Scenario.	P04

*

*

THE PLANNING HORIZON IS ASSUMED TO BE FIFTEEN YEARS.	M01
THE SCOPE OF THE MODEL IS FROM THE FOREST TO THE LOG	M02
DESTINATIONS (MILLS, EXPORTS, LOG SALES). ADDITION-	M03
AL ASSUMPTIONS ARE AS FOLLOWS:	M04
	M05
1. Inflation = 8.0 %	M06
2. Real Price Appreciation = 4.0 %	M07
3. Real Cost Increase = 4.0 %	M08
4. Total Fee Harvest Limit = 400000 MBF	M09
5. Total Stumpage Purchase Limit = 100000 MBF	M10
6. Total Log Purchase limit = 100000 MBF	M11
7. Annual Fee Harvests Required = 10000 MBF	M12
8. Domestic Sales Unconstrained	M13

*

*---

TABLE 2 SPECIES

*---

	> A
DOUGLAS FIR	D
HEMLOCK	H
PINE	P
STANDARD	S

*

*---

TABLE 3 MISCELLANEOUS INFORMATION

*---

	>	INFO
STUMPAGE HARVEST DEADLINE (YRS)	TIME	3
TOTAL FEE LAND LIMIT (MBF)	FEUP	400000
TOTAL STUMPAGE LIMIT (MBF)	STUP	100000
TOTAL PURCHASE LIMIT (MBF)	PRUP	100000

```
*
*
*-------------------------------------------------------------------------
        TABLE 4  REPORTING PERIODS
*-------------------------------------------------------------------------
*
*
                >   92  93  94  95  96  97  98  99  00  01  02  03  04  05  06
     1992        01   1
     1993        02       1
     1994        03           1
     1995        04               1
     1996        05                   1
     1997-2001   06                       1   1   1   1   1
     2002-2006   07                                           1   1   1   1   1
*
*-------------------------------------------------------------------------
        TABLE 5  FINANCIAL INFORMATION
*-------------------------------------------------------------------------
*                          REAL
*               DISCOUNT   PRICE     COST    FIXED
*                 RATE  APPRECIATION INCREASE  COST
*
          >      IADJ       PADJ       CADJ       FIXD
*
*                 (%)        (%)        (%)      (¤000)
*
     1992    92    8.0        4.0        4.0        2000
     1993    93    8.0        4.0        4.0        2000
     1994    94    8.0        4.0        4.0        2000
     1995    95    8.0        4.0        4.0        2000
     1996    96    8.0        4.0        4.0        2000
     1997    97    8.0        4.0        4.0        2000
     1998    98    8.0        4.0        4.0        2000
     1999    99    8.0        4.0        4.0        2000
     2000    00    8.0        4.0        4.0        2000
     2001    01    8.0        4.0        4.0        2000
     2002    02    8.0        4.0        4.0        2000
     2003    03    8.0        4.0        4.0        2000
     2004    04    8.0        4.0        4.0        2000
     2005    05    8.0        4.0        4.0        2000
     2006    06    8.0        4.0        4.0        2000
*
*-------------------------------------------------------------------------
        TABLE 10  TIMBER SETTING AND LOG TYPE CROSS REFERENCE
*-------------------------------------------------------------------------
*
*                                                  TABLE      SPECIES
                                          >          ID          S
* FOREST TYPE
*
     STANDARD FOREST 90% D FIR      DFJEM       '101'       'S'
*
```

```
*
*-------------------------------------------------------------------------
        TABLE 50  FORECASTED LOG VALUES
*-------------------------------------------------------------------------
*
*                          ------------------TIME PERIODS------------------
*                         YEAR  92    93    94    95    96    97    98   99
*
                         >      92    93    94    95    96    97    98   99
*                                                    (¤/MBF)
* DOUG FIR
      Doug Fir Log 1      DLG1 940
      Doug Fir Log 2      DLG2 840
      Doug Fir Log 3      DLG3 610
      Doug Fir Log 4      DLG4 610
      Doug Fir Log 5      DLG5 610
      Doug Fir Log 6      DLG6 595
      Doug Fir Log 7      DLG7 450
      Doug Fir Log 8      DLG8 450
* HEMLOCK
      Hemlock Log  1      HLG1 470
      Hemlock Log  2      HLG2 440
      Hemlock Log  3      HLG3 415
      Hemlock Log  3      HLG4 415
* PINE
      Pine Log Type  1    PLG1 510
      Pine Log Type  2    PLG2 230
      Pine Log Type  3    PLG3 230
      Pine Log Type  4    PLG4 250
*
*                          ------TIME PERIODS------
*                         YEAR  00    01    02    03    04    05    06
*
+R                       >      00    01    02    03    04    05    06
*                                    (¤/MBF)
* DOUG FIR
      Doug Fir Log 1      DLG1
      Doug Fir Log 2      DLG2
      Doug Fir Log 3      DLG3
      Doug Fir Log 4      DLG4
      Doug Fir Log 5      DLG5
      Doug Fir Log 6      DLG6
      Doug Fir Log 7      DLG7
      Doug Fir Log 8      DLG8
* HEMLOCK
      Hemlock Log  1      HLG1
      Hemlock Log  2      HLG2
      Hemlock Log  3      HLG3
      Hemlock Log  4      HLG4
* PINE
      Pine Log Type  1    PLG1
      Pine Log Type  2    PLG2
      Pine Log Type  3    PLG3
      Pine Log Type  4    PLG4
*
```

TABLE 60 FEE VOLUME LIMITS AND COSTS BY FOREST TYPE

		FEE						
		STUMP COST	LOGGING COST	ROAD COST	TRANS COST	MISC. COST	# ACRE	PER AC VOLUME (MBF)
		($/MBF)						
	>	STMP	LOGG	ROAD	TRNS	MISC	ACRE	VOLM
STANDARD	FOREST DFJEM	3	65	25	25	10	125200	31.9

TABLE 65 FEE HARVEST LIMITS BY FOREST TYPE AND TIME PERIOD

		TIME PERIODS									
	YEAR:	92 LO	92 UP	93 LO	93 UP	94 LO	94 UP	95 LO	95 UP	96 LO	96 UP
	>	92LO	92UP	93LO	93UP	94LO	94UP	95LO	95UP	96LO	96UP
		(MMBF)									
TOTAL FEE	TOTAL										
STANDARD	DFJEM	10		10		10		10		10	

		TIME PERIODS									
	YEAR:	97 LO	97 UP	98 LO	98 UP	99 LO	99 UP	00 LO	00 UP	01 LO	01 UP
+R	>	97LO	97UP	98LO	98UP	99LO	99UP	00LO	00UP	01LO	01UP
		(MMBF)									
TOTAL FEE	TOTAL										
STANDARD	DFJEM	10		10		10		10		10	

		TIME PERIODS									
	YEAR:	02 LO	02 UP	03 LO	03 UP	04 LO	04 UP	05 LO	05 UP	06 LO	06 UP
+R	>	02LO	02UP	03LO	03UP	04LO	04UP	05LO	05UP	06LO	06UP
		(MMBF)									
TOTAL FEE	TOTAL										
STANDARD	DFJEM	10		10		10		10		10	

TABLE 70 STUMPAGE VOLUME LIMITS AND COSTS BY FOREST TYPE

		STUMPAGE				
		LOG-GING COST	ROAD COST	TRANS COST	MISC. COST	DOWN PAY'T PRCNT
		(¤/MBF)				%
>		LOGG	ROAD	TRNS	MISC	DOWN
STANDARD	DFJEM	65	25	25	10	10

---STUMPAGE PRICES AND AVAILABLE VOLUME----

		---1992---		---1993---		---1994---		---1995---	
>		92UP MBF	92PR ¤/MBF	93UP MBF	93PR ¤/MBF	94UP MBF	94PR ¤/MBF	95UP MBF	95PR ¤/MB
TOTAL STUMPAGE	TOTAL								
STANDARD	DFJEM	190000	380	190000	380	190000	380	190000	380

---STUMPAGE PRICES AND AVAILABLE VOLUME----

		---1996---		---1997---		---1998---		---1999---	
>		96UP MBF	96PR ¤/MBF	97UP MBF	97PR ¤/MBF	98UP MBF	98PR ¤/MBF	99UP MBF	99PR ¤/MB
TOTAL STUMPAGE	TOTAL								
STANDARD	DFJEM	190000	380	190000	380	190000	380	190000	380

---STUMPAGE PRICES AND AVAILABLE VOLUME----

		---2000---		---2001---		---2002---		---2003---	
>		00UP MBF	00PR ¤/MBF	01UP MBF	01PR ¤/MBF	02UP MBF	02PR ¤/MBF	03UP MBF	03PR ¤/MB
TOTAL STUMPAGE	TOTAL								
STANDARD	DFJEM	190000	380	190000	380	190000	380	190000	380

---STUMPAGE PRICES AND AVAILABLE VOLUME----

		---2004---		---2005---		---2006---	
>		04UP MBF	04PR ¤/MBF	05UP MBF	05PR ¤/MBF	06UP MBF	06PR ¤/MBF
TOTAL STUMPAGE	TOTAL						
STANDARD	DFJEM	190000	380	190000	380	190000	380	190000	380

