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# ROUTES: A Computer Program for Preliminary Route Location

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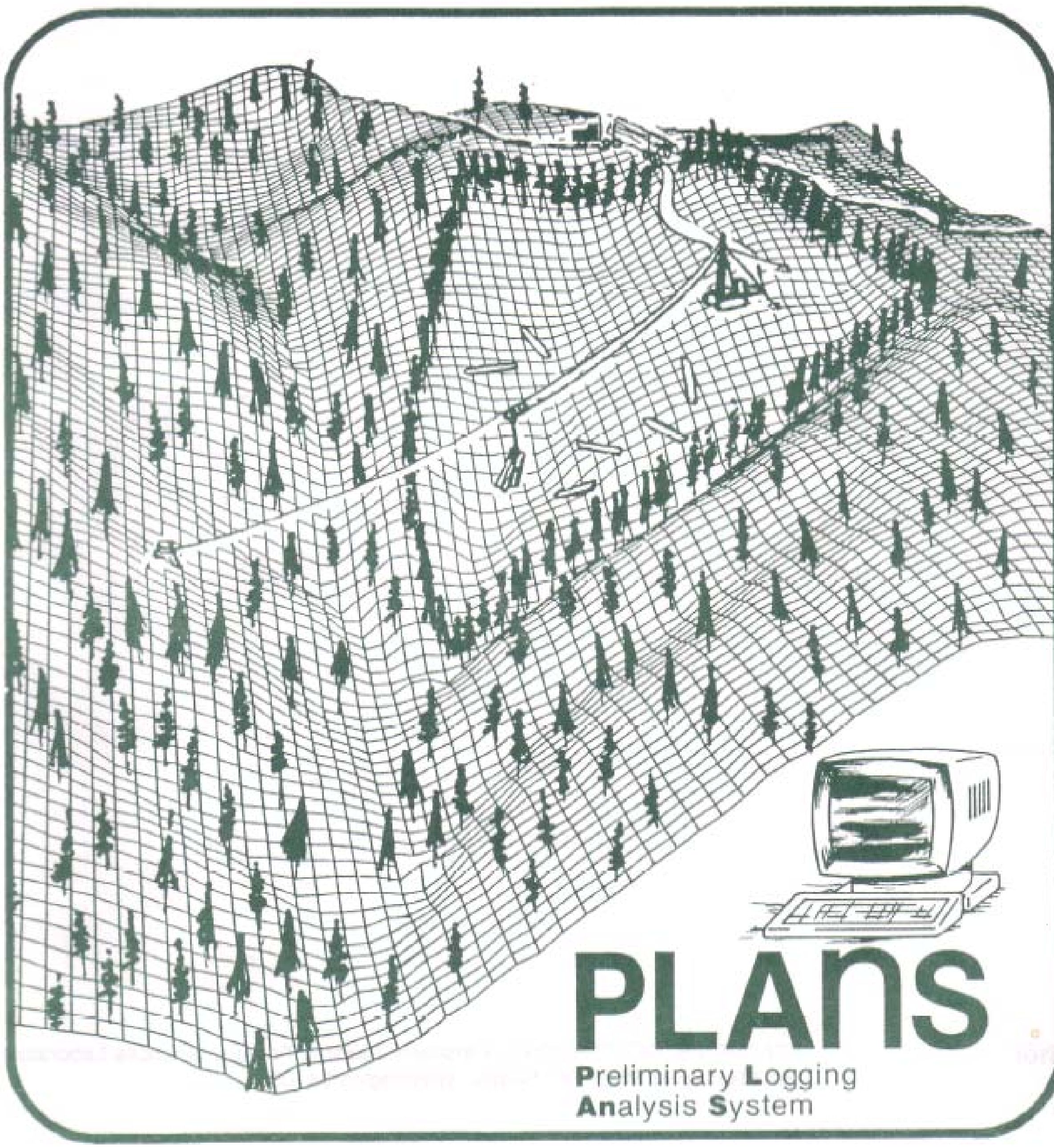

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## Abstract

**Reutebuch, Stephen E. 1988.** ROUTES: a computer program for preliminary route location. Gen. Tech. Rep. PNW-GTR-216. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

An analytical description of the ROUTES computer program is presented. ROUTES is part of the integrated preliminary harvest- and transportation-planning software package, PLANS. The ROUTES computer program is useful where grade and side-slope limitations are important in determining routes for vehicular travel. With the program, planners can rapidly identify route locations on large-scale topographic maps. The program uses a digital terrain model, created by using the MAP computer program in the PLANS package, to produce profile plots and estimates of grades and sides lopes along projected routes. A separate appendix containing detailed instructions for running the ROUTES program is available on request.



Keywords: Timber harvest planning, computer programs/programing, digital terrain model, road location/design.

# Contents

## Introduction

A computer program is presented that projects gradelines on topographic maps through the use of digital terrain data. By using the program ROUTES, a planner can rapidly develop and evaluate alternative, preliminary locations for logging roads through mountainous terrain.

### Background

Development of a forest road system usually begins with selecting the routes. "Route" is defined as "... a road line such as is projected on a map or aerial photograph or a reconnaissance or grade line run in the field. It [the route] represents a narrow belt of land within which minor variations in gradient or alignment may be made during the preliminary or final location survey" (Pearce 1960). Route selection traditionally starts with available topographic maps and aerial photographs of the planning area. Manual techniques for projecting gradelines onto maps have been used for years and are well documented in the literature (Holmes 1982, Pearce 1960, USDA Forest Service 1984). The planner uses the map as a geometric model and attempts to select possible routes before resources are committed to costly field investigations.

The planner measures a series of coordinate points to establish a particular route on the geometric model and to calculate attributes of the route, such as grades, distances, sideslopes, cuts, and fills. The attributes are used to compare alternative routes. This map-based selection of routes aids the planner in setting priorities for where and how much field investigation should be done to check each possible route. If the process is thoroughly and carefully carried out, days or even weeks of field work can be saved. Even greater savings are likely if an exhaustive paper study of alternative routes is done because of improvements in the road system that are identified when several possibilities are examined in detail. These savings are associated with better grades and alignment; which can result in lower construction and maintenance costs of the road and in lower operating and maintenance costs for vehicles on the road. With thorough investigation of alternative routes, the quality of decisions improves.

Given the benefits of a thorough investigation of alternative routes, why do some planners avoid it? The sheer volume of work required is, unfortunately, often beyond the capacity of the available staff. Frequently, a route is' selected not because it is the best but because sufficient time is not available for finding alternatives.

### Digital Terrain Model —A Computerized Map

By using a computer to convert terrain data from maps and photos into digital form, the planner can rapidly develop and evaluate many route alternatives. Figure 1 represents a gridded digital terrain model (DTM). After a DTM of the project area is produced, the planner can superimpose any number of routes on it. The computer can automatically extract ground coordinates from the DTM and compute grades, distances, elevations, and sideslopes along the routes and provide plan and profile plots of the routes in a fraction of the time needed to do these tasks manually.

