A COMPUTER ESTIMATE OF COSTS AND ENGINEERING DATA FOR A PROPOSED TRANSPORTATION NETWORK IN NEW ENGLAND

by

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Abstract approved:

This paper describes a computer program developed for the Hewlett Packard 9830, which analyzes and computes costs and engineering data for paper plan timber harvest road networks. The program will accept up to 110 road segments. Each segment is analyzed individually based on digitized data from a contour map and user defined road construction parameters. Three types of construction are analyzed for each segment: fullbench and sidecast, fullbench and endhaul and balanced construction.

Program results and operation are exemplified in an analysis of a proposed transportation plan in a cable logging study area in New England. The study area is on the Green Mountain National Forest in Central Vermont. The transportation plan contains 99 miles of proposed new road within the 25,000 acre study area. Cost and

engineering data sensitivity to changes in road construction parameters is analyzed. Variations in the subgrade width and surfacing depth seem to affect cost the most.

Fuel consumption of alternative logging systems is also compared in this paper. The results indicate that cable logging initially consumes more fuel due to increased road construction. However, once the roads are established, cable logging systems consume less fuel than tractor logging. This study indicates that it takes approximately 40 to 60 years for cable logging systems to catch and surpass tractor systems in terms of total accumulated fuel consumption.

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INTRODUCTION

Timber harvest and transportation planning is one of the most important factors in the evolution of a cost effective and environmentally sound timber sale program. In the past, the lack of, or inaccurate harvest/transportation planning, has resulted in many timber sale offerings which were substandard in terms of both cost and resource protection. Much of the inaccuracy evident in harvest/transportation plans of the past was due to the oversimplification of available information. The harvest planner was unable to assimilate and analyze the vast amount of potential data available. In depth, accurate analysis of several alternative transportation networks was very difficult using hand computation techniques.

The development of small, high speed desk top computers now makes this type of indepth analysis a reality. This paper will present a method to quickly and accurately analyze alternative transportation network paper plans using the desktop computer. The accuracy of the estimate obtained using the Road Cost Program (R.C.P.) is dependent on the following factors:

1. Contour map accuracy.
2. Amount of route verification in the field.
3. Accuracy of soils and stand data used.

Road Cost Program can analyze up to 110 segments at one time. For networks having more than 110 segments, the user must break up the network accordingly and combine the results. The program is divided into two parts, a and b. Part (a) accumulates specific data for each segment. This specific data is based partly on digitized data taken from the contour map and direct input by the user. Once all the segments in the network have been digitized, this data is stored on tape. Part (b) of (R.C.P.) analyzes the network data stored on tape in terms of user defined construction parameters. These parameters include the following:

1. Running surface width.
2. Ditch? - Yes or No.
3. Surfacing depth.
4. Distance to waste area and rock pit.
5. Cutslope angle.

A very useful feature of (R.C.P.) is the ability to ascertain cost sensitivity to changes in the construction parameters listed above.

Approximately 30 days were spent working on a cable logging study area on the Green Mountain National Forest in Central Vermont (Figures 1 and 2). The study was broken into two parts: cable equipment selection study by Stirler (1980), and cable logging transportation network and road standard alternatives. This paper presents a proposed transportation/harvest proposal which accesses the 25,000 acre study area. (R.C.P.) is applied to the 97 segments in the network. Many computer runs were made using different combinations of construction parameters. The resulting cost sensitivity is displayed in graphical form.

Also included in this report is a comparative analysis of the total accumulated fuel consumption of several logging systems.

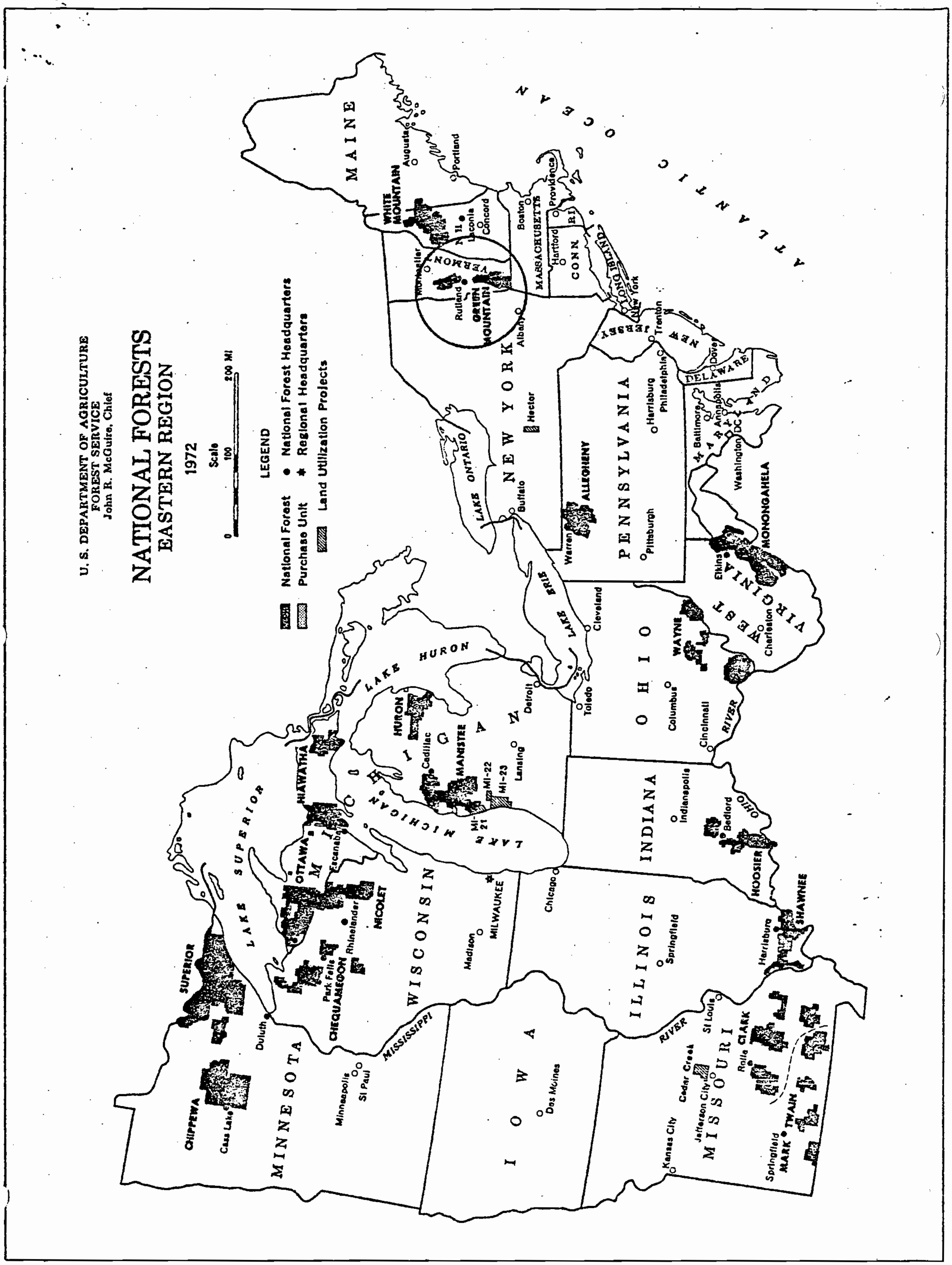


Figure 1. Green Mountain National Forest Vicinity Map

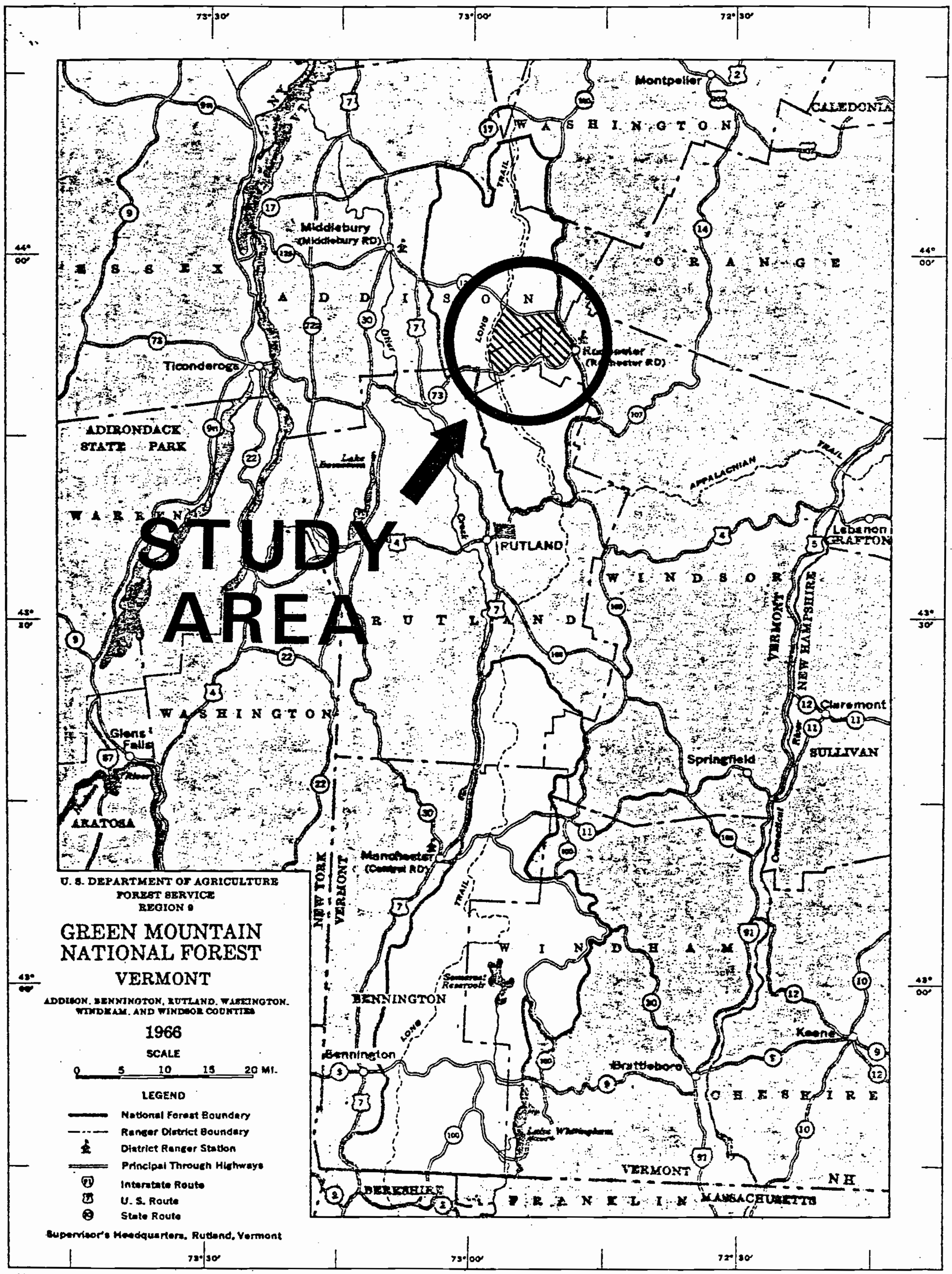


Figure 2. Cable Logging Study Area Vicinity Map

OBJECTIVES

The purpose of this study is twofold. First, to develop a method of quickly and accurately analyzing alternative transportation networks. Second, to analyze and make recommendations concerning transportation networks for cable yarder access and operation in the mixed hardwood forests of New England. The specific objectives are as follows:

1. Develop a computer program written in basic language, which outputs costs and engineering data, based on a paper plan transportation network.
2. Develop a timber harvest/transportation paper plan for the study area.
3. Using soils and stand data supplied by the Green Mountain National Forest, recommend road standards which meet the following objectives:
   a. least cost
   b. minimum resource impact
   c. insure cable equipment access and operability.
4. Display road cost sensitivity to changes in construction parameters.
5. Compare the fuel consumption differences between tractor logging and cable logging.

ROAD COST ANALYSIS

The Road Cost Program (R.C.P.) incorporates most of the important road construction cost factors which are identifiable during the planning stage. The cost factors not included in (R.C.P.) are minor, and are included in actual road appraisals on a case by case basis. The (R.C.P.) should provide an accurate estimate of construction cost in spite of these minor cost factor exclusions, since their percentage of total cost in actual appraisals is minor. The following road cost factors are included in the program.

- Clear and Grub
- Seeding and Mulching
- Common and Rock Excavation
- Riprap
- Fences and Gates
- Buy, Haul, Load and Apply Surfacing
- Outlet Pipe
- Pipe Used on Major Creek Crossings
- Load and Haul Endhaul Material
- Mobilization

The following costs are not included in (R.C.P.), due to the difficulty in quantifying data during the planning stage.

- Develop Water Supply
- Watering

- Bituminous Dust Palliative Treatment
- Under drains and Filter Cloth
- Development of Pits and Quarries
- Gabions and Binwalls

Since construction staking is an activity performed by either the purchaser or the Forest Service, it is not included in this analysis.

The following general assumptions are applicable to the program as a whole. These assumptions deviate from actual ground conditions, because the input is based on map data. This oversimplification will introduce some error, when compared with a completed road cost appraisal. However, since the intent of (R.C.P.) is to provide an estimate for comparative purposes, this introduced error should not be critical.

Assumption #1 - Sideslopes are constant for a given segment.

This assumption should not affect cost significantly, if the user selects the correct segment breaks. In areas with highly variable sideslopes, segment lengths should be short. Longer segments will tend to average all the sideslopes together, and will introduce erroneous construction costs.

Assumption #2 - Road segment lengths are based on their horizontal distance. Due to the small scale maps, usually no differentiation will be made between "P" and "L" lines.

The lengths shown in (R.C.P.) will be slightly shorter than the actual road segment as it is built. This will tend to lower the total estimated construction costs.

Assumption #3 - Bedrock depth, clear and grub difficulty and road grade are consistent over a given segment.

As with Assumption #1, correct choice of segment location and length should minimize this potential error. The user must be aware that bedrock depths, clear and grub difficulty and even the contour maps are estimates in themselves. Shortening segments to account for all changes in the above parameters would probably be counter-productive, due to the great increase in digitizing time.

Assumption #4 - Excavation is assumed over the entire segment length.

(R.C.P.) does not account for thru fill sections. This is primarily due to the problem of identifying fill volumes from small scale mapping. For segments with major creek crossings requiring thru fill construction, an error will be introduced. This error will be the difference between the excavation and embankment cost for the short (50' to 200') section crossing the creek. This cost will vary, due to the length of tractor haul in common material for the embankment, and the bedrock depth for excavation. In most cases, this error will tend to increase the road construction estimates over the actual construction cost.

Assumption #5 - Additional excavation is not calculated for turnouts.

(R.C.P.) assumes outside turnouts placed in areas where additional excavation is minimized.

Assumption #6 - If the sideslope $\geq$ 60%, a balanced section is not computed. Full bench and endhaul costs and excavation data are substituted and included in the balanced section network summary.

Assumption #7 - Turnouts are placed at 1000 foot intervals.

If the road segment is less than 600 feet long, no turnout is figured. If the segment is between 600 feet and 1000 feet, the computer assigns one turnout to this segment. Turnouts are 50 feet long and 8 feet wide with 50 feet of runout on each end.

Assumption #8 - All calculations are based on topog map data, since the program is not intended to do road design.

The following section treats each included cost factor individually, giving descriptions, assumptions and Green Mountain National Forest unit costs.

<u>Cost: Clearing and Grubbing</u>

(R.C.P.) bases clearing and grubbing on existing stand conditions, sideslope and exposed boulders. Total basal area and average D.B.H. are parameters used to classify existing stands for clearing and grubbing. Three levels of clearing and grubbing difficulty are recognized by (R.C.P.): low, medium and high. These levels are based on the R-9 Road and Bridge Cost Estimating Guide (19) (Figure 3).

These definitions are converted to total basal area and average D.B.H. in the following manner.

-LOW-

All stands with an average D.B.H. $\leq$ 5 inches and/or a total basal area $\leq$ 30 square feet.

-MEDIUM-

All stands with an average D.B.H. $\geq$ 6 and $\leq$ 16 inches and/or a total basal area $\geq$ 31 and $\leq$ 119 square feet.

-HIGH-

All stands with an average D.B.H. $\geq$ 17 inches and/or a total basal area $\geq$ 120 square feet.

If a stand contains an average D.B.H. of one difficulty and a total basal area of another, then the basal area dominates. Appendix 3 lists the stand data and clear and grub difficulty for the compartments contained in the study area. Clearing and grubbing difficulties are also displayed in map form (Figure 26). Showing segment parameters also displays the clearing and grubbing difficulty by segment, for the road network analyzed in the study area.

Exposed boulders and steep areas ($\geq$60%) will increase the clear and grub difficulty to the next highest level. The slash cleanup method for road construction used on the Green Mountain National Forest is a combination of scattering and burying (stump dump).

CLEARING AND GRUBBING

I. GENERAL

A. Clearing and Grubbing costs vary depending on the following items:

a. Topography

b. Type of cover, size, and density

c. Method of clearing

d. Method of disposal

e. Difficulty of grubbing, boulders, etc.

f. Area to be cleared and grubbed

g. Season

B. Cost analysis is based on relative efficiency of typical crews, which will vary with the type of job and cover.

C. When reconstructing an existing road the acreage to be estimated is the number of acres outside the existing road prism.

II. DEFINITIONS OF TYPES AND DENSITY OF COVER

A. Brush: Dense growth of vegetation 2-3" in diameter and less. Foot access is difficult. Timber 10"-15" DBH exists with an average of 1-9 trees per acre.

B. Light Clearing & Grubbing: Area includes a mixture of light pole (4"-10" DBH) reproduction, brush and medium timber (10"-15" DBH) with an average density of 10-20 trees per acre. In stands which are predominately pulpwood, light clearing and grubbing consists of 0-200 trees (4"-10" DBH) per acre.

C. Medium Clearing & Grubbing: Area includes a mixture of light pole reproduction, very little brush, mostly medium to large trees 10"-20" DBH with an average density of 20-80 trees per acre. No open areas in the cover exist. In stands which are predominately pulpwood, medium clearing and grubbing consists of 200-500 trees (4"-10" DBH) per acre.

D. Heavy Clearing & Grubbing: Area includes mostly large timber 15"-20" DBH with an average of more than 80 trees per acre. No open areas in the cover exist. In stands which are predominately pulpwood, heavy clearing and grubbing would consist of more than 500 trees (4"-10" DBH) per acre.

Figure 3. Clear & Grub Definitions.

Stump dumps are cleared areas below the road at approximately 500 to 700 foot intervals where stumps and other large debris are buried. The average size of a stump dump is about 0.05 acres (Figure 4).

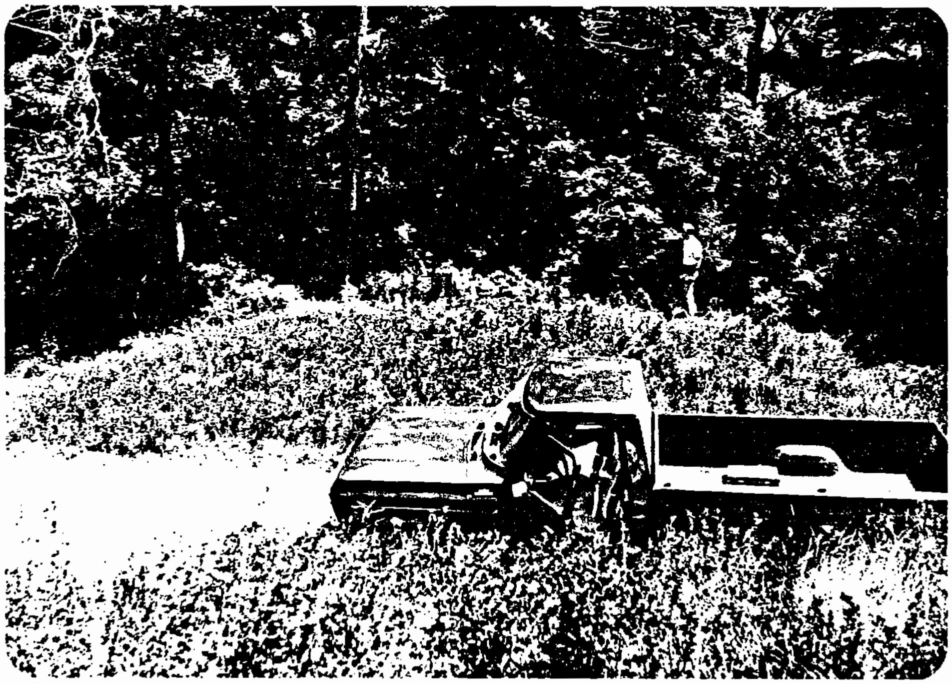


Figure 4. Typical Stump Dump.

Experienced costs for clearing and grubbing on the Green Mountain National Forest are as follows.

Low - $2000.00/acre

Medium - $2300.00/acre

High - $2600.00/acre

(R.C.P.) calculates clearing and grubbing area, based on the horizontal distance from the top of cut to the bottom of the fill, plus four feet.

Cost: Seed, Mulch and Fertilize

(R.C.P.) bases the seed, mulch and fertilize cost on the horizontal projection of the common material in the cut. All common material in the cut is assumed to be seeded. Experienced costs on the Green Mountain National Forest are as follows:

Seed, mulch and fertilize - $700.00/acre

Cost: Common Excavation

All excavation costs in common material are based on the bank cubic yard. If the road prism includes a ditch and has no rock excavation, an additional 2 feet of end area are added. Common excavation costs are based on a combination of the following parameters:

Subgrade Width

Depth to Bedrock

Ditch? (Yes/No)

Cutslope Angle

Sideslope

Segment Length

The experienced costs used on the G.M.N.F. are:

Excavation (common) - $2.30/B.C.Y.

Cost: Rock (ledge) Excavation

As with the common excavation, the rock excavation is based on the bank cubic yard. The cutslope for rock sections is held constant at 1/4:1. Most rock encountered in the study area is very hard. (R.C.P.) assumes all rock excavation will be "shot." Ripable rock is not common to the study area. If a ditch is needed in a rock section, 2 square feet of end area are added. Rock excavation costs are based on a combination of the following parameters:

Subgrade Width

Depth to Bedrock

Ditch? (Yes/No)

Sideslope

Segment Length

Bedrock depths are based on the Soil Resource Inventory for the Green Mountain National Forest. Soil types with similar bedrock depths were combined. The result is displayed on map (see Figure 4). The soil type combinations are shown below:

Soil Type(s)	Bedrock Depths (ft.)
202b - 202d	1
203b - 205b - 014b - 013b - 014d	2
203d	7
205d - 203g	12
210d	22

See Appendix 2 for soil type descriptions.

The experienced costs used on the G.M.N.F. are as follows:

Excavation (rock) - $11.00/B.C.Y.

Cost: Riprap

Riprap is included with all pipes crossing major creeks. It is assumed that each large pipe will need 1.5 loose cubic yards of riprap. Installed riprap costs include a combination of both hand and machine placement. Experienced costs on the G.M.N.F. are as follows:

Riprap (installed) - $40.00/L.C.Y.

Cost: Fences and Gates

Normally, fences and gates are appraised on a lump sum basis. Since during the planning stage it is very difficult to estimate exactly how many fences and gates are needed, this cost is put on a per-mile basis. Based on past road construction projects on the Green Mountain National Forest, the following cost/mile is used.

Fences and Gates - $500.00/mile

Cost: Buy, Haul, Load and Apply Surfacing

Surfacing quantities are first computed as compacted rock on the road. This quantity is then swelled in volume to the loose state. All surfacing costs are based on loose, cubic yards. Turnouts included in the road segment are completely surfaced. On road segments which have a ditch, the taper of the surfacing is 3:1

on both sides of the running surface. If the segment doesn't have a ditch, the surfacing quantities include a 3:1 taper on the outside and a 1:1 cutbank on the inside (Figure 5). The haul distance is input by the user. For the study area, the average haul from the rock pits near Rochester, Vermont is 16 miles. It is probable that new pits will be developed within the study area at a later date.

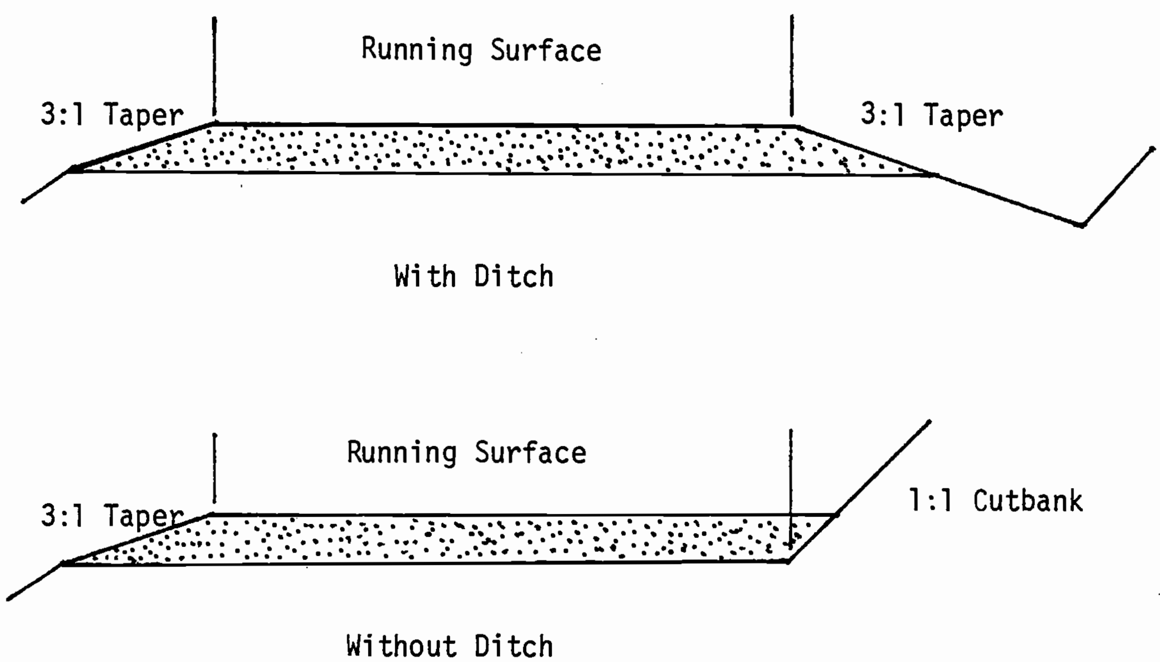


Figure 5. Surfacing Detail.

The following are experienced costs for surfacing on the G.M.N.F.

Buy Surfacing - $1.10/L.C.Y.

Haul Surfacing - $0.28/L.C.Y./mile

Load and Apply Surfacing - $2.80/L.C.Y.

Cost: Outlet Pipe

All outlet pipe is assumed to be 18 inch diameter, 16 gage corrugated steel or aluminum round pipe. Connecting bands are included in the installed price. Outlet pipe spacing is based on the U.S.F.S. Transportation Engineering Handbook (Figure 6). Most soils within the study area have an erosion index of 20. Using this column in the culvert spacing table, the following relationship exists between the road grade in % and the culvert spacing in feet.

$$\text{Spacing} = 2437.5 \times (\text{road grade in } \%)^{-1.00}$$

All outlet pipe is assumed to have a 30° skew with a drainage angle of 3°. Four feet of length are added to each pipe to account for protrusion. If the road segment has no ditch, no outlet pipe is computed. Installed outlet pipe cost on the Green Mountain National Forest is as follows:

Outlet Pipe - $19.64/Lineal Foot

Maximum Spacing in Feet of Lateral Drainage Culverts

Road Gradient in Percent	EROSION INDEX									
	ML SMu 10	ML SMd 20	MH OL 30	CL MH OL 40	CH GM SC OH 50	CH GMd 60	GC 70	SP SW 80	SP SW 90	GP GW 100
2	900	1225								
3	600	815	1070	1205						
4	450	610	800	905	1015					
5	360	490	640	725	810	865	1000			
6	300	410	535	605	675	720	835	1010		
7	255	350	455	515	580	620	715	865	1030	1210
8	225	305	400	450	505	540	625	755	900	1055
9	200	270	355	400	450	480	555	670	800	940
10	180	245	320	360	405	435	500	605	720	845
11	165	220	290	330	370	395	455	550	655	770
12	150	205	265	305	340	360	415	505	600	705
13	140	190	245	280	310	335	385	465	555	650
14	130	175	230	260	290	310	355	430	515	605
15	120	165	215	240	270	300	335	405	480	565
16	115	155	200	225	255	280	310	380	450	530
17	105	145	190	215	240	265	295	355	424	500
18	100	135	180	200	225	250	280	335	400	470

Figure 6. Outlet Pipe Spacing Chart.

Cost: Pipe Used on Major Creek Crossings

Pipe sizing for major creek crossings is based on Talbot's Formula using a "C" factor of 0.2. Talbot's Formula calculates the end area of a pipe needed, based on the drainage area in acres of the creek.

Talbot's Formula:

$$\text{End Area in ft.}^2 = C \times \text{area drained (ac.)}^{0.75}$$

The minimum pipe size used in (R.C.P.) is the same size as the outlet pipe. The maximum pipe is a structural plate pipe-arch with a span of 14' 10" and a rise of 9' 1". The area of this arch is 105 square feet. For drainages that need an end area greater than 105 square feet, (R.C.P.) calculates a bridge crossing. All creeks that drain an area of 4,240 acres will need a bridge crossing. (R.C.P.) uses the following pipes for the end area ranges shown.

Round Corrugated Steel Pipe

Diameter (ft.)	End Area Range (ft.^{2})
1.5	≤ 1.77
2.0	> 1.77 and ≤ 3.14
2.5	> 3.14 and ≤ 4.91
3.0	> 4.91 and ≤ 7.07
3.5	> 7.07 and ≤ 9.62
4.0	> 9.62 and ≤ 12.57
4.5	> 12.57 and ≤ 15.90
5.0	> 15.90 and ≤ 19.63
5.5	> 19.63 and ≤ 23.76

Structural Plate Steel Pipe - Arches

Span (Ft.-In.)	Rise (Ft.-In.)	End Area Range ($ft.^2$)
7' 0"	5' 1"	>23.76 and ≤ 28.40
8' 2"	5' 9"	>28.40 and ≤ 38.00
9' 6"	6' 5"	>38.00 and ≤ 48.70
10' 11"	7' 1"	>48.70 and ≤ 60.70
12' 4"	7' 9"	>60.70 and ≤ 74.10
13' 5"	8' 5"	>74.10 and ≤ 88.70
14' 10"	9' 1"	>88.70 and ≤ 104.8

The pipe length is determined by the grade of the creek as it crosses the road, the subgrade width and the pipe diameter.
All pipes are assumed to have 48 inches of cover directly below the inside edge of the subgrade. This is the controlling height, when figuring pipe length. Two feet of fill widening are then added to the subgrade. Fill slopes of 1-1/2:1 are then projected down from the subgrade, until they catch the groundslope of the creek. This slope distance between the two fill catch points is the pipe length (Figure 14). (R.C.P.) uses the following installed costs for large pipe based on the Green Mountain National Forest.

Diameter or *Span (ft.)	Installed Cost - $/L.F.
1.5	19.64
2.0	25.00
2.5	33.42
3.0	39.60
3.5	56.25
4.0	65.49

4.5	92.42
5.0	103.89
5.5	110.00
*5.09	239.21
*5.78	250.08
*6.44	260.95
*7.09	271.83
*7.75	282.70
*8.44	293.58
*9.10	304.45

Bridge construction is esimated at $700.00/L.F.

* Pipe Arch

Cost: Load and Haul Endhaul Material

All endhaul material is based on the loose cubic yard. Common (B.C.Y.) excavation quantities are swelled by 15%. It is assumed that rock excavation swells by 30% to a loose state. It is also assumed that approximately 30% of the rock will be lost during blasting. Thus, no swell is included with rock endhaul. Endhaul haul distances are estimated by the user. For the study area, the average distance to a waste area is about 0.4 miles. (R.C.P.) uses endhaul costs based on dump trucks and front-end loaders. If scrapers are used, the costs must be adjusted. The following are costs for endhaul generated on the Green Mountain National Forest:

Load Endhaul Material - $0.75/L.C.Y.

Haul Endhaul Material - $0.28/L.C.Y./mile

Cost: Mobilization

As with fences and gates, mobilization is normally paid for on a lump sum basis. Again, based on past sales on the Green Mountain National Forest, one complete move in and move out of construction equipment cost approximately $1,600.00. Assuming that 2 miles of road are built per season, the cost per mile is $800.00.

ROAD COST PROGRAM (R.C.P.)

PROGRAM DESCRIPTION AND FLOW

The road cost program (R.C.P.) is a single program divided into two parts, with each part stored in a different file. Part (a) and (b) are connected by an internal link statement, which automatically loads part (b) (Figures 7 and 8). All variables which are defined in part (a) are retained in part (b) by using this link statement. To run the program, the following is needed:

1. 9830A - Computer
2. 9865A - Cassette Memory
3. 9864A - Digitizer
4. 9866A or Centronics 101 Printer
5. 9162-0050 Digital Cassette Data Tape marked with files of 2000 words
6. 9162-0050 Digital Cassette Program Tape with part (a) (2200 words) and part (b) (5000 words) of (R.C.P.) loaded on two files.

The primary functions of part (a) of (R.C.P.) are: 1) to gather and store road segment data from the contour map, 2) define the constant unit cost variables, and 3) printout common data stored on tape and unit cost listing. If the segment data from the contour map has already been stored, part (a) will simply load the information from the peripheral data tape, do primary functions 2

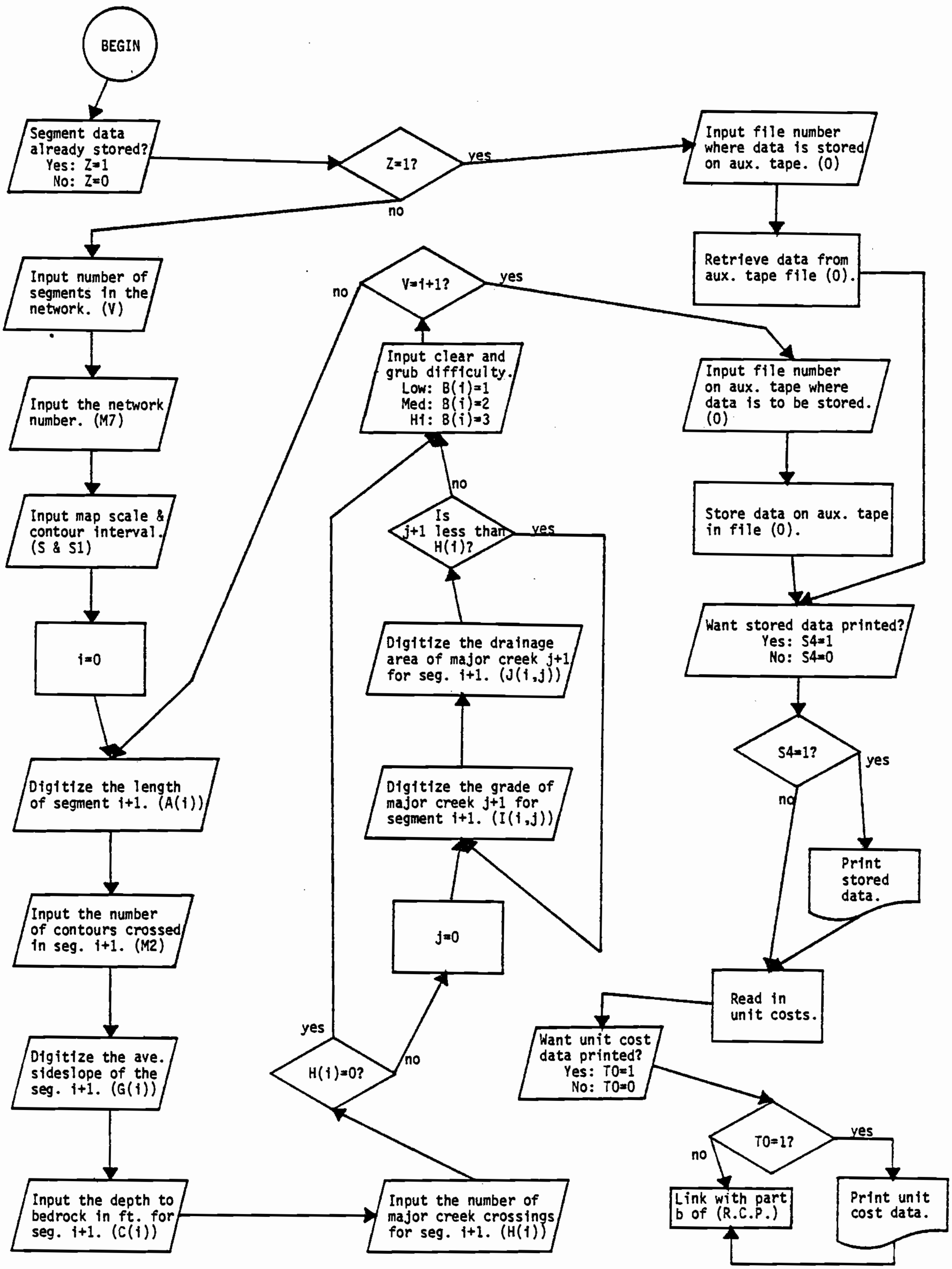


Figure 7. Flow diagram for Road Cost Program(R.C.P.)--part a

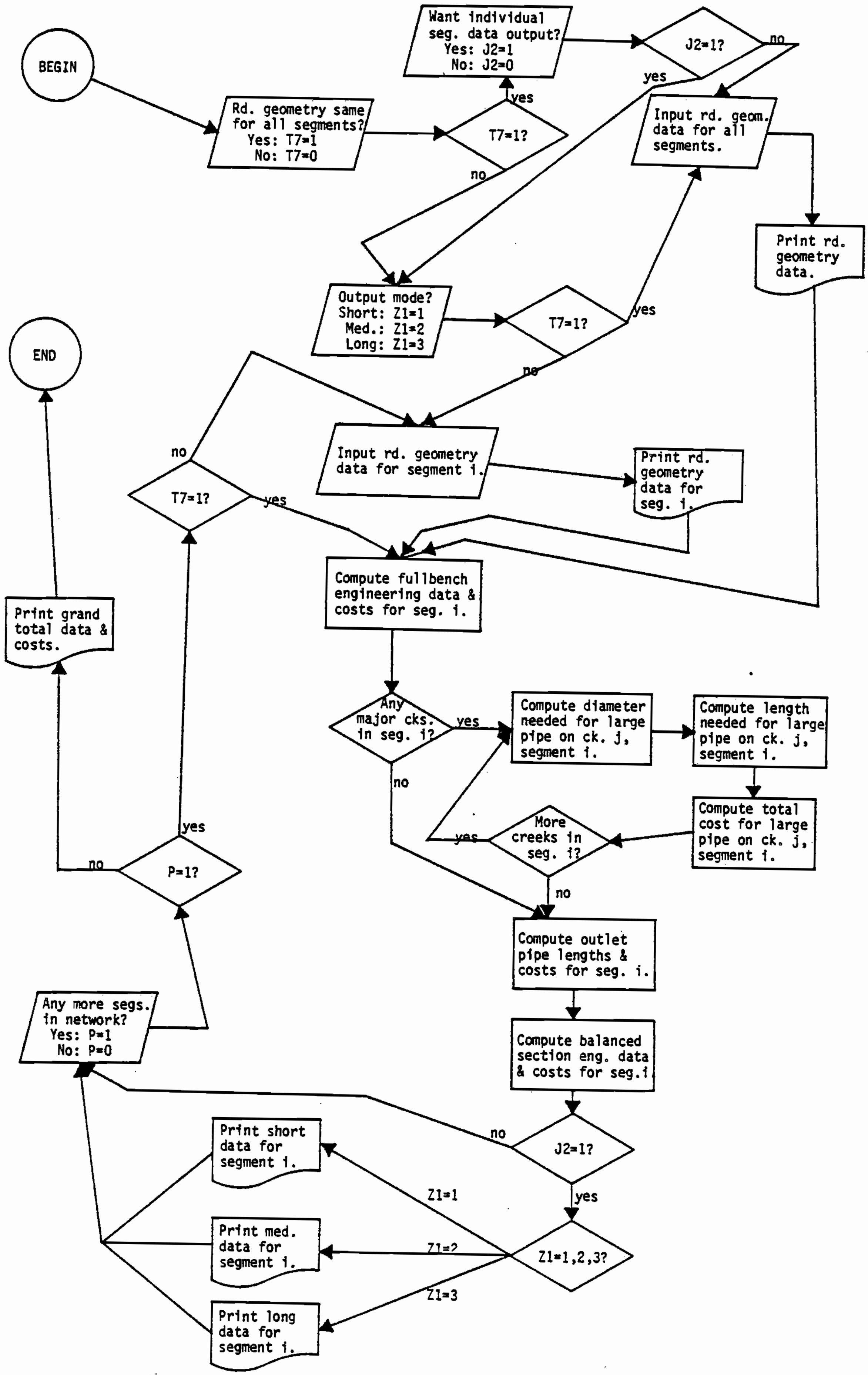


Figure 8. Flow diagram for Road Cost Program(R.C.P.)--part b

and 3, and proceed to link with part (b). This feature of the program saves time, since the segment data needs to be digitized only once. The following data is collected in (R.C.P.) part (a).