TABLE 90 PURCHASED LOGS

TOTAL PURCHASE	TOTL	----1992---- SOURCE: 1 92UP1 (MBF)	92PR1 (¤/MBF)	----1993---- SOURCE: 1 93UP1 (MBF)	93PR1 (¤/MBF)	----1994---- SOURCE: 1 94UP1 (MBF)	94PR1 (¤/MBF)
DOUG FIR							
Doug Fir Log 1	DLG1	940		959		978	
Doug Fir Log 2	DLG2	840		857		874	
Doug Fir Log 3	DLG3	610		622		634	
Doug Fir Log 4	DLG4	610		622		634	
Doug Fir Log 5	DLG5	610		622		634	
Doug Fir Log 6	DLG6	595		607		619	
Doug Fir Log 7	DLG7	450		459		468	
Doug Fir Log 8	DLG8	450		459		468	
HEMLOCK							
Hemlock Log 1	HLG1	470		479		489	
Hemlock Log 2	HLG2	440		449		458	
Hemlock Log 3	HLG3	415		423		432	
Hemlock Log 4	HLG4	415		423		432	
PINE							
Pine Log Type 1	PLG1	510		520		530	
Pine Log Type 2	PLG2	230		235		239	
Pine Log Type 3	PLG3	230		235		239	
Pine Log Type 4	PLG4	250		255		260	

TOTAL PURCHASE	TOTL	----1995---- SOURCE: 1 95UP1 (MBF)	95PR1 (¤/MBF)	----1996---- SOURCE: 1 96UP1 (MBF)	96PR1 (¤/MBF)	----1997---- SOURCE: 1 97UP1 (MBF)	97PR1 (¤/MBF)
DOUG FIR							
Doug Fir Log 1	DLG1	996		1034		1062	
Doug Fir Log 2	DLG2	890		924		949	
Doug Fir Log 3	DLG3	647		671		689	
Doug Fir Log 4	DLG4	647		671		689	
Doug Fir Log 5	DLG5	647		671		689	
Doug Fir Log 6	DLG6	631		654		672	
Doug Fir Log 7	DLG7	477		495		508	
Doug Fir Log 8	DLG8	477		495		508	
HEMLOCK							
Hemlock Log 1	HLG1	498		517		531	
Hemlock Log 2	HLG2	466		484		497	
Hemlock Log 3	HLG3	440		457		469	
Hemlock Log 4	HLG4	440		457		469	
PINE							
Pine Log Type 1	PLG1	541		561		576	
Pine Log Type 2	PLG2	244		253		260	
Pine Log Type 3	PLG3	244		253		260	
Pine Log Type 4	PLG4	265		275		282	

```
*
*                                  ----1998----  ----1999----  ----2000----
*                                  SOURCE:  1    SOURCE:  1    SOURCE:  1
+R                          >       98UP1  98PR1  99UP1  99PR1  00UP1  00PR1
*                                  (MBF) (¤/MBF) (MBF) (¤/MBF) (MBF) (¤/MBF)
* DOUG FIR
      Doug Fir Log 1        DLG1      1081          1109          1128
      Doug Fir Log 2        DLG2       966           991          1008
      Doug Fir Log 3        DLG3       702           720           732
      Doug Fir Log 4        DLG4       702           720           732
      Doug Fir Log 5        DLG5       702           720           732
      Doug Fir Log 6        DLG6       684           702           714
      Doug Fir Log 7        DLG7       518           531           540
      Doug Fir Log 8        DLG8       518           531           540
* HEMLOCK
      Hemlock Log  1        HLG1       540           555           564
      Hemlock Log  2        HLG2       506           519           528
      Hemlock Log  3        HLG3       477           490           498
      Hemlock Log  4        HLG4       477           490           498
* PINE
      Pine Log Type  1      PLG1       586           602           612
      Pine Log Type  2      PLG2       264           271           276
      Pine Log Type  3      PLG3       264           271           276
      Pine Log Type  4      PLG4       288           295           300
*
*
*                                  ----2001----  ----2002----  ----2003----
*                                  SOURCE:  1    SOURCE:  1    SOURCE:  1
+R                          >       01UP1  01PR1  02UP1  02PR1  03UP1  03PR1
*                                  (MBF) (¤/MBF) (MBF) (¤/MBF) (MBF) (¤/MBF)
* DOUG FIR
      Doug Fir Log 1        DLG1      1147          1175          1194
      Doug Fir Log 2        DLG2      1025          1050          1067
      Doug Fir Log 3        DLG3       744           762           775
      Doug Fir Log 4        DLG4       744           762           775
      Doug Fir Log 5        DLG5       744           762           775
      Doug Fir Log 6        DLG6       726           744           756
      Doug Fir Log 7        DLG7       549           562           572
      Doug Fir Log 8        DLG8       549           562           572
* HEMLOCK
      Hemlock Log  1        HLG1       573           588           597
      Hemlock Log  2        HLG2       537           550           559
      Hemlock Log  3        HLG3       506           519           527
      Hemlock Log  4        HLG4       506           519           527
* PINE
      Pine Log Type  1      PLG1       622           638           648
      Pine Log Type  2      PLG2       281           288           292
      Pine Log Type  3      PLG3       281           288           292
      Pine Log Type  4      PLG4       305           312           318
```

			----2004----		----2005----		----2006----	
			SOURCE: 1		SOURCE: 1		SOURCE: 1	
+R		>	04UP1 (MBF)	04PR1 (¤/MBF)	05UP1 (MBF)	05PR1 (¤/MBF)	06UP1 (MBF)	06PR1 (¤/MBF)
* LOG DISTRIBUTION								
* DOUG FIR								
	Doug Fir Log 1	DLG1	1222		1241		1269	
	Doug Fir Log 2	DLG2	1092		1109		1134	
	Doug Fir Log 3	DLG3	793		805		824	
	Doug Fir Log 4	DLG4	793		805		824	
	Doug Fir Log 5	DLG5	793		805		824	
	Doug Fir Log 6	DLG6	774		785		803	
	Doug Fir Log 7	DLG7	585		594		608	
	Doug Fir Log 8	DLG8	585		594		608	
* HEMLOCK								
	Hemlock Log 1	HLG1	611		620		634	
	Hemlock Log 2	HLG2	572		581		594	
	Hemlock Log 3	HLG3	540		548		560	
	Hemlock Log 4	HLG4	540		548		560	
* PINE								
	Pine Log Type 1	PLG1	663		673		688	
	Pine Log Type 2	PLG2	299		304		310	
	Pine Log Type 3	PLG3	299		304		310	
	Pine Log Type 4	PLG4	325		330		338	

```
*
*
*-------------------------------------------------------------------
         TABLE 101 DOUG FIR        J SORT              DFJEM
*-------------------------------------------------------------------
*                                 ------------------TIME PERIODS----------
                           >        92    93    94    95    96    97    98    99
*
      VOL CHANGE %          VOLC   2.8   2.8   2.8   2.8   2.8   2.8   2.8   2.8
* LOG DISTRIBUTION - % BY SPECIES AND SORT
* DOUG FIR
      Doug Fir Log 1        DLG1  12.9  12.9  12.9  12.9  12.9  12.9  12.9  12.9
      Doug Fir Log 2        DLG2   8.6   8.6   8.6   8.6   8.6   8.6   8.6   8.6
      Doug Fir Log 3        DLG3  15.9  15.9  15.9  15.9  15.9  15.9  15.9  15.9
      Doug Fir Log 4        DLG4  12.8  12.8  12.8  12.8  12.8  12.8  12.8  12.8
      Doug Fir Log 5        DLG5  10.2  10.2  10.2  10.2  10.2  10.2  10.2  10.2
      Doug Fir Log 6        DLG6   9.4   9.4   9.4   9.4   9.4   9.4   9.4   9.4
      Doug Fir Log 7        DLG7   9.2   9.2   9.2   9.2   9.2   9.2   9.2   9.2
      Doug Fir Log 8        DLG8  11.2  11.2  11.2  11.2  11.2  11.2  11.2  11.2
* HEMLOCK
      Hemlock Log  1        HLG1   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2
      Hemlock Log  2        HLG2    .5    .5    .5    .5    .5    .5    .5    .5
      Hemlock Log  3        HLG3   1.4   1.4   1.4   1.4   1.4   1.4   1.4   1.4
      Hemlock Log  4        HLG4    .8    .8    .8    .8    .8    .8    .8    .8
* PINE
      Pine Log Type  1      PLG1   1.8   1.8   1.8   1.8   1.8   1.8   1.8   1.8
      Pine Log Type  2      PLG2   1.4   1.4   1.4   1.4   1.4   1.4   1.4   1.4
      Pine Log Type  3      PLG3   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2
      Pine Log Type  4      PLG4   1.5   1.5   1.5   1.5   1.5   1.5   1.5   1.5
*
*                                 ------------------TIME PERIODS----------
+R                         >        00    01    02    03    04    05    06
      VOL CHANGE %          VOLC   2.8   2.8   2.8   2.8   2.8   2.8   2.8
* LOG DISTRIBUTION - % BY SPECIES AND SORT
* DOUG FIR
      Doug Fir Log 1        DLG1  12.9  12.9  12.9  12.9  12.9  12.9  12.9
      Doug Fir Log 2        DLG2   8.6   8.6   8.6   8.6   8.6   8.6   8.6
      Doug Fir Log 3        DLG3  15.9  15.9  15.9  15.9  15.9  15.9  15.9
      Doug Fir Log 4        DLG4  12.8  12.8  12.8  12.8  12.8  12.8  12.8
      Doug Fir Log 5        DLG5  10.2  10.2  10.2  10.2  10.2  10.2  10.2
      Doug Fir Log 6        DLG6   9.4   9.4   9.4   9.4   9.4   9.4   9.4
      Doug Fir Log 7        DLG7   9.2   9.2   9.2   9.2   9.2   9.2   9.2
      Doug Fir Log 8        DLG8  11.2  11.2  11.2  11.2  11.2  11.2  11.2
* HEMLOCK
      Hemlock Log  1        HLG1   1.2   1.2   1.2   1.2   1.2   1.2   1.2
      Hemlock Log  2        HLG2    .5    .5    .5    .5    .5    .5    .5
      Hemlock Log  3        HLG3   1.4   1.4   1.4   1.4   1.4   1.4   1.4
      Hemlock Log  4        HLG4    .8    .8    .8    .8    .8    .8    .8
* PINE
      Pine Log Type  1      PLG1   1.8   1.8   1.8   1.8   1.8   1.8   1.8
      Pine Log Type  2      PLG2   1.4   1.4   1.4   1.4   1.4   1.4   1.4
      Pine Log Type  3      PLG3   1.2   1.2   1.2   1.2   1.2   1.2   1.2
      Pine Log Type  4      PLG4   1.5   1.5   1.5   1.5   1.5   1.5   1.5
```

```
*
*
*-------------------------------------------------------------------------
        TABLE 200   LOG REQUIREMENT DESTINATIONS
*-------------------------------------------------------------------------
*
*                                          LOG
                              >            USE
*                                         OPTIONS
*
      SAWMILL  NO. 1          01
      PLYWOOD  PLANT          02
      DOMESTIC SALES          03
```