Burke (1974) was one of the earliest proponents of constructing DTMs for harvest and transportation planning, and Young and Lemkow (1976) developed several planning routines that rely on DTMs for terrain data. Both of these early attempts demonstrated that terrain data could be efficiently converted into digital form, stored, and manipulated. Both attempts were severely limited, however, by the computer technology of the day.

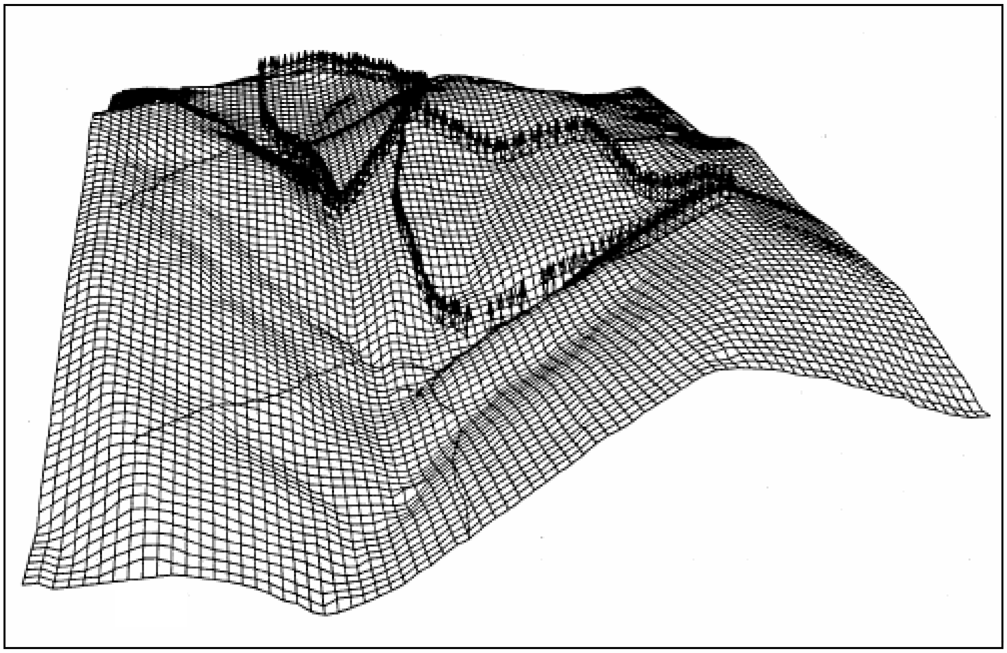

Figure 1—Perspective plot of a gridded digital terrain model.

Computer hardware is no longer a limitation. In the early 1980's, Reutebuch (1981) and Twito (1982) independently developed automated approaches to cable systems planning that were not limited by computing hardware; however, neither successfully addressed the problem of route location using a DTM. Mifflin (1980) developed a DTM-based route-location routine based on concepts developed by Lemkow (1977). Mifflin's routine requires the user to specify the general direction of the route by identifying numerous control points. An algorithm attempts to find a line of constant grade between these control points. Mifflin did not resolve several problems associated with switchbacks, mismatching of the map and the DTM, routes attempting to leave the DTM area, overshooting control points, and crossing areas of flat terrain along a predominantly steep route. All these problems resulted from relying on an algorithm, rather than the user's visual abilities and experience, to guide the direction of the route.

The route-projection routine reported in this paper expands on another concept put forth by Lemkow (1977). The problems encountered by Mifflin are avoided by relying on the user, not an algorithm, to control the direction of the route.

## The ROUTES program

We developed the ROUTES computer program so that the planner can rapidly develop and evaluate route locations based on digital terrain data. The program was developed on the Hewlett-Packard 9020 computer in BASIC 2.0 language.[1] Besides the microcomputer, a printer, a graphics plotter, and a digitizer tablet are needed to execute the program. The program is one in a series, referred to as PLANS (preliminary logging analysis system), developed by the Forest Engineering Systems research work unit of the Pacific Northwest Research Station, USDA Forest Service (Twito and others 1987).

### Sources of Digital Terrain Data

To use the ROUTES program; the planner must obtain a topographic map of the project area and build a DTM of that area. A topographic map with a maximum contour interval of 40 feet and a scale no greater than 1 inch to 1,000 feet should be used for the data source of the ROUTES program.

The DTM is built from the MAP program included in the PLANS package. The topographic map is taped to the digitizer and the project area delineated. Each of the contour lines within the project area is traced. From these data, the MAP program produces a gridded DTM of the project area and stores it in a file for later use by the ROUTES program.

Any DTM from an outside source, such as a U.S. Geological Survey digital elevation model (DEM), that has been converted to the PLANS DTM format can be used by the ROUTES program; however, the PLANS package cannot convert DTMs from outside sources to the PLANS format.

### Preliminary Route Location

In a typical run of the ROUTES program, the topographic map of the project area, with the boundary of DTM coverage marked on it, is taped to the digitizer tablet, and the DTM is loaded into the computer. When the planner moves the digitizer cursor around on the project-area map, the ROUTES program simulates the field locator "walking" on the DTM surface. The cursor can be thought of as a field locator-equipped with a compass, altimeter, clinometer, and tape-that automatically takes measurements while moving over the project-area map.

As the cursor moves, its planimetric position on the project-area map, expressed as an x-v coordinate, is automatically sent by the digitizer to the computer several times a second. When given a point location for the cursor in the horizontal plane, the ROUTES program extracts the elevation of the point from the DTM. With the elevations and locations of successive cursor locations known, grades and distances between points along the path of the cursor can be computed and displayed. These basic calculations are the building blocks of the ROUTES program.

### ROUTES Program-Control Menu

The planner controls the program flow by selecting one of the menu options shown in figure 2. Whenever this menu is displayed on the computer screen, the planner can select any of the nine options by pressing the corresponding number on the digitizer cursor keypad. By using the digitizer cursor instead of the terminal keyboard, the planner can remain at the digitizer throughout the session. This eliminates the need to switch back and forth between the digitizer and the keyboard and allows the planner to look at the map while a route is being projected.

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[1] Use of a trade name does not imply endorsement or approval of any product by the USDA Forest Service to the exclusion of others that may be suitable.