--Direct User Input--

1. Network Number
2. Number of Segments in Network
3. Clear and Grub Difficulty for each Segment
4. Bedrock Depth for each Segment
5. Number of Major Creek Crossings for each Segment
6. Map Scale and Contour Interval

--Digitizer Input--

1. Segment Lengths in Feet
2. Segment Grades in Percent
3. Average Sideslope Adjacent to Segment
4. Creek Channel Grades in Degrees
5. Creek Drainage Areas in Degrees

--Internally Defined Constants--

1. Road Construction Unit Costs

Up to 110 road segments may be digitized and stored on the data tape under the same network number. If the network has more than 110 road segments, the network must be broken up and run as two separate networks. The results may later be combined.

The accuracy of (R.C.P.) is dependent on the accuracy of the data base and the user's choice of segment lengths and break points. Of course, inaccurate contour maps, soil data and stand data will result in erroneous answers. The (R.C.P.) should not be used on contour maps that are known to be inaccurate or on maps with contour intervals greater than 80 feet.

Assuming the map is accurate and the contour intervals are acceptable, inaccuracy can also result in a poor choice of segment lengths and break points. To assure maximum accuracy, segments should be terminated when major changes in the following data are encountered. The parameters which are most sensitive are listed first.

1. Major changes in sideslope
2. Major changes in bedrock depth
3. Major changes in grade
4. Major changes in existing stand conditions which is reflected in the clear and grub difficulty

The user must weigh accuracy against digitizing time. The most accurate method is to change the segment number when any of the above parameters change. This will result in considerable digitizing time due to the increase in the number of segments. Acceptable accuracy should be obtained in most areas by keeping the segment lengths less than one mile in length.

Part (b) of (R.C.P.) analyzes the data obtained in part (a) (Figure 8). The following four output modes are available.

1. Summary Output - This analyzes all the segments in the network and accumulates the following data for each of the 3 construction types.
   a) grand total cost
   b) grand total excavation in B.C.Y.

c) cost per mile

d) total network length in miles

e) road geometry data

2. Short Output - This output includes the summary output, plus the total cost for each segment in the network by construction type.

3. Medium Output - This includes all data in the short output, plus total excavation and percent rock for each segment in the network by construction type.

4. Long Output - This includes all data in the medium output, plus the following for each segment by construction type.

   a) itemized engineering data

   b) itemized costs for each of the cost centers discussed in the cost analysis section

   c) miscellaneous fullbench and balanced section variables. These variables are defined and referenced in the variable definitions and associated figures.

In addition to the output mode, the user has the opportunity to input the following road geometry parameters.

1. Running surface width in feet
2. Cutslope factor (horizontal to vertical)
3. Is there a ditch? (Yes or No)
4. Compacted surfacing depth in feet
5. Number of miles to rock pit
6. Number of miles to the waste area (endhaul)

The (R.C.P.) will allow these parameters to change with each segment conditions, or will analyze the entire network using the same parameters. If the user chooses to use the summary output, the option of changing parameters with each segment is no longer available. If the user chooses to change parameters with each segment, the output will include the road geometry parameters for each segment. Running (R.C.P.) with the road geometry parameters fixed for the entire network will result in a single listing of the parameters used at the beginning of the output printout.

(R.C.P.) internally defines the unit costs used in the analysis. They are input using a read data command. These costs may be easily changed to fit the individual area. Figure 9 shows the unit costs that are applicable on the Green Mountain National Forest.

```
*****************************************************************************
     THE FOLLOWING AVERAGE COSTS ARE USED IN THE COST PROGRAM

C&G/ACRE LO=$2000  MED=$2300  HI=$2600
SEED/ACRE=$ 700.00   MOBILIZATION/MILE=$ 800.00
EXCAVATION/CY:   COMMON=$ 2.30      ROCK=$ 11.00
RIPRAP/CY=$ 40.00      FENCES & GATES=$ 500.00
BUY SURFACING/CY=$ 1.10      HAUL SURFACING/CY/MI=$ 0.28
LOAD AND APPLY SURFACING/CY=$ 2.80      OUTLET PIPE/LF=$ 19.60
HAUL ENDHAUL/CY/MI=$ 0.28      LOAD ENDHAUL/CY=$ 0.75
```

Figure 9. Green Mountain National Forest Road Construction Unit Costs.

(R.C.P.) VARIABLE DEFINITIONS

The variables used in the (R.C.P.) are defined for both parts of the program in alphabetical order. Common and dimension variables will be defined first; followed by the simple variables. All (0/1) variables use 0 = no and 1 = Yes

Part a

Common Variables

AI(i) - An array of segment lengths in feet for each segment i; where i=1 to 110 (maximum).

BI(i) - An array of clearing and grubbing difficulties (low=1, medium=2, high=3) for each segment i; where i=1 to 110 (maximum).

CI(i) - An array of depths to bedrock in feet for each segment i; where i=1 to 110 (maximum).

DI(i) - An array of road grades in percent for each segment i; where i=1 to 110 (maximum).

GI(i) - An array of average segment sideslopes in degrees for each segment i; where i=1 to 110 (maximum).

HI(i) - An array of the number of major creek crossings for each segment i; where i=1 to 110 (maximum).

II(i,j) - An array of creek j grades in degrees for each segment i; where i=1 to 110 (maximum) and j=1 to 5 (maximum).

JI(i,j) - An array of area drained in acres for creek j for each segment i; where i=1 to 110 (maximum) and j=1 to 5 (maximum).

V - Number of segments in network.

M7 - Network designation (any number).

Dimension Variables

EI(i) - An array of clear and grub costs per acre for segment i; where i=1 to 110 (maximum).

Simple Variables

A - Total drainage area from map in square inches for segment i; creek j.

A2 - Area in inches of each triangular slice with corners (X,Y), (X1,Y1) and (X2,Y2) for drainage area of creek j; segment i.

B1 - Clearing and grubbing cost per acre.

B2 - Seeding and mulching cost per acre.

B3 - Common excavation cost per bank cubic yard.

B4 - Rock (ledge) excavation cost per bank cubic yard.

B5 - Mobilization cost/mile.

B6 - Riprap (installed) cost per loose cubic yard.

B7 - Cost to purchase surfacing material per loose cubic yard.

B8 - Cost to load and apply surfacing material per loose cubic yard.

B9 - Cost to haul surfacing material per loose cubic yard/mile.

BØ - Cost to load endhaul material per loose cubic yard.

C1 - Cost to haul endhaul material per loose cubic yard/mile.

C2 - Cost to install fences and gates per mile.

C3 - Cost of outlet pipe (installed) per lineal foot.

C8 - Indicator (0/1) variable which controls termination of drain area subroutine.

D - For/Next variable (loop prints stored data).

F - For/Next variable (loop gathers common array data).

I - Segment number.

I9 - Average segment sideslopes in percent.

J - Creek number.

L - Segment length in feet (used in length subroutine).

M2 - Number of contour lines crossed by segment.

M3 - Vertical elevation in feet between beginning and end of segment.

M9 - Accumulated distance in feet of all segments in network.

O - File number for stored data on peripheral cassette tape.

P - For/Next variable (loop gathers creek data).

P1 - Designated sign of road grade for haul (favorable=1, adverse=2, level=3).

R8 - Digitizer control variable. Denotes horizontal distance between the points (X,Y) and (X2,Y2) in creek drain area subroutine.

S - Map scale in feet per inch.

S1 - Contour interval in feet.

S3 - Drained area in acres (used in area subroutine).

S4 - (0/1) variables. Want list of stored data?

T8 - Horizontal distance between 5 contour lines. (Used to find grade of creek at the point it crosses the road.)

T9 - Grade of creek j in segment i in degrees.

TØ - (0/1) variable. Want unit cost listing?

U6 - Average sideslope in percent.

U7 - Average creek grade in percent.

X,X1,X2 - Digitizer variables denoting X coordinates.

Y,Y1,Y2 - Digitizer variables denoting Y coordinates.

Y7 - For/Next variable (loop gathers average sideslope).

Y8 - Horizontal distance in feet between the points (X1,Y1) and (X,Y) in sideslope determination.

Y9 - Accumulated horizontal distances of 5 sideslope samples for each segment.

Z - (0/1) variable. Segment data already stored?

Part b

Common Variables

Since the two programs are connected by a link statement, the all variables defined in part (a) will be transferred intact to part (b). All common variables defined in part (a) will have the same definition in part (b).

Dimension Variables

The dimension variables are actually defined in part (a) to increase the storage in part (b). They are listed here, since the variables are defined and used in part (b) only.

EI(i) - See part (a).

MS(j) - Total cost of pipe or bridge on major creek j; where j=1 to 5 (maximum).

XS(j) - Length in feet of pipe on major creek j; where j=1 to 5 (maximum).

YS(j) - Cost per lineal foot (installed) of pipe on major creek j; where j=1 to 5 (maximum).

ZS(j) - Diameter or rise of pipe on major creek j; where j=1 to 5 (maximum). If a bridge is needed, this variable denotes bridge length.

Simple Variables

A - The "a" term in the quadratic equation $T = -b + \sqrt{b^2-4ac}/2a$. This is used in the balanced section subroutine to find T.

A9 - Total endhaul cost in balanced section for segment i.

B - The "b" term in the quadratic equation. This is used in the balanced section subroutine to find T.

B2,B3,B4,B5,B6,B7,B8,B9,BØ - See part (a).

C1,C2,C3 - See part (a).

D6 - Total riprap cost for segment i with all construction types.

D7 - Total mobilization cost for segment i with all construction types.

D8 - Total endhaul cost for segment i in the fullbench with endhaul construction.

D9 - Total surfacing cost for segment i with all construction types.

E1 - A collection of terms in the balanced section area equation (see mathematical formulation).

E2 - A collection of terms in the balanced section area equation (see mathematical formulation).

E3,E4,E5,E6,E7 - End area sections in square feet of the balanced section (see Figure 10).

E8,E9 - A collection of terms in the balanced section area equation (see mathematical formulation).

E0 - Slope distance between upper and lower catch point of rock section in balanced subroutine (See Figure 10).

F1 - An angle between the common cutslope and a line normal to the sideslope in balanced subroutine (see Figure 10).

F2 - Same as F1, except used in full bench subroutine (see Figure 12).

F6 - Total common excavation costs for balanced construction on segment i.

F7 - Total rock excavation costs for balanced section construction on segment i.

F8 - Total seeding costs for balanced section construction on segment i.

F9 - Total clearing and grubbing costs for balanced section construction on segment i.

G4 - Total rock excavation in bank cubic yards for balanced section construction on segment i.

G5 - Total common excavation in bank cubic yards for balanced section construction on segment i.

G6 - Total clear and grub acres for balanced section construction on segment i.

G7 - Total seeding acres for balanced section construction on segment i.

H - For/Next variable (loop contains main costing program).

H1,H2,H3,H4 - End area sections in square feet of the full bench section (see Figure 12).

H5 - Total end area section in square feet of full bench section where all excavation is common (see Figure 13).

H6 - Angle between subgrade and cutback in degrees on full bench section with all common excavation (see Figure 13).

H7 - Angle between cutbank and groundslope line in degrees on full bench section with all common excavation (see Figure 13).

I,J - Same as part (a).

J2 - (0/1) variable. Want segment data output?

K - The "c" term in the quadratic equation $T = -b + \sqrt{b^2 - 4ac}\ /2a$. This is used in the balanced section subroutine to find T.

K1 - Total lineal feet of outlet pipe needed in segment i.

K2 - Length of each individual outlet pipe needed in segment i.

K3 - Compacted surfacing depth in feet.

K4 - (I/O) variable. Is there a ditch?

K5 - Cutslope angle in degrees.

K6 - Cutslope factor in common material (horizontal to vertical), i.e., 1-1/2 to 1.

K7 - Running surface width in feet.

K9 - Outlet pipe spacing in feet on segment i.

KØ - Number of outlet pipe installations needed in segment i.

L6 - Total common excavation in bank cubic yards on full bench section on segment i.

L7 - Total rock excavation in bank cubic yards on full bench section on segment i.

L8 - Total seeding acres on full bench section on segment i.

L9 - Total clearing and grubbing acres on full bench section on segment i.

LØ - Total outlet pipe (installed) cost for segment i.

M4 - Horizontal width of common cutbank section in balanced construction (see Figures 10 and 11).

M5 - Horizontal width of fill in balanced construction (see Figures 10 and 11).

M6 - Slope width of M5.

M7 - Same as part (a).

M8 - Percent rock in fullbench construction for segment i.

M9 - Same as part (a).

N6 - Total network length in miles.

N7 - Total segment length in miles.

01,02,03,04,05,06,07,08,09,0Ø - Length and angle variables for fill over pipes crossing major creeks (see Figure 14).

P - For/Next variable (loop sizes pipes and/or bridges crossing major creeks).

P1 - A collection of terms in the balanced section area equation (see mathematical formulation).

P3 - Slope of creek in degrees.

P4 - Subgrade width of fill over pipe on major creek crossing j on segment i.

P5 - Total length of pipe on major creek crossing j on segment i.

PØ - Total cost for fences and gates on segment i.

Q - The angle between the groundslope and the fillslope on balanced section (see Figures 10 and 11).

Q7 - Accumulated major pipe cost for segment i.

Q8 - Total excavation (rock plus common) in bank cubic yards for full bench construction on segment i.

Q9 - Total excavation (rock plus common) in bank cubic yards for balanced construction on segment i.

QØ - Percent rock in balanced construction for segment i.

R - The angle between the groundline and rock cutback on balanced section (see Figures 10 and 11).

R1 - Total rock excavation in bank cubic yards on fullbench section for segment i.

R2 - Total common excavation in bank cubic yards on fullbench section for segment i.

R3 - Total clear and grub acres on fullbench section for segment i.

R4 - Total seeding acres on fullbench section for segment i.

R5 - Total surfacing needed in loose cubic yards for segment i.

R6 - Total number of turnouts in segment i.

R7 - Number of miles to surfacing pit.

R9 - Number of miles to waste area.

S8 - Total cost to construct fullbench and endhaul section on segment i.

S9 - Total cost to construct fullbench and sidecast section on segment i.

SØ - Total cost to construct balanced section on segment i.

T - Distance in feet from the daylight point to inside edge of subgrade on balanced section on segment i (see Figures 10 and 11).

T1 - Distance in feet from the daylight point to catch of the rock section on the subgrade on balanced section on segment i (see Figure 10).

T2 - Distance in feet from catch point of rock section to the inside edge of subgrade on balanced section on segment i (see Figure 10).

T4 - The projection of T1 to slope distance (see Figure 10).

T7 - (0/1) variable. Road geometry same for all segments?

V - Same as part (a).

V1 - End area in square feet of the pipe crossing major creeks. It is based on Talbot's Formula.

V3 - Amount of riprap needed in loose cubic yards for segment i.

W - Subgrade width in feet on both balanced and fullbench construction.

W1,W2,W3,W4,W5,W6,W7 - Lengths in feet of various parts of the end area used in fullbench construction (see Figure 12).

W8 - Grand total network cost using fullbench and endhaul construction.

W9 - Grand total network cost using fullbench and sidecast construction.

WØ - Grand total network cost using balanced construction.

X8 - Grand total excavation (rock plus common) in bank cubic yards for fullbench construction.

XØ - Grand total excavation (rock plus common) in bank cubic yards for balanced construction.

Z1 - Output indicator variable (short=1, medium=2, long=3).

Z8 - A collection of terms in the balanced section area equation (see mathematical formulation).

Z9 - End area in square feet of excavation in balanced section when all excavation is common material (see Figure 11).

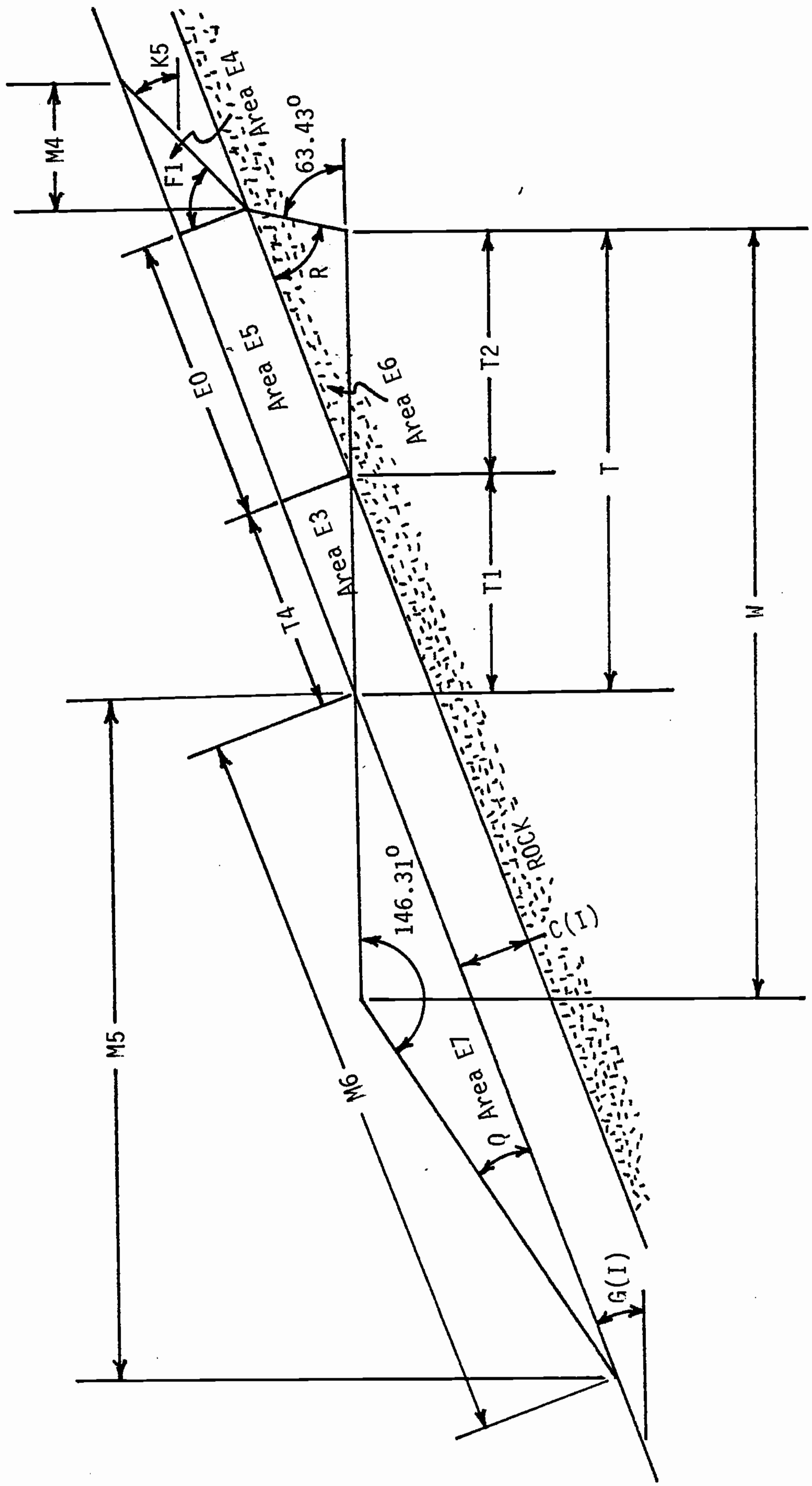


Figure 10. End area diagram for balanced section with rock

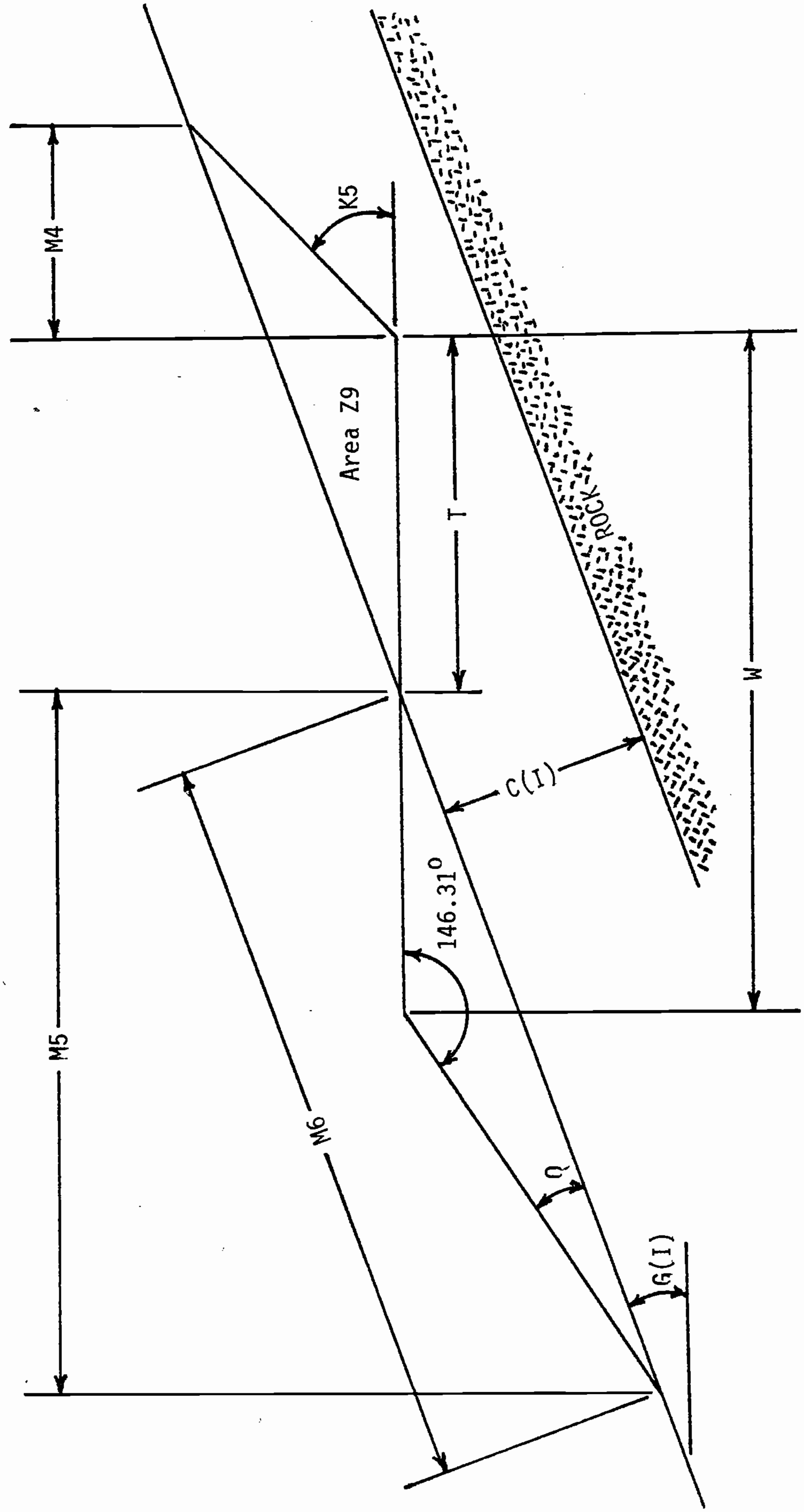


Figure 11. End area diagram for balanced section without rock

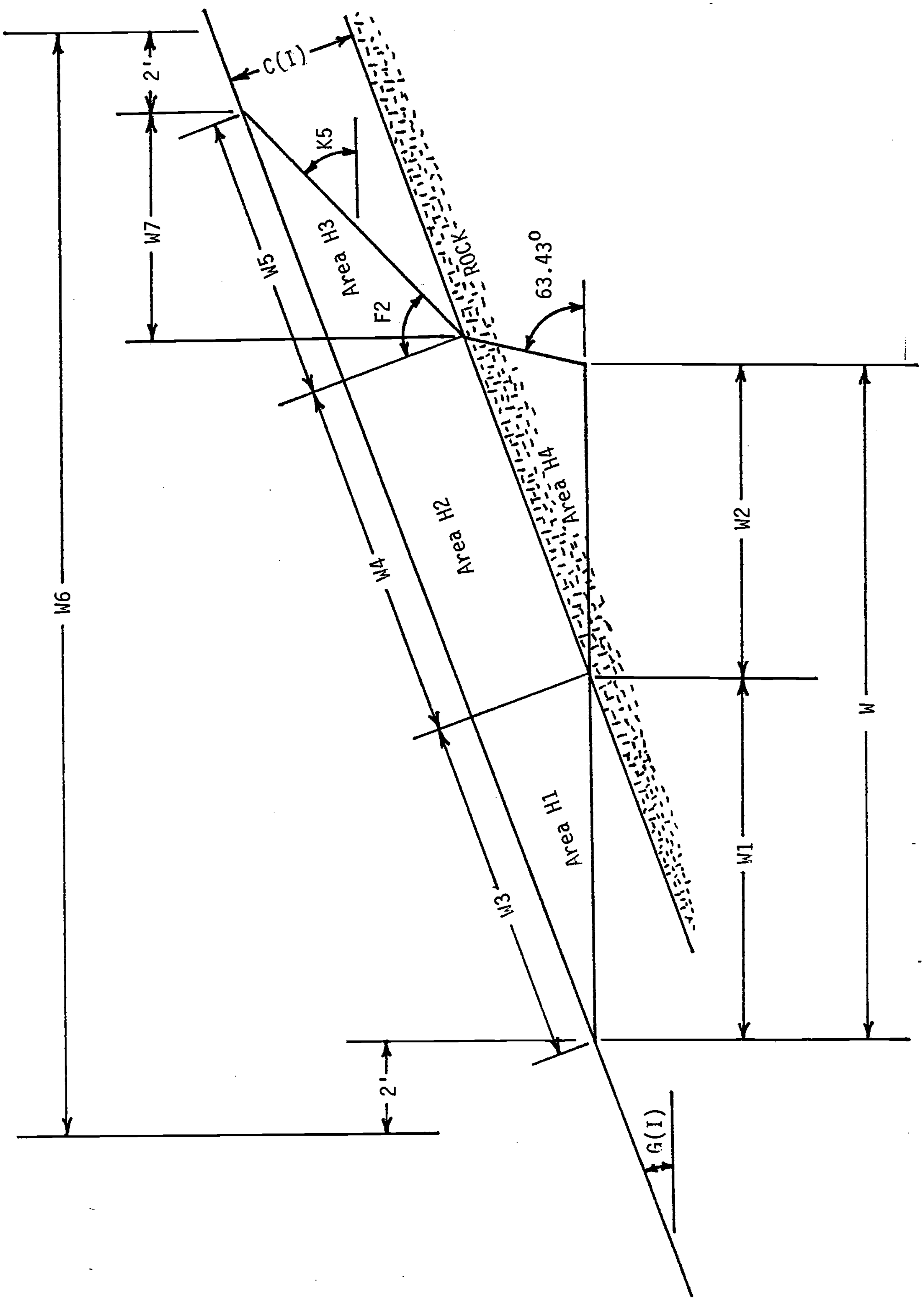


Figure 12. End area diagram for fullbench construction with rock.

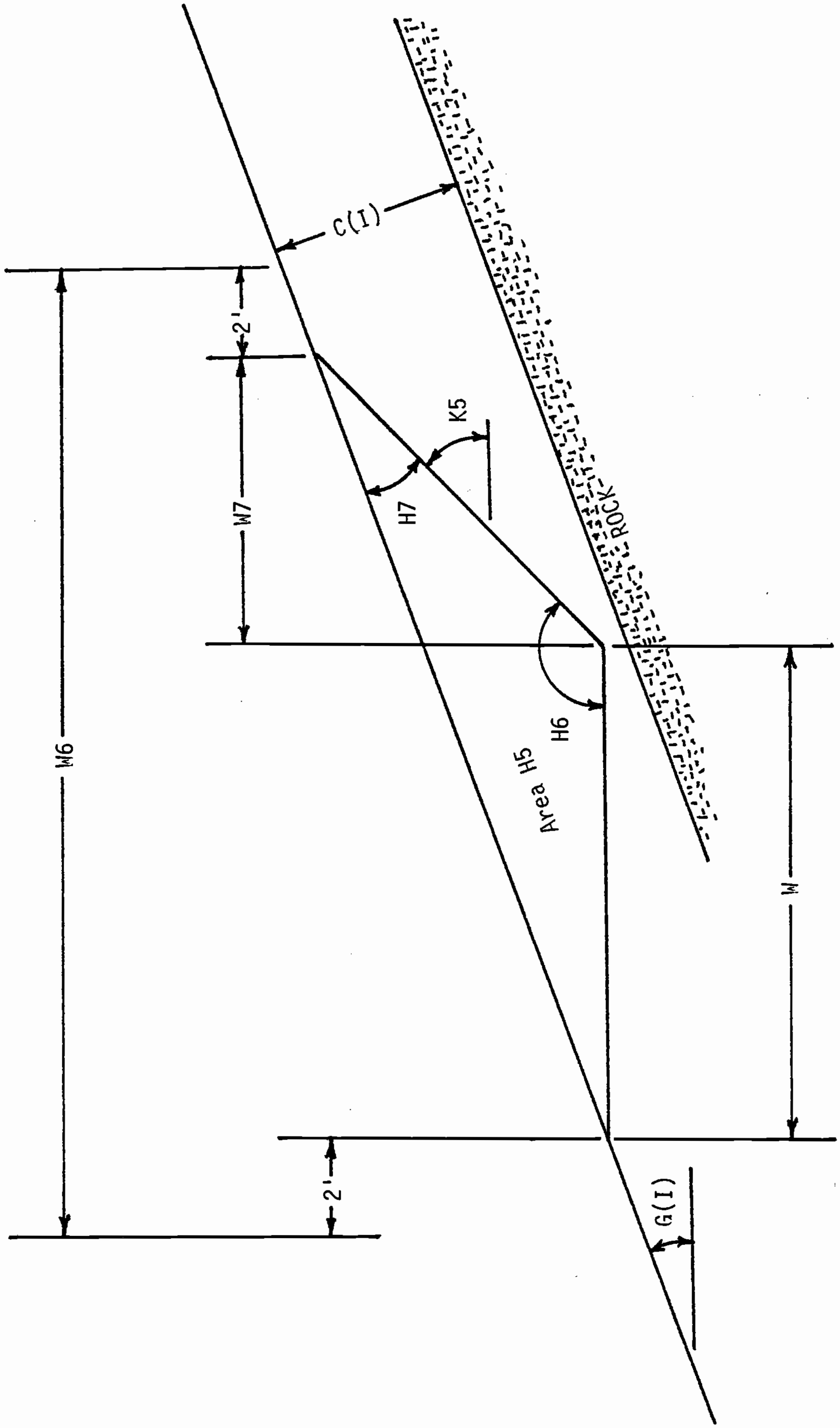


Figure 13. End area diagram for fullbench construction without rock.

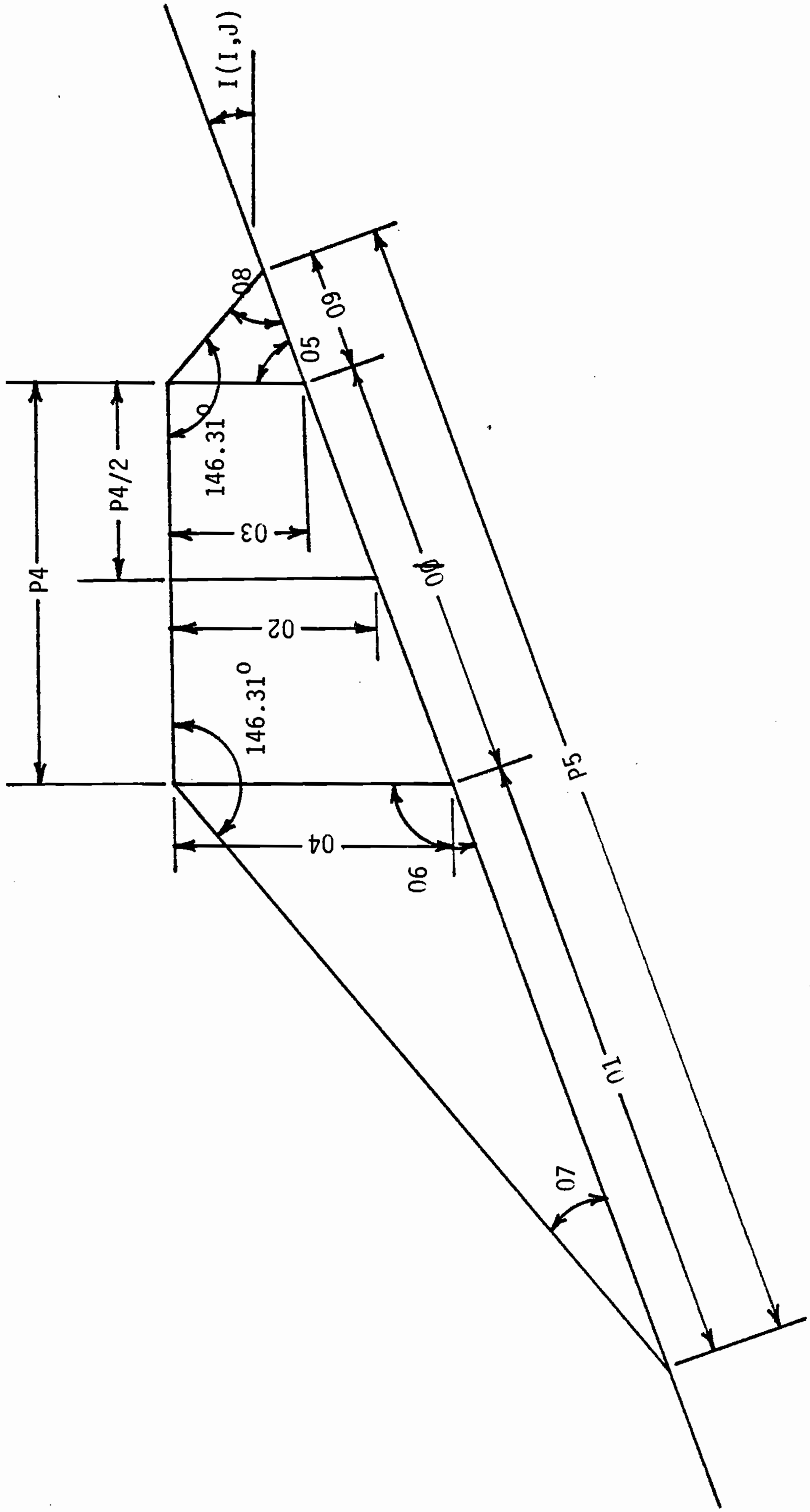


Figure 14. End area diagram for fill covering pipe on major cks.

