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Action Plan for Analysis of The 1983 Landslides on The Manti-LaSal National Forest

Alternative 2

Objective:

The objective of this alternative is to evaluate the extent of landslide activity that occurred in 1983 on the Manti-LaSal National Forest and to use this data to predict landslide susceptibility. This analysis would be a continuation and updating of the information compiled on landslides by Allen Gallegos, Environmental Geologist, while serving on the "Flood and Landslide Damage Assessment Team" in 1983, and the Geologic Hazard [illegible] compiled by Maureen McBrian.

Methods:

The 1:40,000 scale black and white aerial photographs which were taken in September 1983 will be used as the basic reference for landslide occurrances. The photos will be analyzed and compared with earlier photography. All landslides identified as being active in 1983 will be plotted on 7½ minute USGS topographic maps. This process will verify the landslides already mapped during the landslide damage assessment and add those not previously mapped. Symbols will consist of arrows (↓) for long, narrow slides and dashed lines with an arrow showing direction of movement for mass failure (↓).

After the landslides are plotted on the maps, isopleth maps will be developed. These maps will show lines of equal landslide activity. The isopleth maps can be used to quantify zones of landslide activity and also serve as a guide to landslide susceptibility. Two reports are attached which describe this process.

The actual number of landslides and estimated acres disturbed will be tallied by subwatershed. This information will then be summarized to give District, Division, and Forest totals.

Final Product:

1. Topographic maps with all landslides plotted that were active in 1983.
2. Isopleth maps showing landslide occurrance zones and landslide susceptibility.
3. Total number of landslides and acres disturbed by landslides by subwatershed, District, Division, and Forest.
4. Brief report of procedures and results.

Action Plan for Landslide
Analysis on the
Manti-LaSal National Forest

Alternative 3

This alternative would be the same as alternative 2, but would consist of mapping all landslides noted on the 1983 1:40,000 aerial photographs without determining which ones occurred in 1983 specifically.

Alternative 4

This alternative would be the same as alternative 2, but would not include the preparation of isopleth maps.

Suggestions from

<u>Alternative A</u>

Geologic Overview (4) level

- update existing landslide inventory maps; no field work (2pp)

<u>Alternative B</u>

Geologic Reconnaissance (3) or Survey (2) level

- update existing landslide inventory maps
- field checks (appropriate %) (4pp)

<u>Alternative C</u>

Geologic Survey (2) level

- update existing landslide inventory maps
- field checks (appropriate %)
- Isopleth method of determining landslide-susceptability zones
- Analysis of landslide-susceptability zones (10pp)

Preparation and Use of Isopleth Maps of Landslide Deposits

Robert H. Wright, Russell H. Campbell, Tor H. Nilsen
U.S. Geological Survey, Menlo Park, California 94025

ABSTRACT

Isopleth maps derived from landslide inventory maps generalize and quantify the areal distribution of landslide deposits in contour form and may be uniquely useful for some types of regional planning. The isopleth format permits incorporation of landslide information with other quantified map data in the preparation of slope stability maps. The isopleth map of landslide deposits in San Mateo County, California (scale 1:300,000), serves as an example of this technique.

INTRODUCTION

Inventory maps of landslide deposits show where landsliding has occurred in the past and thus serve as a general guide to slope stability. However, quantitative comparisons of the relative proportions of landslide cover among different areas are usually difficult. The inventory maps may also be difficult to use in combination with other types of map data for the derivation of slope stability maps because the information is not quantified. Inventory maps of landslide deposits can be generalized and quantified by preparing an isopleth map, which permits comparison of different areas on the basis of the proportions of those areas that are covered by landslide deposits.

Isopleth maps (see Schmid and MacCannel, 1955, p. 220) show the distribution of landslide deposits by contours (isopleths) drawn through points representing equal percentages of cover by landslide deposits within a unit area. Isopleth maps of landslide deposits have been prepared for the Point Dume quadrangle, California (Campbell, 1973), and the southern San Francisco Bay region (Wright and Nilsen, 1974). These maps were prepared from inventory maps of landslide deposits, using techniques similar to those described by Schmid and MacCannel (1955, p. 234-239). The San Mateo County part of the southern San Francisco Bay region map illustrates the methods used to prepare isopleth maps. Because of different map scales (1:24,000 versus 1:125,000) and landslide densities between the Point Dume and San Francisco Bay region maps, slightly different procedures were used in their construction. The procedures are interchangeable, however, and reproducibility is obtained using either.