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THESE ARE YOUR OPTIONS:

1  PLOT THE PROFILE VIEW OF THE CURRENT ROUTE SEGMENT
2  SPOT CHECK THE CURRENT ROUTE SEGMENT USING THE DIGITIZER CURSOR
3  PRINT THE CURRENT ROUTE SEGMENT SUMMARY
4  ESTIMATE GRADES AND DISTANCES ALONG A ROUTE
5  ENTER A NEW SET OF GRADE LIMITS
6  LAY OUT A ROUTE SEGMENT USING THE SPECIFIED GRADE LIMITS
7  PLOT THE PLAN VIEW OF ANY ROUTE SEGMENT ON THE PLOTTER
8  DELETE A ROUTE SEGMENT
9  TERMINATE THE PROGRAM
```

Figure 2—ROUTES program-control menu. A menu activity is selected by pressing the corresponding key on the digitizer cursor keypad.

## Using the ROUTES Program

The ROUTES program performs three planning functions that rely on measurements taken from topographic maps:

1. Estimating grades and distances between control points;

2. Projecting gradelines at grades selected by the planner;

3. Determining grades, distances, and sideslopes along existing roads.

**Estimating the grade between control points**—The planner usually begins the route-location process by identifying and marking control points on a topographic map of the planning area. Control points include landings, stream crossings, saddles, and junctions with existing roads that must be interconnected by a road, as well as rock outcrops, swamps, and unstable sites to be avoided.

Certain steps are followed to estimate the grades and distances between control points. Menu option 4, the grades and distances estimation routine (see fig. 2), is selected. The digitizer cursor is moved to the start of the route. With the cursor centered over the start point, cursor key *_ is pressed. The planner moves the digitizer cursor along the approximate route that looks most feasible. As the cursor reaches each control point, cursor key 1 is pressed. The distance and grade from the previous control point is printed, along with the total distance from the start of the route to the control point. When the cursor arrives at the end of the route, cursor key # is pressed, and a table of grades and distances along the route is produced.

**Projecting a gradeline**—After estimates of grade are obtained for a route, the planner must enter the target grade limits. This is done by selecting menu option 5, the routine to change grade limits. Menu option 6, the gradeline projection routine (see fig. 2), can then be used to layout the route on the topographic map. The technique is analogous to a person in the field setting an abney level to the selected grade and working up or down the hillside from the first control point to the second control point and so on.

The cursor is set at the start of the route and cursor key 1, 2, or 3 is pressed. Cursor key 1 is pressed if the route ascends to the next control point, cursor key 2 is pressed if the route rolls, and cursor key 3 is pressed if the route descends.

As the planner moves the cursor away from the first control point in the general direction of the second control point, the cursor position is automatically sent to the computer, the elevation is determined using the DTM; and the grade is computed. This computed grade is compared with the target grade for the route section. Beeps from the computer tell the planner whether the moving cursor is on-grade. If the cursor is too low on the hillside, low-pitched beeps prompt the planner to move the cursor up the slope. If the cursor is too high on the hillside, high-pitched beeps prompt the planner to move the cursor down the slope. If the cursor is on-grade, a single medium-pitched beep is emitted and the coordinates of the cursor location are recorded.

This process is repeated until the cursor arrives at the second control point. The planner may then enter a different target grade, by pressing cursor key 5, and continue to the third control point and so forth until all route sections have been projected. At any point during projection, the grade of the route can be changed from ascending to either rolling or descending by pressing cursor key 1, 2, or 3.

When the end of the route is reached, cursor key # is pressed. The planner can obtain profile- and plan-view plots of the route and a tabular listing of the grades, distances, elevations, and sideslopes along the route by selecting options 1, 2, 3, and 7, respectively, from the program menu.

Estimating grades and distances—The planner may want to estimate the grades, distances, and sideslopes along an existing route to, for example, compute the travel time of log truck traffic. To get these estimates, the planner first traces the existing route with the digitizer cursor (see "Estimating the grade between control points," above).

Menu option 1 is selected, and a paper copy of the profile plot of the route is made. The points where major grade breaks occur along the route are identified by using a straight edge (fig. 3).

Menu option 7 is selected next, and a plan-view plot of the route is generated and overlaid onto the map. This allows the planner to accurately mark points on the map where major breaks in grade occur.

The planner traces the route for the second time by using the grade-estimation routine (menu option 4). When the cursor passes over a grade break marked on the map, cursor key 1 is pressed, and the grade and distance from the previous grade break are computed. When the cursor arrives at the end of the route, cursor key # is pressed, and a table of grades and distances along the route is produced.

The program can also generate a table showing the breakdown of the route by sideslope classes. This sides lope summary of an existing road is obtained by selecting the route-summary routine (menu option 3) immediately after an existing route has been traced.

## Storage of Gradeline Data

Gradeline data generated by the ROUTES program is stored in files that can be recalled and edited in the future. This feature allows the planner to begin developing a road network at one time and continue later without rerunning previously analyzed gradelines. The planner can delete individual, discarded route segments from the network in deference to more promising routes.

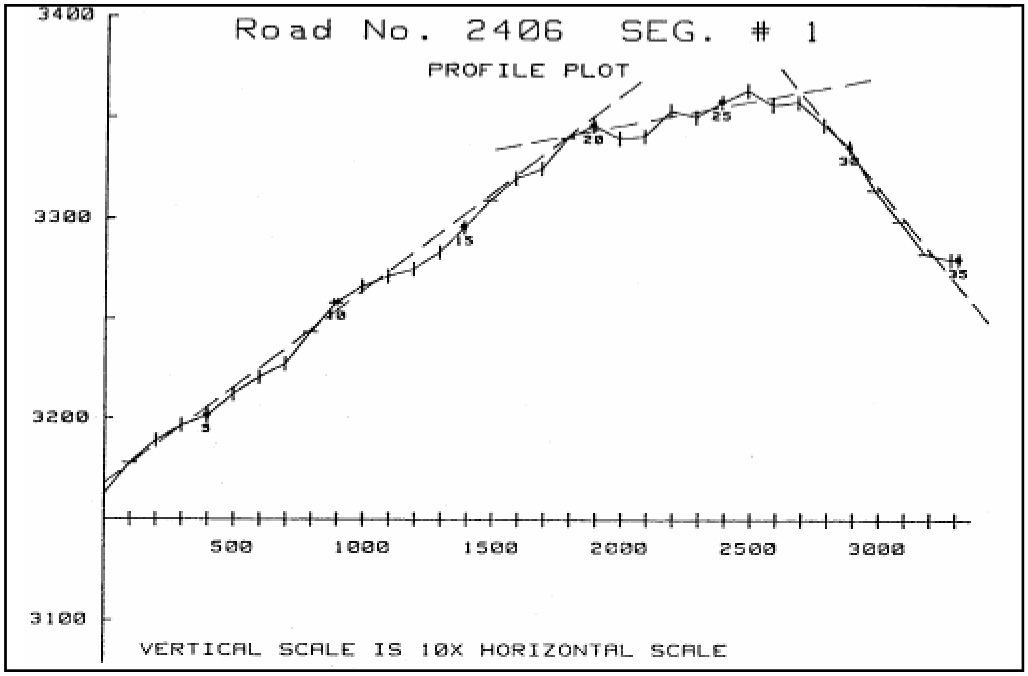


Figure 3—Major breaks in grade can be identified from a profile plot of an existing road. The road was traced after selecting the grade-estimate routine.

When the planner initiates work on a project area, the ROUTES program creates a file, for storing gradeline data. Up to 20 gradelines can be stored in a project data file, and up to eight files can be stored on one flexible disk. Each gradeline is given a number (1 to 20) for identification. During the grade-estimation routine (menu option 4), the X-Y coordinates of the path traced with the digitizer cursor are stored by route number in the project file. During the gradeline projection routine (menu option 6), the X-Y coordinates of the final gradeline are stored. If the same route-identification number is used for two or more route segments within the same project file, only the coordinates of the most recently traced route are stored.

Option 8 on the program menu allows the planner to selectively delete individual gradelines from the project file. The planner can delete entire project data files when the program ends.

## Analytical Description

A brief description of the basic algorithms used in the ROUTES program follows. These algorithms have been used for decades by planners to estimate grades and distances and to project gradelines on topographic maps.

**Grade- and distance-estimation routine**—The grade-estimation routine estimates the grade and distance between a series of user-selected control points. The cursor is positioned at the start of the first section of the route ($X_1, Y_1, Z_1$). $X_1$ and $Y_1$ are measured by the digitizer and $Z_1$ is extracted from the DTM. The planner moves the cursor away from the start of the route and the XYZ coordinates of its new location are updated. The distance it has traveled is computed by:

$$d_n = d_{(n-1)} + [(X_n - X_{(n-1)})^2 + (Y_n - Y_{(n-1)})^2]^{0.5} \; ; \qquad (1)$$

where n = the cursor location number, and

$d_n$ = the horizontal distance the cursor has moved from the start of the route section to the *nth* cursor location.

The grade from the start of the route section to the current position of the cursor is computed by:

$$g_n = [(Z_n - Z_1)/d_n] \times 100\% \; ; \qquad (2)$$

where $g_n$ = the grade from the start of the route section to the *nth* cursor location.

As the cursor is moved farther in the general direction of control point 2, new XYZ coordinates for its location are automatically obtained. For each new cursor location, the incremental distance moved since its previous location is computed using equation (1), and the grade from the start of the route section is computed using equation (2).

When the cursor reaches the second control point, the user presses any cursor key, and the grade from the first to the second control point is printed out. This second control point then becomes the starting location of the second section of the route. This process is repeated until a line connecting all control points in the route has been traced. A table containing the grade and length of each section of the route is produced (fig. 4).

PROJECT NAME: Road No. 2406
ROUTE NUMBER: 1

| GRADE-BREAK POINT | SECTION GRADE (%) | SECTION LENGTH (FT) | SECTION LENGTH (MI) | RUNNING DISTANCE (FT) | RUNNING DISTANCE (MI) |
|---|---|---|---|---|---|
| START | | | | 0 | 0.00 |
| | 2.8 | 1353 | 0.26 | | |
| 1 | | | | 1353 | 0.26 |
| | 10.2 | 1230 | 0.23 | | |
| 2 | | | | 2583 | 0.49 |

THE OVERALL GRADE FROM START TO END OF ROUTE IS 6.3%

Figure 4—Grade and distance estimates produced by the ROUTES program.