MATHEMATICAL FORMULATION

The mathematics used in (R.C.P.) is not difficult or involved. Variations of the following mathematics principles were used.

1. Right Triangle Equations
2. Oblique Triangle Equations
3. Quadratic Formula - $ax^2 + bx + c = 0$

The formulations presented here will start with part (a) progressing in the same order as the program actually executes. Beginning and ending program line numbers in addition to verbal description will be used to identify the separate math routines.

Part a

-Digitize Segment Length-

Program Lines - (340 to 390)

Subroutine Lines - (840 to 1000)

Description: X and Y coordinates are set at the end of the segment. The segment is then digitized in the continuous mode. With this mode (X1,Y1) and (X2,Y2) coordinates are set along the segment. After each (X2,Y2) coordinate is set, the program tests if (X2,Y2) is 0.05 inches from (X,Y). If it is, the routine stops. If it is not, (X2,Y2) becomes (X1,Y1) and a new (X2,Y2) is set. After each iteration, the distance between (X1,Y1) and (X2,Y2) is found and accumulated. This distance is found using the following equation.

$$SQR[(X1-X2)^2 + (Y1-Y2)^2]$$

-Digitize Road Grade-

Program Lines - (400 to 520)

Subroutine Lines - (1010 to 1040)

Description: The user inputs whether the haul is favorable, adverse or level. If the haul is level, the grade equals 0%. If the haul is not level, the user inputs the number of contours crossed by the segment. The contours are then multiplied by the contour interval and then divided by the segment length. Adverse haul changes the sign of the grade to negative.

-Digitize Average Sideslope of Road-

Program Lines - (530 to 660)

Description: Each segment is sampled five times at random along its length. Each sample places (X,Y) coordinates above the road at a contour line and (X1,Y1) coordinates below the road on a contour line five contours below (X,Y). This procedure accumulates the total horizontal distances of the 5 trials and divides them into 25 times the contour interval. The arc-tangent is then used to get this figure in degrees.

-Digitize Creek Grade-

Program Lines - (750 and 760)

Subroutine Lines - (1680 to 1750)

Description: This is similar to the previous routine, except only one sample is taken at each creek where it crosses the road.

-Digitize Area Drained on Each Creek-

Program Lines - (770 and 780)

Subroutine Lines - (1760 to 2000)

Description: X and Y coordinates are set at point on the perimeter of the area drained. The perimeter is then digitized in the continuous mode. With this mode, (X1,Y1) and (X2,Y2) coordinates are set along the perimeter. The program tests to see if (X,Y) is 0.05 inches from (X2,Y2). If it is, the area is closed and the routine stops. If it is not, (X2,Y2) becomes the new (X1,Y1), and a new (X2,Y2) is set. Each iteration results in a very small triangle defined by the three points (X,Y), (X1,Y1) and (X2,Y2). These small triangle areas are accumulated using the double-meridian distance method, using the following equation.

$$\text{Area} = (X1-X)(Y2-Y)/2 - (Y1-Y)(X2-X)/2$$

These small areas are then accumulated to get the total area drained of the creek.

Part b

-Fullbench Volumes and Costs-

Program Line - (250)

Subroutine Lines - (670 to 1330)

Description: The program first checks to see if the road prism intersects the rock section. If it doesn't, it sets the rock excavation equal to zero, and calculates the common excavation directly (Figure 13). If there is rock excavation, end areas are broken into four sections and calculated (Figure 12). The following equations are used throughout this subroutine.

-Right Triangle-

$a = c(\sin A) = B(\tan A) = c(\cos B)$

$b = c(\cos A) = C(\sin B) = a(\tan B)$

$$c = \frac{a}{\cos B} = \frac{b}{\sin B} = \frac{a}{\sin A} = \frac{b}{\cos A}$$

Area = (ab)/2

-Oblique Triangle-

$$b = \frac{a}{\sin A}(\sin B)$$

$$c = \frac{a}{\sin A}[\sin(A+B)]$$

$$\text{Area} = \frac{a^2(\sin B)(\sin C)}{2(\sin A)}$$

-Large Pipe End Area Sizing-

Program Line - (1110)

Subroutine Lines - (1340 to 2140)

Description: This subroutine sizes the major pipe according to Talbot's Formula.

Pipe end area = C x [Area Drained (acres)]$^{.75}$

The C factor used here is very critical. For the study area in question, C was set at 0.2, based on local information. After the pipe end area is calculated, the subroutine enters a series of discreet pipe sizes ranging from 1.77 to 104.8 square feet end area. A pipe is then found which corresponds to the end area for the creek.

If the end area needed is greater than 104.8 square feet, a bridge is used.

-Large Pipe Length Sizing-

Program Line - (2100)

Subroutine Lines - (2270 to 2400)

Description: This subroutine simulates a fill over the creek. The pipe diameter (or rise if arch) is covered by 4 feet of topping at the inside edge of the subgrade (Figure 14). The subgrade includes two feet of fill widening. A 1-1/2 to 1 fill slope is then run from each corner of the subgrade until it catches with the creek grade. This total distance under the fill equals the pipe length.

-Outlet Pipe Length-

Program Line - (1120)

Subroutine Lines - (2150 to 2260)

Description: The outlet pipe spacing is based on the Transportation Engineering Handbook, U.S.F.S., 1966 (Figure 6). A power regression was run on spacing in feet vs. road grade in percent. Erosion class II (unified classification SM and ML) was used for the study area.

$$\text{Spacing (ft.)} = (2437.5) \times (\text{rd. grade } \%)^{-1.00}$$

-Balanced Section Volumes and Costs-

Program Line - (260)

Subroutine Lines - (2410 to 3290)

Description: As with the fullbench subroutine, the balanced section subroutine tests to see if the road prism intersects solid rock. The balanced section subroutine moves the subgrade in and out horizontally until the volume of cut exactly equals the volume of fill (Figure 10). The road prism end area is divided into 5 smaller areas.

-Rock Area-

$$E6 = (T-T1)^2 \times \left(\frac{\sin 116.57° \times \sin G(I)}{2 \times \sin R}\right)$$

Simplifying, we get:

$$\text{Let } E2 = \left(\frac{\sin 116.57° \times \sin G(I)}{2 \times \sin R}\right)$$

$$\therefore E6 = (T-T1)^2 \times E2$$

-Fill Area-

$$E7 = (W-T)^2 \times \left(\frac{\sin 146.31° \times \sin G(I)}{2 \times \sin Q}\right)$$

Simplifying, we get:

$$\text{Let } E1 = \left(\frac{\sin 146.31° \times \sin G(I)}{2 \times \sin Q}\right)$$

$$\therefore E7 = (W-T)^2 \times E1$$

-Common Areas-

$$E3 = ((T4 \times C(I)/2) \times 0.8$$

$$E4 = (((C(I) \times \tan F1) \times C(I))/2) \times 0.8$$

$$E5 = (T-T1) \times \left(\frac{\sin 116.57}{\sin R}\right) \times C(I) \times 0.8$$

Simplifying, we get:

Let $P1 = \left(\frac{\sin 116.57}{\sin R}\right) \times C(I) \times 0.8$

$\therefore E5 = (T-T1) \times P1$

The objective of this subroutine is to make the common cut areas plus the rock cut area equal to the fill area.

$$E3 + E4 + E5 + E6 - E7 = 0$$

or

$$E3 + E4 + ((T-T1) \times P1) + ((T-T1)^2 \times E2) - ((W-T)^2 \times E1) = 0$$

By expanding terms we get:

$$E3 + E4 + (T)(P1) - (T1)(P1) + (T^2)(E2) - (2)(T)(T1)(E2) + (T1^2)(E2) - (W^2)(E1) + (2)(T)(W)(E1) - (T^2)(E1) = 0$$

By collecting like terms we get:

$$(T^2)(E2-E1) + (T)((P1) + ((2)(W)(E1)) - ((2)(T1)(E2)) + K = 0$$

where $K = (T1^2)(E2) + E3 + E4 - ((P1)(T1)) - ((W^2)(E1))$

Recall: $ax^2 + bx + c = 0$

Putting the variables into this form, we get:

$a = (E2 - E1)$

$b = (P1) + ((2)(W)(E1)) - ((2)(T1)(E2))$

$c = K$ (shown above)

Simplifying further, we get:

$E8 = (2)(T1)(E2)$

$E9 = (2)(W)(E1)$ OR

$$(T^2)(E2-E1) + T((P1) + (E9) - (E8) + K = 0$$

The equation is now in the quadratic form where $x = T$. T is solved for by the following equation.

$$T = \frac{-b + \sqrt{b^2 - (4)(a)(K)}}{(2)(a)}$$

If T is greater than T1, then we know that rock is present in the end area section. The subroutine then proceeds to calculate the appropriate end areas using the calculated T. If T is less than T1, the subroutine sets the rock area (E6) equal to zero and calculates a new T base on all common excavation (Figure 11). With this case, the following equations are used.

-Fill Area-

$$E7 = (W-T)^2 \times E1 \text{ (same as before)}$$

-Common Area-

$$Z9 = (T^2) \times \left(\frac{\sin(180-K5) \times \sin G(I)}{2 \times \sin(K5-G(I))}\right) \times 0.8$$

Simplifying, we get:

$$\text{Let } Z8 = \left(\frac{\sin(180-K5) \times \sin G(I)}{2 \times \sin(K5-G(I))}\right) \times 0.8$$

$$\therefore Z9 = (T^2)(Z8)$$

Our equation now becomes:

$$Z9 - E7 = 0 \quad \text{OR}$$

$$(T^2)(Z8) = (W^2-(2)(W)(T) + T^2)(E1) \quad \text{OR}$$

$$(T^2)(Z8) = (W^2)(E1) - (2)(W)(T)(E1) + (T^2)(E1)$$

Bringing all terms to 1 side we get:

$$(T^2)(Z8) - (T^2)(E1) - ((W^2)(E1)) + (2)(W)(T)(E1) = 0$$

Collecting terms we get:

$$(T^2)(Z8-E1) + (T)(2)(W)(E1) - ((W^2)(E1)) = 0$$

Recall: $ax^2 + bx + c = 0$

Putting the variables into this form, we get:

$$a = (Z8-E1)$$

$$b = (2)(W)(E1)$$

$$c = K = -((W^2)(E1))$$

This equation is then put into the quadratic formula, and solves for T. The right and oblique triangle equations are then used to find appropriate areas, lengths and costs.

GREEN MOUNTAIN NATIONAL FOREST STUDY AREA

STUDY AREA DESCRIPTION

-Location-

The study area is located on the Rochester Ranger District on the Green Mountain National Forest. The area is bounded to the West by the Long Trail; the East by State Highway 100; the North by State Highway 125; and the South by State Highway 73. The study area encompasses 25,859 acres wholly within Windsor and Addison Counties. Of this total acreage, approximately 27% or 7,085 acres are in private ownership. Much of the private land is owned by timber producing companies.

-Existing Transportation System-

Most roads in the study area follow major brooks. These roads are built on old locations dating back to pioneer days. These old locations seem to follow the brook until the grade becomes too steep. At this point, the road usually ends. Only recently have extensions to these roads been made in an attempt to gain elevation. Figure 25 shows the existing roads. Many of the older roads in the study area are in very poor condition. They are very narrow; have poor drainage and approach grades of 30%. Some of these roads are being considered for reconstruction to provide future timber access (Figure 15).

Figure 15. A Section of Tunnel Brook Road.

In sharp contrast to these older, very low standard "jeep trails," are the portions of new construction. Most recently constructed roads are single lane, surfaced roads including a ditch. They are built with a design speed of 15 M.P.H. (Figure 16).

-Stand Conditions-

The stands in the study area are extremely variable in terms of both age and size. The average commercial stand contains about 85 square feet of basal area and is about 10 inches average D.B.H.

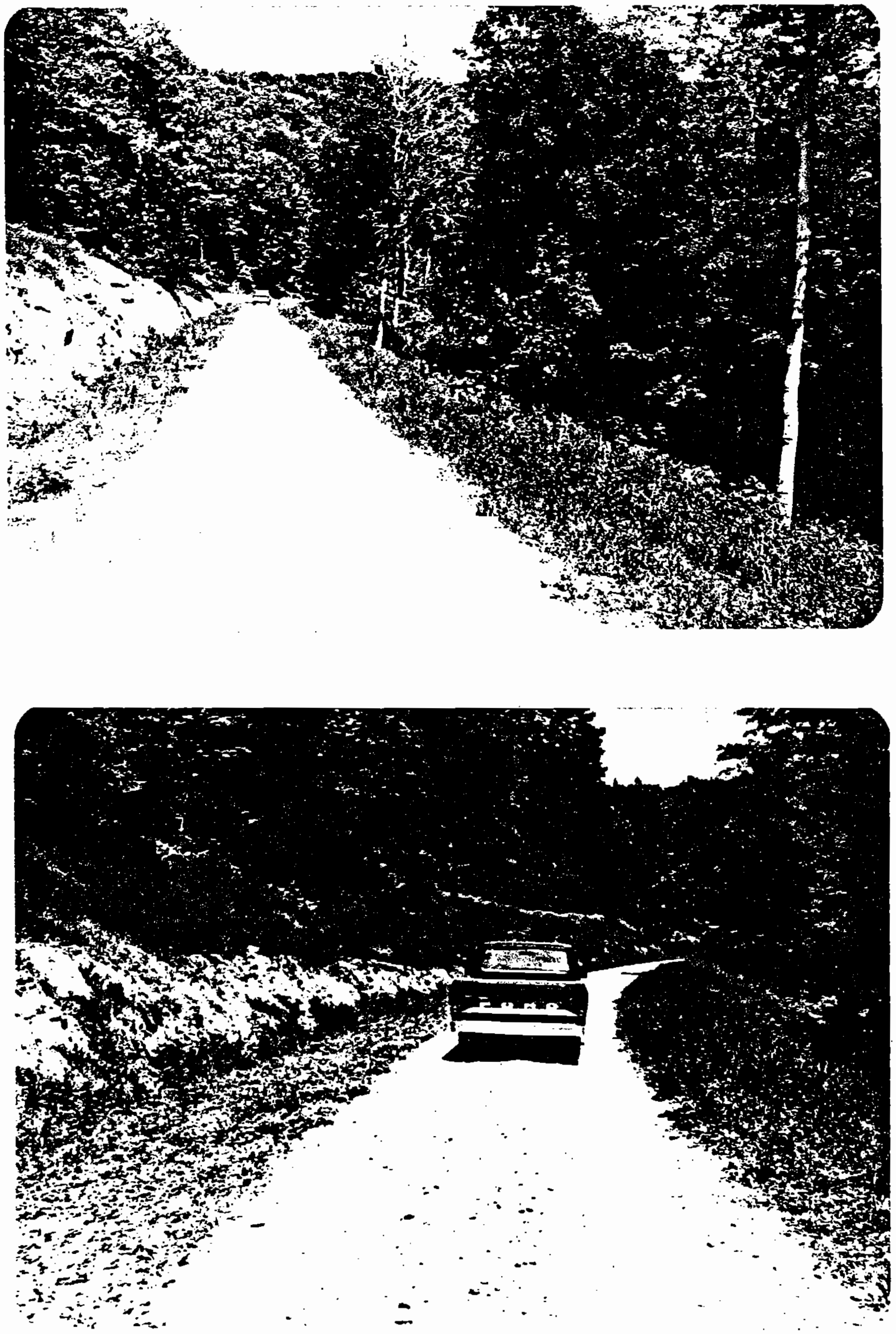


Figure 16. Taylor Brook Road. Typical new construction.

(Appendix 1, 3). The predominant species are Beech, Birch and Maple.

-Silviculture-

Most cutting on the Green Mountain National Forest is geared towards even aged management. The predominant treatment is shelterwood and seed tree cutting. There is evidence that acceptable regeneration results after clearcutting. Many times, shelterwood and seed tree prescriptions are used to satisfy the visual management constraints. Figure 17 shows a typical area that has been shelterwood cut.

Figure 17. Shelterwood Cut.

-Current Logging Methods-

At the present time, all logging is done with tractors and rubber tired skidders. Sales are planned using a minimum of truck roads. Swing trails or "arch roads" radiate from the landing to distances as far as 1-1/2 miles (Figure 18). Average skids of 3/4 mile or more are not uncommon. The timber is usually handled

Figure 18. Typical Arch Road.

twice during the yarding operation. The timber is skidded tree length and bunched at an arch road using a small tractor (Figure 19). Large, rubber tired skidders equipped with as many as 10 chokers are then used to swing the logs down the arch road to the landing (Figure 20). The trees are bucked at the landing in lengths ranging from 8 to 16 feet, depending on the mill to which they are hauled (Figure 21). Self loading trucks then load the logs and haul them

Figure 19. Small Tractor Bunching Logs at Arch Road.

Figure 20. Typical Skidder Swinging on Arch Road.

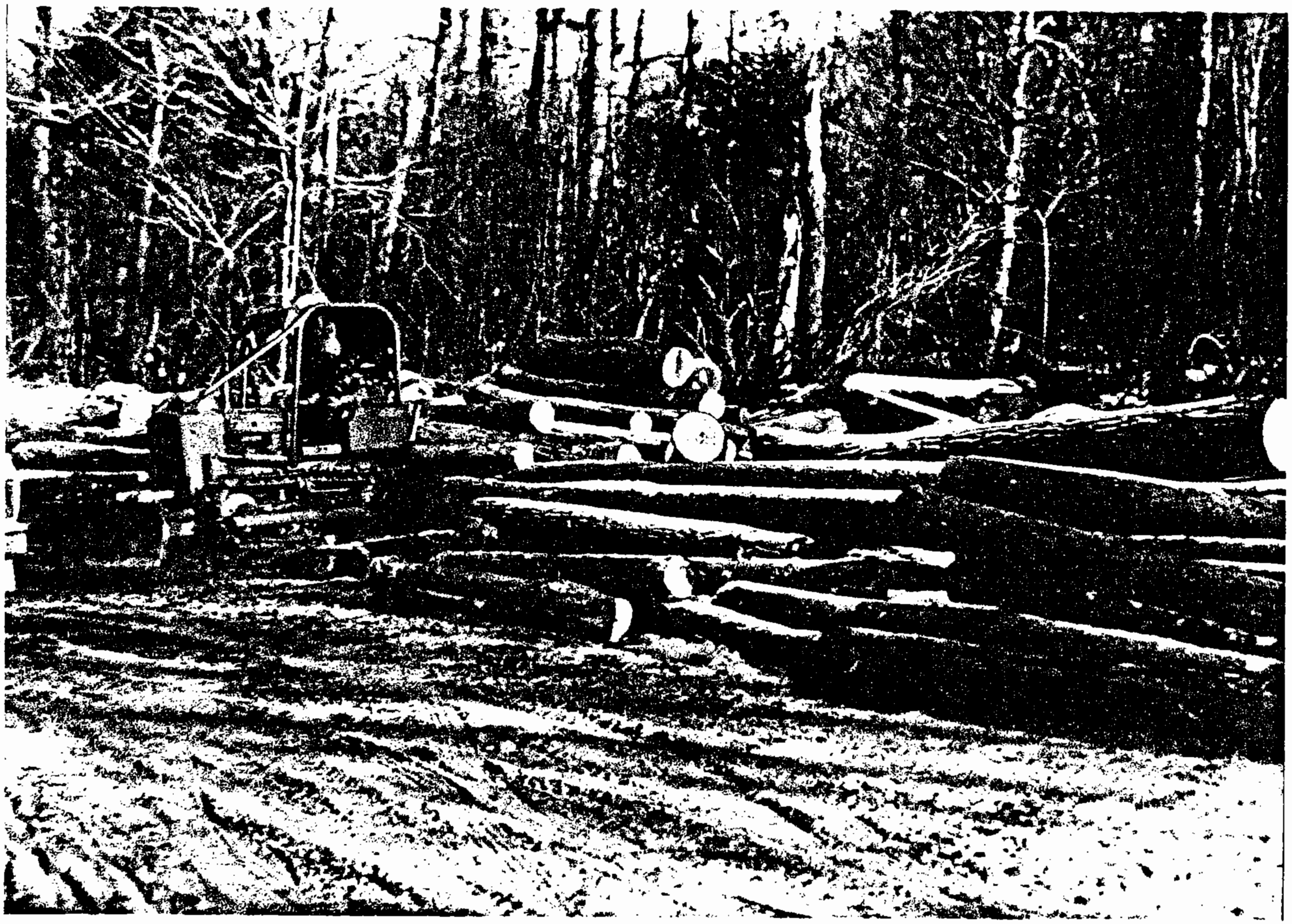


Figure 21. Bucked Logs at the Landing.

to the mill. Most logging trucks in New England are short loggers and don't use a trailer (Figure 22). It is not uncommon to see log trucks with an auxiliary axle in the rear which rides off the ground when unloaded.

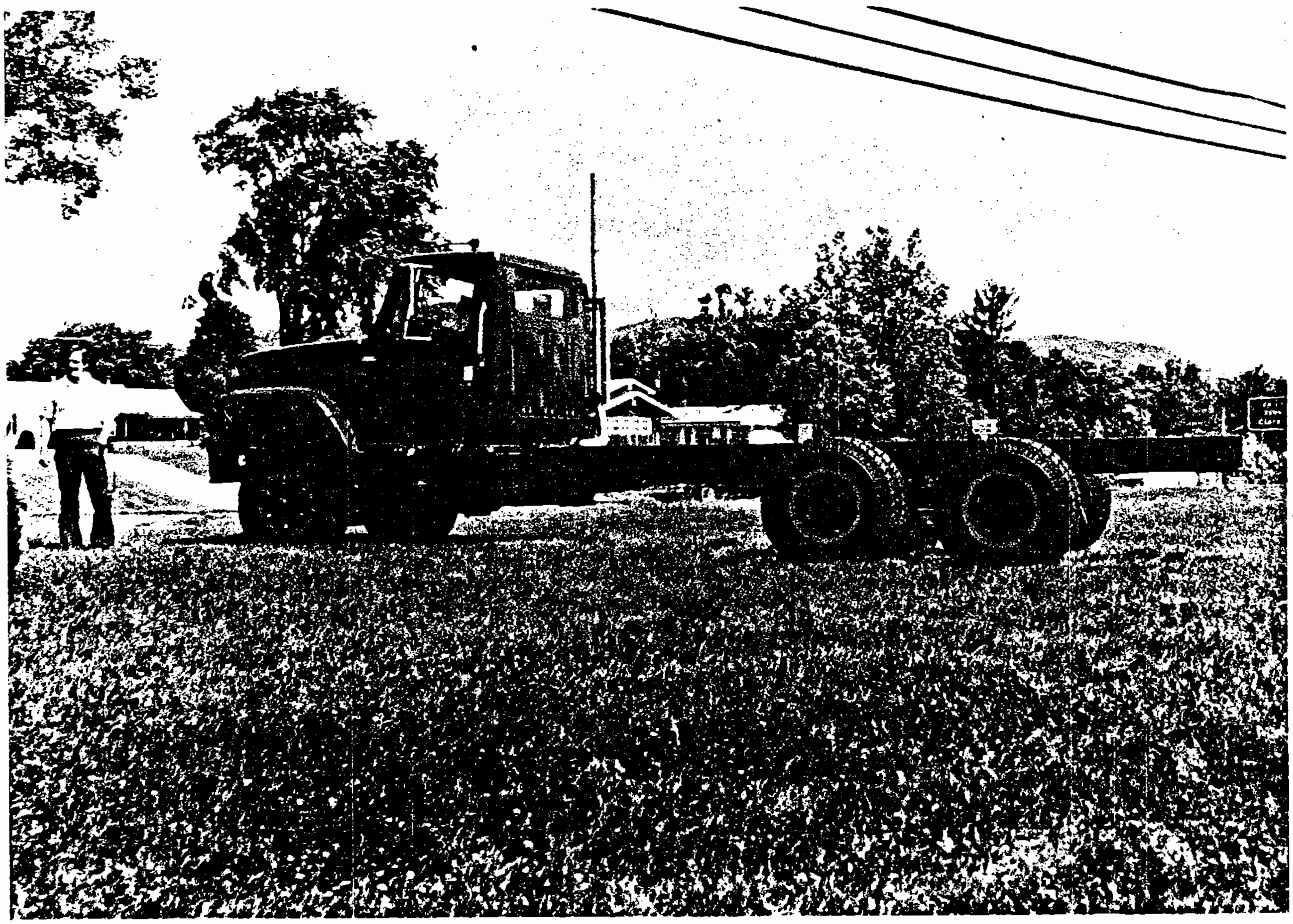


Figure 22. Typical Logging Truck.

ROAD NETWORK DESCRIPTION

Figure 23 shows the proposed transportation/harvest plan for the study area. Approximately 99 miles of new construction are proposed under this plan. Although exact locations will depend on actual ground conditions, this road density closely approximates that which is needed to cable log slopes greater than 35%. The road network accesses all of the U.S.F.S. ownership in the study area except the marginal areas shown in red. These difficult areas could be accessed, but based on their steepness, low site and timber volumes, and recreation value, it was deemed a better resource and capitol allocation to not log them in the near future.

The proposed cable logging areas are clearly marked, and coincide very closely with the steep sideslopes above 35% (Figure 24). The areas not shown as cable or marginal are considered downhill tractor. These tractor areas will have arch road densities of at least double the cable logging truck road density. To improve map clarity, they are not shown in Figure 23. Figures 25 and 26 show the maps used with (R.C.P.). They show major brooks and their drainage areas, clearing and grubbing difficulty and depth to bedrock.

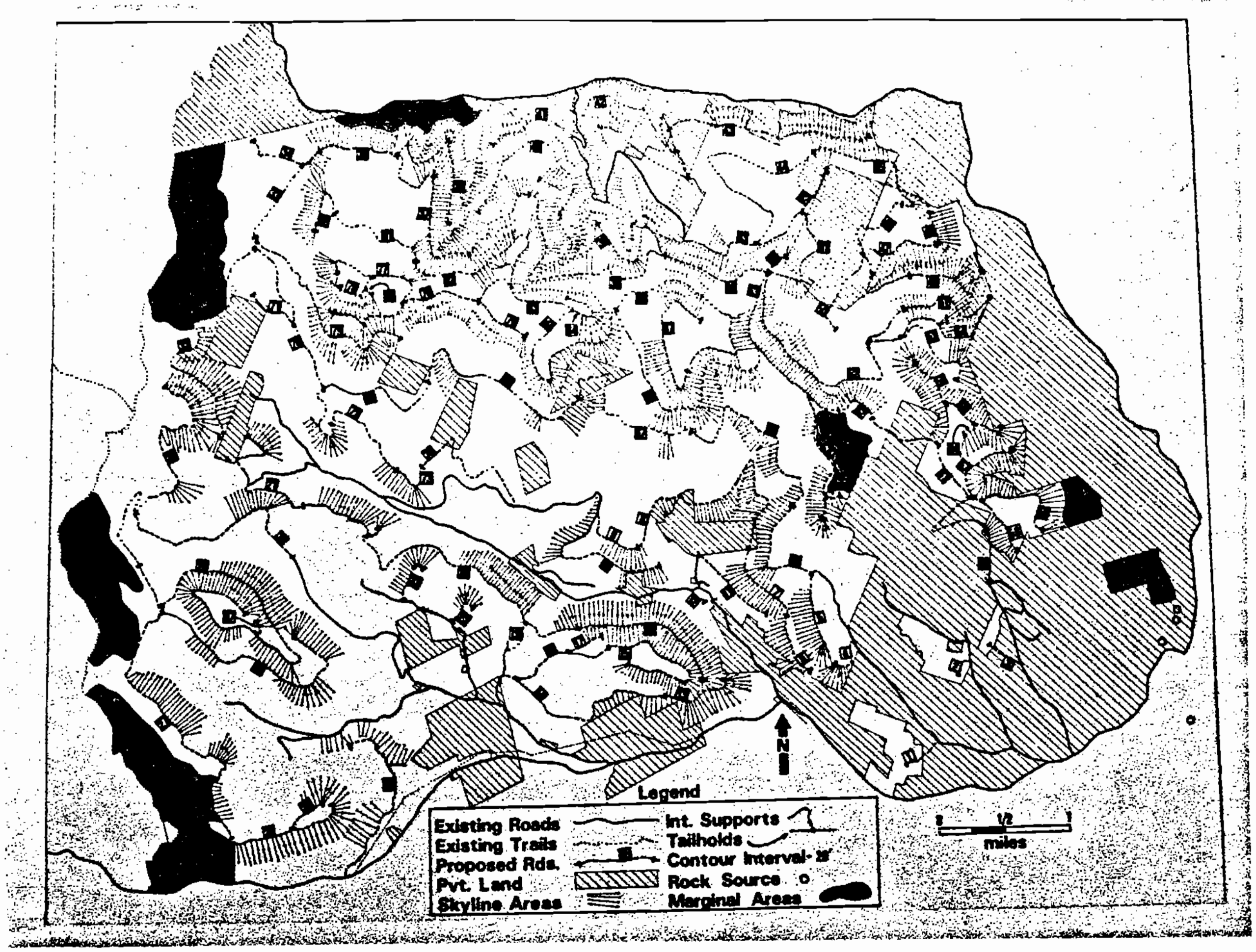


Figure 23. Proposed Study Area Road Network.

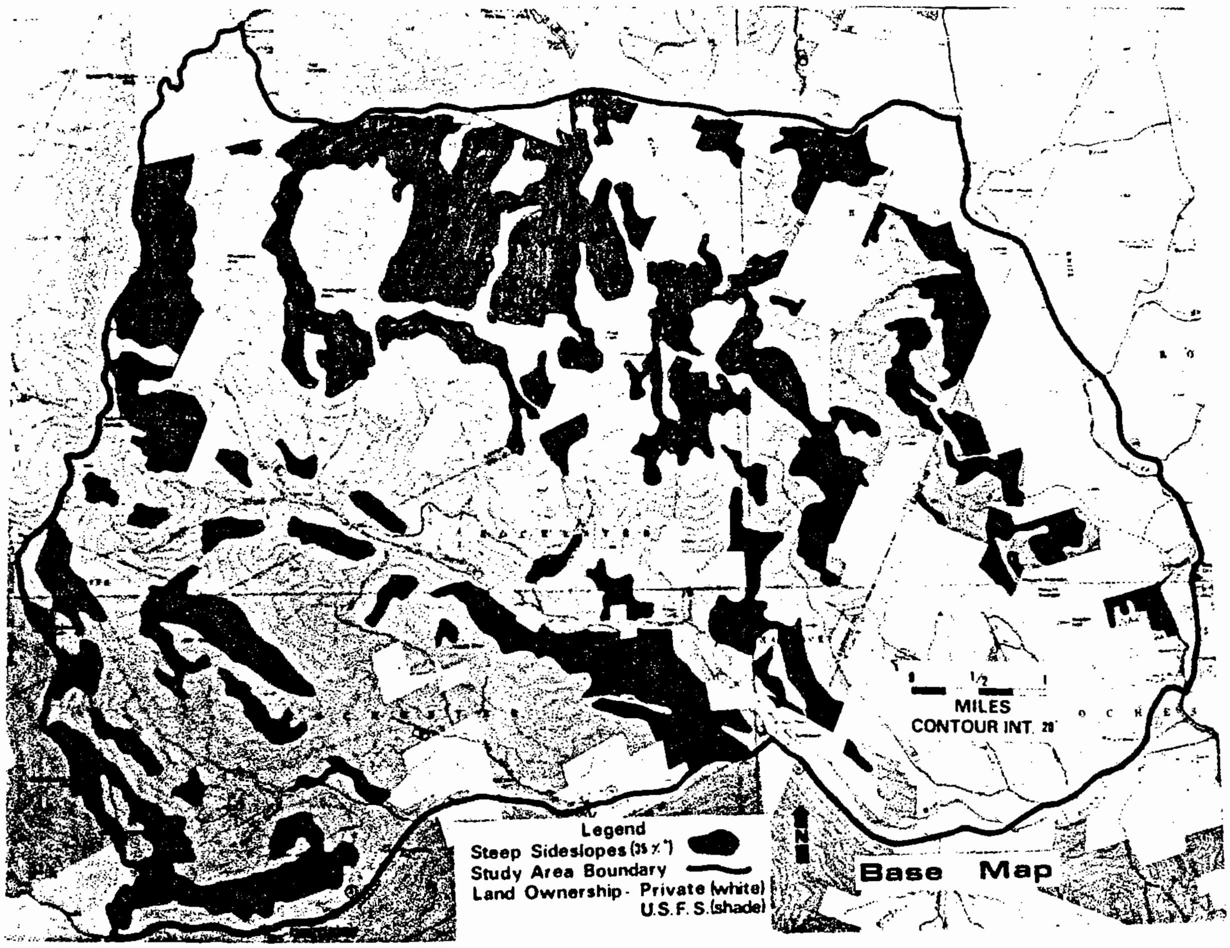


Figure 24. Ownership and Steep Sideslope Map.

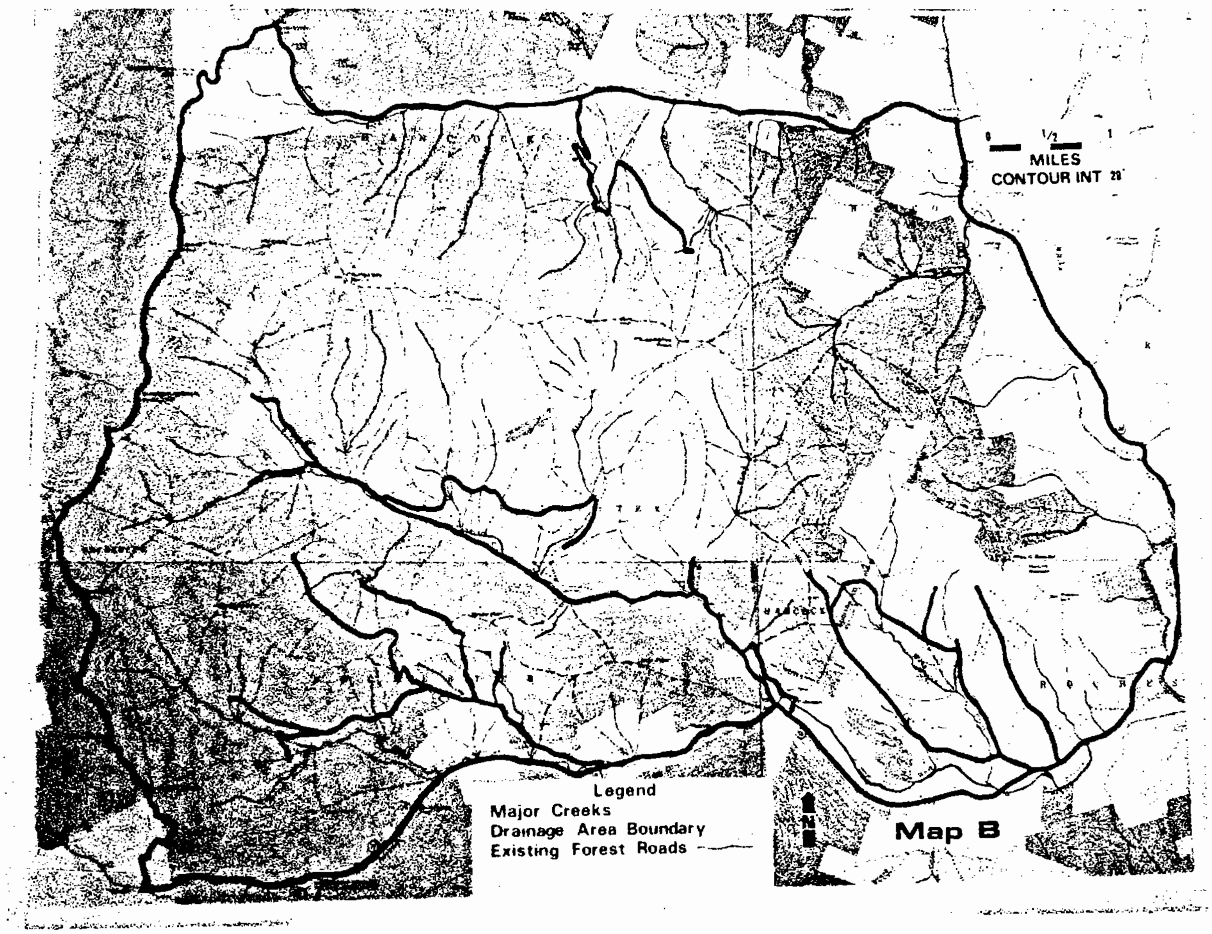


Figure 25. Major Creek and Drainage Area Map.