TABLE 201 SAWMILL NO. 1: LOG REQUIREMENTS

		TIME PERIODS					
	YEAR:	1992	1993	1994	1995	1996	1997
	>	92FX	93FX	94FX	95FX	96FX	97FX
					(MBF)		
DOUG FIR							
Doug Fir Log 1	DLG1	25	25	25	25	25	25
Doug Fir Log 2	DLG2	25	25	25	25	25	25
Doug Fir Log 3	DLG3	25	25	25	25	25	25
Doug Fir Log 4	DLG4	25	25	25	25	25	25
Doug Fir Log 5	DLG5	25	25	25	25	25	25
Doug Fir Log 6	DLG6	25	25	25	25	25	25
Doug Fir Log 7	DLG7	2330	2446	2568	2696	2831	2973
Doug Fir Log 8	DLG8	1035	1087	1141	1198	1258	1321
HEMLOCK							
Hemlock Log 1	HLG1	25	25	25	25	25	25
Hemlock Log 2	HLG2	25	25	25	25	25	25
Hemlock Log 3	HLG3	25	25	25	25	25	25
Hemlock Log 4	HLG4	25	25	25	25	25	25
PINE							
Pine Log Type 1	PLG1	25	25	25	25	25	25
Pine Log Type 2	PLG2	25	25	25	25	25	25
Pine Log Type 3	PLG3	25	25	25	25	25	25
Pine Log Type 4	PLG4	25	25	25	25	25	25

		TIME PERIODS						
	YEAR:	1998	1999	2000	2001	2002	2003	2004
+R	>	98FX	99FX	00FX	01FX	02FX	03FX	04FX
					(MBF)			
DOUG FIR								
Doug Fir Log 1	DLG1	25	25	25	25	25	25	25
Doug Fir Log 2	DLG2	25	25	25	25	25	25	25
Doug Fir Log 3	DLG3	25	25	25	25	25	25	25
Doug Fir Log 4	DLG4	25	25	25	25	25	25	25
Doug Fir Log 5	DLG5	25	25	25	25	25	25	25
Doug Fir Log 6	DLG6	25	25	25	25	25	25	25
Doug Fir Log 7	DLG7	2330	2446	2568	2696	2831	2973	3122
Doug Fir Log 8	DLG8	1035	1087	1141	1198	1258	1321	1387
HEMLOCK								
Hemlock Log 1	HLG1	25	25	25	25	25	25	25
Hemlock Log 2	HLG2	25	25	25	25	25	25	25
Hemlock Log 3	HLG3	25	25	25	25	25	25	25
Hemlock Log 4	HLG4	25	25	25	25	25	25	25
PINE								
Pine Log Type 1	PLG1	25	25	25	25	25	25	25
Pine Log Type 2	PLG2	25	25	25	25	25	25	25
Pine Log Type 3	PLG3	25	25	25	25	25	25	25
Pine Log Type 4	PLG4	25	25	25	25	25	25	25

```
*
*
*
*                          ------------------TIME PERIODS-------------------
*                       YEAR:     2005    2006
*
+R                        >        05FX    06FX
*                                             (MBF)
*
* DOUG FIR
       Doug Fir Log 1        DLG1     25      25
       Doug Fir Log 2        DLG2     25      25
       Doug Fir Log 3        DLG3     25      25
       Doug Fir Log 4        DLG4     25      25
       Doug Fir Log 5        DLG5     25      25
       Doug Fir Log 6        DLG6     25      25
       Doug Fir Log 7        DLG7   2330    2446
       Doug Fir Log 8        DLG8   1035    1087
* HEMLOCK
       Hemlock Log  1        HLG1     25      25
       Hemlock Log  2        HLG2     25      25
       Hemlock Log  3        HLG3     25      25
       Hemlock Log  4        HLG4     25      25
* PINE
       Pine Log Type  1      PLG1     25      25
       Pine Log Type  2      PLG2     25      25
       Pine Log Type  3      PLG3     25      25
       Pine Log Type  4      PLG4     25      25
*
```

*
*
*--

TABLE 202 PLYWOOD PLANT: LOG REQUIREMENTS

*--
*

		TIME PERIODS					
	YEAR:	1992	1993	1994	1995	1996	1997
	>	92FX	93FX	94FX	95FX (MBF)	96FX	97FX
* DOUG FIR							
Doug Fir Log 1	DLG1	25	25	25	25	25	25
Doug Fir Log 2	DLG2	25	25	25	25	25	25
Doug Fir Log 3	DLG3	25	25	25	25	25	25
Doug Fir Log 4	DLG4	25	25	25	25	25	25
Doug Fir Log 5	DLG5	25	25	25	25	25	25
Doug Fir Log 6	DLG6	25	25	25	25	25	25
Doug Fir Log 7	DLG7	2330	2446	2568	2696	2831	2973
Doug Fir Log 8	DLG8	1035	1087	1141	1198	1258	1321
* HEMLOCK							
Hemlock Log 1	HLG1	25	25	25	25	25	25
Hemlock Log 2	HLG2	25	25	25	25	25	25
Hemlock Log 3	HLG3	25	25	25	25	25	25
Hemlock Log 4	HLG4	25	25	25	25	25	25
* PINE							
Pine Log Type 1	PLG1	25	25	25	25	25	25
Pine Log Type 2	PLG2	25	25	25	25	25	25
Pine Log Type 3	PLG3	25	25	25	25	25	25
Pine Log Type 4	PLG4	25	25	25	25	25	25