```
WHEN A GRADELINE IS LAID OUT, THE FOLLOWING CURSOR KEYS
ARE USED TO SELECT THE DESIRED GRADES:

KEY    GRADE-PROJECTION MODE

-1-    CLIMB AT ANY GRADE BETWEEN 8.0 % AND 10.0 %

-2-    ROLL THE GRADE AT ANY GRADE BETWEEN -4.0 % AND 2.0 %

-3-    DESCEND AT ANY GRADE BETWEEN -12.0 % AND -12.0 %

PRESS CURSOR KEY -5- TO CHANGE ANY OF THESE GRADES
```

Figure 5—The table of grade limits used by the gradeline-projection routine (menu option 6). These grade limits can be changed by the user at any time.

Gradeline-projection routine—After the user has an estimate of the required grades between control points, the gradeline can be projected on the map by using the gradeline-projection routine. The planner enters a set of grade limits (a set for climbing sections of the route, a set for rolling sections, and a set for descending sections of the route) within which the grade of the route IS maintained. Each set of grade limits contains the maximum and minimum grade the gradeline must stay between as it is projected on the map (fig. 5). For instance, the planner may want the grade of climbing sections of a route to be in the range of +8 to +10 percent. To specify this range, the planner enters the maximum allowable climbing grade as +10 percent and the minimum allowable climbing grade as +8 percent. If the planner wants a discrete grade of -12 percent, rather than a grade range for descending sections, 12 percent is specified for both the maximum and minimum allowable descending grades. The gradeline projection routine allows the planner to change these grade limits at any time before or during the projection procedure. The planner may also change the grade from climbing to rolling or descending at any time as the route is being projected by simply pressing the appropriate digitizer cursor key.

After the target grade limits have been entered, the planner centers the digitizer cursor over the starting point of the route and presses cursor key 1, 2, or 3. Cursor key 1 is pressed if the route climbs from its starting point to the second control point, cursor key 2 is pressed if this first section of the route is rolling, and cursor key 3 is pressed if it is descending. The starting point of the route is the first control point in the route segment and is assumed to be on-grade. The digitizer sends the X-Y coordinates of the cursor to the computer, and the program determines the elevation of the starting point ($Z_s$) from the DTM. The planner then moves the cursor in the general direction of the next control point. As the cursor moves, its coordinates

$(X_c,Y_c)$ are continually sent to the computer and its elevation $(Z_c)$ is computed from the DTM. Given the coordinates and elevation of the starting point and the cursor location, the distance $(d_c)$ and grade $(g_c)$ from the starting point of the route to the cursor can be computed by using equations (3) and (4):

$$d_c = [(X_c - X_s)^2 + (Y_c - Y_s)^2]^{0.5} ; \qquad (3)$$

where $d_c$ = the horizontal distance from the current cursor position to the previous point that was on-grade,

$(X_c,Y_c$ = the coordinates of the current cursor position, and

$(X_s,Y_s)$ = the coordinates of the previous cursor position that was on-grade;

and

$$g_c = [(Z_c - Z_s)/d_c] \times 100\% ; \qquad (4)$$