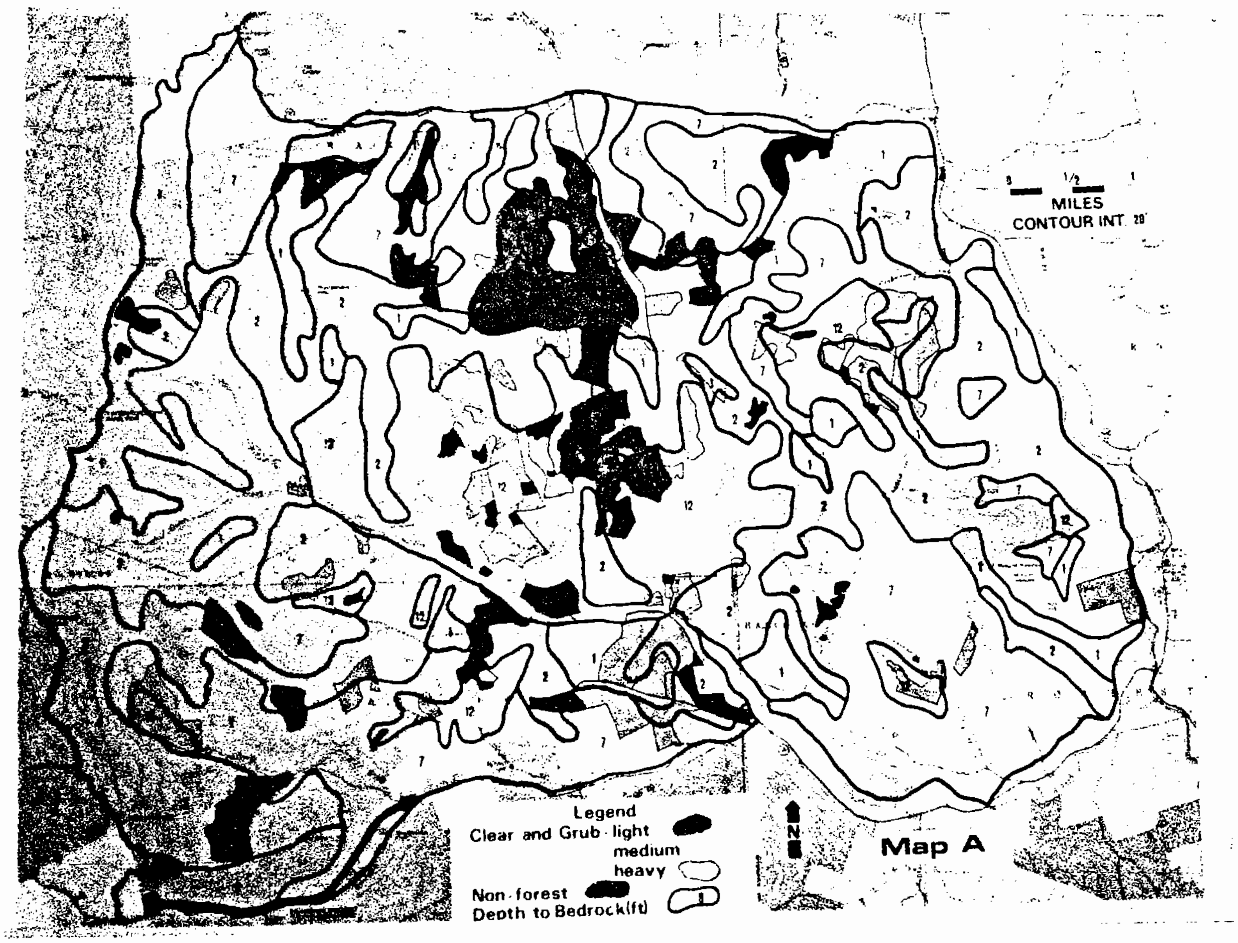


Figure 26. C & G Difficulty and Bedrock Depth Map.

ROAD PARAMETER COST SENSITIVITY

The road network displayed in Figure 23 was run through the Road Cost Program. Figures 25 and 26 show the creek, bedrock depth and clear and grub data which was used. Appendix 6 shows (R.C.P.) output for the 97 segments in the proposed network. A summary of this data is as follows:

12' Running Surface with Ditch

	Seg. #	Fullbench & Endhaul	Fullbench & Sidecast	Balanced
High	18	$243,680/mi.	$222,536/mi.	$102,901/mi.
Low	19	37,016/mi.	33,106/mi.	27,631/mi.
Average	--	114,708/mi.	101,875/mi.	50,906/mi.

14' Running Surface with Ditch

	Seg. #	Fullbench & Endhaul	Fullbench & Sidecast	Balanced
High	18	$298,540/mi.	$272,754/mi.	$123,679/mi.
Low	19	42,531/mi.	37,828/mi.	31,029/mi.
Average	--	140,285/mi.	124,700/mi.	59,573/mi.

NOTE: Both sections used the same data below:

Cutslope Angle - 1:1

Surfacing Depth - 6" (compacted)

0.4 miles to waste area

16.0 miles average haul to rock pit

Appendix 7 varies important road construction parameters and shows how total cost is changed. The following parameters are used.

Surfacing Depth - Varies from 0 to 12 inches

Distance to Waste Area - Varies from 0.2 to 1.0 miles

Distance to Rock Pit - Varies from 4 to 16 miles

Cutslope Angles - Varies from .75:1 to 1.5:1

ROAD STANDARDS FOR CABLE LOGGING

In order for cable logging to become a profitable activity in New England, truck roads will have to be built on the correct location with lower standards than recent new construction (Figure 31). Upgrading of old locations in brook bottoms should be considered only if they access tractor ground, or if they provide the opportunity for gaining elevation with additional road. Well constructed, minimum standard parallel truck roads seem to offer much better cable system access with much less impact on the brooks.

Truck Road Densities

-Sideslopes greater than 45% - These steeper slopes should have road densities of from 4 to 5 miles per section. This is based on uphill cable yarding with road spacing of 800' to 1200' slope distance. The amount of intermediate supports needed will vary with topography. It is estimated that approximately 40% of the uphill cable settings greater than 600 feet will need intermediate supports.

-Sideslopes less than 45% - These slopes present the opportunity to downhill cable log. In these areas, a combination of uphill and downhill cable logging will decrease the road density to 2.5 to 3.5 miles per section. This is based on uphill and downhill yarding to the same truck road.

Landings

Landing spacing and size will depend on the direction of yarding and silvicultural prescription. Clearcut prescriptions will need landings spaced 300' to 400' along the truck roads. This wide spacing is due to the fan-shaped settings possible in clearcuts. Any prescription which leaves residual trees will be logged using a slackpulling carriage with lateral yarding capability. In these areas, landings should be planned 140' to 170' apart.

On sideslopes less than 25%, the landed logs will be stable on the natural sideslope. In these areas, both uphill and downhill landings will require no additional excavation.

All downhill landings on slopes steeper than 25% will need room for the yarder, plus adequate "run out" distance for safety. See Figure 27 for diagram of safe and unsafe downhill landings.

Uphill landings on slopes exceeding 25% will also need an area where the logs can be safely chased. Figure 28 shows how the new Oregon State Safety Law treats minimum landing size.

Road Standards

-Road Width - Minimum of 12' running surface.

-Construction Type - Balanced if possible, single lane.

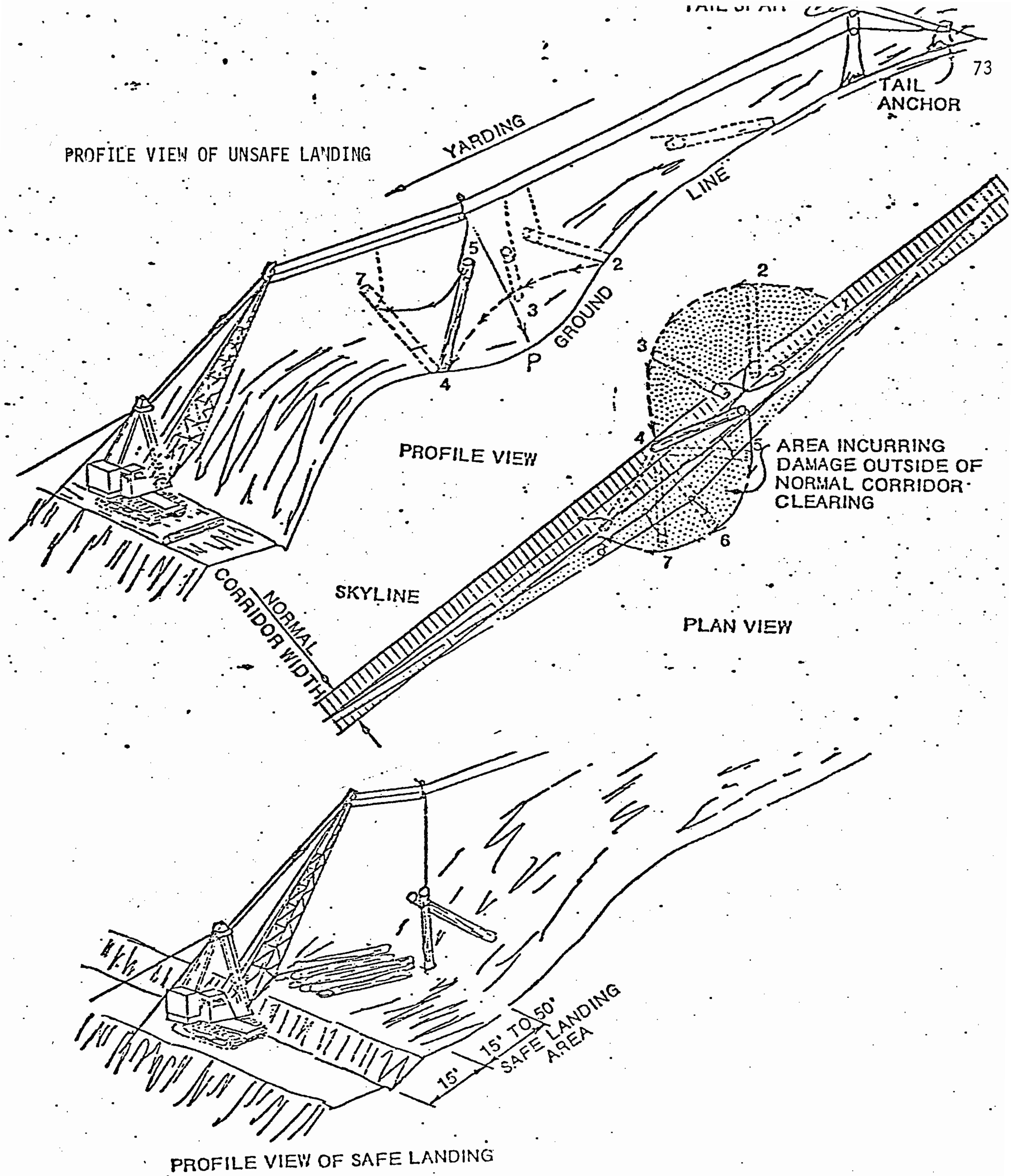


Figure 27. Safe and Unsafe Downhill Landings

YARDING, SWINGING AND LOADING

80-325 LANDING AREAS. (1) Unless otherwise specified, landing areas shall:

(a) Be large enough to heel and swing logs without striking standing timber, rigging, or other equipment or objects;

(b) Be large and level enough to land and deck logs so that they will not slide or roll in the direction of workers or equipment;

(c) Be large enough for safe movement of all machinery;

(d) Be kept chunked out and have an even surface; and

(e) Not have materials pushed, thrown or dumped over the edge in a manner or at a time that will endanger workers.

(Formerly 16-9-1. Amended 12-21-79 by WCD Admin. Order, Safety 11-1979; filed 12-24-79; effective 3-1-80.)

(2) Landing chutes shall be long and level enough so that at least 2/3 of the longest bucked log to be yarded shall rest on the ground.

EXCEPTION: This is not intended to restrict the yarding or loading of logs for poles piling, or an infrequent long break or tree length, provided the log is secured before unhooking the choker.

(Adopted 12-21-79 by WCD Admin. Order, Safety 11-1979; filed 12-24-79; effective 3-1-80.)

(3) During uphill yarding, the landing chute shall be cleared of logs before the next turn of logs is landed.

EXCEPTION: This rule does not apply:

(a) If logs are fully contained in the landing chute, or

(b) If there is no possibility workers working below the landing may be struck by rolling objects coming off the landing.

(Adopted 12-21-79 by WCD Admin. Order, Safety 11-1979; filed 12-24-79; effective 3-1-80.)

(4) Roadside or "continuous" landings shall be large and wide enough to safely operate and maintain the yarding or loading equipment. Outrigger pads, tracks, or wheels shall be on firm, stable ground.

(Adopted 12-21-79 by WCD Admin. Order, Safety 11-1979; filed 12-24-79; effective 3-1-80.)

(5) In logging operations where the yarder is set up in the haul road and logs are landed on the slope below the road, the following shall apply:

(a) If the landing chute slope is 20% or less, logs may be landed and decked in the chute provided the logs can be left in a stable position;

(b) If the landing chute slope exceeds 20%, decking is not permitted in the chute if a chaser is required to unhook the rigging from the logs or if workers are working below the landing chute and are exposed to rolling or sliding logs;

(c) If logs are to be decked below the road, the logs shall be effectively secured from rolling or sliding down the hill; or

Figure 28. Oregon State Safety Rules Concerning Landings.

-Design Speed - This will depend on the amount of timber to be hauled over the road. Roads accessing small volumes should be designed with a slower speed. This reduces costs, increases safety, as well as decreasing the amount of total excavation, since the roads will tend to fit the natural lay of the land better. For most roads, the design speed should not exceed 10 M.P.H.

-Cutslope Angle - This will depend on the soil conditions. Steeper cut angles should be examined in terms of economics to determine if slide removal over time is less than the initial increase in construction costs.

-Ditches - Here again, this depends on the local conditions. It is very important to design for good drainage on truck roads.

-Surfacing - Surfacing is a very important item in truck road construction. Even though it is a very high cost item, it should not be sacrificed to save money. Engineering analysis based on the logging season, volume hauled and native soil types should be done on all roads to arrive at a reasonable surfacing depth. The forest might consider rock pit development within the study area to reduce surfacing costs.

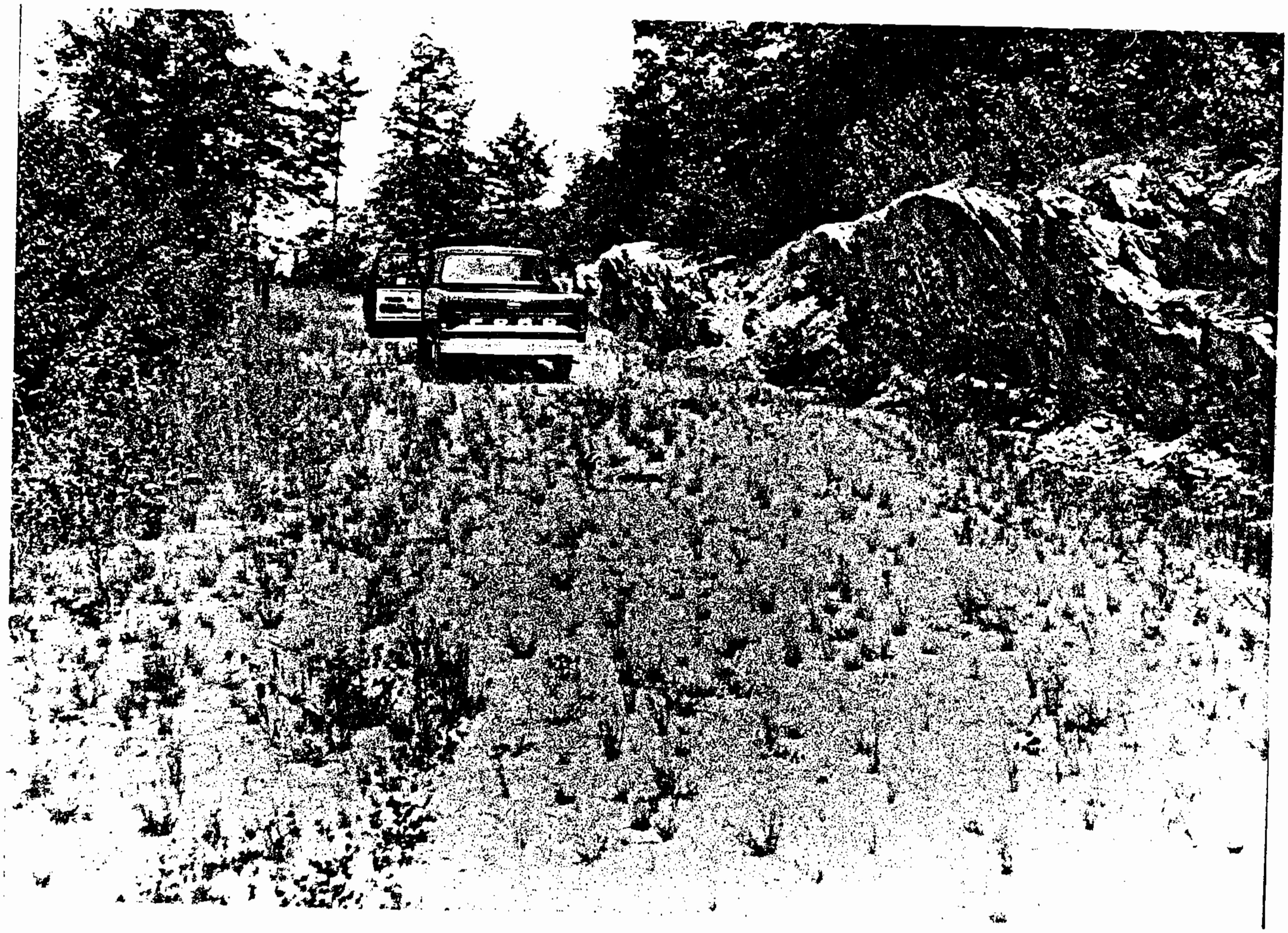


Figure 29. Unfinished Subgrade on Boyden Brook Road.

FUEL CONSUMPTION OF ALTERNATIVE SYSTEMS

CABLE VS. TRACTOR

Todays shortage of petroleum warrants careful consideration of the fuel consumption of alternative logging systems. All activities involving the use of internal combustion engines should be considered. This analysis will consider the estimated total fuel consumption for harvesting two treatment areas in a section of land over a 50-year period. The example treatment areas each encompass 250 acres (Figure 30).

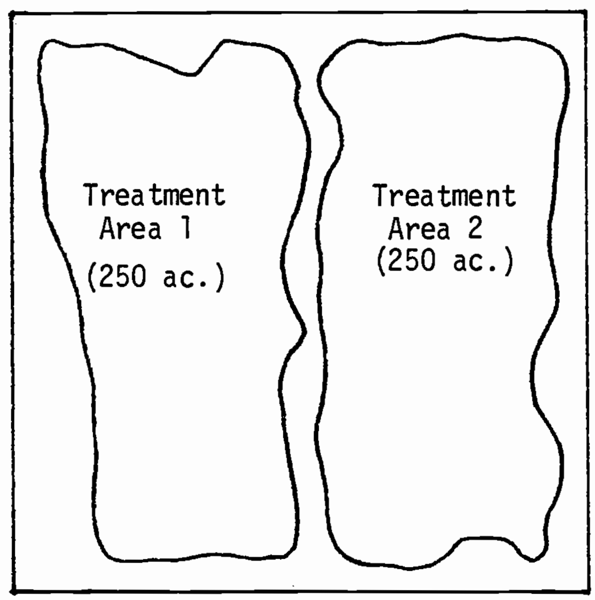


Figure 30. Example Section and Treatment Areas.

Accumulated fuel consumption will be computed for the following logging systems and their associated transportation networks.

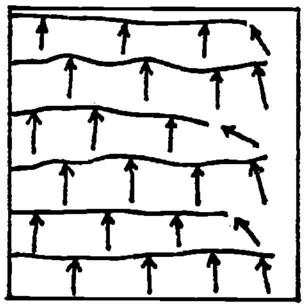
1. Uphill Cable Yarding (900' average external yarding distance)

2. Downhill Cable Yarding (900' average external yarding distance)
3. Combination Uphill/Downhill Cable (900' average external yarding distance)
4. Tractor Downhill (1 mile average external yarding distance)

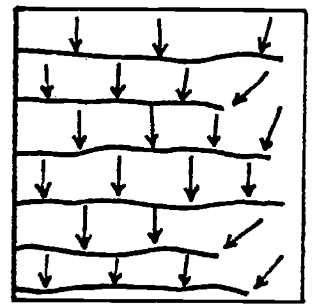
Based on the average external yarding distance of each system, the following truck road densities are assumed for the example section (Figure 31).

1. Uphill Cable Density/Section = 4.8 miles
2. Downhill Cable Density/Section = 4.8 miles
3. Uphill/Downhill Cable Combination/Section = 3.0 miles
4. Tractor Density/Section = 0.8 miles

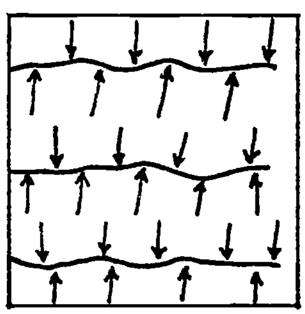
Based on an average arch road spacing of 500 feet, tractor logging arch road density will be 10 miles/section.



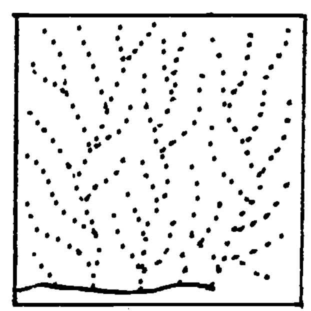
Uphill Cable
(4.8 miles)



Downhill Cable
(4.8 miles)



Uphill/Downhill Cable Combination
(3.0 miles)



Tractor
(0.8 miles) & (10 miles
arch roads)

Truck Road ———

Arch Road ··········

Cable Yarding Direction ↑↑

Figure 31. Road Densities.

Production, fuel consumption and equipment types used for both yarding and road construction are shown on the following pages.

ROAD CONSTRUCTION:

EQUIPMENT	USE	PRODUCTION	REMARKS	FUEL CONSUMPTION Load Factor	Gallons Per Hr.	M.P.G.
Tractor (Cat. D6D)	Clear & Grub	28.8 hrs./acre		Med.	5.2	----
Tractor (Cat. D6D)	Excavation	44 c.y./hr.	200' Ave. Haul	Med.	5.2	----
Skidder (Cat. 518)	Clear & Grub	20.2 hrs./acre		Med.	2.2	----
Grader (Cat. 130G)	Shape Subgrade	20% of Dozer		Med.	4.8	----
Grader (Cat. 130G)	Maintenance	3 M.P.H.	3 Passes	Med.	4.8	----
Dump Truck	Haul Surfacing	14 c.y./trip		Med. to High	---	3-6
Lowboy	Move Construction Equip.	4 trips/job		Med. to High	---	3-6
Loader (Cat. 950)	Load Surfacing	.15 hrs./load		Med. to High	---	3-6

NOTE: Production based on R-9 Road Cost Guide.

YARDING:

EQUIPMENT	USE	PRODUCTION	REMARKS	FUEL CONSUMPTION Load Factor	Gallons Per Hr.	M.P.G.
Tractor (Cat. D3B)	Dowhill Skidding	12 M.B.F./day	Shelterwood	Med.	2.4	----
Skidder (Cat. 518)				Med.	2.2	----
Tractor (Cat. D3B)	Downhill Skidding	10 M.B.F./day	Overstory Removal	Med.	2.4	----
Skidder (Cat. 518)				Med.	2.2	----
Tractor (Cat. D3B)	Downhill Skidding	6 M.B.F./day	Thinning	Med.	2.4	----
Skidder (Cat. 518)				Med.	2.2	----
Ecologger II	Uphill Yarding	20 M.B.F./day	Shelterwood	Med.	2.6	----
Ecologger II	Uphill Yarding	16 M.B.F./day	Overstory Removal	Med.	2.6	----
Ecologger II	Downhill Yarding	17 M.B.F./day	Shelterwood	Low	2.3	----
Ecologger II	Downhill Yarding	13 M.B.F./day	Overstory Removal	Low	2.3	----
Smith Timbermaster	Uphill Yarding	6 M.B.F./day	Thinning	Med.	0.8	----
Smith Timbermaster	Downhill Yarding	5 M.B.F./day	Thinning	Low	0.6	----

See Page 83 for NOTES:

NOTES:

1) Yarding production rates are based on experienced data from the Green Mountain National Forest and the results of Stirler (15), 1980.
2) This analysis does not endorse any particular manufacturer. Equivalent machines may be substituted.
3) Cable yarding production reflects some use of intermediate supports.
4) Fuel consumption rates are based on experienced data and the Caterpillar Performance Handbook, Edition 10(3).

Truck and arch road construction are assumed to be built according to the following specifications:

Truck Roads

Construction Type - Balanced

Running Width - 12 feet

Ditch? - Yes

Compacted Surfacing Depth - 6 inches

Cutslope Angle - 1:1

Rock Haul Distance - 16 miles

Grade - 4%

Arch Roads

Width - 10 feet

Maximum Grade - 25%

For comparative purposes, the example section is treated as a homogeneous unit. The following ground, stand and cut conditions apply to the entire section.

<u>Ground Conditions</u>

Average Sideslope - 40%

Bedrock Depth - 4 feet

Clear & Grub Difficulty - Medium

<u>Stand Conditions</u>

Mixed Hardwood @ 9-12 M.B.F./acre

<u>Cutting Conditions</u>

Shelterwood - Remove 6 M.B.F./acre

Overstory Removal - Remove 3 M.B.F./acre

Thinning - Remove 1.5 M.B.F./acre

The Road Cost Program was used to arrive at quantities per mile for truck roads. These quantities were then analyzed using the production and fuel consumption rates. The results are as follows:

Total Excavation - 8165 c.y.

Clearing & Grubbing Area - 5.19 acres

Total Surfacing - 1717 c.y.

Truck Road Construction/Mile

Activity	Equipment	Total Gallons Consumed
Clear & Grub	Tractor	777
	Skidder	231
Excavation	Tractor	967
	Grader	178
Surfacing	Dump Truck	1161
	Loader	113
Survey	Pick-up	19

TOTAL: 3446 gallons/mile

Arch Road Construction/Mile

Activity	Equipment	Total Gallons Consumed
Log R.O.W.	Skidder	11
Build Arch Road	Tractor	26

TOTAL: 37 gallons/mile

Logging Fuel Consumption

Activity	Equipment	Volume Removed M.B.F.	Total Gallons Consumed
Uphill Cable - Shelterwood	Ecologger II	1,500	1,560
Uphill Cable - O.S.R.	Ecologger II	800	1,040
Uphill Cable - Thinning	Smith Timbermaster	375	400
Downhill Cable - Shelterwood	Ecologger II	1,500	1,623
Downhill Cable - O.S.R.	Ecologger II	800	1,132
Downhill Cable - Thinning	Smith Timbermaster	375	360
Downhill Tractor - Shelterwood	Tractor/Skidder	1,500	4,600
Downhill Tractor - O.S.R.	Tractor/Skidder	800	2,944
Downhill Tractor - Thinning	Tractor/Skidder	375	2,300

Miscellaneous Activity Fuel Consumption

Activity	Equipment	Total Gallons Consumed
Move in/out Tractor Logging Equip.	Lowboys	15
Move in/out Cable Logging Equip.	Lowboys	8
Move in/out Const. Equip.	Lowboys	31
Waterbar Tractor Arch Roads	Tractor	20
Open Tractor Arch Roads & Landings	Tractor	25
Build Tractor Landings	Tractor	10
Maintenance/yr./mile	Grader	4.8
Build Uphill Cable Landings	Tractor	60
Build Downhill Cable Landings	Tractor	120
Open Uphill Cable Landings	Tractor	30
Open Downhill Cable Landings	Tractor	40

Reshape & Finish Truck rd./mi.	Grader	10
Move in/out Landing Tractor	Lowboy	8

The following timber harvest schedule is assumed for this analysis:

Year 0 - Treatment Area #1 - S.H. - 1,500 M.B.F.

Year 5 - Treatment Area #1 - O.S.R. - 800 M.B.F.

Year 20 - Treatment Area #2 - S.H. - 1,500 M.B.F.

Year 25 - Treatment Area #2 - O.S.R. - 800 M.B.F.

Year 30 - Treatment Area #1 - Thin - 375 M.B.F.

Year 50 - Treatment Area #2 - Thin - 375 M.B.F.

This analysis assumes each logging system accomplishes the same silvicultural activities at the years specified above. The road construction schedule is as follows:

	TRACTOR			
	Arch Roads	Truck Roads	Uphill/Downhill Comb. Truck Rds.	Uphill & Downhill Truck Rds.
Year 0	5 mi.	0.8 mi.	1.5 mi.	2.4 mi.
Year 5	----	----	--------	--------
Year 20	5 mi.	----	1.5 mi.	2.4 mi.
Year 25	----	----	--------	--------
Year 30	----	----	--------	--------
Year 50	----	----	--------	--------

Maintenance is assumed on a yearly basis for all truck roads which exist. Reshape and finish is assumed on all existing truck roads, when they reach an age of 25 years.

The results of this study show that initially, cable logging has a higher fuel consumption due to the extra amount of road construction. However, since actual yarding with cable is more fuel efficient, over the long run cable logging actually consumes less fuel. The total fuel consumption at the end of the 50 year harvest period by logging system is as follows:

Uphill Cable - 23,916 gallons (Figure 34)

Downhill Cable - 24,306 gallons (Figure 35)

Uphill/Downhill Combination Cable - 18,027 gallons (Figure 33)

Tractor - 23,402 gallons (Figure 32)

It appears that with this harvest schedule, cable logging surpasses tractor logging after the following years:

Uphill Cable - about 50 years

Downhill Cable - about 60 years

Uphill/Downhill Combination Cable - about 25 years

At first glance, the uphill/downhill combination is the best alternative. This is only feasible on slopes flatter than about 40%, due to the landing size needed for safe downhill yarding. On slopes over 40%, either tractor or uphill cable should be used. Also, on slopes greater than 40%, full suspension should be used on all downhill cable shows. This is because partial suspension, downhill logging results in erratic swinging and hopping of the log. This type of log behavior results in excessive soil displacement, as well as a safety hazard to the rigging crew. Based solely on fuel consumption, the following logging systems should be used.

Slopes greater than 40% - Uphill Cable

Slopes less than 40% - Uphill/Downhill Cable Combination

Of course, the final determination should include other considerations, such as: visual management, recreation, soil and water impact, etc.