*
*

		TIME PERIODS						
	YEAR:	1998	1999	2000	2001	2002	2003	2004
+R	>	98FX	99FX	00FX	01FX (MBF)	02FX	03FX	04FX
* DOUG FIR								
Doug Fir Log 1	DLG1	493	518	544	571	600	630	662
Doug Fir Log 2	DLG2	1435	1507	1582	1661	1744	1831	1923
Doug Fir Log 3	DLG3	638	670	704	739	776	815	856
Doug Fir Log 4	DLG4	400	420	441	463	486	510	536
Doug Fir Log 5	DLG5	25	25	25	25	25	25	25
Doug Fir Log 6	DLG6	25	25	25	25	25	25	25
Doug Fir Log 7	DLG7	25	25	25	25	25	25	25
Doug Fir Log 8	DLG8	25	25	25	25	25	25	25
* HEMLOCK								
Hemlock Log 1	HLG1	25	25	25	25	25	25	25
Hemlock Log 2	HLG2	25	25	25	25	25	25	25
Hemlock Log 3	HLG3	25	25	25	25	25	25	25
Hemlock Log 4	HLG4	25	25	25	25	25	25	25
* PINE								
Pine Log Type 1	PLG1	25	25	25	25	25	25	25
Pine Log Type 2	PLG2	25	25	25	25	25	25	25
Pine Log Type 3	PLG3	25	25	25	25	25	25	25
Pine Log Type 4	PLG4	25	25	25	25	25	25	25

```
*
*
*                          --------------------TIME PERIODS---------------------
*                      YEAR:     2005    2006
*
+R                        >       05FX    06FX
*                                            (MBF)
*
* DOUG FIR
       Doug Fir Log 1        DLG1    695     730
       Doug Fir Log 2        DLG2   2019    2120
       Doug Fir Log 3        DLG3    899     944
       Doug Fir Log 4        DLG4    563     591
       Doug Fir Log 5        DLG5     25      25
       Doug Fir Log 6        DLG6     25      25
       Doug Fir Log 7        DLG7     25      25
       Doug Fir Log 8        DLG8     25      25
* HEMLOCK
       Hemlock Log  1        HLG1     25      25
       Hemlock Log  2        HLG2     25      25
       Hemlock Log  3        HLG3     25      25
       Hemlock Log  4        HLG4     25      25
* PINE
       Pine Log Type  1      PLG1     25      25
       Pine Log Type  2      PLG2     25      25
       Pine Log Type  3      PLG3     25      25
       Pine Log Type  4      PLG4     25      25
```

```
*
*
*-------------------------------------------------------------------------
         TABLE 203   DOMESTIC SALES: LOG REQUIREMENTS
*-------------------------------------------------------------------------
*                          --------------------TIME PERIODS--------------------
*                    YEAR:      92    92    93    93    94    94    95    95
*                               LO    UP    LO    UP    LO    UP    LO    UP
                      >       92LO  92UP  93LO  93UP  94LO  94UP  95LO  95UP
*                                              (MBF)
* DOUG FIR
      Doug Fir Log 1      DLG1
      Doug Fir Log 2      DLG2
      Doug Fir Log 3      DLG3
      Doug Fir Log 4      DLG4
      Doug Fir Log 5      DLG5
      Doug Fir Log 6      DLG6
      Doug Fir Log 7      DLG7
      Doug Fir Log 8      DLG8
* HEMLOCK
      Hemlock Log  1      HLG1
      Hemlock Log  2      HLG2
      Hemlock Log  3      HLG3
      Hemlock Log  4      HLG4
* PINE
      Pine Log Type  1    PLG1
      Pine Log Type  2    PLG2
      Pine Log Type  3    PLG3
      Pine Log Type  4    PLG4
*                          --------------------TIME PERIODS--------------------
*                YEAR:            96    96    97    97    98    98    99    99
*                                 LO    UP    LO    UP    LO    UP    LO    UP
+R                      >       96LO  96UP  97LO  97UP  98LO  98UP  99LO  99UP
*                                              (MBF)
* DOUG FIR
      Doug Fir Log 1      DLG1
      Doug Fir Log 2      DLG2
      Doug Fir Log 3      DLG3
      Doug Fir Log 4      DLG4
      Doug Fir Log 5      DLG5
      Doug Fir Log 6      DLG6
      Doug Fir Log 7      DLG7
      Doug Fir Log 8      DLG8
* HEMLOCK
      Hemlock Log  1      HLG1
      Hemlock Log  2      HLG2
      Hemlock Log  3      HLG3
      Hemlock Log  4      HLG4
* PINE
      Pine Log Type  1    PLG1
      Pine Log Type  2    PLG2
      Pine Log Type  3    PLG3
      Pine Log Type  4    PLG4
```

```
*
*
*                          --------------------TIME PERIODS--------------------
*                YEAR:              00    00    01    01    02    02    03    03
*                                    LO    UP    LO    UP    LO    UP    LO    UP
+R                          >      00LO  00UP  01LO  01UP  02LO  02UP  03LO  03UP
*                                                 (MBF)
* DOUG FIR
      Doug Fir Log 1      DLG1
      Doug Fir Log 2      DLG2
      Doug Fir Log 3      DLG3
      Doug Fir Log 4      DLG4
      Doug Fir Log 5      DLG5
      Doug Fir Log 6      DLG6
      Doug Fir Log 7      DLG7
      Doug Fir Log 8      DLG8
* HEMLOCK
      Hemlock Log  1      HLG1
      Hemlock Log  2      HLG2
      Hemlock Log  3      HLG3
      Hemlock Log  4      HLG4
* PINE
      Pine Log Type  1    PLG1
      Pine Log Type  2    PLG2
      Pine Log Type  3    PLG3
      Pine Log Type  4    PLG4
*
*
*                          --------------------TIME PERIODS------------------
*                YEAR:              04    04    05    05    06    06
*                                    LO    UP    LO    UP    LO    UP
+R                          >      04LO  04UP  05LO  05UP  06LO  06UP
*                                                 (MBF)
* DOUG FIR
      Doug Fir Log 1      DLG1
      Doug Fir Log 2      DLG2
      Doug Fir Log 3      DLG3
      Doug Fir Log 4      DLG4
      Doug Fir Log 5      DLG5
      Doug Fir Log 6      DLG6
      Doug Fir Log 7      DLG7
      Doug Fir Log 8      DLG8
* HEMLOCK
      Hemlock Log  1      HLG1
      Hemlock Log  2      HLG2
      Hemlock Log  3      HLG3
      Hemlock Log  4      HLG4
* PINE
      Pine Log Type  1    PLG1
      Pine Log Type  2    PLG2
      Pine Log Type  3    PLG3
      Pine Log Type  4    PLG4
```

```
*
*
*
*-------------------------------------------------------------------------------
         TABLE 300   LOG SUBSTITUTIONS
*-------------------------------------------------------------------------------
*
*                                  ------------ALLOWABLE SUBSTITUTIONS-----------
*
*                                  SAWMILL     SAWMILL     PLYWOOD  DOMESTIC  EXPORT
*                                   NO. 3       NO. 5       PLANT     SALES     SALES
*
                           >         01          02          03        04        05
*
* DOUG FIR
      Doug Fir Log 1      DLG1
      Doug Fir Log 2      DLG2
      Doug Fir Log 3      DLG3
      Doug Fir Log 4      DLG4
      Doug Fir Log 5      DLG5
      Doug Fir Log 6      DLG6
      Doug Fir Log 7      DLG7
      Doug Fir Log 8      DLG8
* HEMLOCK
      Hemlock Log  1      HLG1
      Hemlock Log  2      HLG2
      Hemlock Log  3      HLG3
      Hemlock Log  4      HLG4
* PINE
      Pine Log Type  1    PLG1
      Pine Log Type  2    PLG2
      Pine Log Type  3    PLG3
      Pine Log Type  4    PLG4
*
```

APPENDIX B - OPTIMAL REPORT FOR MOST LIKELY SCENARIO

HARVEST SCHEDULING MODEL
Engineering Management 535
Project Run: Most Likely

11 MAR 92 8:22

HARVEST PLANNING SYSTEM

YEARS: 1992 - 2006

HARVEST SCHEDULING MODEL
MODEL OUTPUT

11 MAR 92 8:22

** PURPOSE OF THE RUN **

To Evaluate Harvest Scheduling
Decisions Under the Assumed
Most Likely Scenario.

MODIFICATIONS

THE PLANNING HORIZON IS ASSUMED TO BE FIFTEEN YEARS. THE SCOPE OF THE MODEL IS FROM THE FOREST TO THE LOG DESTINATIONS (MILLS, EXPORTS, LOG SALES). ADDITIONAL ASSUMPTIONS ARE AS FOLLOWS:

1. Inflation = 8.0 %
2. Real Price Appreciation = 4.0 %
3. Real Cost Increase = 4.0 %
4. Total Fee Harvest Limit = 400000 MBF
5. Total Stumpage Purchase Limit = 100000 MBF
6. Total Log Purchase limit = 100000 MBF
7. Annual Fee Harvests Required = 10000 MBF
8. Domestic Sales Unconstrained

Engineering Management 535
Project Run: Most Likely

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OVERALL FINANCIAL SUMMARY

(¤000)

TOTAL NPV = 214117

	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
LOG REVENUES	12687	28192	31806	32155	32514	83834	112494
COSTS							
STUMPAGE	0	0	0	0	0	5065	11463
LOG PURCHASES	1332	232	0	0	0	0	41690
LOGGING	1201	2766	2944	2784	2633	5886	3259
ROADING	462	1064	1132	1071	1013	2264	1253
HAULING	462	1064	1132	1071	1013	2264	1253
MISCELLANEOUS	185	426	453	428	405	905	501
TOTAL VAR. COSTS	3642	5552	5661	5353	5063	16383	59421
FIXED COSTS	2000	1852	1715	1588	1470	5870	3995
TOTAL COSTS	5642	7403	7376	6941	6533	22253	63416
NET PRESENT VALUE	7045	20789	24430	25214	25981	61581	49078
VOLUME SUMMARY - MBF							
STUMPAGE	0	0	0	0	0	25812	74188
LOG PURCHASES	2960	545	0	0	0	0	96495
FEE	18482	45964	52826	53949	55107	123671	50000

Engineering Management 535
Project Run: Most Likely

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OPTIMAL FEE HARVEST SCHEDULE BY FOREST TYPE
(MBF)

SPECIES / / FOREST TYPE		1992	1993	1994	1995	1996	1997 -2001	2002 -2006
STANDARD								
90% D FIR		579	1441	1656	1691	1728	3877	1567
LOG SUMMARY								
DOUGLAS FIR	- %	90.2	90.2	90.2	90.2	90.2	90.2	90.2
HEMLOCK	- %	3.9	3.9	3.9	3.9	3.9	3.9	3.9
PINE	- %	5.9	5.9	5.9	5.9	5.9	5.9	5.9
DOUGLAS FIR	- MBF	523	1300	1494	1525	1558	3497	1414
HEMLOCK	- MBF	23	56	65	66	67	151	61
PINE	- MBF	34	85	98	100	102	229	92

OPTIMAL STUMPAGE HARVEST SCHEDULE BY FOREST TYPE
(MBF)

SPECIES / / FOREST TYPE		1992	1993	1994	1995	1996	1997 -2001	2002 -2006
STANDARD								
90% D FIR							25812	74188
LOG SUMMARY								
DOUGLAS FIR	- %						90.2	90.2
HEMLOCK	- %						3.9	3.9
PINE	- %						5.9	5.9
DOUGLAS FIR	- MBF						23282	66918
HEMLOCK	- MBF						1007	2893
PINE	- MBF						1523	4377

Engineering Management 535
Project Run: Most Likely

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TOTAL LOG SOURCING
(MBF)

LOG TYPE	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
DOUGLAS FIR							
Doug Fir Log 1	2334	6045	7152	7511	7889	3219	99205
Doug Fir Log 2	1539	4014	4751	4990	5243	858	165
Doug Fir Log 3	2889	7463	8826	9269	9735	3939	3302
Doug Fir Log 4	2316	5998	7096	7452	7828	3298	2822
Doug Fir Log 5	1835	4770	5644	5928	6227	2967	2690
Doug Fir Log 6	1687	4392	5198	5459	5735	2730	2475
Doug Fir Log 7	2330	2446	2568	2696	2831	25	25
Doug Fir Log 8	1035	3118	3971	4168	4377	2090	1896
HEMLOCK							
Hemlock Log 1	172	517	620	653	689	305	272
Hemlock Log 2	42	186	229	243	258	98	84
Hemlock Log 3	209	612	732	771	812	364	326
Hemlock Log 3	98	328	397	419	442	187	165
PINE							
Pine Log Type 1	283	801	955	1005	1058	482	433
Pine Log Type 2	209	612	732	771	812	364	326
Pine Log Type 3	172	517	620	653	689	305	272
Pine Log Type 4	227	659	787	829	873	394	353
TOTALS	17377	42476	50276	52817	55496	21623	114811
LOG SUMMARY							
DOUGLAS FIR - %	91.9	90.0	89.9	89.9	89.9	88.4	98.1
HEMLOCK - %	3.0	3.9	3.9	3.9	4.0	4.4	0.7
PINE - %	5.1	6.1	6.2	6.2	6.2	7.1	1.2
DOUGLAS FIR - MBF	15966	38246	45205	47473	49865	19125	112579
HEMLOCK - MBF	521	1643	1977	2086	2200	953	847
PINE - MBF	890	2588	3094	3258	3431	1545	1385