where $g_c$ = the grade between the previous cursor position that was on-grade and the current cursor position,

$Z_c$ = the elevation at the current cursor location, and

$Z_s$ = the elevation of the previous point that was within the current grade limits.

This trial grade, $g_c$ is checked to see if it falls within the target grade limits:

$$(g_l - T) < g_c < (g_u + T);$$

where $g_l$ = the lower grade limit,

$g_u$ = the upper grade limit, and

T = the allowable tolerance (2 percent is the tolerance value used in the program) .

If the trial grade lies within this range, its coordinates are retained and it becomes the base point $(X_s,Y_s,Z_s)$ that subsequent trial grades are computed from. If it does not lie in this range, the coordinates of the current cursor location $(X_c,Y_c,Z_c)$ are discarded and a series of beeps tells the planner that the grade to the current cursor position is either too steep or too low.

This process of computing and checking the trial grade and signaling the planner is continually repeated for subsequent cursor locations as the planner reacts to the pitch of the beeps. At any time, the planner may change the target grade limits by pressing cursor key 5 and entering a new set of limits. Also, the grade projection mode can be switched between climbing, rolling, and descending by pressing cursor key 1, 2, or 3 as the route progresses from one control point to the next.

If the projected grade misses a control point, the planner can back up to the previous grade-change point by pressing cursor key 0. The grade limits can then be adjusted and the route section rerun.

This process of moving the cursor up and down the slope in response to high- and low-pitched beeps results in a preliminary gradeline that contains randomly spaced points within ±2 percent of the grade limits.

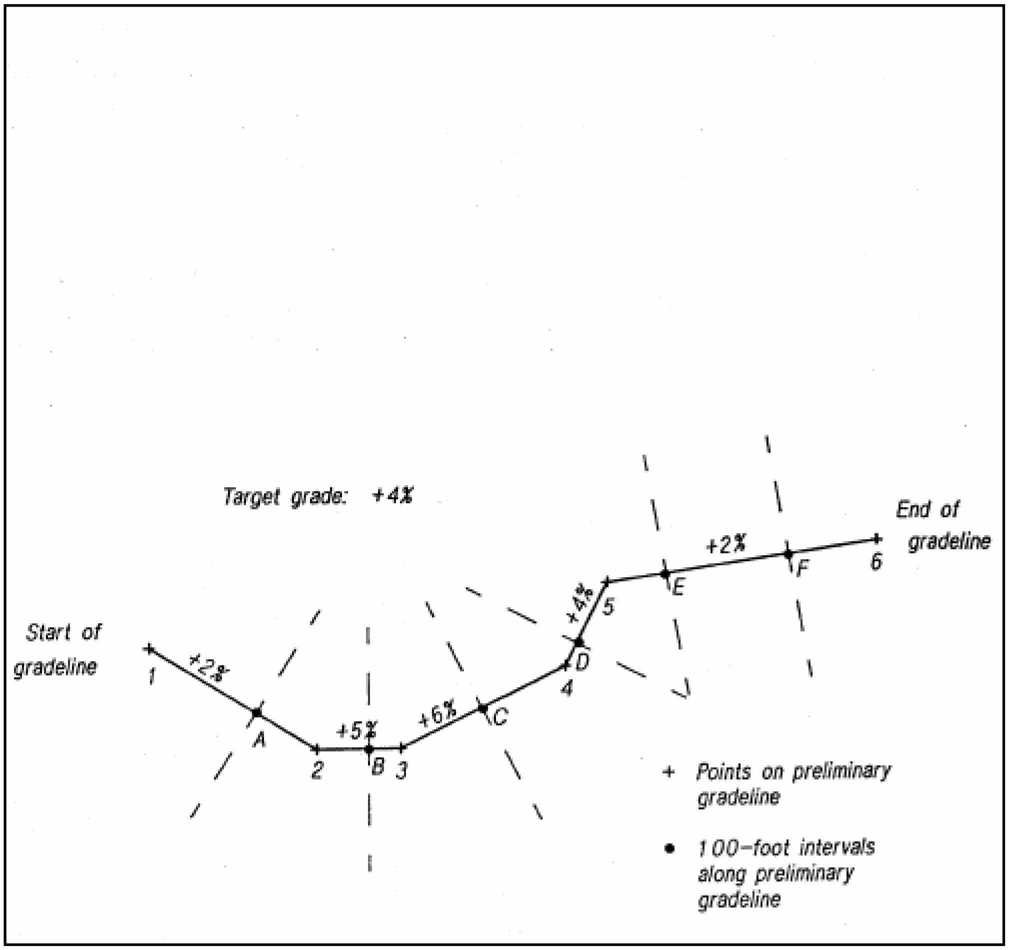


Figure 6—Plan view of the preliminary gradeline with perpendiculars at evenly spaced intervals.

At 100-foot intervals along the preliminary grade line, perpendiculars are constructed (fig. 6). A search is made along each of these perpendiculars to locate a terrain point such that the result is a grade within the grade limits (fig. 7). A terrain point that lies on-grade (+4 percent) could not be found along the perpendicular at point C in figure 7. Here, the depth of the cut needed at point C to achieve the target +4 percent grade is computed (fig. 8). Required fill depths are measured similarly.

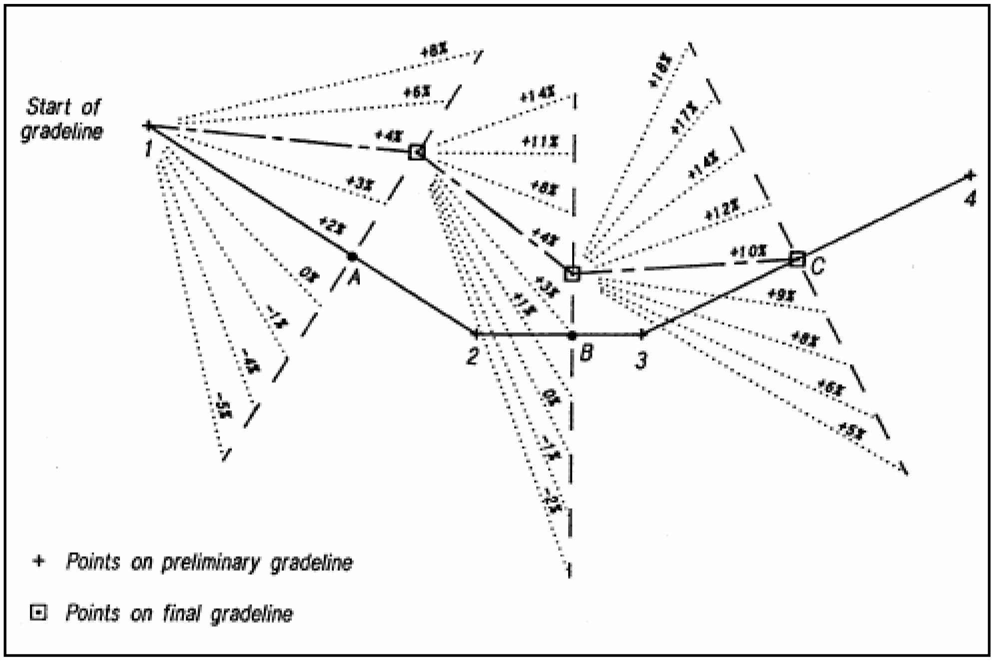


Figure 7—Plan view of the search pattern used to find terrain points that are on-grade (+4 percent here) at about 100-foot intervals along the final gradeline, An on-grade terrain point could not be found at point C along the perpendicular,

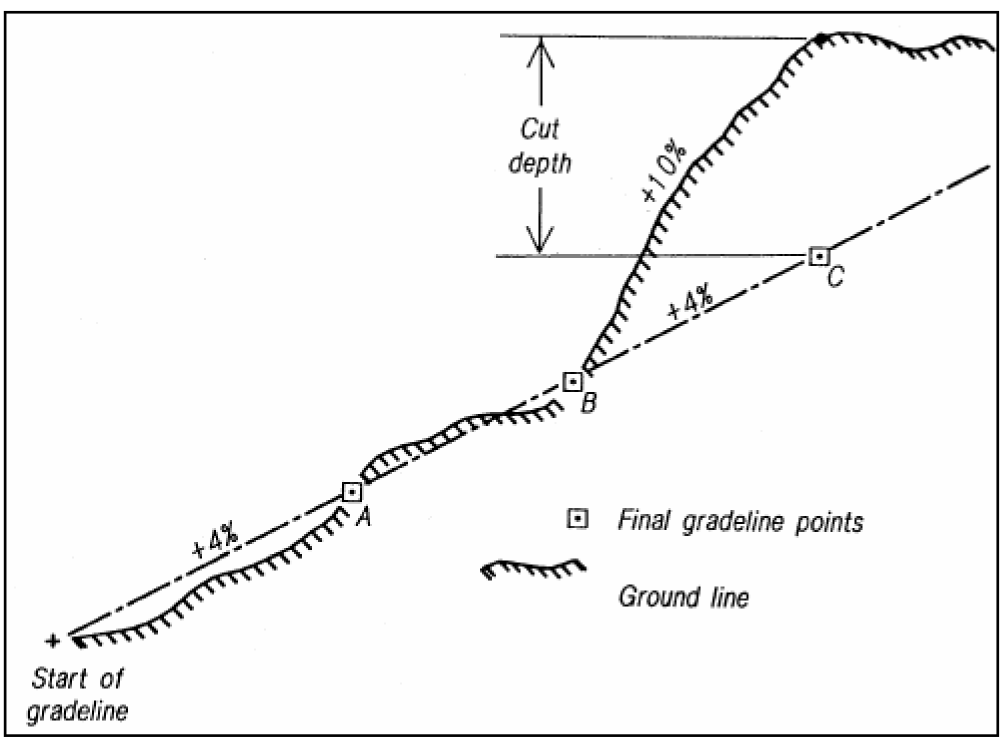


Figure 8—Profile view to illustrate how cut depth is measured when an on-grade terrain point cannot be found.

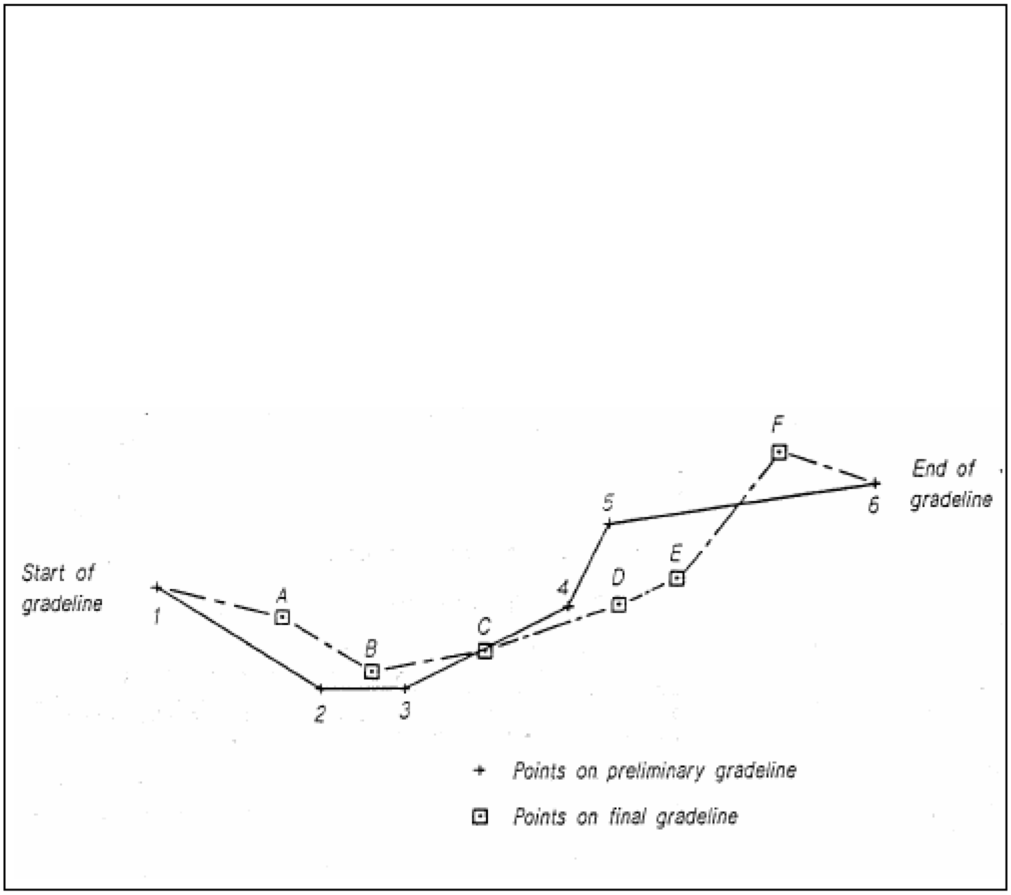


Figure 9—Plan view of the final gradeline location superimposed over the preliminary grade line location. The starting and ending points must be the same for both gradelines.

In figure 9, the final gradeline is superimposed on the preliminary gradeline. The routine always forces the final gradeline to terminate at the last point on the preliminary gradeline, so a cut or fill is often needed to get on-grade at the end of the route.