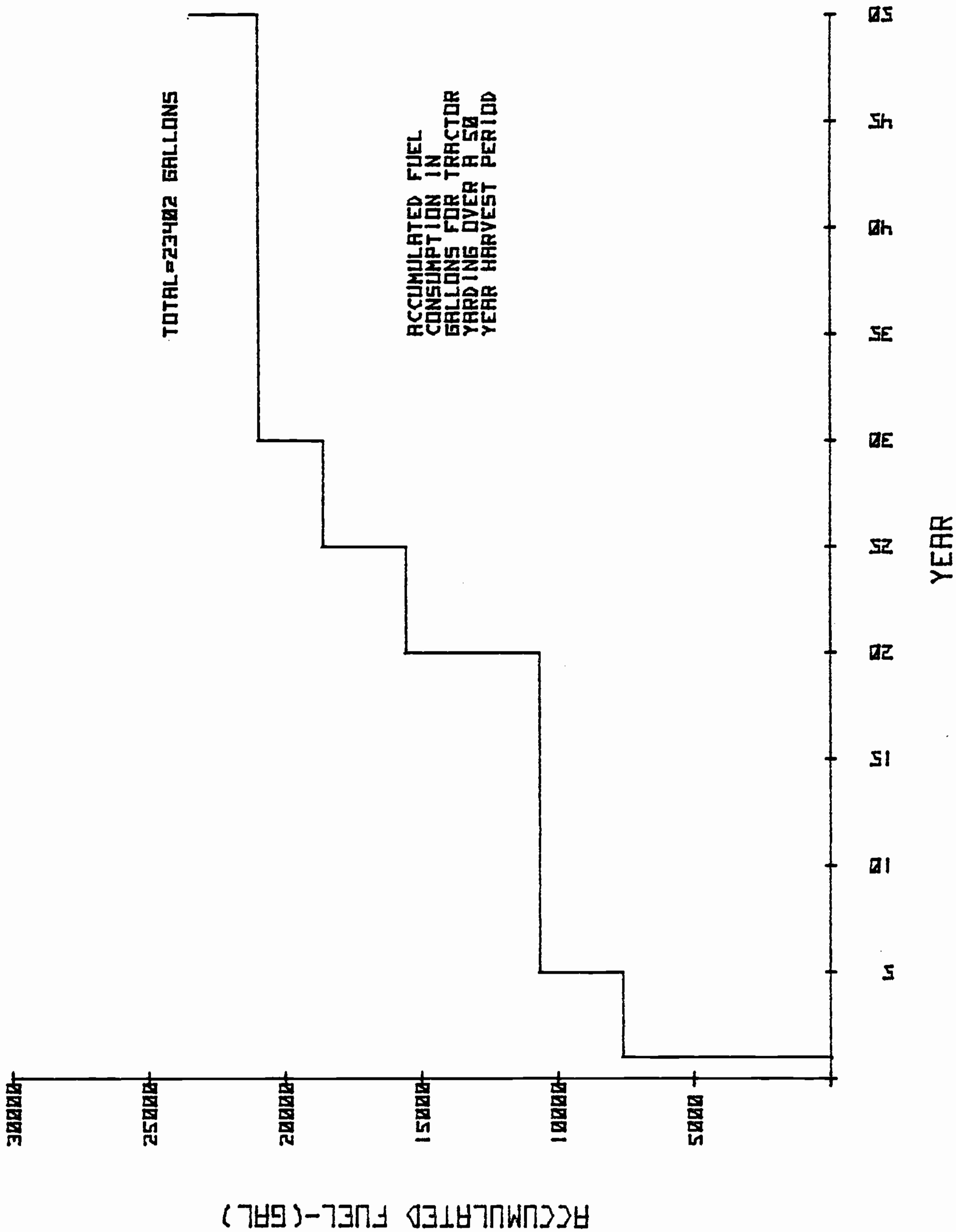


Figure 32. Accumulated Fuel Consumption-Tractor

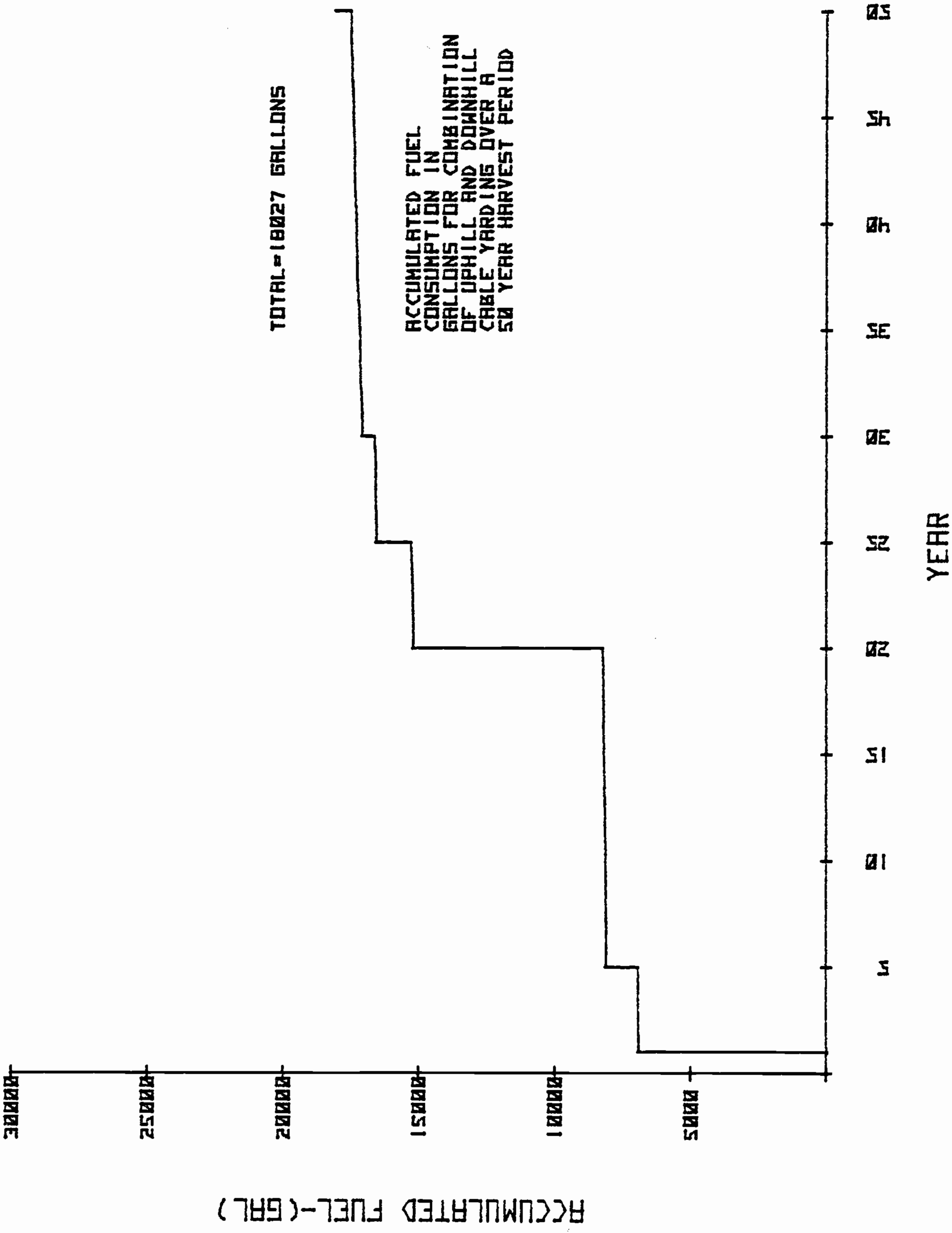


Figure 33. Accumulated Fuel Consumption-Uphill/Downhill

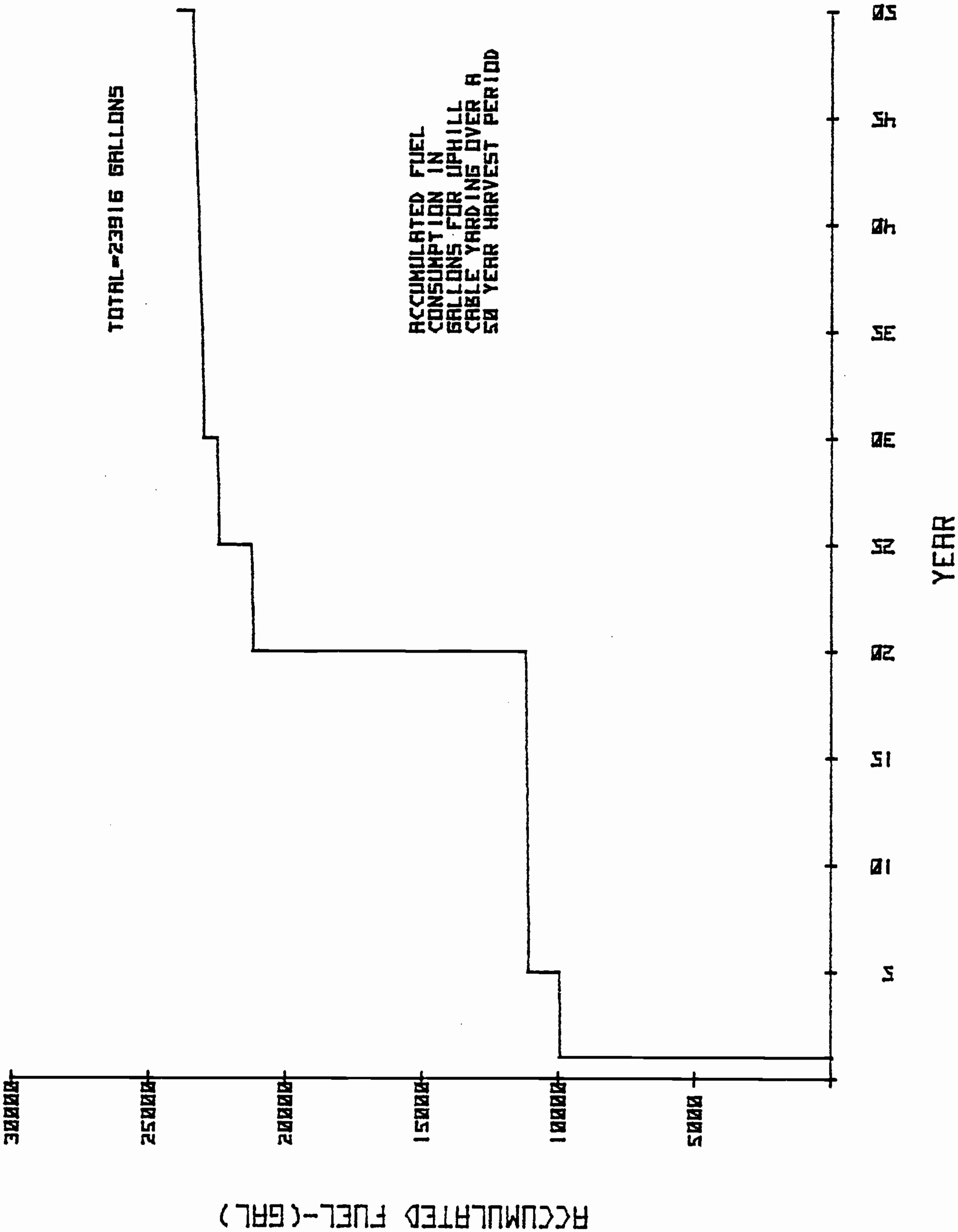


Figure 34. Accumulated Fuel Consumption-Uphill Cable

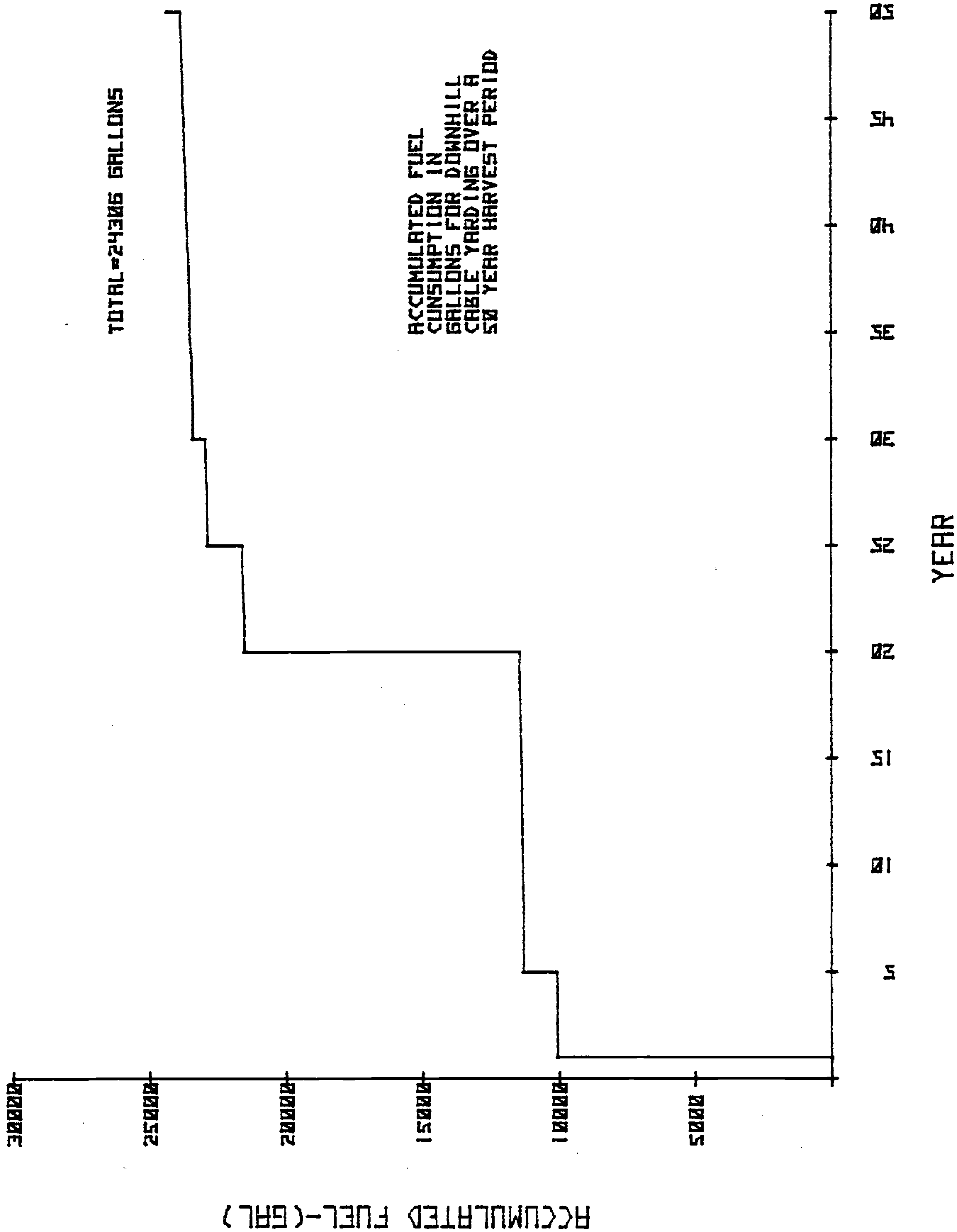


Figure 35. Accumulated Fuel Consumption-Downhill Cable

CONCLUSIONS

Cable logging appears to be a viable tool for accessing timber on steep slopes in New England. To make this type of logging a reality, significant changes in both attitude and engineering practices are necessary. First, the land manager, as well as the public, will have to accept the change in visual character of the landscape which is associated with cable logging transportation systems. Truck road systems with densities of 4 to 5 miles per section will dominate the landscape much more than tractor arch roads.

Second, the high costs associated with cable logging place much more emphasis on intensive engineering planning. Road cost minimization is a must, if economically viable cable sales are to be offered. Design speed and road standards should be carefully calculated and justified on a case by case basis, based on the estimated volume to be removed. Continued overdesign of higher standard roads than necessary will only result in deficit cable sale offerings. Break-even analysis coupled with (R.C.P.) could be used to arrive at an optimum road stand in terms of both resource protection and cost effectiveness.

SUGGESTIONS FOR FURTHER RESEARCH

There appears to be good opportunities for further research regarding both the Road Cost Program, as well as the impacts and costs of the cable logging transportation systems needed to harvest hardwood in New England.

The Road Cost Program should be rewritten to take advantage of increased memory of the H.P. 9845. (R.C.P.) on the 9845 would be much easier to digitize, and would be faster. With the increase in memory, several additions could be implemented. By adding the capability to enter tributary timber volumes by segment, coupled with a harvest schedule, break-even analysis could be run.

Due to the lack of data on parallel midslope road construction on the Green Mountain National Forest, potential resource impacts are currently based on professional speculation. The monitoring of actual construction projects for the first few cable sales should be considered. The resulting data would provide the land manager with more concrete information with which to base future long-term decisions. These trial projects would also be useful to arrive at the accuracy of the cost estimate of (R.C.P.).

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APPENDIX 1

AREA OF ALL RCFL BY TYPE AND PRODUCTIVITY CLASS
GREEN MOUNTAIN NATIONAL FOREST

Forest Type	Type Acres	PRODUCTIVITY CLASS (acres) 7 (20)*	6 (20-49)*	5 (50-84)*	4 (85-119)*	3 (120-164)*	2 (165-224)*	1 (125+)*
Beech-Birch-Maple	187,314	11,374	151,615		24,325			
Paper Birch	2,161	1,363	798					
Oak Hickory	236			236				
Spruce	13,961		405	4,057	5,475	4,024		
Spruce-Fir	4,038		134	2,095	1,190	619		
Other Softwoods	1,045		340	520		185		
Totals	208,755	12,737	153,292	6,908	30,990	4,828		
Percent	100.0%	6.1%	73.4%	3.3%	14.9%	2.3%		

Class	Site Potential in Productivity Classes
1	225 or more cubic feet per acre per year
2	165 to 225 " " " " " "
3	120 to 165 " " " " " "
4	85 to 120 " " " " " "
5	50 to 85 " " " " " "
6	20 to 50 " " " " " "
7	Less than 20 " " " " " "

*Potential yield in cubic feet per acre per year.

Date: As of 6/30/75

FOREST TYPES BY STAND CONDITION ON ALL
REGULATED COMMERCIAL FOREST LAND
GREEN MOUNTAIN NATIONAL FOREST

Forest Type	Total Type Acres	STAND CONDITION: Non-Stocked	High Risk	Sparse	Low Quality	Mature	Immature	All Aged	Two Aged	In Process of Regeneration
Beech-Birch-Maple	187,314	--	222	26,439	37,675	11,630	93,453	207	--	17,688
Paper Birch	2,161	--	--	--	--	576	1,490	--	--	95
Oak Hickory	236	--	--	--	--	--	236	--	--	--
Spruce	13,961	--	4,130	1,506	1,105	1,295	5,632	--	--	293
Spruce-Fir	4,038	--	318	--	--	--	3,720	--	--	--
Other Softwoods	1,045	--	--	--	--	--	1,045	--	--	--
Total	208,755	--	4,670	27,945	38,780	13,501	105,576	207	--	18,076
Percent	100.0%	--	2.2%	13.4%	18.6%	6.4%	50.6%	.1%	--	8.7%

Date as of 6/30/75.

AREA OF FOREST TYPES BY SIZE CLASSES AND STOCKING
ON ALL REGULATED COMMERCIAL FOREST LAND
GREEN MOUNTAIN NATIONAL FOREST

Forest Type	Total Type Acres	Size Class: Seedlings & Saplings			Poletimber			Sawtimber		
		Poor	Medium	Well	Poor	Medium	Well	Poor	Medium	Well
Beech-Birch-Maple	187,314	3,893	10,481	9,199	2,182	8,825	39,282	21,847	42,386	49,219
Paper Birch	2,161	--	341	--	--	787	938	95	--	--
Oak Hickory	236	--	--	--	--	236	--	--	--	--
Spruce	13,961	293	392	1,565	119	657	1,895	2,702	4,554	1,784
Spruce-Fir	4,038	--	187	187	--	2,692	719	--	--	253
Other Softwoods	1,045	--	--	--	--	424	96	--	--	525
Total Stocked	208,755	4,186	11,401	10,951	2,301	13,621	42,930	24,644	46,940	51,781

Lowland Brush	0
Upland Brush	0
Open	0

Total Regulated Commercial Forest Land: 208,758 acres as of 6/30/75.

APPENDIX 2

SOIL TYPE DESCRIPTIONS

1. General Description of Soils on the Forest

   a. Origin - Wisconsin Period glacial deposits. Approximately 10,000 to 12,000 years since deglaciation. The upper parts of the mountains, most ridges, and most first order watersheds, in general, were dominated by subglacial processes - subglacial scouring or deposition. Nearly impermeable basal (lodgment) tills are the common result of subglacial deposition. There are a few spots of aeolian deposits and a small amount of relic cryoplanation (frost churning).

      In the bottom of second, third, or fourth order watersheds, and on some of the gentler terrain on the Forest, superglacial deposition (ablation till), outwash, and fluvial deposits occasionally occur.

   b. Textural Classification - According to an extensive engineering survey completed a number of years ago, soil substrata textures are predominantly SM or ML (unified System), A-2 or A-4 groups, particularly A-2-4 (AASHO) for unsorted glacial tills, especially in your study area. It is almost impossible to give typical textures for materials which have been sorted. They can fall anywhere between GW and SP (Unified) and A-1, A-3, or possibly even A-4 (AASHO) depending upon the amount of sorting. Clay contents seldom exceed 15% and typically are less than 10% by volume.

c. Strength - Our engineers normally test for P.I., but not for shear resistance or cohesion in pounds per square foot. However, I was able to obtain some typical values for soil classified as SM in the Unified System. These values are for remolded samples. I do not have any values for in-place materials. Cohesion - 1,050 pounds per square foot moist, 420 pounds per square foot saturated. Phi angle 34°.

d. Density for Surface Soils (Upper 6" to 8") 60 to 80 pounds per cubic foot (1.0 to 1.3 grams per cubic centimeter). Uncompacted subsoils and substrata - 90 to 110 pounds per cubic foot (1.4 to 1.7 grams per cubic centimeter). Basal till substrata if present - 120 to 135 pounds per cubic foot (1.9 to 2.2 grams per cubic centimeter).

2. Engineering Characteristics

a. Areas or Conditions Where No Roads Should Be Built - There are few soil related situations where roads should absolutely not be built. It is as important to recognize what is needed to avoid adversely altering the land over the long term; for example, allow for imperceptible drainage through an area where a road could become a dam or increase frequency of run-off structures at higher elevations, 2500'+, due to higher storm intensities, etc. There are two situations where we should, if at all possible, avoid building roads:

(1) Streambanks adjacent to deeply incised streams, especially if substratum is a basal till. Excavations here often

lead to mass failures in the form of rotational slips, or more commonly, small debris slides.

(2) Sideslopes in excess of 45% unless fully benched into bedrock. Road excavations on these steeper slopes result in long thin fills or high cuts which are hard to stabilize.

b. Range of Stable Cut Bank Angles -

1:1	If longitudinal height of cut is less than 3 feet.
1.5:1	If longitudinal height of cut is greater than 3 feet, but less than or equal to 8 feet.
2:1	If longitudinal height of cut is greater than 8 feet. Vertical if in bedrock.

3. Special Problem Areas in Study Area

ELT's 202d, 220d, and other ELT's with a "b" suffix will require quite a bit of rock excavation for truck roads. Soils are normally less than 3 feet deep to hard bedrock, but there are often few or nearly imperceptible outcrops, especially on 203b and 205b where the surface shape is often smooth and linear (vertical by horizontal). There is at least one 221d on an upper tributary of Boyden Brook. This is a steep slope above a stream where we should not build roads.

SPECIFIC SOIL TYPE DESCRIPTIONS IN STUDY AREA

ELT 202b - Soils are fine sandy loams, well drained, consistently 1-1/2 feet to bedrock. This ELT is slightly convex to linear with a choppy or slightly hummocky surface appearance with numerous outcrops. Slope gradients are relatively steep, typically about 40%, but ranging from 30% to 50%. Coarse fragments (stones) approximately 2 feet in diameter comprise about 25% of the soil volume. With some exceptions, this ELT occurs around the median point of 2200 feet elevation. Present stands in this ELT may vary in condition, but as a result of preliminary analysis of current ELT field data, the following ecological tendencies predominate:

ELT 202d - Soils are highly organic, fine sandy loams, approximately 1 foot deep over bedrock. Slope gradients are typically steep (50% or greater), typically centered around 2700 feet elevation on slightly convex to linear ridges with choppy appearance. Stones comprise a large portion (65% of the soil volume). Ecological tendencies:

ELT 203b and 205b - The descriptions for these two ELT's have been combined since they are similar in nature. Soils in these ELT's are well drained, fine sandy loams with a discontinuous basal till between a 1.5 and 2.0 foot depth between gentle or inconspicuous outcrops or shallow spots. Depth to bedrock is uniformly about 3 feet or less. The occurrence of surface fragments is very irregular ranging from nearly 0% coverage to over 50%. The elevation range within which this ELT occurs is very broad, but centers around 2000 to 2100 feet. Surface shapes are slightly convex to linear, often undulating or hummocky on mid-sideslopes. Seepage between hummocks and at bases of slopes is common. Ecological Tendencies:

ELT 014b - Soils are fine sandy loam textured, well drained, and average three feet to bedrock. Slopes are severe, averaging 50% with 3 foot deep entrenched intermittent streams approximately 400 feet apart. The topography is linear and smooth outcrops are widely scattered. Elevation ranges from 2100 to 4000 feet with the bulk of the unit above 3000 feet. Gravel, cobbles, and stones comprise approximately 25% of the soil volume, with surface stones averaging 2 feet in length and widely scattered. The dominant feature is the presence of numerous old landslides in this unit.

ELT 013b - Soils are fine sandy loam textured, well drained, averaging two foot depth to bedrock. A very discontinuous basal till (compacted) layer occurs at 1.5 foot depth. This is a high elevation ELT, range is 2100 to 3600 feet. Slopes are steep, averaging 45%, and topography is slightly convex and smooth. Some subglacial scouring has occurred in the unit as evidenced by the scattered rounded outcrops and surface stones averaging two feet in length. Very shallow, intermittent streams are present. Seepage over bedrock at base of outcrops can occur. Gravel, stones and cobbles comprise an average of 30% of the subsoil volume.

ELT 014d - Fine sandy loam textured soils, averaging two feet to bedrock at highest elevations 3000 to 4000 feet.

ELT 203d - Soils are well drained or moderately well drained (seasonal wetness), fine sandy loams with a firm basal till at about a 25" depth. Surface seeps are scattered and primarily seasonal. Depth to bedrock is 5 feet or more. Slope gradients vary slightly, around 20%. This ELT occurs on long linear or gently convex, smooth, lower sideslopes (approximately 1700 feet). Ecological Tendencies:

ELT 205d - Soils are well drained to moderately well drained in swales with depth to bedrock greater than 10 feet. Depending upon the season, the water table varies between 3 and 10 feet from the surface. Small streams normally develop channels entrenched 4 to 5 feet below the surrounding ground surface. The terrain is overall convex, but variably smooth or abruptly hummocky near valley bottoms or margins at low elevations (1700 feet). Ecological Tendencies:

ELT 203a - Soils are somewhat poorly drained, fine sandy loams with a firm basal till at approximately a 20 inch depth from the surface. Surface seeps are frequent, normally occurring every 50 feet or less. This ELT occurs on lower elevation (1500 feet), smooth, broad, concave, swales with slope gradients typically $\leq$ 10%.

ELT 210d - Soil substrata are sands and gravels excessively drained (droughty), usually greater than 20 feet deep to bedrock. Water table is usually more than 10 feet from the surface. Deeply entrenched stream channels are typical. This ELT occurs at low elevations (1000 feet) along valley bottoms and margins, with gentle convex knolls and ridges. Ecological Tendencies: Insufficient data.

APPENDIX 3

COMPARTMENT #72

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	54	45	6		
2	150	65	13		
3	84	57	6		
4	410	95	13		
5	316	70	12		
6	70	36	3		L
7	160	72	13	(TIZ) Steep	

COMPARTMENT #77

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	28	100	9	Rock Outcrops	
2	22	60	12		
3	21	100	10	Rock Outcrops	
4	9	90	13		
5	6	70	11		
6	6	50	12		
7	9	70	11		

COMPARTMENT #78

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	170	80	15		
2	46	98	12		
3	28	90	6		
4	80	87	12		
5	203	77	13		
6	8	0	0	Grazing	N.C.

COMPARTMENT #79

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	27	100	14		
2	51	70	10	(Piper Bk. Sale)	
3	207	100	17	(Piper Bk. Sale)	H
4	56	90	12	Unit #7	
5	40	85	9	Unit #6	
6	75	100	12		
7	80	77	16		
8	33	30	1	Unit #8	L
9	15	0	0		N.C.
10	51	100	14		
11	17	100	14		
12	5	50	8		
13	56	30	2	Units #2&3	L
14	40	30	2	Unit #1	L
15	10	30	16	Unit #5	L
16	44	30	2	Unit #4	L

COMPARTMENT #80

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	105	70	9		
2	91	40	1		L
3	16	80	12		
4	38	130	5		H
5	170	40	0		L
6	51	150	5		H
7	9	70	10		

COMPARTMENT #80 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
8	27	150	5		H
9	33	150	5		H
10	366	40	0		L
11	61	60	6		

COMPARTMENT #81

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	31	92	10		
2	72	74	10	Rock Outcrops	
3	66	68	12		
4	21	70	11		
5	48	63	12	Shallow to Bed.	
6	26	0	3	Steep & Rocky	N.C.
7	38	26	3		L
8	115	78	12		
9	43	72	14		
10	48	72	9		
11	21	62	11		
12	64	92	9		
13	11	70	12		
14	106	52	13		
15	40	38	4		L
16	26	30	2		L
17	104	57	7		
18	3	212	10		H
19	30	72	14		
20	15	70	12		

COMPARTMENT #82

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	1	215	10	(TIZ)	H
2	23	70	14	(TIZ)	
3	37	78	12		
4	23	37	7	Steep	
5	38	80	8	Steep-Shallow Soil	H
6	34	62	8		
7	31	65	12		
8	53	62	12		
9	123	53	11		
10	10	23	6		L
11	106	71	14		
12	11	110	13		
13	40	76	12		
14	23	70	12		
15	71	80	8		

COMPARTMENT #83

1	293	51	9		
2	61	60	7		
3	10	170	9		H
4	11	50	6		
5	81	66	13		
6	12	90	10		
7	20	86	9		
8	22	48	9		

COMPARTMENT #83 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
9	19	50	8		
10	20	74	12		
11	14	62	14		
12	98	77	17		H
13	36	52	10		
14	37	77	17		H

COMPARTMENT #84

1	23	70	7		
2	32	0	4		N.C.
3	26	94	11		
4	15	35	5		L
5	16	43	11		
6	48	73	10		
7	44	50	5		
8	40	75	9		
9	11	56	9		
10	45	110	14		
11	68	70	11		
12	26	78	11		
13	48	95	11		
14	39	102	13		
15	20	93	10		
16	13	90	10	Rock Outcrops	
17	39	90	12	(TIZ)	

COMPARTMENT #84 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
18	16	43	11		
19	16	43	11		
20	10	56	9		
21	20	110	14		
22	23	110	14		
23	17	78	11		

COMPARTMENT #93

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	117	66	15		
2	16	100	7		
3	53	70	6		
4	21	70	6		
5	67	90	16		
6	50	70	5		
7	50	60	13		
8	528	80	16		
9	56	90	5		
10	30	60	3		
11	30	60	3		
101	6	0	0	Beaver Ponds	N.C.

COMPARTMENT #94

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	68	100	5	Shallow Soil	
2	131	90	8		
3	70	100	10		

COMPARTMENT #94 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
4	114	50	9		
5	10	90	12		
6	49	100	10		
7	9	50	9	(TIZ)	
8	73	50	9		
9	15	100	10		
10	20	50	9		
11	37	70	13		
12	17	70	13		

COMPARTMENT #95

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	77	62	7		
2	38	77	10		
3	17	116	9		
4	24	65	12		
5	34	65	9		
6	43	66	8		
7	43	96	11		
8	10	73	11	70% Slope	H
9	44	54	10		
10	20	72	12		
11	47	160	10		H
12	17	120	12		H
13	9	105	15		
14	25	90	14		

COMPARTMENT #95 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
15	65	96	12		
16	52	74	7		
17	11	0	2		L
18	57	138	10		H
19	23	122	13		H
20	12	125	11		H
21	43	95	8		
22	10	97	8		
23	26	125	10		H
24	46	87	11		
25	11	80	9		
26	10	110	7		
27	40	155	12		H
28	7	140	7		H
29	7	235	12		H
30	13	96	8		
31	23	110	10		
32	12	80	10	(W IZ)	
33	2	86	11	(W IZ)	
34	1	110	10	(W IZ)	
101-107	18	0	0		N.C.

COMPARTMENT #96

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	46	90	8		
2	50	70	8	Shallow Soils	
3	141	20	1		L
4	133	80	7		
5	37	80	8		
6	73	110	6		
7	43	120	9		H
8	16	0	0		N.C.
9	23	120	9		H
10	130	100	10		
11	16	120	7	Exposed Bedrock	H
12	23	90	4		
13	69	0	0		N.C.
14	65	70	8	Shallow Soils	
15	3	90	8		
101	47	0	0		N.C.
102	1	0	0		N.C.

COMPARTMENT #97

1	3	80	9		
2	3	123	7		H
3	5	113	8		
4	5	80	9		
5	6	100	8		
6	60	80	9		

COMPARTMENT #97 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
7	7	83	7	Steep w/rock	H
8	10	126	7		H
9	50	0	1		L
10	63	0	3		L
11	22	106	12		
12	29	90	7		
13	9	133	10		H
14	5	163	11		H
15	16	65	8		
16	11	100	11		
17	9	106	9		
18	3	126	7		H
19	15	113	12		
20	17	0	1		L
101-103	26	0	0		W.C.

COMPARTMENT #98

1	8	60	11		
2	45	80	11		
3	23	80	9		
4	53	80	7	Steep	H
5	57	90	8		
6	57	70	8		
7	57	70	10		
8	78	90	8		

COMPARTMENT #98 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
9	47	80	14		
10	15	140	12	Steep	H
11	9	90	8		
12	4	70	10		
21	23	80	10	Exposed Rock	
22	17	80	8		
23	72	100	9		
24	13	110	12		
25	50	90	14	Steep	H
26	26	90	8	Steep	H
27	31	70	8		
28	50	100	9		
29	49	80	16		
30	12	20	9		
31	41	140	9		H
32	5	80	14		
33	65	90	8		
34	5	90	8		
102	9	0	0		N.C.

COMPARTMENT #99

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	15	100	9		
2	37	100	10		
3	19	110	10		
4	28	70	13		

COMPARTMENT #99 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
5	27	80	9		
6	40	80	9		
7	15	70	8		
8	40	80	9		
9	61	110	10		
10	21	100	11		
11	21	90	7		
12	55	90	11		
13	43	80	7		
14	35	120	10		H
15	22	90	12		
16	18	100	10		
17	26	120	12		H
18	29	120	10		H
19	12	90	12		
20	33	150	10		H
21	150	60	10		
22	63	80	7		
23	60	90	9		
24	23	120	11		H
25	67	120	12		H
26	34	100	10		
27	67	100	9		
28	32	70	14		
29	20	90	9		
30	82	80	10		

COMPARTMENT #100

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	46	80	10		
2	19	90	9	Steep/shallow Soils	H
3	6	180	10		H
4	53	120	7		H
5	8	150	9	Shallow soils	H
6	49	90	10		
7	20	73	10		
8	23	100	8		
9	36	73	10		

COMPARTMENT #101

NO DATA AVAILABLE. ASSUME MEDIUM C & G DIFFICULTY.

COMPARTMENT #102

1	38	120	10	Steep	H
2	33	110	11		
3	21	70	7		
4	21	140	8	Steep	H
5	10	0	0	Dwelling Site	N.C.
6	42	80	10	Steep/Rock Outcrop	H

COMPARTMENT #103

1	41	80	9
2	40	60	4
3	11	50	6

COMPARTMENT #103 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
4	17	90	6		
5	20	80	11		
6	5	60	1		L
7	13	60	4		
8	52	78	10		
9	15	100	9		
10	12	83	10		
11	28	70	8		
12	18	110	9		
13	21	130	11		H
14	21	140	10		H
101-107	23	0	0		N.C.

COMPARTMENT #104

NO DATA AVAILABLE. ASSUME MEDIUM C & G DIFFICULTY.

COMPARTMENT #105

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	87	83	12		
2	14	60	12	Steep/rocky	H
3	30	106	10		
4	80	96	12		
5	22	100	11		
6	20	86	8		
7	23	56	6		
8	107	83	8		

COMPARTMENT #105 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
9	22	137	14		H
10	18	72	14		
11	163	96	14		
12	11	70	5		
13	125	106	14		
14	32	110	16		
15	11	74	10		
16	18	100	12		
17	25	83	12		
18	19	96	14		
19	26	96	14		
20	55	96	14		
21	11	20	1		L
22	52	0	0		N.C.
23	40	96	14		
101	9	0	0	Rec. Site	N.C.

COMPARTMENT #106

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	7	70	6		
2	13	80	7		
3	11	65	9		
4	25	92	14		
5	12	60	8		
6	124	128	11		H
7	29	90	12		

COMPARTMENT #106 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
8	25	72	11		
9	16	90	18		
10	247	78	9		
11	58	72	10		
12	25	70	12		
13	23	90	15		
14	77	75	9		
15	34	75	9		
16	12	70	12		
17	28	92	14		
18	25	72	11		

COMPARTMENT #112

1	42	76	8		
2	25	90	12		
3	36	52	0		
4	92	85	10		
5	45	95	13		
6	102	40	11		L
7	57	75	9		
8	36	77	6		
9	37	90	10		
10	18	80	12		
11	12	70	10		

COMPARTMENT #112 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
12	3	0	0	Powerline	N.C.
13	25	40	11		L
14	25	40	11		L

COMPARTMENT #113

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	8	70	10		
2	50	40	6	Steep	
3	6	60	4	(TIZ)	
4	18	30	6	Steep	L
5	41	90	14		
6	14	80	12		
7	49	82	8		
8	21	60	8		
9	29	66	7		
10	17	90	14		
11	23	89	13	(TIZ)	
12	85	70	13		
13	54	80	12		
14	79	78	10		
15	53	0	0	Powerline	N.C.
101-102	14	0	0		N.C.

COMPARTMENT #114

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
1	10	80	11		
2	32	107	10		
3	26	40	8		L
4	30	100	9		
5	50	117	9		
6	27	100	9		
7	30	138	12		H
8	30	110	8		
9	40	70	8		
10	14	93	12		
11	32	80	7		
12	20	110	10		
13	11	193	14		H
14	17	103	11		
15	14	75	9		
16	20	50	9		
17	11	0	0		N.C.
20	25	80	13		
21	30	110	12		
22	35	80	9		
23	16	85	11		
24	8	70	6		
25	3	60	9		
26	46	80	13		
101-104	10	0	0		N.C.

COMPARTMENT #115

1	53	80	12		
2	90	120	11		H
3	48	120	10		H
4	21	20	1		L
5	5	30	1		L
6	100	90	10		
7	24	100	11	(TIZ)	
8	75	80	10		
9	7	120	10		H
10	20	80	7		
11	27	90	10		
12	26	90	11		
13	7	0	0		N.C.
14	9	80	9		
15	62	80	9		
16	23	90	10		
101-104	42	0	0		N.C.

COMPARTMENT #142

1	115	100	8		
2	19	20	2		L
3	85	90	7	Exposed Boulders	H
4	89	80	11	Exposed Boulders	
5	301	100	11		
6	23	130	10	Shallow Soils	H
7	26	150	10		H

COMPARTMENT #142 (CONT.)

Stand No.	Acres	Basal Area	D.B.H.	Remarks	C&G Difficulty
8	13	130	8		H
9	48	140	10		H
10	15	140	10		H
11	51	90	10		
12	14	90	10		
13	8	90	10		
14	14	130	10		H
15	7	100	8		
16	22	100	8		
17	17	100	8		
18	6	100	8		
19	1	0	0		N.C.
20	2	0	0		N.C.
21	3	0	0		N.C.
101-102	21	0	0		N.C.

NOTE: (WIZ) = Water Influence Zone

(TIZ) = Travel Influence Zone

H = High

L = Low

N.C. = Non-commercial

If C & G Difficulty has no designation, it is medium.