Engineering Management 535
Project Run: Most Likely

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LOG USE -- DOMESTIC SALES
(MBF)

LOG TYPE	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
DOUGLAS FIR							
Doug Fir Log 1	2334	6045	7152	7511	7889	20279	112441
Doug Fir Log 2	1539	4014	4751	4990	5243	8702	3163
Doug Fir Log 3	2889	7463	8826	9269	9735	24900	19482
Doug Fir Log 4	2316	5998	7096	7452	7828	20507	16427
Doug Fir Log 5	1835	4770	5644	5928	6227	17584	15080
Doug Fir Log 6	1687	4392	5198	5459	5735	16186	13878
Doug Fir Log 7							
Doug Fir Log 8		3118	3971	4168	4377	12380	10620
HEMLOCK							
Hemlock Log 1	172	517	620	653	689	1848	1553
Hemlock Log 2	42	186	229	243	258	624	501
Hemlock Log 3	209	612	732	771	812	2198	1854
Hemlock Log 3	98	328	397	419	442	1149	952
PINE							
Pine Log Type 1	283	801	955	1005	1058	2897	2455
Pine Log Type 2	209	612	732	771	812	2198	1854
Pine Log Type 3	172	517	620	653	689	1848	1553
Pine Log Type 4	227	659	787	829	873	2373	2004
TOTALS	14012	40030	47708	50121	52665	135673	203819
SUMMARY							
DOUGLAS FIR - %	89.9	89.4	89.4	89.3	89.3	88.8	93.8
HEMLOCK - %	3.7	4.1	4.1	4.2	4.2	4.3	2.4
PINE - %	6.4	6.5	6.5	6.5	6.5	6.9	3.9
DOUGLAS FIR - MBF	12601	35800	42637	44777	47034	120538	191090
HEMLOCK - MBF	521	1643	1977	2086	2200	5819	4861
PINE - MBF	890	2588	3094	3258	3431	9316	7867

APPENDIX C - OPTIMAL REPORT FOR WORST CASE SCENARIO

HARVEST SCHEDULING MODEL
Engineering Management 535
Project Run: Worst Case

11 MAR 92 9:16

HARVEST PLANNING SYSTEM

YEARS: 1992 - 2006

HARVEST SCHEDULING MODEL
MODEL OUTPUT

11 MAR 92 9:16

** PURPOSE OF THE RUN **

To Evaluate Harvest Scheduling
Decisions Under the Assumed
Worst Case Scenario.

MODIFICATIONS

THE PLANNING HORIZON IS ASSUMED TO BE FIFTEEN YEARS. THE SCOPE OF THE MODEL IS FROM THE FOREST TO THE LOG DESTINATIONS (MILLS, EXPORTS, LOG SALES). ADDITIONAL ASSUMPTIONS ARE AS FOLLOWS:

1. Inflation = 8.0 %
2. Real Price Appreciation = 2.0 %
3. Real Cost Increase = 6.0 %
4. Total Fee Harvest Limit = 400000 MBF
5. Total Stumpage Purchase Limit = 100000 MBF
6. Total Log Purchase limit = 100000 MBF
7. Annual Fee Harvests Required = 10000 MBF
8. Domestic Sales Unconstrained

HARVEST SCHEDULING MODEL
MODEL OUTPUT

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Engineering Management 535
Project Run: Worst Case

11 MAR 92 9:16

OVERALL FINANCIAL SUMMARY

(¤000)

TOTAL NPV = 183850

	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
LOG REVENUES	159744	8077	7904	104375	12268	29873	24862
COSTS							
STUMPAGE	0	0	0	27029	2904	0	0
LOG PURCHASES	0	2112	2111	48295	1308	4982	3370
LOGGING	16900	602	557	5139	975	1908	1298
ROADING	6500	231	214	1977	375	734	499
HAULING	6500	231	214	1977	375	734	499
MISCELLANEOUS	2600	93	86	791	150	293	200
TOTAL VAR. COSTS	32500	3269	3183	85208	6087	8651	5867
FIXED COSTS	2000	1852	1715	1588	1470	5870	3995
TOTAL COSTS	34500	5121	4898	86795	7557	14520	9861
NET PRESENT VALUE	125244	2956	3006	17579	4712	15352	15001
VOLUME SUMMARY - MBF							
STUMPAGE	0	0	0	89602	10398	0	0
LOG PURCHASES	0	4969	5262	61083	3595	13908	11183
FEE	260000	10000	10000	10000	10000	50000	50000

Engineering Management 535
Project Run: Worst Case

11 MAR 92 9:16

OPTIMAL FEE HARVEST SCHEDULE BY FOREST TYPE
(MBF)

SPECIES / / FOREST TYPE		1992	1993	1994	1995	1996	1997 -2001	2002 -2006
STANDARD								
90% D FIR		8150	313	313	313	313	1567	1567
LOG SUMMARY								
DOUGLAS FIR	- %	90.2	90.2	90.2	90.2	90.2	90.2	90.2
HEMLOCK	- %	3.9	3.9	3.9	3.9	3.9	3.9	3.9
PINE	- %	5.9	5.9	5.9	5.9	5.9	5.9	5.9
DOUGLAS FIR	- MBF	7352	283	283	283	283	1414	1414
HEMLOCK	- MBF	318	12	12	12	12	61	61
PINE	- MBF	481	18	18	18	18	92	92

OPTIMAL STUMPAGE HARVEST SCHEDULE BY FOREST TYPE
(MBF)

SPECIES / / FOREST TYPE		1992	1993	1994	1995	1996	1997 -2001	2002 -2006
STANDARD								
90% D FIR					89602	10398		
LOG SUMMARY								
DOUGLAS FIR	- %				90.2	90.2		
HEMLOCK	- %				3.9	3.9		
PINE	- %				5.9	5.9		
DOUGLAS FIR	- MBF				80821	9379		
HEMLOCK	- MBF				3494	406		
PINE	- MBF				5287	613		

Engineering Management 535
Project Run: Worst Case

11 MAR 92 9:16

TOTAL LOG SOURCING
(MBF)

LOG TYPE	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
DOUGLAS FIR							
Doug Fir Log 1	33490	1276	1313	74991	2848	1058	1144
Doug Fir Log 2	22310	834	859	9256	1882	1661	2120
Doug Fir Log 3	41290	1585	1630	17155	3522	1275	1371
Doug Fir Log 4	33230	1266	1303	13800	2825	1153	1268
Doug Fir Log 5	26470	999	1028	10987	2241	1258	1451
Doug Fir Log 6	24390	916	943	10121	2062	1155	1334
Doug Fir Log 7	19260	2446	2568	4563	2831	25	25
Doug Fir Log 8	27050	1087	1141	9723	1258	213	537
HEMLOCK							
Hemlock Log 1	3070	73	77	1248	220	104	127
Hemlock Log 2	1250	1	3	491	62	14	24
Hemlock Log 3	3590	94	98	1465	264	130	156
Hemlock Log 3	2030	32	35	816	130	53	68
PINE							
Pine Log Type 1	4630	135	140	1898	354	181	215
Pine Log Type 2	3590	94	98	1465	264	130	156
Pine Log Type 3	3070	73	77	1248	220	104	127
Pine Log Type 4	3850	104	109	1573	287	142	171
TOTALS	252570	11016	11421	160799	21271	8654	10293
LOG SUMMARY							
DOUGLAS FIR - %	90.1	94.5	94.4	93.7	91.5	90.1	89.9
HEMLOCK - %	3.9	1.8	1.9	2.5	3.2	3.5	3.6
PINE - %	6.0	3.7	3.7	3.8	5.3	6.4	6.5
DOUGLAS FIR - MBF	227490	10408	10785	150595	19469	7798	9250
HEMLOCK - MBF	9940	201	212	4020	676	300	374
PINE - MBF	15140	407	424	6184	1125	556	668

Engineering Management 535
Project Run: Worst Case

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LOG USE -- DOMESTIC SALES
(MBF)

LOG TYPE	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
DOUGLAS FIR							
Doug Fir Log 1	33490	1276	1313	74991	2848	5555	5549
Doug Fir Log 2	22310	834	859	9256	1882	937	
Doug Fir Log 3	41290	1585	1630	17155	3522	6752	6667
Doug Fir Log 4	33230	1266	1303	13800	2825	5897	6110
Doug Fir Log 5	26470	999	1028	10987	2241	5942	6859
Doug Fir Log 6	24390	916	943	10121	2062	5457	6302
Doug Fir Log 7	19260			4563			
Doug Fir Log 8	27050			9723		953	1593
HEMLOCK							
Hemlock Log 1	3070	73	77	1248	220	479	586
Hemlock Log 2	1250	1	3	491	62	54	98
Hemlock Log 3	3590	94	98	1465	264	600	726
Hemlock Log 3	2030	32	35	816	130	236	308
PINE							
Pine Log Type 1	4630	135	140	1898	354	843	1005
Pine Log Type 2	3590	94	98	1465	264	600	726
Pine Log Type 3	3070	73	77	1248	220	479	586
Pine Log Type 4	3850	104	109	1573	287	661	795
TOTALS	252570	7483	7712	160799	17182	35442	37911
SUMMARY							
DOUGLAS FIR - %	90.1	91.9	91.8	93.7	89.5	88.9	87.3
HEMLOCK - %	3.9	2.7	2.8	2.5	3.9	3.9	4.5
PINE - %	6.0	5.4	5.5	3.8	6.6	7.3	8.2
DOUGLAS FIR - MBF	227490	6875	7076	150595	15380	31493	33080
HEMLOCK - MBF	9940	201	212	4020	676	1368	1718
PINE - MBF	15140	407	424	6184	1125	2582	3112

APPENDIX D - OPTIMAL REPORT FOR BEST CASE SCENARIO

HARVEST SCHEDULING MODEL
Engineering Management 535
Project Run: Best Case

11 MAR 92 7:58

HARVEST PLANNING SYSTEM

YEARS: 1992 - 2006

HARVEST SCHEDULING MODEL
MODEL OUTPUT

11 MAR 92 7:58

** PURPOSE OF THE RUN **

To Evaluate Harvest Scheduling
Decisions Under the Assumed
Best Case Scenario.