MAP PREPARATION

The inventory map of landslide deposits for San Mateo County, including those originally mapped as questionable or possible, is shown in Figure 1 reduced to 1:300,000 scale, and a part of this map is shown in Figure 2A at a scale of 1:125,000. Landslide deposits enclosed by contacts are larger than 500 ft in longest dimension; solid dots represent deposits between 200 and 500 ft in longest dimension. Deposits smaller than about 200 ft in longest dimension generally were omitted.

The density of landslide cover was determined at 1:125,000 scale from the inventory map by comparing different areas of constant size. A 1-in.-diameter plastic counting circle enclosing an inscribed 20 X 20 per inch grid (Fig. 2B) was systematically positioned with its center on the intersections of a grid overlain on the inventory map (Fig. 2C; grid omitted). The maximum spacing between center positions was 0.5 in., and at each position the number of grid squares within the circle covered by mapped deposits was counted and recorded (Fig. 2D). The spacing between center positions was reduced to 0.25 in. in areas transitional from foothill terrain to valleys (used to determine contours in Fig. 2E but omitted in Fig. 2C, D) to determine isopleth positions more precisely. Where landslide data bordering the map were inadequate or unavailable, a symmetrical distribution was assumed.

Contour lines (isopleths) were then drawn through numbers equivalent to 1, 10, 20, 30, 40, 50, 60, 70, 80, and 90 percent of area covered by landslide deposits (Fig. 2E; offshore isopleths shown for illustration). The isopleth map thus shows the percentage of the area covered by landslide deposits within a 1-in.-diameter circle centered at any point on the map. Maximum and minimum determined values were labeled within closed contours; they are not centroid values (Schmid and MacCannel, 1955, p. 238). Figure 3 shows the isopleth map of landslide deposits for San Mateo County at 1:300,000 scale.

MAP USES

The isopleth map generalizes the distribution of landslide deposits and permits quantitative comparisons among different parts of a map area. The contour format is easy to combine with other quantified map data for the preparation of higher order derivative maps and may be more suitable for some regional planning purposes than the inventory maps. Areas with many small landslides can be compared quantitatively with areas containing fewer but larger landslides. Trends and geographic orientations of zones of landslide deposits can be recognized easily. Where different types of landslide deposits have been mapped, separate isopleth maps for each type may illustrate significant differences in the topographic, geologic, and climatic factors that contribute to landsliding. The smoothing of the landslide data by the isopleths diminishes the importance of errors of nonrecognition and misidentification of specific landslides in the inventory maps. When other data are available, the isopleth map can easily be correlated with maps showing the distribution of soils, bedrock lithology and structure, slope, rainfall, vegetation, seismic zones,