APPENDIX 4

Road Cost Program (R.C.P.)--part a

```
10 COM A[110],B[110],C[110],D[110],G[110],H[110],I[110,5],J[110,5],V,M7
20 DIM X$[5],Y$[5],Z$[5],M$[5],E[110]
30 DEG
40 FIXED 2
50 PRINT "THIS PROGRAM WILL ACCEPT UP TO 110 SEGMENTS--COSTS AND ENGINEERING"
60 PRINT "DATA ARE COMPUTED AND DISPLAYED FOR THE FOLLOWING CONST. METHODS"
70 PRINT
80 PRINT TAB20"1.) FULL BENCH AND SIDECAST."
90 PRINT TAB20"2.) FULL BENCH AND ENDHAUL."
100 PRINT TAB20"3.) BALANCED CONSTRUCTION."
110 DISP "SEG DATA ALREADY STORED(1 OR 0)";
120 INPUT Z
130 IF Z=0 THEN 180
140 DISP "FILE NUMBER";
150 INPUT O
160 LOAD  DATA #5,O
170 GOTO 230
180 DISP "NO. OF SEGMENTS IN NETWORK";
190 INPUT V
200 DISP "NETWORK NUMBER";
210 INPUT M7
220 PRINT
230 PRINT TAB20"RD. NETWORK"M7"HAS"V"SEGMENTS"
240 PRINT
250 IF Z=1 THEN 1080
260 DISP "MAP SCALE FEET/INCH";
270 INPUT S
280 DISP "CONTOUR INTERVAL IN FEET";
290 INPUT S1
300 I=M9=0
310 FOR F=1 TO V+0.0001
320 L=0
330 I=I+1
340 DISP "DIGITIZE SEG."I""
350 WAIT 3000
360 DISP ""
370 GOSUB 840
380 A[I]=L
390 M9=M9+A[I]
400 DISP "NOW FIND AVG. GRADE OF RD SEG."
410 WAIT 3000
420 DISP "FAVORABLE=1,ADVERSE=2,LEVEL=3";
430 INPUT P1
440 IF P1=3 THEN 520
450 M3=M2=0
460 GOSUB 1010
470 IF P1=2 THEN 500
480 D[I]=(M3*100)/A[I]
490 GOTO 530
500 D[I]=(M3*-100)/A[I]
510 GOTO 530
520 D[I]=0
530 DISP "NOW FIND AVG SIDESLOPE OF SEG."
540 WAIT 3000
550 Y7=Y8=Y9=0
560 FOR Y7=1 TO 5
570 DISP "DIGITIZE CONTOUR ABOVE/BELOW"
```

```
580 WAIT 3000
590 ENTER (9,*)X,Y
600 ENTER (9,*)X1,Y1
610 WRITE (9,*)
620 Y8=(SQR((X1-X)^2+(Y1-Y)^2))*S
630 Y9=Y9+Y8
640 NEXT Y7
650 I9=(S1*25)/Y9
660 G[I]=ATN(I9)
670 DISP "DEPTH TO BEDROCK IN FEET";
680 INPUT C[I]
690 DISP "NUMBER OF CK. CROSSINGS IN SEG";
700 INPUT H[I]
710 IF H[I]=0 THEN 800
720 J=0
730 FOR P=1 TO H[I]+0.0001
740 J=J+1
750 GOSUB 1680
760 I[I,J]=I9
770 GOSUB 1760
780 J[I,J]=S3
790 NEXT P
800 DISP "C&G DIFFICULTY(LO=1,MED=2,HI=3)";
810 INPUT B[I]
820 NEXT F
830 GOTO 1050
840 DISP "PRESS S ON CURSOR AT END OF SEG"
850 WAIT 3000
860 X=Y=X1=Y1=X2=Y2=0
870 ENTER (9,*)X,Y
880 DISP "NOW DIGITIZE THE RD IN C MODE"
890 WAIT 3000
900 ENTER (9,*)X1,Y1
910 ENTER (9,*)X2,Y2
920 L=L+(SQR((X1-X2)^2+(Y1-Y2)^2))*S
930 IF ABS(X2-X)<0.05 AND ABS(Y2-Y)<0.05 THEN 970
940 X1=X2
950 Y1=Y2
960 GOTO 910
970 WRITE (9,*)
980 WAIT 100
990 WRITE (9,*)
1000 RETURN
1010 DISP "NUMBER OF CONTOURS CROSSED";
1020 INPUT M2
1030 M3=M2*S1
1040 RETURN
1050 DISP "STORE SEG DATA IN FILE NO.";
1060 INPUT O
1070 STORE  DATA #5,O
1080 DISP "WANT LIST OF STORED DATA(1 OR 0)";
1090 INPUT S4
1100 IF S4=0 THEN 1350
1110 I=0
1120 WRITE (15,1530)
1130 FOR D=1 TO V+0.0001
1140 FIXED 0
```

```
1150 I=I+1
1160 J=0
1170 U6=TAN(G[I])*100
1180 PRINT "  SEG      LENGTH     GRADE(%)    SIDESLOPE(%)    BED-DEPTH    C AND G "
1190 PRINT "  ---      ------     --------    ------------    ---------    -------"
1200 PRINT TAB2""I""TAB10""A[I]""TAB21""D[I]""TAB33""U6""TAB49""C[I]"",""B[I]""
1210 IF H[I]=0 THEN 1310
1220 PRINT
1230 PRINT TAB8"     CK NUMBER         CK GRADE(%)         AREA DRAINED(AC)        "
1240 PRINT "            ---------       -----------       ----------------"
1250 FOR P=1 TO H[I]+0.0001
1260 J=J+1
1270 U7=TAN(I[I,J])*100
1280 PRINT TAB14""J""TAB31""U7""TAB49""J[I,J]""
1290 PRINT
1300 NEXT P
1310 NEXT D
1320 PRINT
1330 FIXED 2
1340 WRITE (15,1530)
1350 READ B2,B3,B4,B5,B6,B7,B8,B9,B0,C1,C2,C3
1360 DATA 700,2.3,11,800,40,1.1,2.8,0.28,0.75,0.28
1370 DATA 500,19.6
1380 I=0
1390 FOR D=1 TO V+0.0001
1400 I=I+1
1410 GOTO B[I] OF 1420,1440,1460
1420 B1=2000
1430 GOTO 1470
1440 B1=2300
1450 GOTO 1470
1460 B1=2600
1470 E[I]=B1
1480 NEXT D
1490 DISP "WANT UNIT COST LISTING(1 OR 0)";
1500 INPUT T0
1510 IF T0=0 THEN 2010
1520 WRITE (15,1530)
1530 FORMAT 80"*"
1540 PRINT TAB5"THE FOLLOWING AVERAGE COSTS ARE USED IN THE COST PROGRAM"
1550 PRINT
1560 PRINT "C&G/ACRE LO=$2000  MED=$2300  HI=$2600 "
1570 PRINT "SEED/ACRE=$"B2" MOBILIZATION/MILE=$"B5""
1580 PRINT "EXCAVATION/CY:  COMMON=$"B3" ROCK=$"B4""
1590 PRINT
1600 PRINT "RIPRAP/CY=$"B6"  FENCES & GATES=$"C2""
1610 PRINT
1620 PRINT "BUY SURFACING/CY=$"B7" HAUL SURFACING/CY/MI=$"B9""
1630 PRINT "LOAD AND APPLY SURFACING/CY=$"B8" OUTLET PIPE/LF=$"C3""
1640 PRINT
1650 PRINT "HAUL ENDHAUL/CY/MI=$"C1" LOAD ENDHAUL/CY=$"B0""
1660 PRINT
1670 GOTO 2010
1680 DISP "DIGIT CK"J"GRADE"
1690 WAIT 3000
1700 ENTER (9,*)X,Y
1710 ENTER (9,*)X1,Y1
```

```
1720 WRITE (9,*)
1730 T8=(SQR((X1-X)^2+(Y1-Y)^2))*S
1740 T9=ATN(5*S1/T8)
1750 RETURN
1760 X=Y=X1=X2=Y1=Y2=A=C8=S3=0
1770 DISP "SET ORIGIN AT PT ON DRAIN AREA"
1780 WAIT 3000
1790 DISP "DIGITIZE AREA"
1800 WAIT 2000
1810 ENTER (9,*)X,Y
1820 ENTER (9,*)X1,Y1
1830 ENTER (9,*)X2,Y2
1840 IF C8=1 THEN 1880
1850 R8=SQR((X2-X)^2+(Y2-Y)^2)
1860 IF R8<0.05 THEN 1880
1870 C8=1
1880 R8=SQR((X2-X)^2+(Y2-Y)^2)
1890 A2=(X1-X)*(Y2-Y)/2-(Y1-Y)*(X2-X)/2
1900 A=A+A2
1910 X1=X2
1920 Y1=Y2
1930 IF C8#1 THEN 1830
1940 IF R8>0.05 THEN 1830
1950 WRITE (9,*)
1960 WAIT 100
1970 WRITE (9,*)
1980 A=A*S^2
1990 S3=ABS(A/43560)
2000 RETURN
2010 LINK 1,50,50
```

Road Cost Program (R.C.P.)--part b

```
10 DISP "RD. GEOM SAME FOR ALL SEGS(1/0)";
20 INPUT T7
30 IF T7=0 THEN 70
40 DISP "WANT SEG. DATA OUTPUT-(1/0)";
50 INPUT J2
60 IF J2=0 THEN 100
70 DISP "OUTPUT-(SHORT=1,MED=2,LONG=3)";
80 INPUT Z1
90 J2=1
100 I=W8=W9=X8=X0=S8=S9=S0=Q8=Q9=M8=Q0=W0=M9=0
110 PRINT TAB13"COSTS AND ENGINEERING DATA FOR NETWORK#"M7""
120 FORMAT 70"*"
130 PRINT
140 IF T7=0 THEN 180
150 GOSUB 490
160 GOSUB 3300
170 IF J2=0 THEN 200
180 IF Z1=2 OR Z1=3 THEN 200
190 GOSUB 3600
200 FOR H=1 TO V+0.0001
210 I=I+1
220 N7=A[I]/5280
230 IF T7=1 THEN 250
240 GOSUB 490
250 GOSUB 670
260 GOSUB 2410
270 IF J2=0 THEN 340
280 GOSUB Z1 OF 3650,3740,3860
290 IF Z1=1 THEN 340
300 IF H[I]=0 THEN 330
310 GOSUB 3450
320 GOTO 340
330 PRINT TAB12"NO MAJOR CREEK CROSSINGS IN THIS SEGMENT"
340 M9=M9+A[I]
350 NEXT H
360 PRINT
370 WRITE (15,120)
380 PRINT TAB4"GRAND TOTAL COST"TAB26"$"W8""TAB43"$"W9""TAB60"$"W0""
390 PRINT
400 PRINT TAB4"GRAND TOTAL EXC (CY)"TAB27""X8""TAB44""X8""TAB61""X0""
410 PRINT
420 N6=M9/5280
430 PRINT TAB4"TOTAL NETWORK LENGTH="N6"MILES"
440 PRINT
450 PRINT TAB4"AVG  COST/MILE"TAB27"$"W8/N6""TAB43"$"W9/N6""TAB60"$"W0/N6""
460 PRINT
470 WRITE (15,120)
480 END
490 DISP "RUNNING SURFACE WIDTH (FT)";
500 INPUT K7
510 DISP "CUTSLOPE FACTOR (HORIZ TO VERT)";
520 INPUT K6
530 K5=ATN(1/K6)
540 DISP "IS THERE A DITCH (1 OR 0)";
550 INPUT K4
560 DISP "COMPACTED SURFACING DEPTH (FT)";
```

```
570 INPUT K3
580 DISP "NO  MILES TO SURFACING PIT";
590 INPUT R7
600 DISP "NO  MILES TO WASTE AREA";
610 INPUT R9
620 IF K4=1 THEN 650
630 W=K7+(3*K3)
640 GOTO 660
650 W=K7+(6*K3)+4
660 RETURN
670 IF C[I]>(W*SIN(G[I])) THEN 860
680 W1=C[I]/SIN(G[I])
690 W2=W-W1
700 W4=(W2/SIN(63.43-G[I]))*SIN(116.57)
710 W3=W1*COS(G[I])
720 F2=90-K5+G[I]
730 W5=C[I]*TAN(F2)
740 W6=((W3+W4+W5)*COS(G[I]))+4
750 W7=(W5/SIN(F2))*COS(K5)
760 H1=(W3*C[I])/2
770 H2=W4*C[I]
780 H3=(W5*C[I])/2
790 H4=((W2^2)*SIN(116.57)*SIN(G[I]))/(2*SIN(63.43-G[I]))
800 H6=H7=0
810 IF K4=1 THEN 830
820 GOTO 840
830 H4=H4+2
840 H5=H1+H2+H3
850 GOTO 950
860 H4=W1=W2=W3=W4=W5=F2=H1=H2=H3=0
870 H6=180-K5
880 H7=K5-G[I]
890 H5=(W^2*SIN(H6)*SIN(G[I]))/(2*SIN(H7))
900 IF K4=1 THEN 920
910 GOTO 930
920 H5=H5+2
930 W7=((W/SIN(H7))*SIN(H7+H6))*COS(K5)
940 W6=(((W/SIN(H7))*SIN(H6))*COS(G[I]))+4
950 R1=(H4*A[I])/27
960 R2=(H5*A[I])/27
970 R3=(W6*A[I])/43560
980 R4=(W7*A[I])/43560
990 R6=INT(A[I]/1000)
1000 IF R6=0 AND A[I]>600 THEN 1020
1010 GOTO 1030
1020 R6=1
1030 IF K3=0 THEN 1090
1040 R5=((((K7*K3)+((3*K3^2)/2)+((K3^2)/2))*A[I])/27+(R6*((K3*8*150)/27)))*1.2
1050 IF K4=1 THEN 1070
1060 GOTO 1100
1070 R5=R5+(((((K3^2*3)/2)*A[I])/27)-((((K3^2)/2)*A[I])/27))*1.2
1080 GOTO 1100
1090 R5=0
1100 IF H[I]=0 THEN 1120
1110 GOSUB 1340
1120 GOSUB 2150
1130 L6=R2*B3
```

```
1140 L7=R1*R4
1150 L8=R4*R2
1160 L9=R3*E[I]
1170 L0=K1*C3
1180 IF H[I]=0 THEN 1210
1190 D6=B6*V3
1200 GOTO 1220
1210 D6=O7=V3=0
1220 D7=B5*(A[I]/5280)
1230 D8=(((R1*1.15)+R2)*B0)+(((R1*1.15)+R2)*C1*R9)
1240 D9=(R5*B7)+(R5*B8)+(R5*B9*R7)
1250 P0=C2*(A[I]/5280)
1260 S8=L6+L7+L8+L9+D6+D7+D8+D9+P0+O7
1270 S9=S8-D8
1280 O8=R1+R2
1290 M8=(R1/O8)*100
1300 W8=W8+S8
1310 W9=W9+S9
1320 X8=X8+O8
1330 RETURN
1340 J=V3=O7=0
1350 FOR P=1 TO H[I]+0.0001
1360 V3=V3+1.5
1370 J=J+1
1380 V1=0.2*(J[I,J]^0.75)
1390 IF V1<1.77 THEN 1560
1400 IF V1 >= 1.77 AND V1<3.14 THEN 1590
1410 IF V1 >= 3.14 AND V1<4.91 THEN 1620
1420 IF V1 >= 4.91 AND V1<7.07 THEN 1650
1430 IF V1 >= 7.07 AND V1<9.62 THEN 1680
1440 IF V1 >= 9.62 AND V1<12.57 THEN 1710
1450 IF V1 >= 12.57 AND V1<15.9 THEN 1740
1460 IF V1 >= 15.9 AND V1<19.63 THEN 1770
1470 IF V1 >= 19.63 AND V1<23.76 THEN 1800
1480 IF V1 >= 23.76 AND V1<28.4 THEN 1830
1490 IF V1 >= 28.4 AND V1<38 THEN 1860
1500 IF V1 >= 38 AND V1<48.7 THEN 1890
1510 IF V1 >= 48.7 AND V1<60.7 THEN 1920
1520 IF V1 >= 60.7 AND V1<74.1 THEN 1950
1530 IF V1 >= 74.1 AND V1<88.7 THEN 1980
1540 IF V1 >= 88.7 AND V1<104.8 THEN 2010
1550 IF V1 >= 104.8 THEN 2040
1560 Z[J]=1.5
1570 Y[J]=19.6
1580 GOTO 2090
1590 Z[J]=2
1600 Y[J]=25
1610 GOTO 2090
1620 Z[J]=2.5
1630 Y[J]=33.42
1640 GOTO 2090
1650 Z[J]=3
1660 Y[J]=39.6
1670 GOTO 2090
1680 Z[J]=3.5
1690 Y[J]=56.25
1700 GOTO 2090
```

```
1710 Z[J]=4
1720 Y[J]=65.49
1730 GOTO 2090
1740 Z[J]=4.5
1750 Y[J]=92.42
1760 GOTO 2090
1770 Z[J]=5
1780 Y[J]=103.89
1790 GOTO 2090
1800 Z[J]=5.5
1810 Y[J]=110
1820 GOTO 2090
1830 Z[J]=5.09
1840 Y[J]=239.2
1850 GOTO 2090
1860 Z[J]=5.78
1870 Y[J]=250.1
1880 GOTO 2090
1890 Z[J]=6.44
1900 Y[J]=260.9
1910 GOTO 2090
1920 Z[J]=7.09
1930 Y[J]=271.8
1940 GOTO 2090
1950 Z[J]=7.75
1960 Y[J]=282.7
1970 GOTO 2090
1980 Z[J]=8.44
1990 Y[J]=293.6
2000 GOTO 2090
2010 Z[J]=9.1
2020 Y[J]=304.4
2030 GOTO 2090
2040 Y[J]=700
2050 DISP "BRIDGE LENGTH IN FEET";
2060 INPUT Z[J]
2070 M[J]=Z[J]*Y[J]
2080 GOTO 2120
2090 O3=4+Z[J]
2100 GOSUB 2270
2110 M[J]=Y[J]*X[J]
2120 O7=O7+M[J]
2130 NEXT P
2140 RETURN
2150 IF K4=0 THEN 2250
2160 IF D[I] <= 4 THEN 2180
2170 GOTO 2200
2180 K9=865
2190 GOTO 2210
2200 K9=2437.5*D[I]^(-1)
2210 K0=INT(A[I]/K9)
2220 K2=(((K7+(6*K3))/COS(30))/COS(3))+4
2230 K1=K2*K0
2240 GOTO 2260
2250 K1=0
2260 RETURN
2270 P4=K7+2+6*K3
```

```
2280 P3=I[I,J]
2290 O2=O3+(P4/2*TAN(P3))
2300 O4=O2+(P4/2*TAN(P3))
2310 O5=90-P3
2320 O6=90+P3
2330 O7=180-56.31-O6
2340 O8=180-56.31-O5
2350 O1=(O4/SIN(O7))*SIN(56.31)
2360 O9=(O3/SIN(O8))*SIN56.31
2370 O0=P4/COS(P3)
2380 P5=O1+O0+O9
2390 X[I,J]=P5
2400 RETURN
2410 IF G[I]>30.97 THEN 3150
2420 Q=33.69-G[I]
2430 R=63.43-G[I]
2440 F1=90-K5+G[I]
2450 T1=C[I]/SIN(G[I])
2460 IF T1>W THEN 2820
2470 T4=T1*COS(G[I])
2480 E1=(SIN(146.31)*SIN(G[I]))/(2*SIN(Q))
2490 E2=((SIN(116.57)*SIN(G[I]))/(2*SIN(R)))
2500 E3=((T4*C[I])/2)*0.8
2510 E4=(((C[I]*TAN(F1))*C[I])/2)*0.8
2520 P1=((SIN(116.57)/SIN(R))*C[I])*0.8
2530 E8=2*T1*E2
2540 E9=2*W*E1
2550 K=((T1^2)*E2)-(T1*P1)+E4+E3-((W^2)*(E1))
2560 A=E2-E1
2570 B=(P1)-(E8)+(E9)
2580 IF K4=1 THEN 2600
2590 GOTO 2610
2600 K=((T1^2)*E2)-(T1*P1)+E4+E3-((W^2)*(E1))+2
2610 T=(-B+SQR(B^2-4*A*K))/(2*A)
2620 IF T<T1 THEN 2820
2630 T2=T-T1
2640 E0=(T2/SIN(R))*SIN(116.57)
2650 E6=(T2^2)*E2
2660 E3=E3/0.8
2670 E4=E4/0.8
2680 IF K4=1 THEN 2700
2690 GOTO 2710
2700 E6=E6+2
2710 E5=E0*C[I]
2720 G5=((E3+E4+E5)*A[I])/27
2730 G4=(E6*A[I])/27
2740 E7=((W-T)^2)*E1
2750 M4=(C[I]/COS(F1))*COS(G[I]+(90-F1))
2760 G7=(M4*A[I])/43560
2770 M6=((W-T)/SIN(Q))*SIN(146.31)
2780 M5=M6*COS(G[I])
2790 Z8=Z9=0
2800 G6=(((M5+T1+M4)+(E0*COS(G[I]))+4)*A[I])/43560
2810 GOTO 3030
2820 E6=E2=E3=E4=E5=E7=E8=E9=E0=T2=T4=P1=0
2830 Z8=(((SIN(180-K5))*(SIN(G[I])))/(2*(SIN(K5-G[I]))))*0.8
2840 E1=(SIN(146.31)*SIN(G[I]))/(2*SIN(Q))
```

```
2850 A=(78-E1)
2860 B=2*W*E1
2870 K=(W^2)*-E1
2880 IF K4=1 THEN 2900
2890 GOTO 2910
2900 K=((W^2)*-E1)+1.6
2910 T=(-B+SQR(B^2-4*A*K))/(2*A)
2920 Z9=((T^2)*78)/0.8
2930 G4=E6
2940 IF K4=1 THEN 2960
2950 GOTO 2970
2960 Z9=Z9+2
2970 G5=(Z9*A[I])/27
2980 M4=((T/SIN(K5-G[I]))*SIN(180-G[I]))*COS(K5)
2990 M6=((W-T)/SIN(Q))*SIN(146.31)
3000 M5=M6*COS(G[I])
3010 G6=((M5+M4+T+4)*A[I])/43560
3020 G7=(M4*A[I])/43560
3030 F6=G5*B3
3040 A9=0
3050 F7=G4*B4
3060 F8=G7*B2
3070 F9=G6*E[I]
3080 S0=F6+F7+F8+F9+L0+D6+D7+D9+P0+Q7
3090 Q9=G4+G5
3100 IF G4#0 THEN 3130
3110 Q0=0
3120 GOTO 3270
3130 Q0=(G4/Q9)*100
3140 GOTO 3270
3150 S0=S8
3160 G5=R2
3170 G4=R1
3180 G6=R3
3190 G7=R4
3200 F6=L6
3210 F7=L7
3220 F8=L8
3230 F9=L9
3240 A9=D8
3250 Q9=Q8
3260 Q0=M8
3270 W0=W0+S0
3280 X0=X0+Q9
3290 RETURN
3300 IF T7=0 THEN 3330
3310 PRINT
3320 WRITE (15,120)
3330 PRINT
3340 PRINT
3350 PRINT "SUBGRADE       RUNNING        CUTSLOPE       SURFACING"
3360 PRINT " WIDTH          WIDTH          ANGLE          DEPTH            DITCH?"
3370 PRINT " ------         ------         ------         ------           ------"
3380 PRINT ""W""TAB14""K7""TAB28""K5""TAB43""K3""TAB57""K4""
3390 PRINT
3400 PRINT TAB5"NO. OF MILES TO WASTE AREA="R9""
3410 PRINT
```

```
3420 PRINT TAB5"NO. OF MILES TO SURFACING PIT="R7""
3430 PRINT
3440 RETURN
3450 PRINT
3460 J=0
3470 PRINT TAB10"CK. #"TAB18"PIPE LENGTH"TAB33"DIA(FT)"TAB46"COST/LF"TAB59"COST"
3480 PRINT TAB10"----"TAB18"-----------"TAB33"-------"TAB46"-------"TAB58"------
3490 FOR P=1 TO H[I]+0.0001
3500 J=J+1
3510 IF Y[J]=600 THEN 3550
3520 PRINT TAB10""J""TAB20""X[J]""TAB34""Z[J]""TAB46"$"Y[J]""TAB59"$"M[J]""
3530 PRINT
3540 GOTO 3560
3550 PRINT TAB10""J""TAB20""Z[J]""TAB34"BRIDGE"TAB46"$600"TAB59"$"M[J]""
3560 NEXT P
3570 PRINT
3580 WRITE (15,120)
3590 RETURN
3600 WRITE (15,120)
3610 PRINT TAB26"FULLBENCH &"TAB43"FULLBENCH &"TAB61"BALANCED"
3620 PRINT "SEG. #"TAB27"ENDHAUL"TAB44"SIDECAST"TAB61"SECTION"
3630 PRINT "-----"TAB26"----------"TAB43"----------"TAB60"----------"
3640 RETURN
3650 PRINT ""I""TAB7"TOTAL COST"TAB26"$"S8""TAB43"$"S9""TAB60"$"S0""
3660 IF T7=1 THEN 3720
3670 PRINT
3680 GOSUB 3300
3690 IF T7=0 THEN 3710
3700 GOTO 3720
3710 WRITE (15,120)
3720 RETURN
3730 PRINT
3740 GOSUB 3600
3750 PRINT ""I""TAB7"TOTAL COST"TAB26"$"S8""TAB43"$"S9""TAB60"$"S0""
3760 PRINT
3770 PRINT TAB9"TOTAL EXC. (CY)"TAB27""O8""TAB44""O8""TAB61""O9""
3780 PRINT
3790 PRINT TAB9"PERCENT ROCK"TAB27""M8"%"TAB44""M8"%"TAB61""O0"%"
3800 PRINT TAB9"AVE. COST/MILE"TAB26"$"S8/N7""TAB43"$"S9/N7""TAB60"$"S0/N7""
3810 IF T7=1 THEN 3850
3820 GOSUB 3300
3830 IF Z1=3 THEN 3850
3840 WRITE (15,120)
3850 RETURN
3860 GOSUB 3740
3870 PRINT
3880 PRINT TAB20"ITEMIZED ENGINEERING DATA"
3890 PRINT
3900 PRINT "COMMON EXC. (CY)"TAB27""R2""TAB44""R2""TAB61""G5""
3910 PRINT "ROCK EXC. (CY)"TAB27""R1""TAB44""R1""TAB61""G4""
3920 PRINT "ACRES C & G "TAB27""R3""TAB44""R3""TAB61""G6""
3930 PRINT "ACRES SEEDING"TAB27""R4""TAB44""R4""TAB61""G7""
3940 PRINT "SURFACING(CY)"TAB27""R5""TAB44""R5""TAB61""R5""
3950 PRINT "TURNOUT#"TAB27""R6""TAB44""R6""TAB61""R6""
3960 PRINT "OUTLET PIPE(LF)"TAB27""K1""TAB44""K1""TAB61""K1""
3970 PRINT "RIPRAP(CY)"TAB27""V3""TAB44""V3""TAB61""V3""
```

```
3980 PRINT
3990 PRINT
4000 PRINT TAB25"ITEMIZED COSTS"
4010 PRINT
4020 PRINT "COMMON EXC."TAB27"$"L6""TAB44"$"L6""TAB61"$"F6""
4030 PRINT "ROCK EXC."TAB27"$"L7""TAB44"$"L7""TAB61"$"F7""
4040 PRINT
4050 PRINT "SEEDING"TAB27"$"L8""TAB44"$"L8""TAB61"$"F8""
4060 PRINT "C&G"TAB27"$"L9""TAB44"$"L9""TAB61"$"F9""
4070 PRINT "OUTLET PIPE(18)"TAB27"$"L0""TAB44"$"L0""TAB61"$"L0""
4080 PRINT "RIPRAP"TAB27"$"D6""TAB44"$"D6""TAB61"$"D6""
4090 PRINT "MOBILIZATION"TAB27"$"D7""TAB44"$"D7""TAB61"$"D7""
4100 PRINT "ENDHAUL"TAB27"$"D8""TAB44"$ 0 00"TAB61"$"A9""
4110 PRINT "SURFACING"TAB27"$"D9""TAB44"$"D9""TAB61"$"D9""
4120 PRINT "FENCES & GATES"TAB27"$"P0""TAB44"$"P0""TAB61"$"P0""
4130 PRINT "LARGE PIPE"TAB27"$"O7""TAB44"$"O7""TAB61"$"O7""
4140 PRINT
4150 RETURN
```

APPENDIX 5

```
THIS PROGRAM WILL ACCEPT UP TO 110 SEGMENTS--COSTS AND ENGINEERING
DATA ARE COMPUTED AND DISPLAYED FOR THE FOLLOWING CONST. METHODS

                    1. ) FULL BENCH AND SIDECAST.
                    2. ) FULL BENCH AND ENDHAUL.
                    3. ) BALANCED CONSTRUCTION.

                    RD. NETWORK 1.00    HAS 97.00   SEGMENTS

********************************************************************************
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   1       1697       -8            19             7          2
            CK. NUMBER        CK. GRADE(%)       AREA DRAINED(AC)
            ---------         -----------        ----------------
               1                  18                  94
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   2       791        -5            18            12          3
            CK. NUMBER        CK. GRADE(%)       AREA DRAINED(AC)
            ---------         -----------        ----------------
               1                   9                  430
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   3       1465       -5            12             7          2
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   4       1572        1            25             2          2
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   5       2891        0            40             1          2
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   6       2479       -5            31             1          2
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   7       3399       -6            32             2          2
            CK. NUMBER        CK. GRADE(%)       AREA DRAINED(AC)
            ---------         -----------        ----------------
               1                  34                  106
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   8       11028       1            25            12          2
            CK. NUMBER        CK. GRADE(%)       AREA DRAINED(AC)
            ---------         -----------        ----------------
               1                  21                  193
               2                  14                  409
               3                  16                  163
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   9       2593        2            27             2          2
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   10      4563       -2            31             7          2
  SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
  ---     ------    --------   ------------   ---------    -------
   11      3635        3            29             2          2
            CK. NUMBER        CK. GRADE(%)       AREA DRAINED(AC)
            ---------         -----------        ----------------
               1                   7                  925
```

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
12	625	6	16	2	3

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
13	2827	-5	49	2	3

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
14	7857	1	18	7	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	16	60

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
15	6518	2	49	1	3

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
16	4277	6	16	2	3

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
17	1527	-3	25	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
18	6133	5	47	1	3

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
19	1350	-6	11	12	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
20	14807	2	31	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	9	443

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
21	6232	4	29	6	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	19	207
2	5	847
3	14	191

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
22	1180	0	18	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
23	1811	-2	21	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
24	7351	1	19	7	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
25	4575	-2	47	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
26	1588	0	29	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
27	14039	-1	27	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	31	81

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
28	15993	2	38	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
29	9822	-1	31	4	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	23	56

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
30	12744	-3	25	7	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	16	240

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
31	8249	3	29	1	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	19	107

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
32	10753	-1	32	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	21	94

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
33	4684	-5	14	7	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
34	2584	-5	14	7	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	9	356

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
35	3299	0	45	1	1

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	14	179

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
36	6503	1	38	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	21	209

```
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 37       11284        3           34             6            2
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 18                 162
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 38       10482        2           38             2            1
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 39       11474       -1           40             2            1
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 47                 71
              2                 23                 140
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 40       7936         0           38             2            2
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 41       3791         3           38             2            2
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 42       12113       -3           36             3            2
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 11                 720
              2                 9                  557
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 43       9571         0           38             2            2
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 47                 83
              2                 31                 120
              3                 29                 65
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 44       10020       -4           23             5            2
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 12                 52
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 45       5849         2           34             1            2
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 42                 57
SEG      LENGTH     GRADE(%)   SIDESLOPE(%)   BED-DEPTH    C AND G
---      ------     --------   -----------    ---------    -------
 46       7046        -4           23             8            2
           CK. NUMBER       CK. GRADE(%)      AREA DRAINED(AC)
           ---------        ----------        ---------------
              1                 9                  961
```

```
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 47      3434       -2            19             7          2
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                   9                191
              2                  14                 62
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 48      1282       -5            47             2          2
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 49      3807       -4            36             7          2
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                  18                172
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 50      3661        2            16             8          2
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                   9                244
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 51      4410       -3            38             5          3
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                  34                 99
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 52     11921       -4            23             7          2
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                   7                259
              2                  19                 66
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 53      5531        6            27             2          3
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 54      3636       -3            38             2          3
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                  31                 53
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 55      3837        3            23             1          2
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 56      2742       -2            31             1          2
SEG     LENGTH    GRADE(%)   SIDESLOPE(%)   BED-DEPTH   C AND G
---     ------    --------   ------------   ---------   -------
 57      5790       -1            21             2          2
          CK. NUMBER         CK. GRADE(%)     AREA DRAINED(AC)
          ----------         ------------     ----------------
              1                  14                 48
```

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
58	2875	8	40	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
59	3888	-9	36	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
60	6738	8	25	5	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
61	3216	-2	23	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
62	1865	0	32	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
63	7584	0	34	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
64	5256	0	42	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
65	4566	-2	27	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
66	8703	-2	27	12	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	14	103
2	16	85
3	19	151

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
67	7459	0	29	12	1

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	25	47
2	19	95
3	16	155
4	21	92
5	14	72

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
68	8752	0	29	12	3

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	23	197

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
69	5542	3	27	10	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	14	128
2	16	122

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
70	9904	5	18	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
71	2149	-5	19	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
72	4109	3	25	12	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	12	157
2	23	193
3	18	40

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
73	1805	0	40	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
74	6898	2	19	12	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	11	351
2	12	339

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
75	8916	2	31	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	42	70

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
76	6551	4	32	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	27	34

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
77	4697	6	25	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
78	1850	0	18	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
79	2357	2	51	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
80	2528	4	25	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
81	4428	2	31	7	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
82	7988	0	32	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
83	4601	3	34	2	1

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
84	2088	-4	27	2	1

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
85	8284	3	32	2	2

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	29	51

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
86	10380	0	32	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
87	5913	0	32	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
88	9711	3	34	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
89	4493	0	38	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
90	953	8	32	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
91	4726	6	32	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
92	1998	0	27	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
93	5506	1	32	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
94	690	9	45	1	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
95	584	0	36	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
96	313	0	32	2	2

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
97	645	12	38	2	1

****

APPENDIX 6

COSTS AND ENGINEERING DATA FOR NETWORK# 1. 00

****

SUBGRADE WIDTH	RUNNING WIDTH	CUTSLOPE ANGLE	SURFACING DEPTH	DITCH?
21. 00	14. 00	45. 00	0. 50	1. 00

NO. OF MILES TO WASTE AREA= 0. 40
NO. OF MILES TO SURFACING PIT= 16. 00

****

SEG. #		FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
1. 00	TOTAL COST	$ 21349. 31	$ 18358. 54	$ 13362. 47
2. 00	TOTAL COST	$ 13914. 90	$ 12672. 35	$ 10406. 83
3. 00	TOTAL COST	$ 12681. 53	$ 11144. 46	$ 8789. 05
4. 00	TOTAL COST	$ 32797. 62	$ 29275. 04	$ 13177. 61
5. 00	TOTAL COST	$ 135384. 22	$ 123633. 04	$ 51689. 31
6. 00	TOTAL COST	$ 82808. 53	$ 75629. 21	$ 31047. 93
7. 00	TOTAL COST	$ 103301. 83	$ 92890. 59	$ 39965. 89
8. 00	TOTAL COST	$ 166131. 84	$ 139642. 53	$ 97341. 12
9. 00	TOTAL COST	$ 59422. 51	$ 53105. 80	$ 23237. 33
10. 00	TOTAL COST	$ 77074. 46	$ 62637. 75	$ 39274. 99
11. 00	TOTAL COST	$ 103834. 32	$ 94245. 54	$ 48001. 48
12. 00	TOTAL COST	$ 7868. 64	$ 7022. 18	$ 4495. 38
13. 00	TOTAL COST	$ 146573. 28	$ 132059. 64	$ 58718. 11
[illegible]. 00	TOTAL COST	$ 85858. 10	$ 73515. 84	$ 55106. 81
15. 00	TOTAL COST	$ 390772. 31	$ 357000. 58	$ 163157. 33
16. 00	TOTAL COST	$ 53211. 31	$ 47418. 83	$ 31591. 12
17. 00	TOTAL COST	$ 31865. 15	$ 28443. 41	$ 12820. 05
18. 00	TOTAL COST	$ 346771. 12	$ 316819. 03	$ 143659. 91
19. 00	TOTAL COST	$ 10874. 47	$ 9672. 10	$ 7933. 55
20. 00	TOTAL COST	$ 408893. 35	$ 366741. 55	$ 158432. 66
21. 00	TOTAL COST	$ 118400. 82	$ 100365. 62	$ 71338. 86
22. 00	TOTAL COST	$ 21324. 63	$ 19491. 76	$ 9454. 91
23. 00	TOTAL COST	$ 30908. 11	$ 27523. 52	$ 14152. 27
24. 00	TOTAL COST	$ 84383. 89	$ 71428. 59	$ 51487. 66
25. 00	TOTAL COST	$ 257541. 20	$ 235198. 01	$ 103682. 26
26. 00	TOTAL COST	$ 39691. 76	$ 35502. 77	$ 14953. 84
27. 00	TOTAL COST	$ 325048. 02	$ 290848. 18	$ 131532. 47
28. 00	TOTAL COST	$ 591551. 69	$ 531390. 45	$ 217580. 62
29. 00	TOTAL COST	$ 192186. 30	$ 163723. 94	$ 86554. 70
30. 00	TOTAL COST	$ 181235. 46	$ 150624. 31	$ 101802. 19
31. 00	TOTAL COST	$ 257998. 25	$ 235841. 56	$ 100084. 15
32. 00	TOTAL COST	$ 319861. 67	$ 286924. 93	$ 120657. 02
33. 00	TOTAL COST	$ 43733. 90	$ 38042. 86	$ 29922. 74
34. 00	TOTAL COST	$ 29286. 13	$ 26146. 58	$ 21315. 38
35. 00	TOTAL COST	$ 177517. 11	$ 162344. 59	$ 70956. 48
36. 00	TOTAL COST	$ 244228 11	$ 219765 62	$ 92017. 77
37. 00	TOTAL COST	$ 224262. 88	$ 183637. 94	$ 109031. 76
38. 00	TOTAL COST	$ 385427 44	$ 345997 05	$ 139710. 05
[illegible] 00	TOTAL COST	$ 459734 86	$ 413686 33	$ 171942. 80
[illegible]. 00	TOTAL COST	$ 293439. 01	$ 263585. 97	$ 107899. 74

41.00	TOTAL COST	$ 140097.96	$ 125837.27	$ 51327.73
42.00	TOTAL COST	$ 369104.59	$ 326448.81	$ 150003.56
43.00	TOTAL COST	$ 364488.87	$ 328485.41	$ 140791.81
44.00	TOTAL COST	$ 132738.35	$ 110925.52	$ 76453.88
45.00	TOTAL COST	$ 228349.11	$ 208823.98	$ 87780.68
46.00	TOTAL COST	$ 105307.69	$ 89969.04	$ 65851.63
47.00	TOTAL COST	$ 44023.71	$ 37971.68	$ 28314.52
48.00	TOTAL COST	$ 62082.48	$ 55884.36	$ 23758.51
49.00	TOTAL COST	$ 82723.64	$ 67277.62	$ 40031.11
50.00	TOTAL COST	$ 39719.92	$ 34636.06	$ 27174.00
51.00	TOTAL COST	$ 110009.25	$ 92660.42	$ 49672.14
52.00	TOTAL COST	$ 162022.08	$ 136070.90	$ 95018.99
53.00	TOTAL COST	$ 128053.49	$ 114579.64	$ 55105.41
54.00	TOTAL COST	$ 137351.50	$ 123673.87	$ 52531.58
55.00	TOTAL COST	$ 92864.04	$ 84827.70	$ 37339.01
56.00	TOTAL COST	$ 91546.36	$ 83605.39	$ 34659.72
57.00	TOTAL COST	$ 100781.27	$ 89960.33	$ 47027.90
58.00	TOTAL COST	$ 134637.42	$ 122951.27	$ 54195.46
59.00	TOTAL COST	$ 133634.58	$ 119949.08	$ 48877.23
60.00	TOTAL COST	$ 98097.40	$ 81918.06	$ 58719.38
61.00	TOTAL COST	$ 61089.20	$ 54490.41	$ 26268.00
62.00	TOTAL COST	$ 66846.40	$ 61040.11	$ 25112.68
63.00	TOTAL COST	$ 242134.02	$ 217203.60	$ 89202.97
64.00	TOTAL COST	$ 223284.76	$ 200813.24	$ 83398.08
65.00	TOTAL COST	$ 104743.64	$ 93620.59	$ 41710.76
66.00	TOTAL COST	$ 136303.63	$ 113322.94	$ 76623.21
67.00	TOTAL COST	$ 127406.75	$ 105820.66	$ 70731.05
68.00	TOTAL COST	$ 144617.02	$ 119289.03	$ 78805.82
69.00	TOTAL COST	$ 88010.56	$ 73376.64	$ 49835.95
70.00	TOTAL COST	$ 136275.69	$ 121219.49	$ 71496.47
71.00	TOTAL COST	$ 33104.84	$ 29469.31	$ 16223.11
72.00	TOTAL COST	$ 65562.80	$ 55692.96	$ 39713.12
73.00	TOTAL COST	$ 71460.52	$ 64216.53	$ 26303.49
74.00	TOTAL COST	$ 89051.70	$ 76894.76	$ 57947.60
75.00	TOTAL COST	$ 246132.88	$ 220751.27	$ 95208.90
76.00	TOTAL COST	$ 194983.99	$ 174918.09	$ 73479.41
77.00	TOTAL COST	$ 98222.61	$ 87697.46	$ 43314.71
78.00	TOTAL COST	$ 25303.16	$ 22490.77	$ 12397.97
79.00	TOTAL COST	$ 129618.06	$ 116777.76	$ 52759.45
80.00	TOTAL COST	$ 66716.92	$ 60938.99	$ 25936.33
81.00	TOTAL COST	$ 74820.59	$ 60811.01	$ 38208.04
82.00	TOTAL COST	$ 235930.96	$ 211463.49	$ 87989.02
83.00	TOTAL COST	$ 145848.45	$ 130723.86	$ 52891.65
84.00	TOTAL COST	$ 47507.00	$ 42420.51	$ 18479.07
85.00	TOTAL COST	$ 246890.00	$ 221515.87	$ 93311.35
86.00	TOTAL COST	$ 306782.27	$ 274988.04	$ 114680.64
87.00	TOTAL COST	$ 212345.97	$ 193937.09	$ 79870.68
88.00	TOTAL COST	$ 310050.87	$ 278128.49	$ 114579.64
89.00	TOTAL COST	$ 166139.99	$ 149238.56	$ 61051.92
90.00	TOTAL COST	$ 34267.25	$ 31300.28	$ 13858.81
91.00	TOTAL COST	$ 169719.60	$ 155006.19	$ 66714.79
92.00	TOTAL COST	$ 57114.07	$ 52153.77	$ 21950.15
93.00	TOTAL COST	$ 162662.53	$ 145797.49	$ 60594.14
94.00	TOTAL COST	$ 36672.16	$ 33498.76	$ 15088.67
95.00	TOTAL COST	$ 19971.99	$ 17916.34	$ 6962.36
96.00	TOTAL COST	$ 9183.37	$ 8224.64	$ 3222.93
97.00	TOTAL COST	$ 23802.87	$ 21376.56	$ 9731.53