MODIFICATIONS

THE PLANNING HORIZON IS ASSUMED TO BE FIFTEEN YEARS. THE SCOPE OF THE MODEL IS FROM THE FOREST TO THE LOG DESTINATIONS (MILLS, EXPORTS, LOG SALES). ADDITIONAL ASSUMPTIONS ARE AS FOLLOWS:

1. Inflation = 8.0 %
2. Real Price Appreciation = 6.0 %
3. Real Cost Increase = 2.0 %
4. Total Fee Harvest Limit = 400000 MBF
5. Total Stumpage Purchase Limit = 100000 MBF
6. Total Log Purchase limit = 100000 MBF
7. Annual Fee Harvests Required = 10000 MBF
8. Domestic Sales Unconstrained

HARVEST SCHEDULING MODEL
MODEL OUTPUT

11 MAR 92 7:58

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Engineering Management 535
Project Run: Best Case

11 MAR 92 7:58

OVERALL FINANCIAL SUMMARY

(¤000)

TOTAL NPV = 284415

	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
LOG REVENUES	8254	8394	8536	8681	8831	38949	303726
COSTS							
STUMPAGE	0	0	0	0	0	0	14353
LOG PURCHASES	2111	2112	2111	2110	2147	4982	25627
LOGGING	650	602	557	516	478	1908	9286
ROADING	250	231	214	198	184	734	3571
HAULING	250	231	214	198	184	734	3571
MISCELLANEOUS	100	93	86	79	74	293	1429
TOTAL VAR. COSTS	3361	3269	3183	3102	3065	8651	57837
FIXED COSTS	2000	1852	1715	1588	1470	5870	3995
TOTAL COSTS	5361	5121	4898	4690	4535	14520	61832
NET PRESENT VALUE	2894	3273	3638	3992	4295	24429	241894
VOLUME SUMMARY - MBF							
STUMPAGE	0	0	0	0	0	0	100000
LOG PURCHASES	4690	4969	5262	5572	5900	13908	59699
FEE	10000	10000	10000	10000	10000	50000	300000

Engineering Management 535
Project Run: Best Case

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OPTIMAL FEE HARVEST SCHEDULE BY FOREST TYPE
(MBF)

SPECIES / / FOREST TYPE		1992	1993	1994	1995	1996	1997 -2001	2002 -2006
STANDARD								
90% D FIR		313	313	313	313	313	1567	9404
LOG SUMMARY								
DOUGLAS FIR	- %	90.2	90.2	90.2	90.2	90.2	90.2	90.2
HEMLOCK	- %	3.9	3.9	3.9	3.9	3.9	3.9	3.9
PINE	- %	5.9	5.9	5.9	5.9	5.9	5.9	5.9
DOUGLAS FIR	- MBF	283	283	283	283	283	1414	8483
HEMLOCK	- MBF	12	12	12	12	12	61	367
PINE	- MBF	18	18	18	18	18	92	555

OPTIMAL STUMPAGE HARVEST SCHEDULE BY FOREST TYPE
(MBF)

SPECIES / / FOREST TYPE		1992	1993	1994	1995	1996	1997 -2001	2002 -2006
STANDARD								
90% D FIR								100000
LOG SUMMARY								
DOUGLAS FIR	- %							90.2
HEMLOCK	- %							3.9
PINE	- %							5.9
DOUGLAS FIR	- MBF							90200
HEMLOCK	- MBF							3900
PINE	- MBF							5900

Engineering Management 535
Project Run: Best Case

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TOTAL LOG SOURCING
(MBF)

LOG TYPE	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
DOUGLAS FIR							
Doug Fir Log 1	1240	1276	1313	1351	1391	1058	113885
Doug Fir Log 2	810	834	859	884	910	1661	35125
Doug Fir Log 3	1540	1585	1630	1677	1726	1275	67937
Doug Fir Log 4	1230	1266	1303	1341	1379	1153	54855
Doug Fir Log 5	970	999	1028	1058	1089	1258	44154
Doug Fir Log 6	890	916	943	971	1000	1155	40687
Doug Fir Log 7	2330	2446	2568	2696	2831	25	37399
Doug Fir Log 8	1035	1087	1141	1198	1258	213	47425
HEMLOCK							
Hemlock Log 1	70	73	77	80	84	104	5150
Hemlock Log 2	25	1	3	4	6	14	2117
Hemlock Log 3	90	94	98	102	106	130	6017
Hemlock Log 3	30	32	35	37	39	53	3417
PINE							
Pine Log Type 1	130	135	140	146	151	181	7751
Pine Log Type 2	90	94	98	102	106	130	6017
Pine Log Type 3	70	73	77	80	84	104	5150
Pine Log Type 4	100	104	109	113	118	142	6451
TOTALS	10650	11016	11421	11842	12279	8654	483538
LOG SUMMARY							
DOUGLAS FIR - %	94.3	94.5	94.4	94.4	94.3	90.1	91.3
HEMLOCK - %	2.0	1.8	1.9	1.9	1.9	3.5	3.5
PINE - %	3.7	3.7	3.7	3.7	3.7	6.4	5.2
DOUGLAS FIR - MBF	10045	10408	10785	11177	11584	7798	441467
HEMLOCK - MBF	215	201	212	224	236	300	16701
PINE - MBF	390	407	424	441	459	556	25369