After the coordinates of each point on the final gradeline have been found, a profile plot of the route can be made by selecting menu option 1 (fig. 10). The plot routine allows the planner to choose the amount of vertical exaggeration for this profile plot. An exaggeration factor of 5 results in well-proportioned plots in steep terrain. A factor of 10 is more appropriate in relatively flat terrain.

Menu option 2 produces a plan view of the preliminary gradeline on the computer screen. The location of the digitizer cursor within the map area is represented on the plot by a small, flashing cross. As the digitizer cursor is moved, this small cross moves about the plot. By positioning the digitizer cursor at critical control points along the route, the planner can quickly determine if the final gradeline passes through these points.

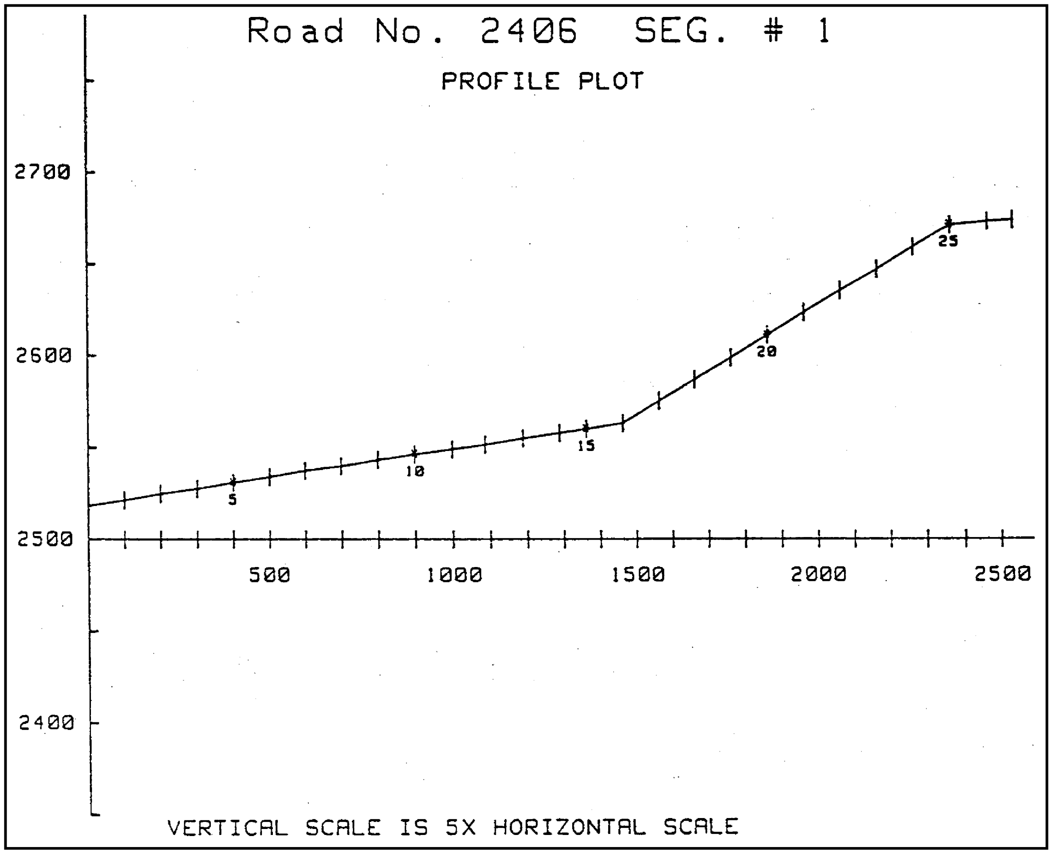


Figure 1—The route profile plot produced by the ROUTES program.

Menu option 3 produces a tabular summary of the stationing, elevations, grades, cuts and fills, and sideslopes along the final gradeline (fig. 11). Also included is a sideslope summary table that breaks the route into 10-percent sideslope classes. The table is often useful to the engineer making rough estimates of construction costs. The sideslope at each point along the gradeline is the maximum sides lope found when slopes are computed from the gradeline point to the perimeter of a circle 100 feet in diameter that has its center at the gradeline point (fig. 12).

Menu option 7 produces a plan-view plot of the final gradeline, at map scale, on the graphics plotter (fig. 13). This plot can be transferred to the topographic map, and the location of each terrain point on the gradeline plot can be marked. This allows the planner to quickly correlate the tabularized route data (fig. 11) with actual locations on the map. Areas where large cuts or fills are needed or areas where sideslopes are steep can be marked on the map and evaluated.

PROJECT NAME: Road No. 2406 ROUTE SEGMENT NO.: 1

| GRADELINE POINT | STATION (FT) | ELEVATION (FT) | SIDESLOPE (%) | PERCENT GRADE |
|---|---|---|---|---|
| 1 | 0 | 2518 | 63 | |
| | | | | 3 |
| 3 | 200 | 2524 | 63 | |
| | | | | 3 |
| 5 | 400 | 2531 | 90 | |
| | | | | 3 |
| 7 | 600 | 2537 | 67 | |
| | | | | 3 |
| 9 | 802 | 2544 | 56 | |
| | | | | 3 |
| 11 | 1004 | 2550 | 82 | |
| | | | | 3 |
| 13 | 1178 | 2556 | 55 | |
| | | | | 3 |
| 15 | 1362 | 2561 | 71 | |
| | | | | 3 |
| 16 | 1467 | 2564 | 76 | |

GRADE IN THIS ROUTE SECTION IS 3.2%

| GRADELINE POINT | STATION (FT) | ELEVATION (FT) | SIDESLOPE (%) | PERCENT GRADE |
|---|---|---|---|---|
| | | | | 12 |
| 17 | 1568 | 2577 | 72 | |
| | | | | 12 |
| 19 | 1764 | 2600 | 81 | |
| | | | | 12 |
| 21 | 1972 | 2625 | 66 | |
| | | | | 12 |
| 23 | 2173 | 2650 | 76 | |
| | | | | 12 |
| 25 | 2372 | 2675 | 55 | |

GRADE IN THIS ROUTE SECTION IS 12.2%

| GRADELINE POINT | STATION (FT) | ELEVATION (FT) | SIDESLOPE (%) | PERCENT GRADE |
|---|---|---|---|---|
| | | | | 3 |
| 27 | 2556 | 2680 | 39 | |

GRADE IN THIS ROUTE SECTION IS 2.9%

| SLOPE CLASS (%) | QUANTITY OF ROUTE (FT) | QUANTITY OF ROUTE (%) |
|---|---|---|
| 0 - 10 | 0 | 0 |
| 10 - 20 | 0 | 0 |
| 20 - 30 | 0 | 0 |
| 30 - 40 | 42 | 2 |