****

GRAND TOTAL COST	$ 13937362.87	$ 12389000.57	$ 5918575.30
GRAND TOTAL EXC. (CY)	1699553.73	1699553.73	588987.70

TOTAL NETWORK LENGTH= 99.35 MILES

AVG. COST/MILE	$ 140285.75	$ 124700.80	$ 59573.09

****

COSTS AND ENGINEERING DATA FOR NETWORK# 1.00

****

SUBGRADE WIDTH	RUNNING WIDTH	CUTSLOPE ANGLE	SURFACING DEPTH	DITCH?
19.00	12.00	45.00	0.50	1.00

NO. OF MILES TO WASTE AREA= 0.40
NO. OF MILES TO SURFACING PIT= 16.00

****

SEG. #		FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
1.00	TOTAL COST	$ 18454.26	$ 15986.37	$ 11920.38
2.00	TOTAL COST	$ 12466.91	$ 11440.60	$ 9579.22
3.00	TOTAL COST	$ 10992.37	$ 9717.16	$ 7811.60
4.00	TOTAL COST	$ 26488.85	$ 23588.42	$ 11415.43
5.00	TOTAL COST	$ 110476.06	$ 100837.20	$ 43054.52
6.00	TOTAL COST	$ 67683.27	$ 61788.61	$ 26148.20
7 00	TOTAL COST	$ 83589.72	$ 75033.35	$ 33962.10
8.00	TOTAL COST	$ 142585.22	$ 120773.49	$ 86546.38
9 00	TOTAL COST	$ 47942.48	$ 42744.66	$ 19969.88
10.00	TOTAL COST	$ 65203.54	$ 53332.89	$ 34396.90
11.00	TOTAL COST	$ 85630.11	$ 77743.76	$ 42295.50
12.00	TOTAL COST	$ 6543.93	$ 5842.19	$ 4005.77
13.00	TOTAL COST	$ 118118.78	$ 106203.63	$ 48229.75
14.00	TOTAL COST	$ 73902.50	$ 63708.20	$ 48912.51
15.00	TOTAL COST	$ 318893.86	$ 291205.16	$ 135337.23
16.00	TOTAL COST	$ 44146.05	$ 39343.89	$ 28097.57
17.00	TOTAL COST	$ 25736.98	$ 22919.58	$ 11107.02
18.00	TOTAL COST	$ 283047 44	$ 258488.14	$ 119526.11
19 00	TOTAL COST	$ 9464.53	$ 8464.63	$ 7064.92
20.00	TOTAL COST	$ 330264.95	$ 295611.24	$ 134984.13
21.00	TOTAL COST	$ 102440.53	$ 87604.84	$ 64096.60
22.00	TOTAL COST	$ 17554.19	$ 16043.85	$ 8207.75
23.00	TOTAL COST	$ 25077.66	$ 22285.95	$ 12533.11
24.00	TOTAL COST	$ 72316.89	$ 61626.61	$ 45548.27
25.00	TOTAL COST	$ 210087.78	$ 191767.42	$ 85988.71
26.00	TOTAL COST	$ 31983.69	$ 28538.43	$ 12739.67
27.00	TOTAL COST	$ 262740.00	$ 234597.98	$ 113454.49
28.00	TOTAL COST	$ 476264.49	$ 426855.05	$ 180998.16
29.00	TOTAL COST	$ 155943.19	$ 132222.32	$ 75938.76
30.00	TOTAL COST	$ 154558.02	$ 129352.29	$ 89854.86
31.00	TOTAL COST	$ 211292.08	$ 193094.73	$ 84855.22
32.00	TOTAL COST	$ 257930.07	$ 230861.33	$ 101978.99
33.00	TOTAL COST	$ 37801.23	$ 33088.33	$ 26585.15
34.00	TOTAL COST	$ 25773.20	$ 23173.26	$ 19268.44
35.00	TOTAL COST	$ 145202.00	$ 132759 94	$ 59223.92
36.00	TOTAL COST	$ 197153.97	$ 177063 33	$ 76960.65
37.00	TOTAL COST	$ 191656.73	$ 157096.35	$ 95423.96
38.00	TOTAL COST	$ 310045.54	$ 277662.01	$ 115967.49
39 00	TOTAL COST	$ 370796.79	$ 332983.23	$ 143000.96
40.00	TOTAL COST	$ 236231.53	$ 211713.72	$ 89743.81

41.00	TOTAL COST	$ 112770.15	$ 101058.07	$ 42668.27
42.00	TOTAL COST	$ 297373.83	$ 262180.76	$ 129867.70
43.00	TOTAL COST	$ 294865.24	$ 265296.19	$ 118258.65
44.00	TOTAL COST	$ 113362.21	$ 95390.29	$ 67528.24
45.00	TOTAL COST	$ 186891.44	$ 170867.71	$ 73910.40
46.00	TOTAL COST	$ 91162.56	$ 78524.82	$ 59043.21
47.00	TOTAL COST	$ 38149.79	$ 33155.85	$ 25336.50
48.00	TOTAL COST	$ 49991.64	$ 44903.13	$ 19504.18
49.00	TOTAL COST	$ 68358.03	$ 55560.66	$ 35089.03
50.00	TOTAL COST	$ 34496.12	$ 30292.10	$ 24301.58
51.00	TOTAL COST	$ 89441.20	$ 74889.16	$ 43477.66
52.00	TOTAL COST	$ 138764.99	$ 117383.42	$ 84199.00
53.00	TOTAL COST	$ 103478.05	$ 92390.83	$ 47635.51
54.00	TOTAL COST	$ 110949.95	$ 99716.74	$ 44005.31
55.00	TOTAL COST	$ 76097.56	$ 69489.33	$ 31906.07
56.00	TOTAL COST	$ 74816.45	$ 68296.42	$ 29204.46
57.00	TOTAL COST	$ 82055.05	$ 73129.62	$ 41783.58
58.00	TOTAL COST	$ 109867.12	$ 100281.60	$ 45335.74
59.00	TOTAL COST	$ 107567.32	$ 96325.63	$ 40788.89
60.00	TOTAL COST	$ 79935.69	$ 66608.93	$ 51832.88
61.00	TOTAL COST	$ 49476.72	$ 44039.17	$ 23026.90
62.00	TOTAL COST	$ 54594.24	$ 49828.13	$ 21089.41
63.00	TOTAL COST	$ 194975.03	$ 174491.83	$ 74828.99
64.00	TOTAL COST	$ 179788.92	$ 161338.02	$ 68915.93
65.00	TOTAL COST	$ 84528.53	$ 75375.71	$ 35890.13
66.00	TOTAL COST	$ 116413.75	$ 97501.08	$ 67807.20
67.00	TOTAL COST	$ 108931.24	$ 91174.60	$ 62722.92
68.00	TOTAL COST	$ 123091.58	$ 102256.87	$ 69497.52
69.00	TOTAL COST	$ 75286.02	$ 63242.58	$ 44179.84
70.00	TOTAL COST	$ 111843.01	$ 99388.23	$ 63407.95
71.00	TOTAL COST	$ 27005.16	$ 24002.70	$ 13163.56
72.00	TOTAL COST	$ 56580.52	$ 48453.54	$ 35503.51
73.00	TOTAL COST	$ 57504.71	$ 51556.17	$ 21775.29
74.00	TOTAL COST	$ 77252.03	$ 67220.53	$ 51920.91
75.00	TOTAL COST	$ 198731.65	$ 177865.00	$ 81044.82
76.00	TOTAL COST	$ 157239.56	$ 140748.60	$ 62100.23
77.00	TOTAL COST	$ 79372.55	$ 70706.33	$ 37686.32
78.00	TOTAL COST	$ 20739.30	$ 18412.84	$ 10965.77
79.00	TOTAL COST	$ 104419.35	$ 93877.86	$ 43160.79
80.00	TOTAL COST	$ 54624.80	$ 49875.88	$ 22057.71
81.00	TOTAL COST	$ 63300.89	$ 51781.44	$ 33467.57
82.00	TOTAL COST	$ 190012.60	$ 169904.25	$ 74198.23
83.00	TOTAL COST	$ 117314.97	$ 104888.38	$ 44263.52
84.00	TOTAL COST	$ 38295.98	$ 34110.46	$ 15869.72
85.00	TOTAL COST	$ 199148.10	$ 178294.62	$ 78902.64
86.00	TOTAL COST	$ 247113.70	$ 220983.91	$ 96746.39
87.00	TOTAL COST	$ 173500.39	$ 158389.38	$ 67130.33
88.00	TOTAL COST	$ 249665.72	$ 223437.83	$ 96140.07
89.00	TOTAL COST	$ 133751.73	$ 119870.87	$ 50777.19
90.00	TOTAL COST	$ 28006.50	$ 25571.05	$ 11713.29
91.00	TOTAL COST	$ 138672.04	$ 126594.47	$ 56250.77
92.00	TOTAL COST	$ 46706.13	$ 42630.84	$ 18590.51
93.00	TOTAL COST	$ 131011.74	$ 117151.38	$ 51097.60
94.00	TOTAL COST	$ 29936.14	$ 27333.83	$ 12589.02
95.00	TOTAL COST	$ 16056.53	$ 14367.97	$ 5774.68
96.00	TOTAL COST	$ 7384.12	$ 6596.20	$ 2698.54
97.00	TOTAL COST	$ 19164.32	$ 17171.63	$ 8168.04

****

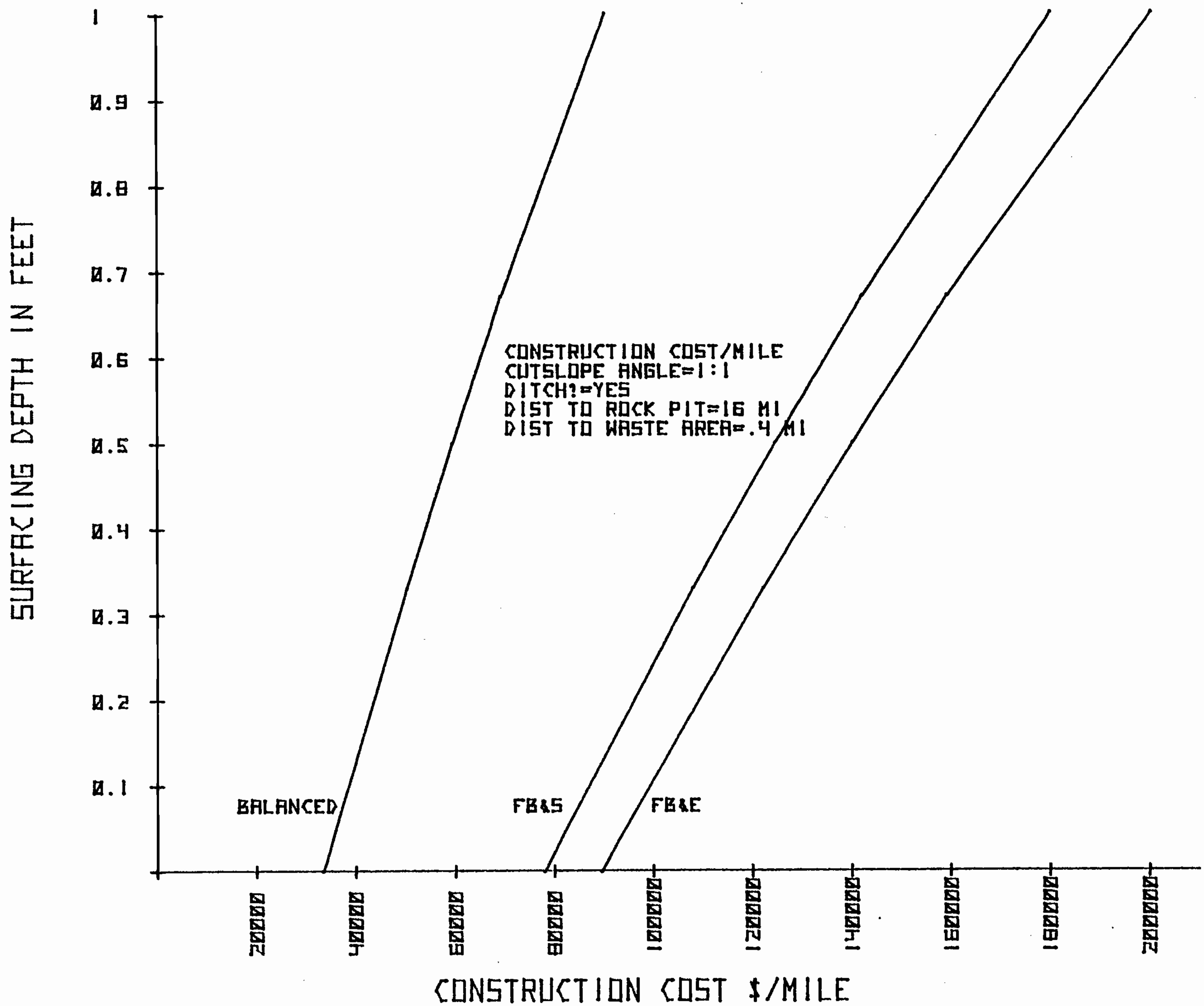
GRAND TOTAL COST	$ 11396316.04	$ 10121339.52	$ 5057534.77
GRAND TOTAL EXC. (CY)	1405052.04	1405052.04	489825.47

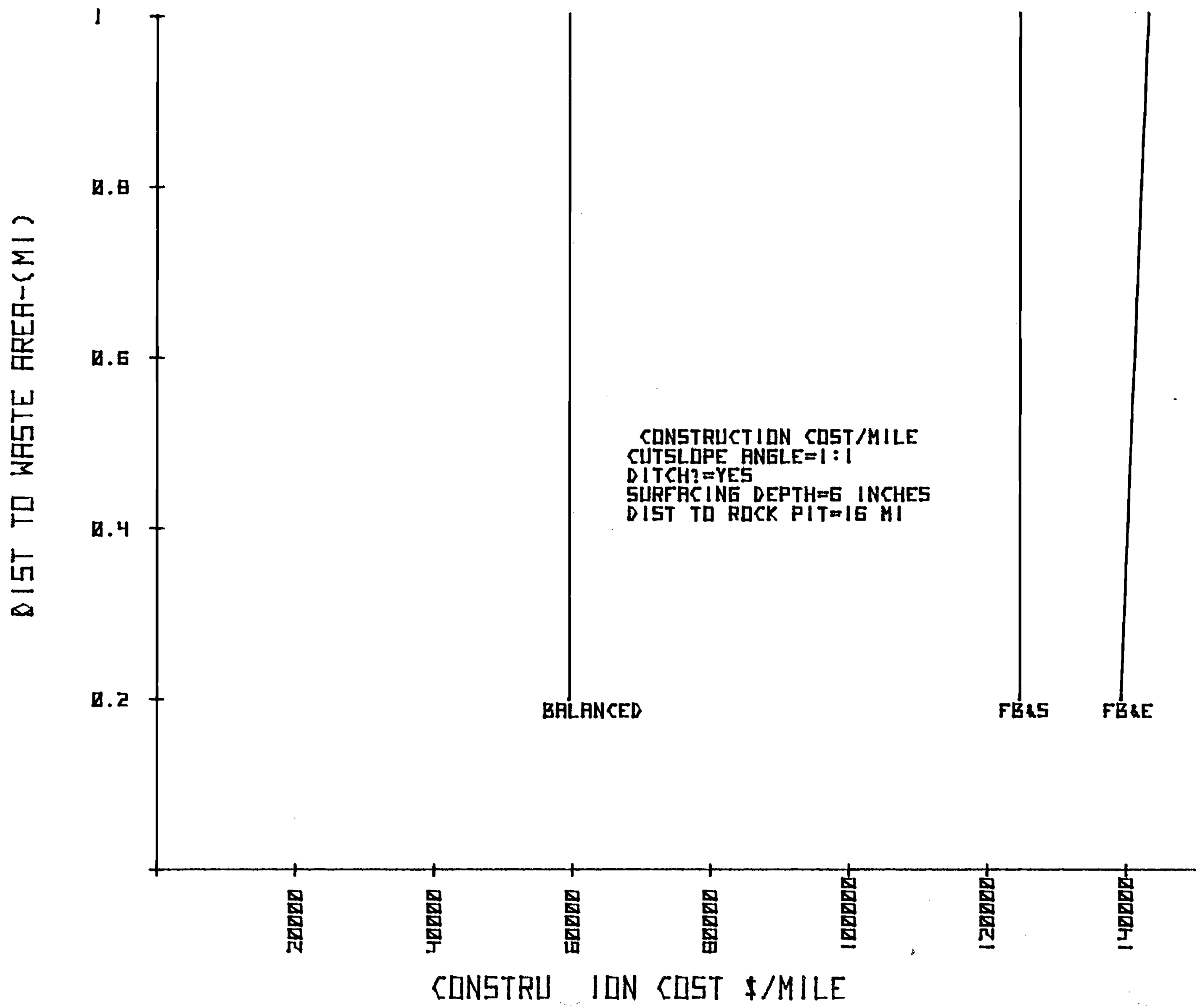
TOTAL NETWORK LENGTH= 99.35 MILES

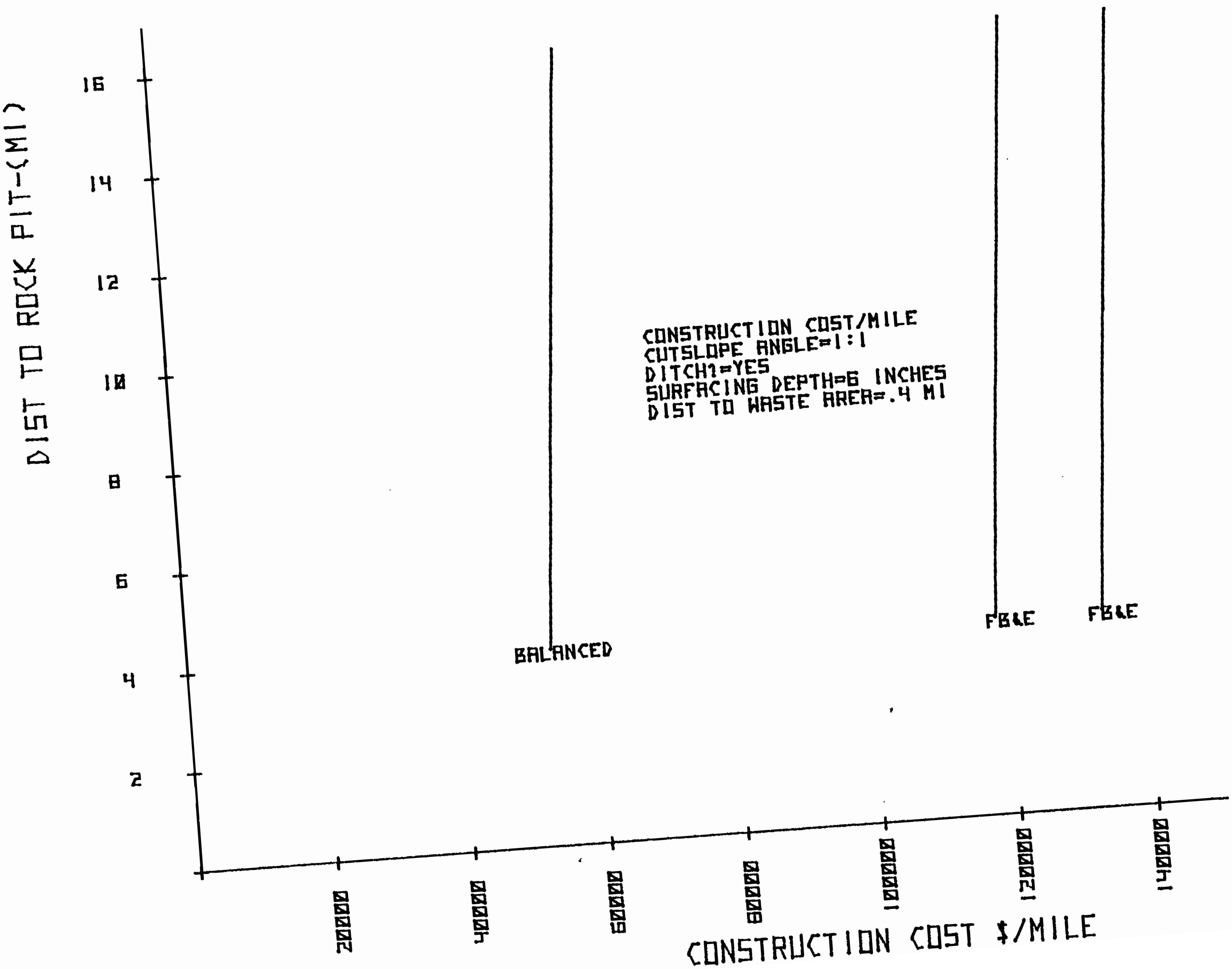
AVG COST/MILE	$ 114708.99	$ 101875.78	$ 50906.34

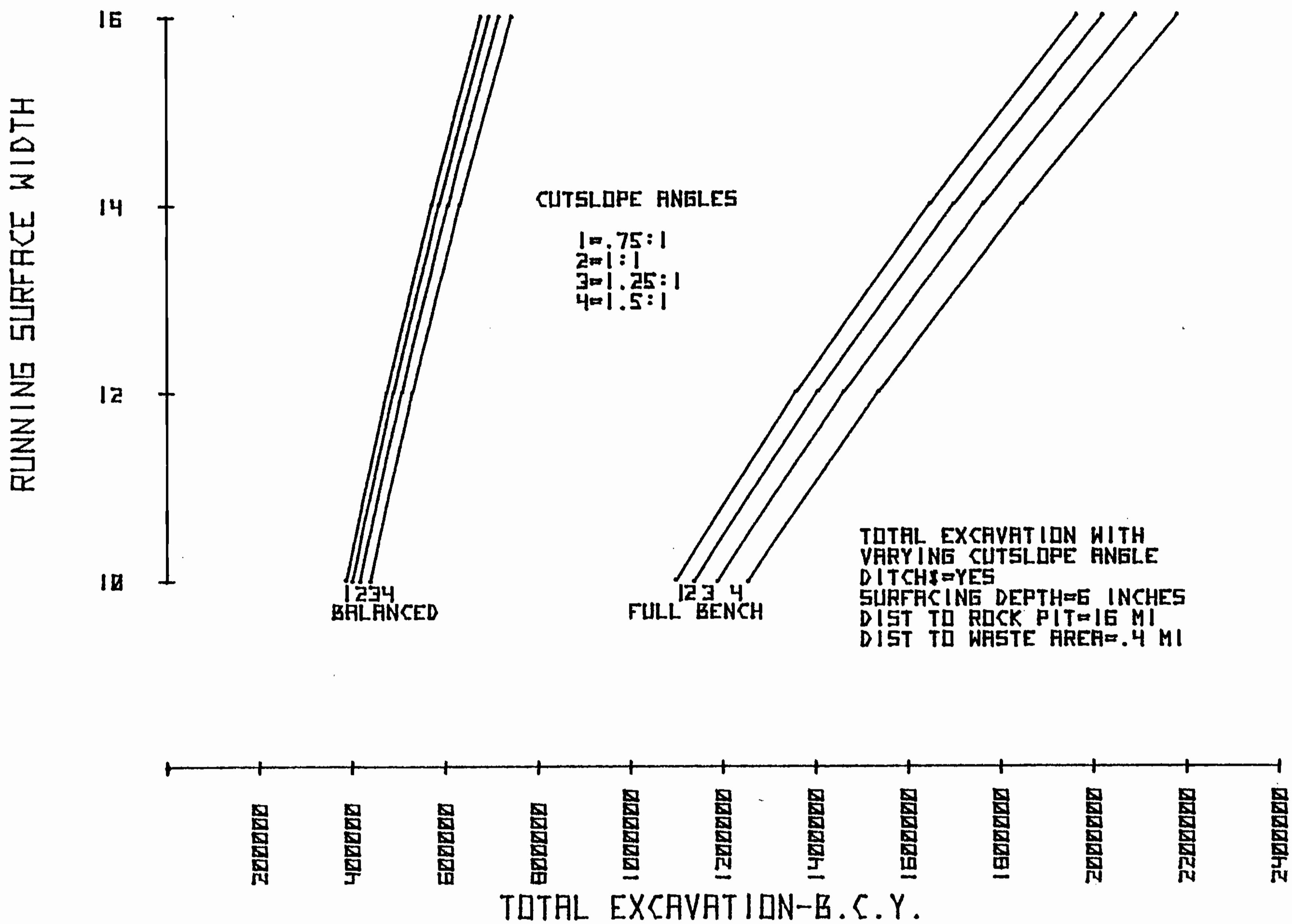
****

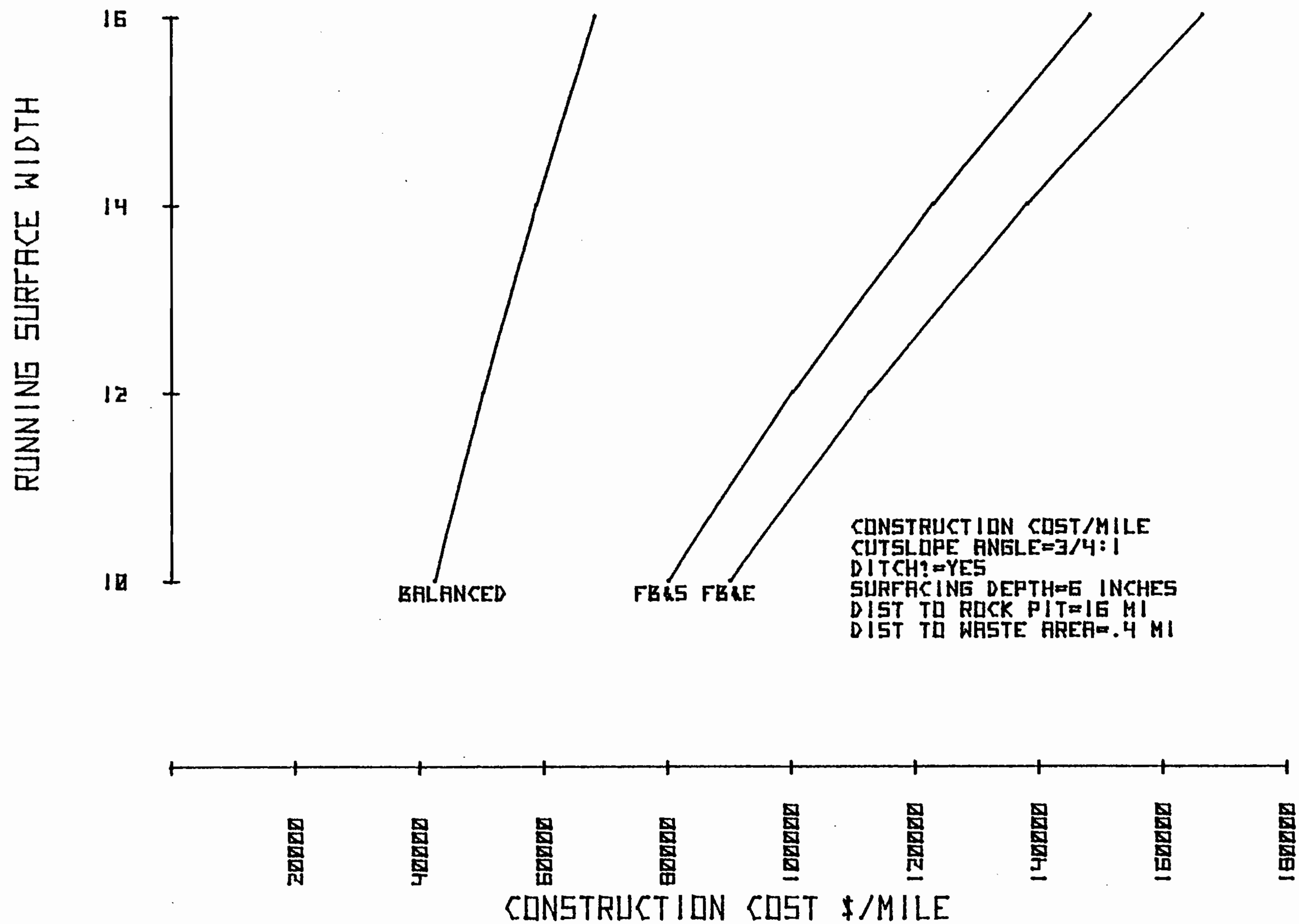
APPENDIX 7

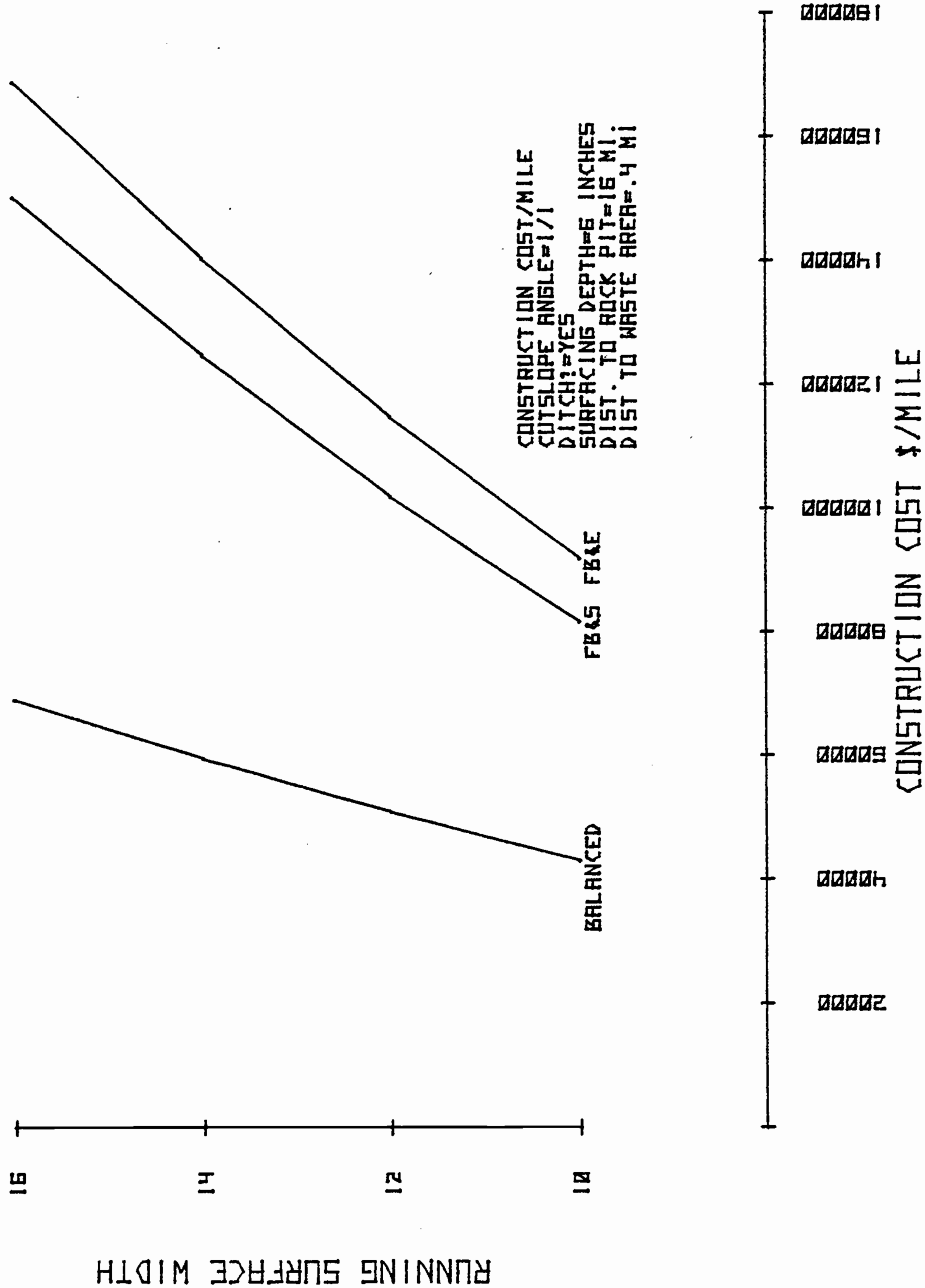

CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1:1
DITCH?=YES
DIST TO ROCK PIT=16 MI
DIST TO WASTE AREA=.4 MI
BALANCED
FB&S
FB&E
SURFACING DEPTH IN FEET
CONSTRUCTION COST $/MILE
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000

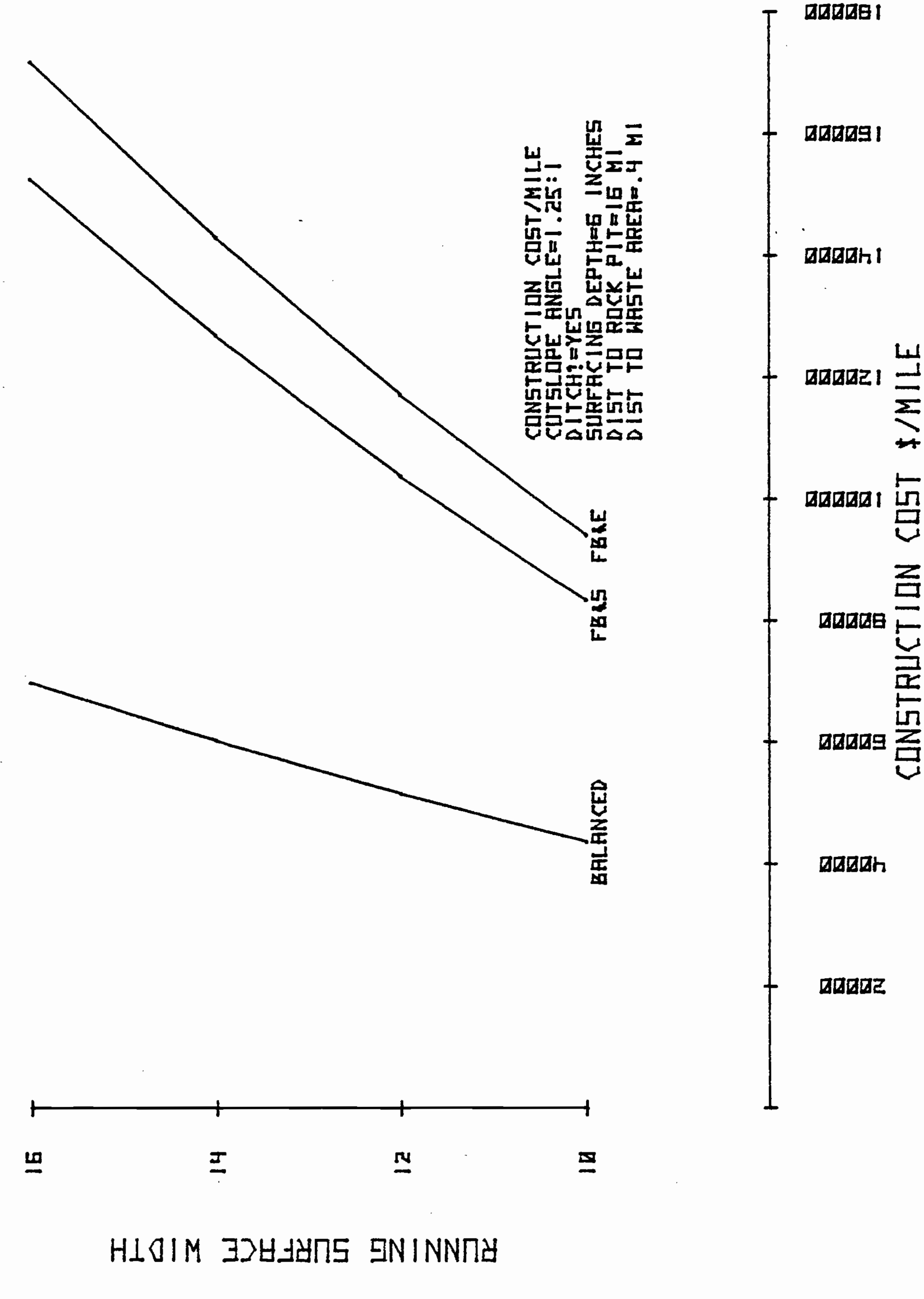

DIST TO WASTE AREA-(MI)
1
0.8
0.6
0.4
0.2
CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1:1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI
BALANCED
FB&S
FB&E
20000
40000
60000
80000
100000
120000
140000
CONSTRU ION COST $/MILE