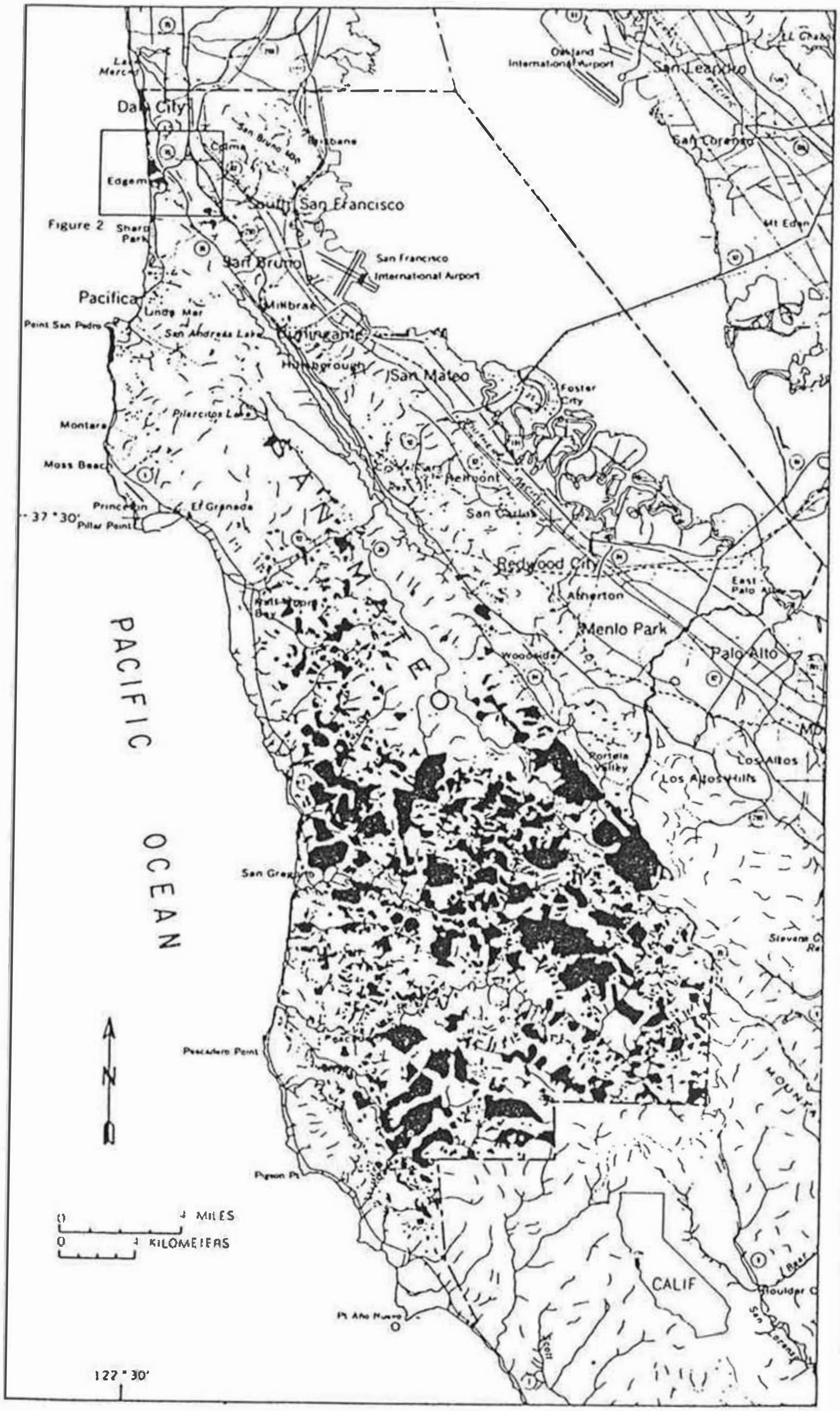

Figure 1. Inventory map of landslide deposits in San Mateo County, California (after Brabb and Pampeyan, 1972).

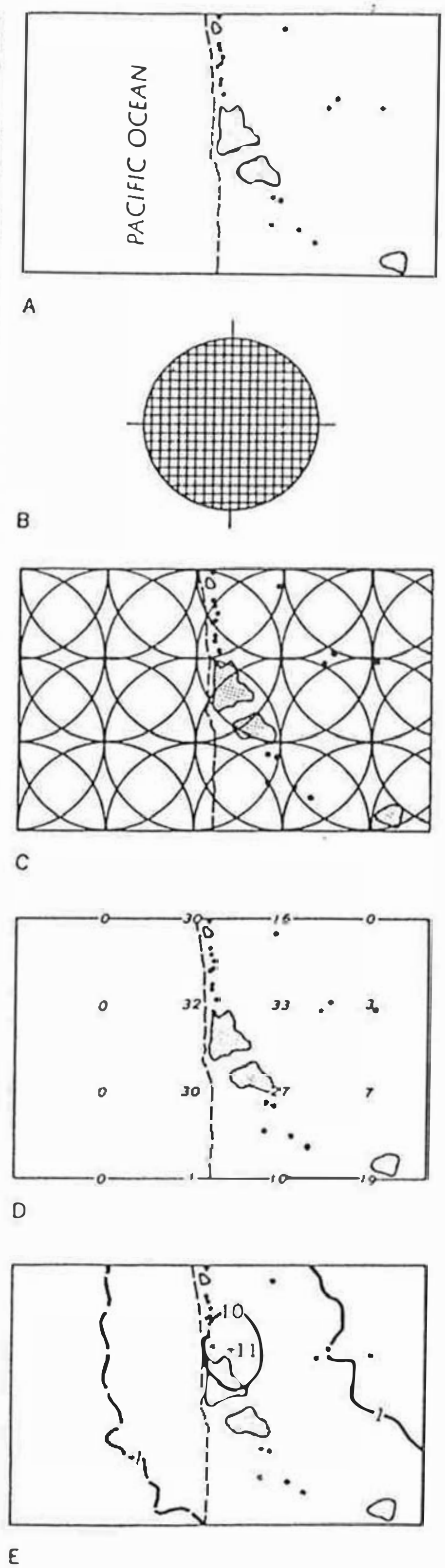

Figure 2. Steps in preparation of isopleth map. See text for discussion. Location of area used in this example is shown in Figure 1.