| 40 - 50 | 0 | 0 |
| 50 - 60 | 580 | 23 |
| 60 - 70 | 651 | 25 |
| 70 - 80 | 596 | 23 |
| 80 - 90 | 687 | 27 |
| 90 -100 | 0 | 0 |
| 100+ | 0 | 0 |

Figure 11—The route summary report produced by the ROUTES program. .

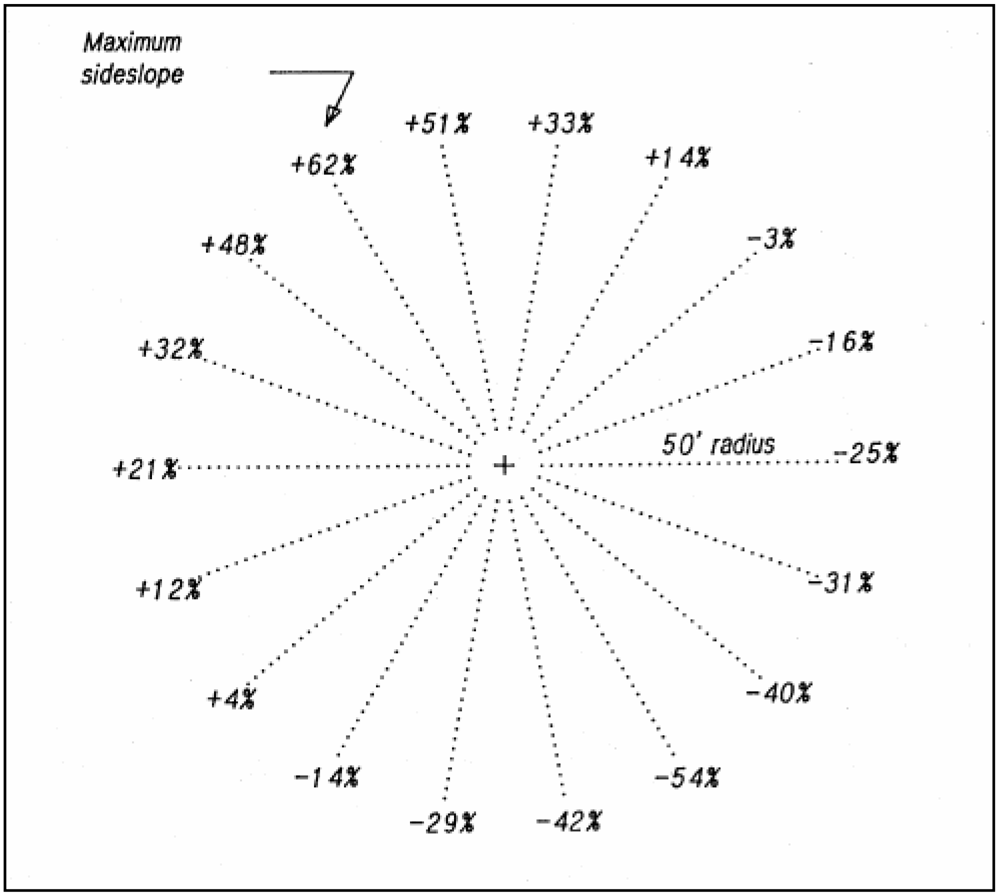


Figure 12—For each point on the gradeline, the slope of the ground is computed in all directions, and the maximum value is selected to represent the sideslope at that point.

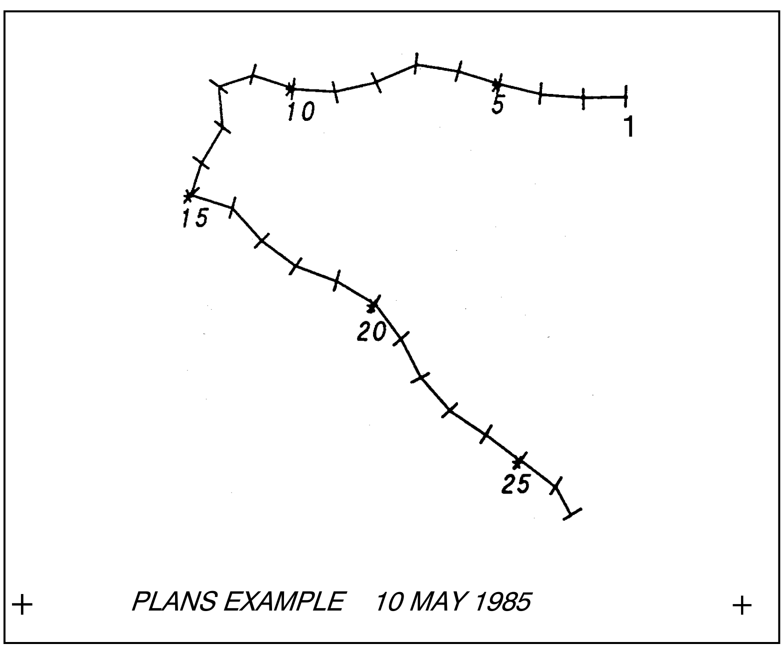


Figure 13— The route plan-view plot produced by the ROUTES program.

## Limitations of the ROUTES program

The ROUTES program is intended to identify, through the use of terrain data contained in a DTM, potential route locations to be fully investigated in the field. To successfully identify routes, the DTM used by the ROUTES program must accurately describe the actual terrain. If the DTM does not accurately model the ground surface, the grade lines identified by the program will not fit. Some discrepancy between the gradelines projected by using the DTM and gradelines projected on the actual ground surface should always be expected.

Discrepancies can have three sources. The first and most important source is elevation errors in the DTM. Elevation errors come from errors made during map compilation and can be quite large. For instance, a topographic map with 20-foot contours plotted from aerial photographs can have errors in selected ground-point elevations of up to 100 feet or more when heavy vegetation conceals the ground surface from the stereoplotter operator. The contour lines represent the operator's best guess at the actual shape of the ground surface below the canopy of the forest. Even under the best viewing circumstances, the contour lines produced by a stereoplotter are somewhat smoothed (Wolf 1983, p. 293). The planner can also make errors when tracing contour lines from the topographic map. These errors are minor if they are small deviations from the contour line made during tracing; they are major if the elevation of the contour line was misread before tracing began.

The second source of discrepancy is the process used to construct the gridded DTM from the the contour lines, in which points are interpolated between adjacent contour lines to get an elevation for each grid point in the DTM (Lemkow 1977). Because this elevation was not measured, its value is subject to an error of plus or minus one-half the contour interval.

The third source of discrepancy is errors in estimating point elevations between the stored elevations of the DTM grid points. This interpolation occurs whenever the gradeline point does not correspond exactly with a grid point in the DTM. Lemkow (1977) found these last two sources of error to be of minor importance.

When projecting gradelines on topographic maps, by using either the ROUTES program or a manual method, the planner must always be aware that factors other - than terrain shape or geometry affect the alignment of a route. Surface rock, wet soil, and slope stability are not apparent on topographic maps, but the presence of such features may require the route to be drastically altered or abandoned altogether.