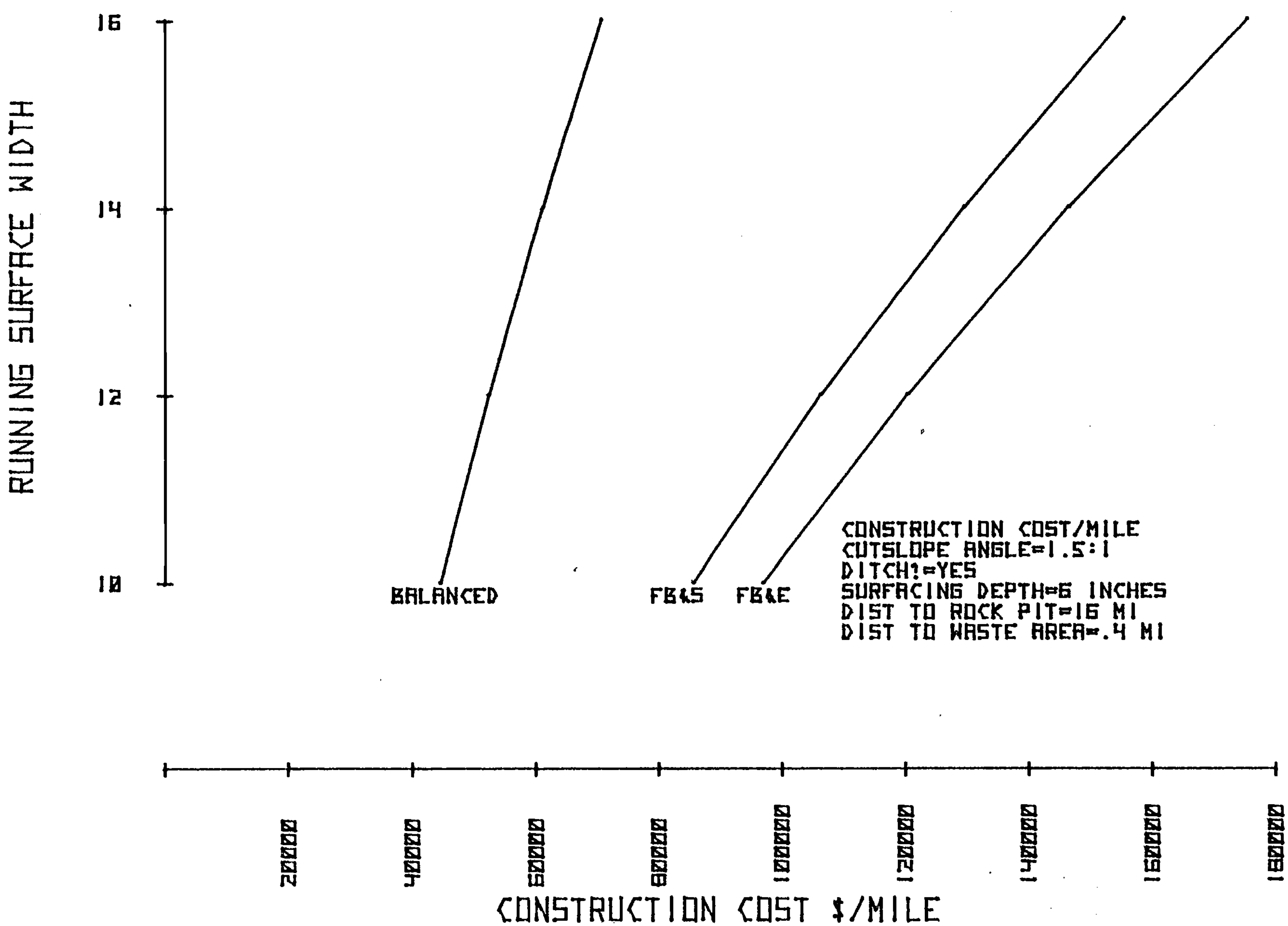

CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1:1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST TO WASTE AREA=.4 MI
BALANCED
FB&E
FB&E
DIST TO ROCK PIT-(MI)
16
14
12
10
8
6
4
2
20000
40000
60000
80000
100000
120000
140000
CONSTRUCTION COST $/MILE

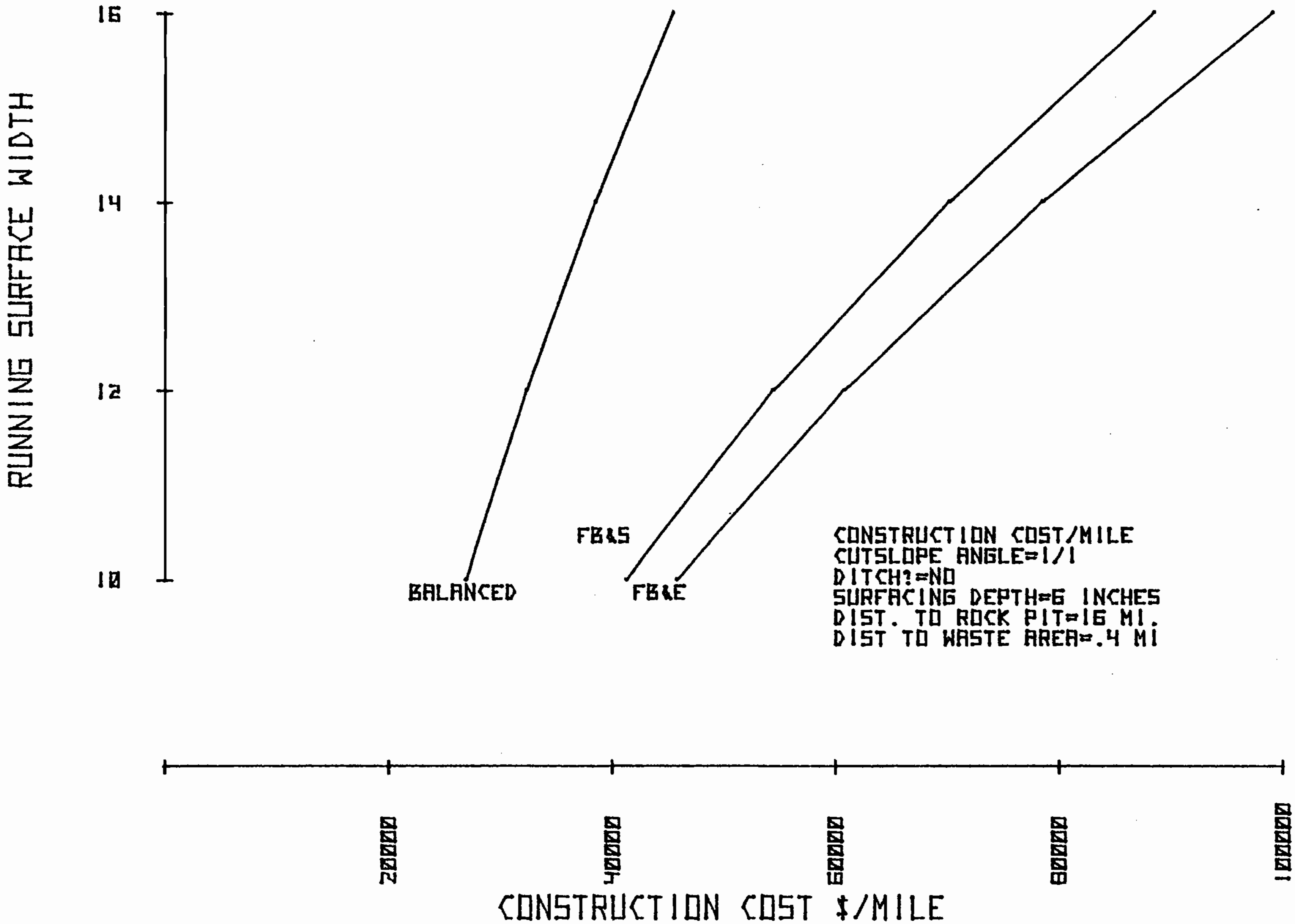

RUNNING SURFACE WIDTH
16
14
12
10
CUTSLOPE ANGLES
1=.75:1
2=1:1
3=1.25:1
4=1.5:1
1234
BALANCED
123 4
FULL BENCH
TOTAL EXCAVATION WITH
VARYING CUTSLOPE ANGLE
DITCH$=YES
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI
DIST TO WASTE AREA=.4 MI
200000
400000
600000
800000
1000000
1200000
1400000
1600000
1800000
2000000
2200000
2400000
TOTAL EXCAVATION-B.C.Y.

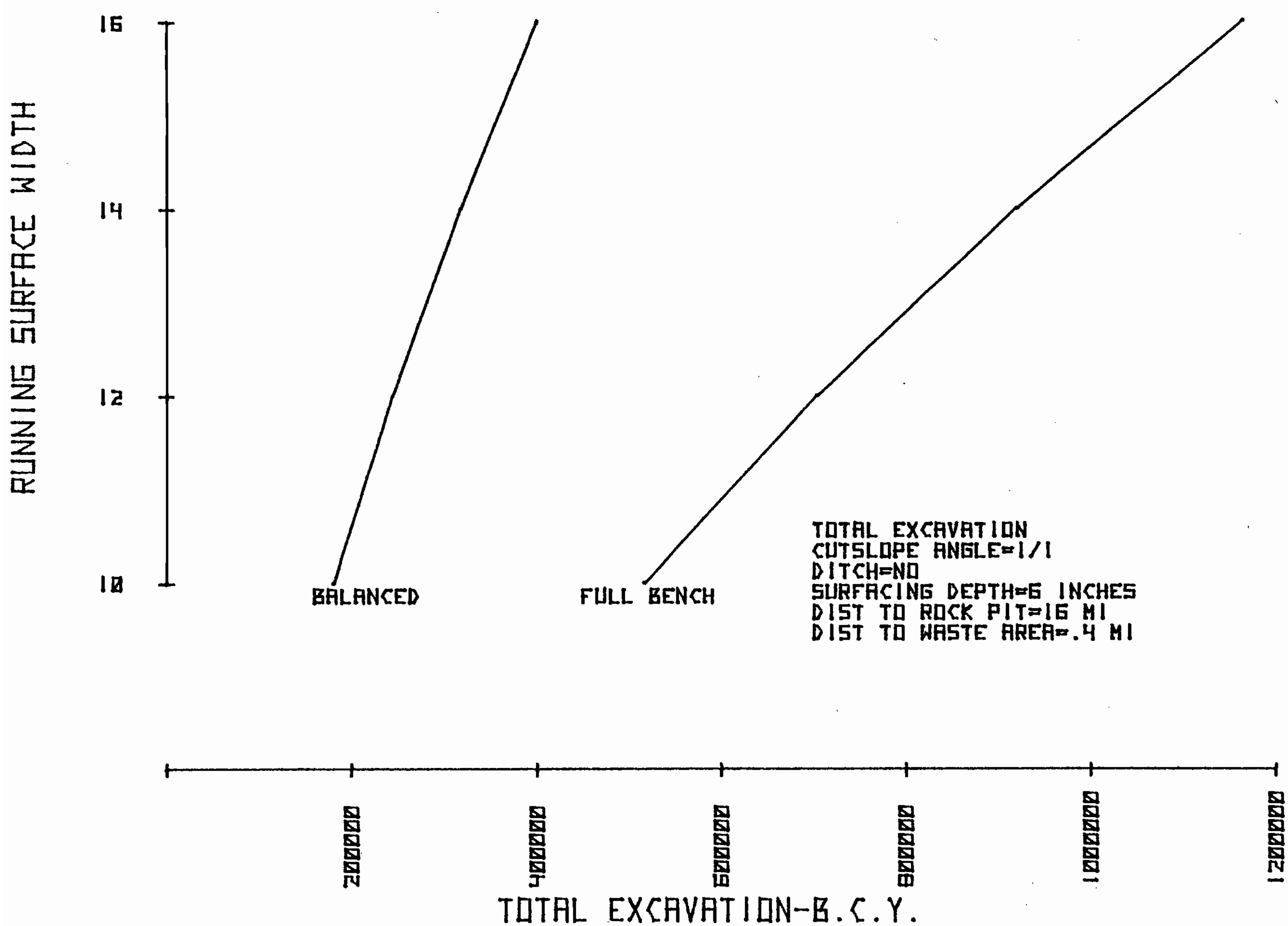

RUNNING SURFACE WIDTH
16
14
12
10
BALANCED
FB&S
FB&E
CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=3/4:1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI
DIST TO WASTE AREA=.4 MI
20000
40000
60000
80000
100000
120000
140000
160000
180000
CONSTRUCTION COST $/MILE

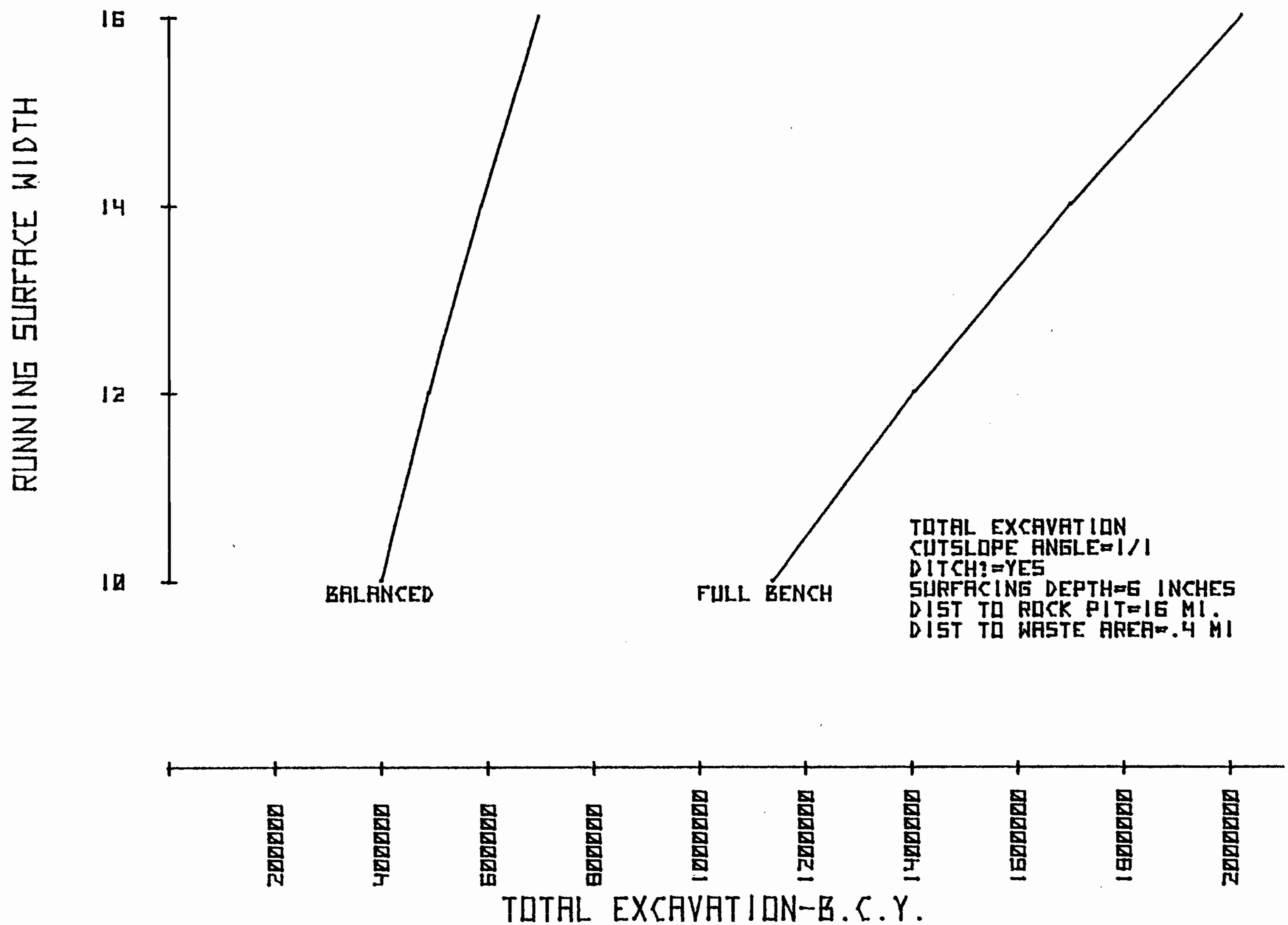

CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1/1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST. TO ROCK PIT=16 MI.
DIST TO WASTE AREA=.4 MI
FB&E
FB&S
BALANCED
10
12
14
16
RUNNING SURFACE WIDTH
20000
40000
60000
80000
100000
120000
140000
160000
180000
CONSTRUCTION COST $/MILE


CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1.25:1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI
DIST TO WASTE AREA=.4 MI
FB&E
FB&S
BALANCED
180000
160000
140000
120000
100000
80000
60000
40000
20000
CONSTRUCTION COST $/MILE
16
14
12
10
RUNNING SURFACE WIDTH


RUNNING SURFACE WIDTH
16
14
12
10
BALANCED
FB&S
FB&E
CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1.5:1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI
DIST TO WASTE AREA=.4 MI
20000
40000
60000
80000
100000
120000
140000
160000
180000
CONSTRUCTION COST $/MILE


RUNNING SURFACE WIDTH
16
14
12
10
BALANCED
FB&S
FB&E
CONSTRUCTION COST/MILE
CUTSLOPE ANGLE=1/1
DITCH?=NO
SURFACING DEPTH=6 INCHES
DIST. TO ROCK PIT=16 MI.
DIST TO WASTE AREA=.4 MI
20000
40000
60000
80000
100000
CONSTRUCTION COST $/MILE


RUNNING SURFACE WIDTH
16
14
12
10
BALANCED
FULL BENCH
TOTAL EXCAVATION
CUTSLOPE ANGLE=1/1
DITCH=NO
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI
DIST TO WASTE AREA=.4 MI
200000
400000
600000
800000
1000000
1200000
TOTAL EXCAVATION-B.C.Y.


RUNNING SURFACE WIDTH
16
14
12
10
BALANCED
FULL BENCH
TOTAL EXCAVATION
CUTSLOPE ANGLE=1/1
DITCH?=YES
SURFACING DEPTH=6 INCHES
DIST TO ROCK PIT=16 MI.
DIST TO WASTE AREA=.4 MI
200000
400000
600000
800000
1000000
1200000
1400000
1600000
1800000
2000000
TOTAL EXCAVATION-B.C.Y.

APPENDIX 8

USER'S GUIDE: ROAD COST PROGRAM (RCP)

PROCEDURE

The road cost program is a tool to quickly analyze paper plan road networks. Up to 110 segments may be analyzed on a single network. Due to memory limitations of the H.P. 9830, the program is divided into two parts connected by a link statement. The first program gathers and stores pertinent road data from the map using the H.P. 9864 digitizer. The second program analyzes the network based on road parameters supplied interactively by the user. Three output modes (short, medium and long) are available, depending on the amount of information wanted. The program evaluates each road segment using three construction methods.

1. Full Bench and Sidecast
2. Full Bench and Endhaul
3. Balanced Section

An example network evaluation using the RCP program is attached.

MATERIALS NEEDED

The following materials are needed to successfully run the RCP program.

1. Program tape
2. Data tape with files marked to a length of 2000 words
3. Contour map with road network and drainage areas shown

4. The following itemized information for each road segment
   a. depth to bedrock
   b. surfacing depth
   c. running surface width
   d. cutslope angle
   e. ditch (yes or no)
   f. distance to rock source
   g. distance to waste area
   h. clearing and grubbing difficulty

OPERATING NOTES

1. The length of each segment is very important. Segments should reflect similar conditions. To facilitate accurate evaluation, the following conditions should be relatively constant for each segment.
   a. road grade
   b. sideslope
   c. clear and grud difficulty
   d. depth to bedrock

   Significant changes in these four parameters within a segment will result in poor data, due to averaging. Of course, if the segments are too short, evaluation time will increase.
2. Since the RCP program can only evaluate 5 creeks per segment, segments should be broken up accordingly.
3. The decision concerning which of the 3 output modes to use depends on the needs of the user. The following is a description

of each mode.

-SHORT OUTPUT-

A. Total cost by construction type for each segment.

B. Accumulated total costs by construction type.

C. Accumulated total excavation by construction type.

D. Total network length.

-MEDIUM OUTPUT-

A. All data in short output.

B. Percent rock by construction type for each segment.

C. Total excavation by construction type for each segment.

D. Road cost per mile by construction type for each segment.

-LONG OUTPUT-

A. All data in medium output.

B. Itemized costs by construction type for each segment.

C. Itemized engineering data by construction type for each segment.

D. Miscellaneous internal variables used by construction type for each segment. These variables are useful as a check. They are defined at the end of the user's guide.

4. Additional output is available following the execution of the first program. The user interactively decides if the following two outputs are needed.

Stored Data Listing:

The stored data list shows the user all the parameter stored on tape for each segment. The following data for each segment is printed.

a. segment number

b. segment length in feet

c. segment grade in percent

d. sideslope in percent

e. bedrock depth in feet

f. clear and grub difficulty (low=1, medium=2, high=3)

g. creek number

h. creek grade in percent

i. area drained in acres

Unit Cost Listing:

The unit cost listing shows the user the following unit costs used in program number 2. These costs cannot be changed interactively by the user. They must be changed by altering the data statements in lines and in the first program.

a. clear and grub cost/acre (low, medium, high)

b. seeding cost/acre

c. mobilization cost/mile

d. excavation cost/c.y. (common and rock)

e. riprap cost/c.y.

f. fences and gate cost

g. purchase surfacing cost/c.y.

h. haul surfacing cost/c.y.

i. load and apply surfacing cost/c.y.

j. outlet pipe cost/l.f.

k. haul endhaul cost/c.y.

l. load endhaul cost/c.y.

5. RCP uses the code

Ø = no

1 = yes

EXAMPLE ROAD NETWORK

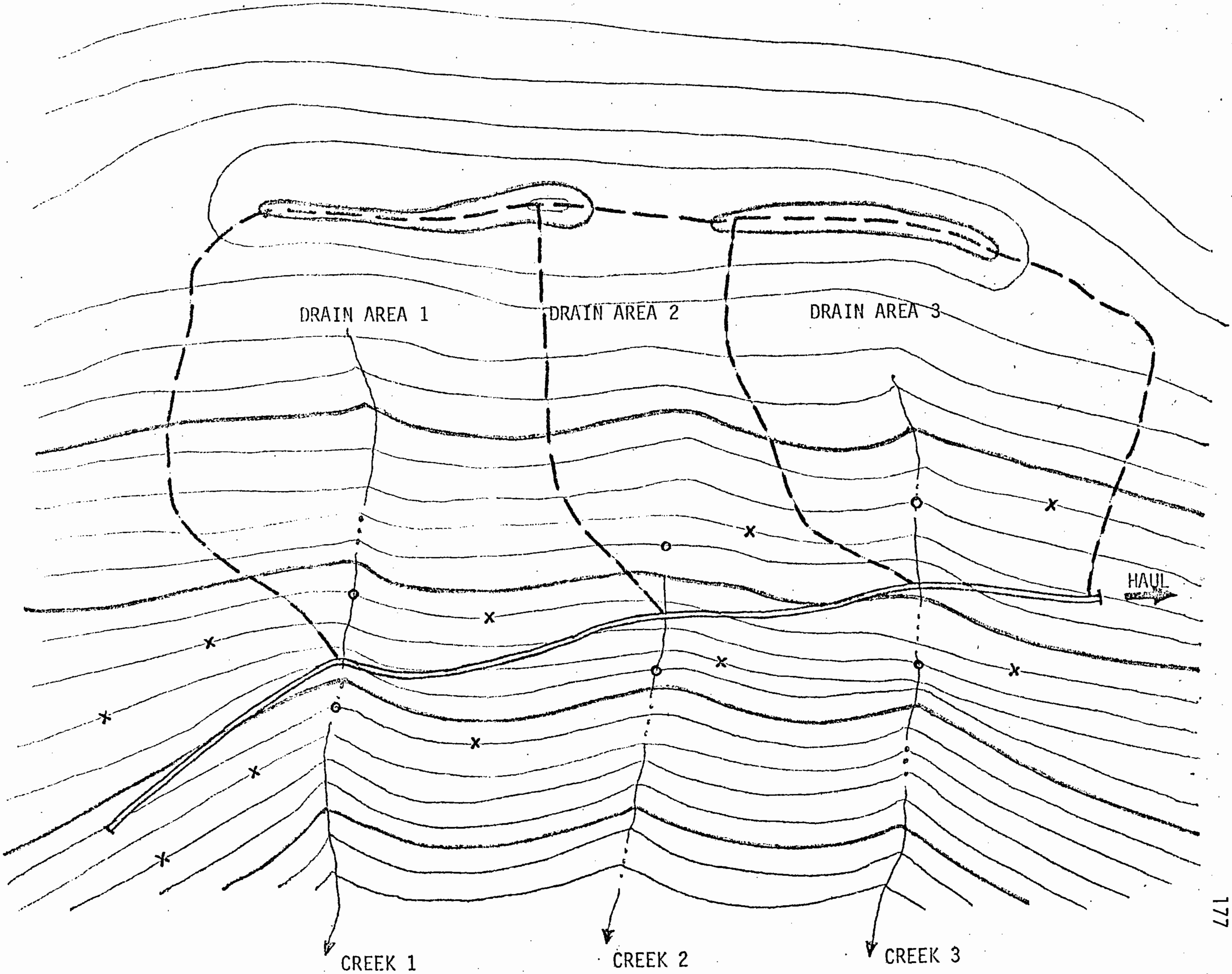
The following short road network of 1 segment is carried through the user's guide as an example.

Given:
1. The network on the map below
2. C & G difficulty - low
3. Bedrock depth - 4 feet
4. Running surface 14 feet with a ditch
5. Cutslope angle - 1:1
6. Surfacing depth (compacted) - .5 feet
7. Distance to rock pit - 18 miles
8. Waste area - .8 miles
9. Map scale - 1320' = 1 inch
10. Contour interval - 40'
11. Adverse grade
12. 3 creek crossings
13. Store in file #4
14. Road geometry is same

LOADING THE PROGRAM

1. Turn on H.P. 9830, H.P. 9865A peripheral cassette, H.P. 9864A digitizer and printer.
2. Press SCRATCH A, EXECUTE
3. Insert data tape into peripheral cassette and rewind.
4. Insert program tape in H.P. 9830 and rewind.
5. Press LOAD Ø, EXECUTE, then wait for "lazy tee" on display.
6. Press RUN, EXECUTE
7. Follow Visual Promptors on display.

The following program execution explanation uses the previously described example road network.



User's Guide Example Road Segment

VISUAL DISPLAY	KEYBOARD INPUT	DESCRIPTION
1) Seg. data already stored (1 or 0)	0	Press 1 if the data to be analyzed has already been digitized. If 0 is pressed, go to visual display number 3. If 1 is pressed, go to display #2.
2) File number	N.A.	Press the number of the file where the data is stored. Program jumps to visual display #21.
3) No. of Segments in Network	3	Press total # of segments in network
4) Map scale Feet/Inch	1320	
5) Contour interval in Feet	40	
6) Digitize segment "___"	None	Prompts the user that the program is ready to digitize.
7) Press S on cursor at end of segment	None	Follow display.
8) Now digitize the road in C mode	None	Digitize the road and stop when "beep" is heard. Press C again.
9) Now find average grade of road segment	None	Prompts the user that the program is ready to input road grade.
10) Favorable-1, Adverse=2, Level=3	2	Follow display.

VISUAL DISPLAY	KEYBOARD INPUT	DESCRIPTION
11) Number of contours crossed		Follow display.
12) Now find average sideslope of segment	None	Prompts the user that the program is ready to input sideslope.
13) Digitize contour above/below	None	Shown as "X's" on example problem Digitize with S on cursor. A contour above and below road segment. Contours must be 200' apart. Repeat 5 times/ segment.
14) Depth to bedrock in feet	4	Follow Display.
15) Number of creek crossings in segment	3	Follow display. If this number is 0, then go to display number.
16) Digit CK"j" grade	None	Shown as "O's" on example map. Prompts the user to digitize along the creek a contour above and below the road 200' apart on CK"j".
17) Set origin at point on drain area	None	Prompts the user to press O and S at a point on perimeter of drain area on creek "j".
18) Digitize area	None	Prompts the user to go around perimeter in C mode. Stop at "beep." Press C to stop.

VISUAL DISPLAY	KEYBOARD INPUT	DESCRIPTION
19) C & G difficulty (low=1, medium=2, high=3)	1	Follow display.
20) Store segment in file no.	4	Follow display - this refers to file # on peripheral cassette.
21) Want list of stored data (1 or 0)	1	Press 1 if you want listing.
22) Want unit cost listing (1 or 0)	1	Press 1 if you want listing.
PROGRAM NOW LINKS TO PART b. (TAPE WILL ADVANCE.)		
1) Road geometry same for all segments (1 or 0)	1	If 0 is pressed, go to display number 3.
2) Want segment data output (1/0)	1	If 0 is pressed, go to display #4.
3) Output (short=1, medium=2, long=3)	2	Follow display. Output depends on user needs.
4) Running surface width (ft.)	14	Follow display.
5) Cutslope factor (horizontal to vertical)	1	Follow display.
6) Is there a ditch (1 or 0)	1	Follow display 1-Yes 0=No.
7) No. of miles to surfacing pit	18	Follow display.
8) No. of miles to waste area	.8	Follow display.

VISUAL DISPLAY	KEYBOARD INPUT	DESCRIPTION
9) Bridge length in feet	N.A.	If a bridge is needed, this display will appear.

If the road geometry is different for each segment, display 4 to 9 will be repeated for each segment. If the road geometry is the same for the entire network, display numbers 4 to 9 will be displayed only once. The road geometry input will then be used for the entire road network. The following output was obtained for the example segment.

THIS PROGRAM WILL ACCEPT UP TO 90 SEGMENTS--COSTS AND ENGINEERING DATA ARE COMPUTED AND DISPLAYED FOR THE FOLLOWING CONST. METHODS

1.) FULL BENCH AND SIDECAST.
2.) FULL BENCH AND ENDHAUL.
3.) BALANCED CONSTRUCTION.

RD. NETWORK 1.00 HAS 1.00 SEGMENTS

****

SEG	LENGTH	GRADE(%)	SIDESLOPE(%)	BED-DEPTH	C AND G
1	10733	-3	14	4	1

CK. NUMBER	CK. GRADE(%)	AREA DRAINED(AC)
1	18	376
2	16	197
3	12	285

****
****

THE FOLLOWING AVERAGE COSTS ARE USED IN THE COST PROGRAM

C&G/ACRE LO=$2000 MED=$2300 HI=$2500
SEED/ACRE=$ 600.00 MOBILIZATION/MILE=$ 800.00
EXCAVATION/ACRE: COMMON=$ 2.90 ROCK=$ 11.00
RIPRAP/CY=$ 40.00 FENCES & GATES=$ 500.00
BUY SURFACING/CY=$ 1.10 HAUL SURFACING/CY=$ 0.28
LOAD AND APPLY SURFACING/CY=$ 2.80 OUTLET PIPE/LF=$ 18.50
HAUL ENDHAUL/CY=$ 0.28 LOAD ENDHAUL/CY=$ 1.60

(R.C.P.)-Short Output Example

COSTS AND ENGINEERING DATA FOR NETWORK# 1.00

****

SUBGRADE WIDTH	RUNNING WIDTH	CUTSLOPE ANGLE	SURFACING DEPTH	DITCH?
21.00	14.00	45.00	0.50	1.00

NO. OF MILES TO WASTE AREA= 0.80
NO. OF MILES TO SURFACING PIT= 13.00

****

SEG. #		FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
1.00	TOTAL COST	$ 107577.41	$ 81980.43	$ 56974.69

****

	FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
GRAND TOTAL COST	$ 107577.41	$ 81980.43	$ 56974.69
GRAND TOTAL EXC. (CY)	15128.24	15128.24	4593.54

TOTAL NETWORK LENGTH= 2.03 MILES

AVG. COST/MILE	$ 52921.71	$ 40329.51	$ 28028.17

****

COSTS AND ENGINEERING DATA FOR NETWORK# 1.00

****

SUBGRADE WIDTH	RUNNING WIDTH	CUTSLOPE ANGLE	SURFACING DEPTH	DITCH?
21.00	14.00	45.00	0.50	1.00

NO. OF MILES TO WASTE AREA= 0.50
NO. OF MILES TO SURFACING PIT= 18.00

****

SEG. #		FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
1.00	TOTAL COST	$ 107577.41	$ 81980.43	$ 56974.69
	TOTAL EXC. (CY)	15128.24	15128.24	4593.54
	PERCENT ROCK	0.00 %	0.00 %	0.00 %
	AVE. COST/MILE	$ 52921.71	$ 40329.51	$ 28028.17

CK. #	PIPE LENGTH	DIA(FT)	COST/LF	COST
1.00	55.71	5.00	$ 103.89	$ 5787.68
2.00	50.98	4.00	$ 65.49	$ 3338.93
3.00	50.06	4.50	$ 92.42	$ 4626.35

****

****

	FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
GRAND TOTAL COST	$ 107577.41	$ 81980.43	$ 56974.69
GRAND TOTAL EXC. (CY)	15128.24	15128.24	4593.54

TOTAL NETWORK LENGTH= 2.03 MILES

AVG. COST/MILE	$ 52921.71	$ 40329.51	$ 28028.17

****

COSTS AND ENGINEERING DATA FOR NETWORK# 1.00
(R.C.P.)-Long Output Example

****

SUBGRADE WIDTH	RUNNING WIDTH	CUTSLOPE ANGLE	SURFACING DEPTH	DITCH?
21.00	14.00	45.00	0.50	1.00

NO. OF MILES TO WASTE AREA= 0.80
NO. OF MILES TO SURFACING PIT= 18.00

****

SEG. #		FULLBENCH & ENDHAUL	FULLBENCH & SIDECAST	BALANCED SECTION
1.00	TOTAL COST	$ 107577.41	$ 81980.43	$ 56974.69
	TOTAL EXC. (CY)	15128.24	15128.24	4593.54
	PERCENT ROCK	0.00 %	0.00 %	0.00 %
	AVE. COST/MILE	$ 52921.71	$ 40329.51	$ 28028.17

ITEMIZED ENGINEERING DATA

COMMON EXC. (CY)	15128.24	15128.24	4593.54
ROCK EXC. (CY)	0.00	0.00	0.00
ACRES C & G	7.00	7.00	7.27
ACRES SEEDING	0.85	0.85	0.44
SURFACING(CY)	786.63	786.63	786.63
TURNOUT#	10.00	10.00	10.00
OUTLET PIPE(LF)	283.88	283.88	283.88
RIPRAP(CY)	3.00	3.00	3.00

ITEMIZED COSTS

COMMON EXC.	$ 43871.90	$ 43871.90	$ 13321.27
ROCK EXC.	$ 0.00	$ 0.00	$ 0.00
SEEDING	$ 507.67	$ 507.67	$ 261.35
C&G	$ 13992.84	$ 13992.84	$ 14532.23
OUTLET PIPE(18)	$ 5251.82	$ 5251.82	$ 5251.82
RIPRAP	$ 180.00	$ 180.00	$ 180.00
MOBILIZATION	$ 1626.21	$ 1626.21	$ 1626.21
ENDHAUL	$ 25596.98	$ 0.00	$ 0.00
SURFACING	$ 7032.47	$ 7032.47	$ 7032.47
FENCES & GATES	$ 1016.38	$ 1016.38	$ 1016.38
LARGE PIPE	$ 13752.96	$ 13752.96	$ 13752.96

MISCELLANEOUS FULL BENCH VARIABLES

W1= 0.00	W2= 0.00	W3= 0.00	W4= 0.00	W5= 0.00
W6= 28.40	W7= 3.43	F2= 0.00	H1= 0.00	H2= 0.00
H3= 0.00	H4= 0.00	H5= 38.06	H6= 135.00	H7= 37.00

MISCELLANEOUS VARIABLES BALANCED SECTION

Q= 25.69	R= 55.43	F1= 53.00	T1= 28.74	T= 10.81
E1= 0.09	E2= 0.00	E3= 0.00	E4= 0.00	E5= 0.00
E6= 0.00	E7= 0.00	E8= 0.00	E9= 0.00	E0= 0.00
T2= 0.00	T4= 0.00	P1= 2.00	Z8= 0.07	Z9= 11.56
K=-37.67	A=-0.02	B= 3.74	M4= 1.77	M5= 12.91
M6= 13.04				

CK #	PIPE LENGTH	DIA(FT)	COST/LF	COST
1.00	55.71	5.00	$ 103.89	$ 5787.68
2.00	50.98	4.00	$ 65.49	$ 3338.93
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

GRAND TOTAL COST	$ 107577.41	$ 81980.43	$ 56974.69
GRAND TOTAL EXC. (CY)	15128.24	15128.24	4593.54
TOTAL NETWORK LENGTH= 2.03 MILES			
AVG. COST/MILE	$ 52921.71	$ 40329.51	$ 28028.17