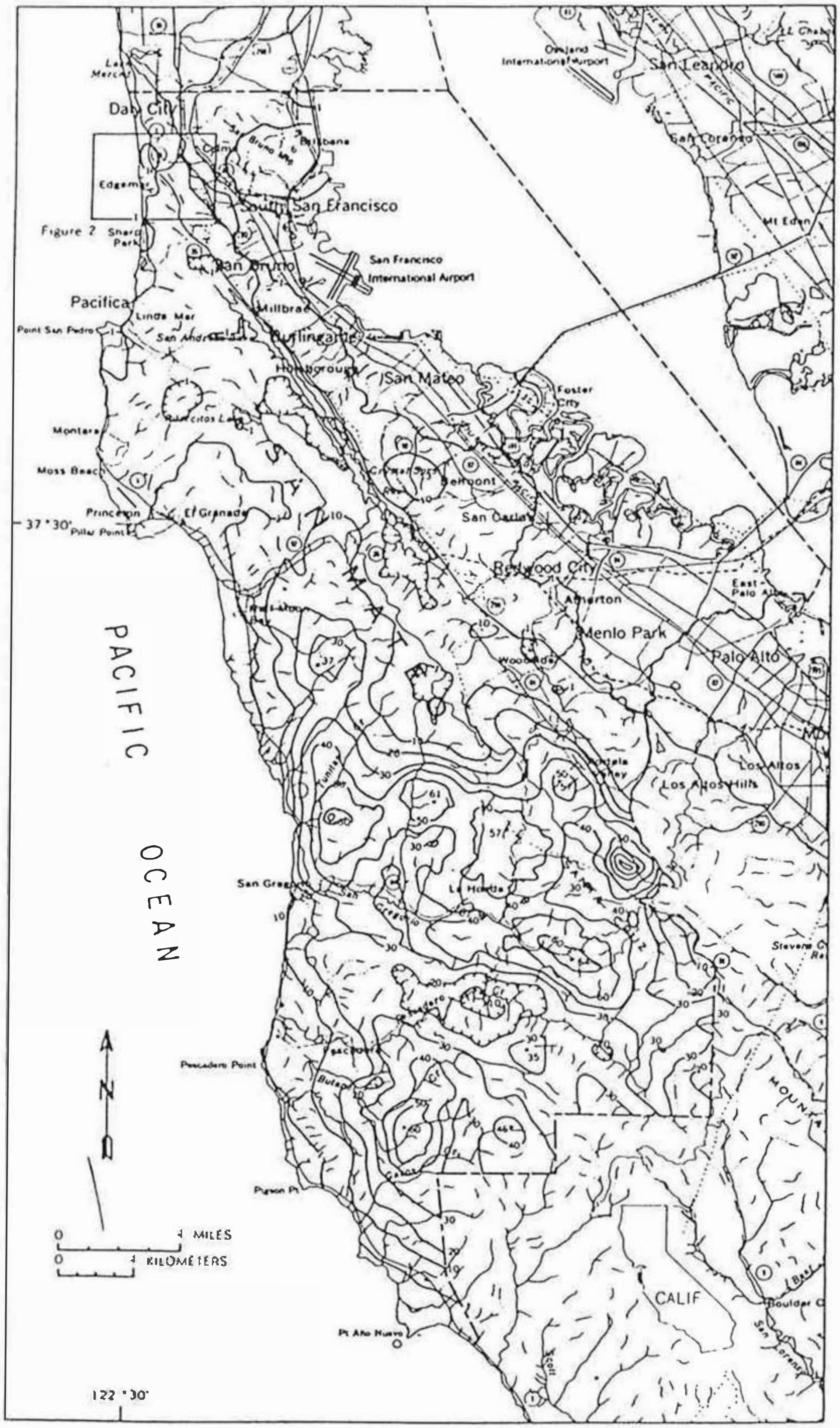

Figure 3. Isopleth map of landslide deposits, San Mateo County, California (after Wright and Nilsen, 1974).

urbanization, and other factors that affect landsliding. When other data relating to slope stability are unavailable, the isopleth map alone might serve as a generalized guide to landslide susceptibility. The construction of isopleth maps is mechanical, relatively rapid, and amenable to computer processing and contouring techniques. Isopleth maps can be constructed for many kinds of data and may be useful in a variety of geologic and environmental studies.