Engineering Management 535
Project Run: Best Case

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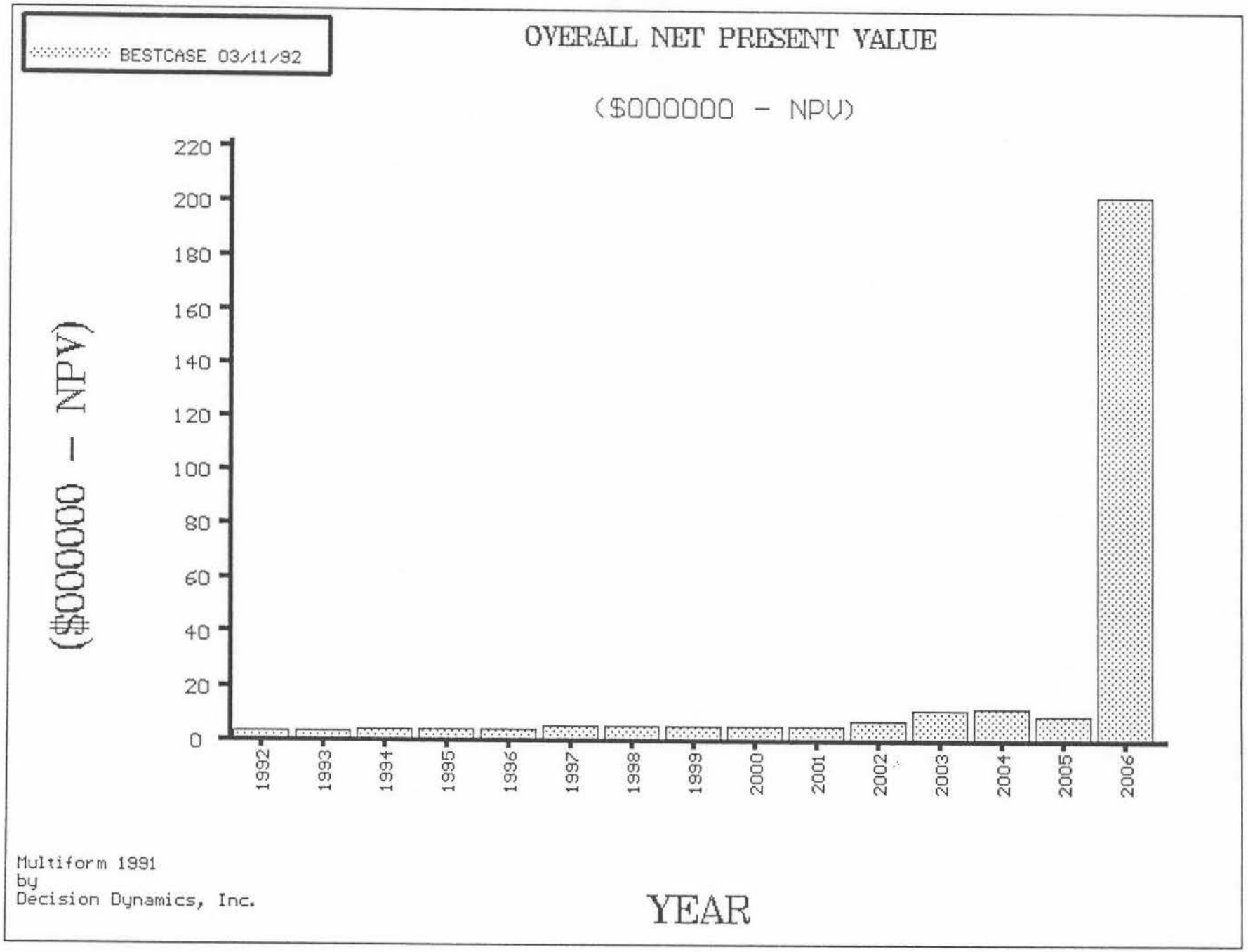
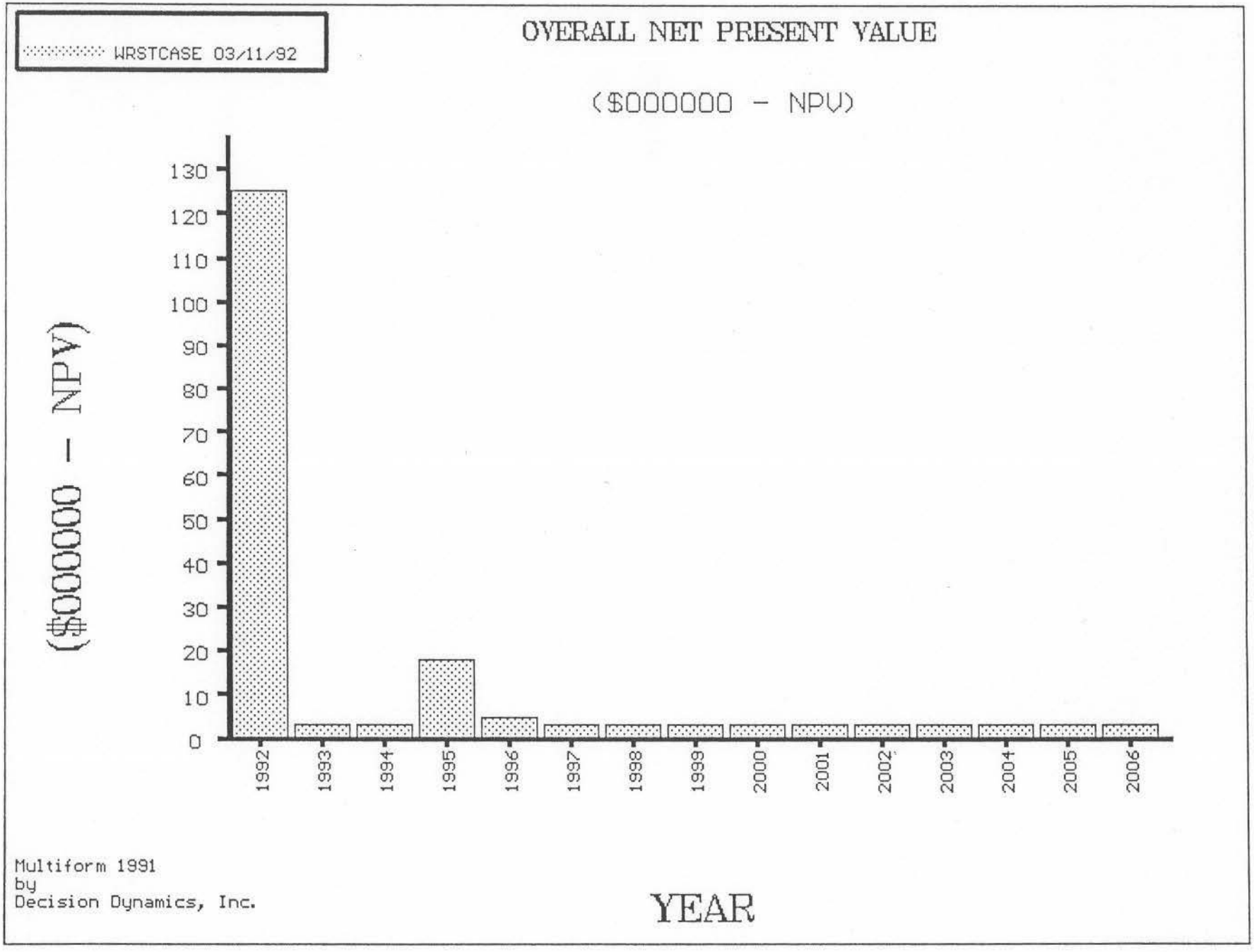
LOG USE -- DOMESTIC SALES
(MBF)

LOG TYPE	1992	1993	1994	1995	1996	1997 -2001	2002 -2006
DOUGLAS FIR							
Doug Fir Log 1	1240	1276	1313	1351	1391	5555	125770
Doug Fir Log 2	810	834	859	884	910	937	37222
Doug Fir Log 3	1540	1585	1630	1677	1726	6752	82452
Doug Fir Log 4	1230	1266	1303	1341	1379	5897	67119
Doug Fir Log 5	970	999	1028	1058	1089	5942	55476
Doug Fir Log 6	890	916	943	971	1000	5457	51105
Doug Fir Log 7							37399
Doug Fir Log 8						953	54976
HEMLOCK							
Hemlock Log 1	70	73	77	80	84	479	6306
Hemlock Log 2		1	3	4	6	54	2482
Hemlock Log 3	90	94	98	102	106	600	7399
Hemlock Log 3	30	32	35	37	39	236	4121
PINE							
Pine Log Type 1	130	135	140	146	151	843	9584
Pine Log Type 2	90	94	98	102	106	600	7399
Pine Log Type 3	70	73	77	80	84	479	6306
Pine Log Type 4	100	104	109	113	118	661	7945
TOTALS	7260	7483	7712	7948	8190	35442	563060
SUMMARY							
DOUGLAS FIR - %	92.0	91.9	91.8	91.6	91.5	88.9	90.8
HEMLOCK - %	2.6	2.7	2.8	2.8	2.9	3.9	3.6
PINE - %	5.4	5.4	5.5	5.5	5.6	7.3	5.5
DOUGLAS FIR - MBF	6680	6875	7076	7283	7495	31493	511520
HEMLOCK - MBF	190	201	212	224	236	1368	20307
PINE - MBF	390	407	424	441	459	2582	31234