The program does not provide estimates of the amount of material that must be moved to construct a road. The amount of earth moved has a major bearing on the cost of a project, but we felt that estimates of volumes calculated from cross sections derived from the DTM would not be any more accurate than estimates made using the sideslope information already generated by the ROUTES program.

The ROUTES program has no provision for identifying the best route location given a set of constraints specified by the planner. The program only provides a tool for rapidly developing a set of alternative locations using varying grade limits. The full responsibility for evaluating alternative locations, in both the economic and environmental senses, remains with the planner.

## Operating Instructions and Worked Examples

An appendix to this report containing step-by-step operating instructions for the ROUTES program is available. A copy can be obtained by completing and returning the last page of this publication. The appendix includes three examples illustrating how the ROUTES program can be used. The examples demonstrate how to (1) estimate grades and distances, (2) project in a gradeline at a selected-grade, and (3) estimate grades and distances along an existing road. All necessary data to run each example are included as well as the results produced by the program.

## Metric Equivalents

1 inch = 2.54 centimeters

1 foot = 0.3048 meter

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An appendix to this report containing step-by-step operating instructions for the ROUTES program is available on request from the Pacific Northwest Research Station. A copy of this appendix can be obtained by photocopying this page, filling in the necessary information, and sending it to:

USDA Forest Service
Pacific Northwest Research Station
Forestry Sciences Lab
Forest Engineering Systems
4043 Roosevelt Way NE
Seattle, WA 98105

If you wish to receive the PLANS program set, which includes ROUTES stored on diskettes, send five 5-1/4-inch double-,sided, double-density, flexible mini disks.

Please send supplementary material for the ROUTES program to:

NAME ______________________________
ADDRESS ____________________________
____________________________
CITY ______________________________
STATE ______________ ZIP CODE ____________
PHONE _____________________________

**Reutebuch, Stephen E. 1988**. ROUTES: a computer program for preliminary route location. Gen. Tech. Rep. PNW-GTR-216. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

An analytical description of the ROUTES computer program is presented. ROUTES is part of the integrated preliminary harvest- and transportation-planning software package, PLANS. The ROUTES computer program is useful where grade and sideslope limitations are important in determining routes for vehicular travel. With the program, planners can rapidly identify route locations on large-scale topographic maps. The program uses a digital terrain model, created by using the MAP computer program in the PLANS package, to produce profile plots and estimates of grades and sides lopes along projected routes. A separate appendix containing detailed instructions for running the ROUTES program is available on request.

Keywords: Timber harvest planning, computer programs/programing, digital terrain model, road location/design.



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