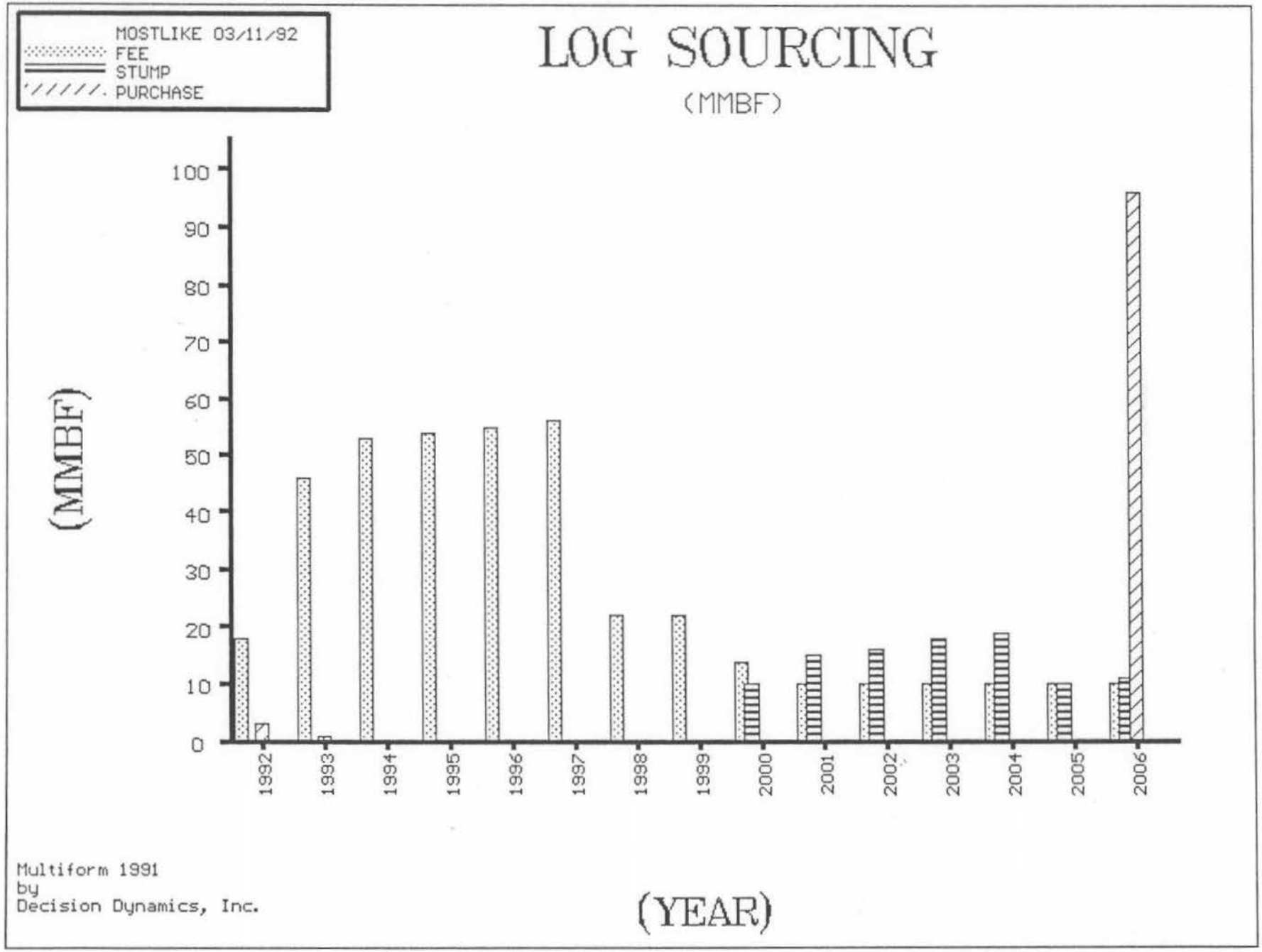
APPENDIX E - OVERALL NPV GRAPHS

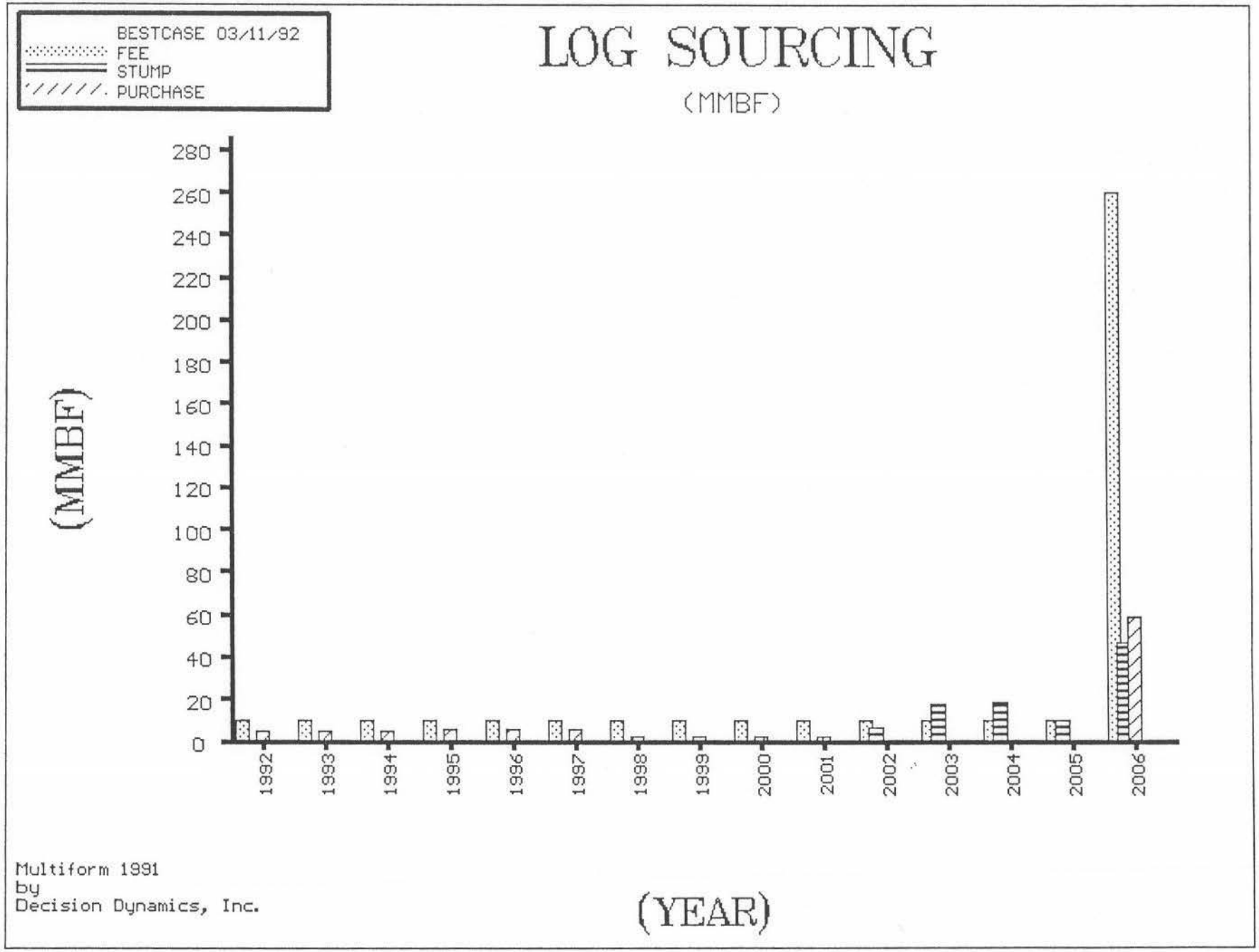
OVERALL NET PRESENT VALUE
($000000 - NPV)
MOSTLIKE 03/11/92
($000000 - NPV)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
YEAR
Multiform 1991
by
Decision Dynamics, Inc.

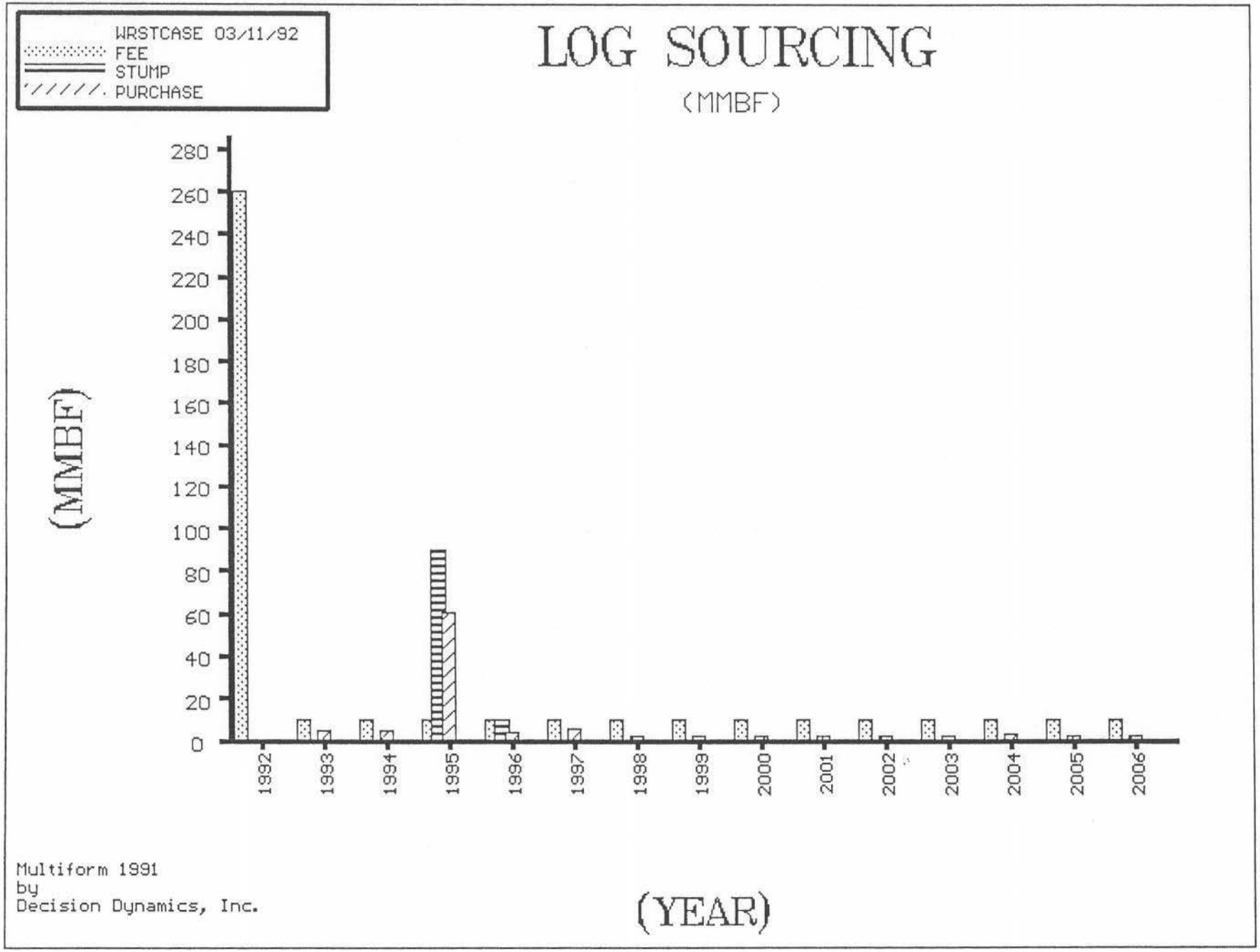

BESTCASE 03/11/92
OVERALL NET PRESENT VALUE
($000000 - NPV)
($000000 - NPV)
220
200
180
160
140
120
100
80
60
40
20
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Multiform 1991
by
Decision Dynamics, Inc.
YEAR


WRSTCASE 03/11/92
OVERALL NET PRESENT VALUE
($000000 - NPV)
($000000 - NPV)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Multiform 1991
by
Decision Dynamics, Inc.
YEAR

APPENDIX F - LOG SOURCING GRAPHS


MOSTLIKE 03/11/92
FEE
STUMP
PURCHASE
LOG SOURCING
(MMBF)
(MMBF)
100
90
80
70
60
50
40
30
20
10
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
(YEAR)
Multiform 1991
by
Decision Dynamics, Inc.


BESTCASE 03/11/92
FEE
STUMP
PURCHASE
LOG SOURCING
(MMBF)
(MMBF)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Multiform 1991
by
Decision Dynamics, Inc.
(YEAR)


WRSTCASE 03/11/92
FEE
STUMP
PURCHASE
LOG SOURCING
(MMBF)
(MMBF)
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
(YEAR)
Multiform 1991
by
Decision Dynamics, Inc.

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