Users of isopleth maps of landslide deposits must recognize certain limitations and qualifications. The maps quantify terrain solely on the basis of proximity to recognized and suspected landslide deposits. The effects of individual factors that determine slope stability, such as slope, bedrock and soil type, geologic structure, climate, and earth shaking, may vary with time and from place to place and are not considered independently. The isopleth maps are constructed from inventory maps that usually represent compilations from source maps of differing reliability, accuracy, and scale; a close review of source maps and data should therefore be part of any evaluation of planned or proposed land uses.

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Schmid, C. F., and MacCannel, E. H., 1955, Basic problems, techniques, and theory of isopleth mapping: Am. Statistical Assoc. Jour., v. 50, no. 269, p. 220-239.

Wright, R. H., and Nilsen, T. H., 1974, Isopleth map of landslide deposits, southern San Francisco Bay region, California: U.S. Geol. Survey Misc. Field Studies Map MF-550, scale 1:125,000.

ACKNOWLEDGMENTS

Reviewed by G. B. Cleveland, D. M. Morton, and R. F. Yerkes.

E. E. Brabb gave us helpful suggestions.

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MANUSCRIPT ACCEPTED AUGUST 5, 1974

United States Department of Agriculture

Forest Service

Price RD

Reply to: 2880 Geologic Services

Date: February 10, 1984

Subject: Geologic Overview of the Slope Stability Conditions in the South Fork Thistle Creek Area

To: Sanpete And Price District Rangers

ABSTRACT

A slope stability condition analysis was conducted at a geologic overview level using an isopleth method to determine landslide-susceptibility zones. Slope stability conditions were determined to assess the feasibility of a proposed gas pipeline realignment route and any other possible routes.

Analysis of available data concludes that the proposed route is the most suitable location from the slope stability aspect. The proposed route was determined to be the most suitable because the route traverses over less known landslide-susceptibility zones and minimal landslide problems are anticipated.

Avoiding known moderate landslide-susceptibility zones, minimizing cuts and drainage control should effectively mitigate accelerated erosion. In addition, a geologic survey level study should be conducted to determine detailed site specific mitigation measures.

Alan J. Gallegos

ALAN J. GALLEGOS
Geologist

GEOLOGIC OVERVIEW OF THE SLOPE STABILITY CONDITIONS IN THE SOUTH FORK THISTLE CREEK AREA

ALAN J. GALLEGOS
GEOLOGIST

REVIEWED BY:

EARL OLSEN
REGIONAL ENVIRONMENTAL GEOLOGIST

INTRODUCTION

Mountain Fuel Company operates a gasline under a special use permit. The current location of the gasline is severly threatened by landslides in the South Fork Thistle Creek Area. The Company has proposed realignment routes that were designed to circumvent unstable slopes and minimize shearing forces on the pipeline. The project area shall be referred to as the South Fork Thistle Creek area (see Fig 1).

On November 8, 1983 a field review of the proposal was conducted with members of the ID Team and Mountain Fuel Company personnel. Field conditions were such that snow cover prevented on the ground review of the whole proposal. The field review consisted of driving along Skyline Drive to review that portion of the project.

This report is a summary of slope stability conditions, landslide susceptibility and recommendations for the proposed pipeline realignment project.

South Fork Thistle Creek Area

PROJECT DESCRIPTION

The proposed pipeline realignment route for the South Fork Thistle Creek area will follow Skyline Drive for approximately 1.5 miles and Haystack Ridge for approximately 2.3 miles (see Fig. 1). The pipeline will cross Skyline Drive four times to gain access to Haystack Ridge, to circumvent unstable slopes to the south and to short cut a curve in the road. The section of pipeline along Skyline Drive will be constructed in the shoulder and road bed. The section of pipeline on Haystack Ridge will follow the crest of Haystack Ridge along an existing two track road. Project activities include construction of a temporary road on Haystack Ridge to accommodate the pipeline construction. Heavy equipment necessary for construction includes bulldozers, backhoes, cranes and several support vehicles.

SLOPE STABILITY ANALYSIS

Slope stability analysis for the South Fork Thistle Creek area was conducted at a geologic overview level. Aerial photographic data was used to construct an isopleth map. Isopleth maps were constructed as a tool for analyzing slope stability conditions and determining landslide susceptibility zones. Isopleth maps are a statistical method of portraying the data in a form that smooths and generalizes the raw data.

Isopleth maps of landslide disturbed terrain show the distribution of landslides by contours (isopleths) drawn through points representing equal percentages of cover by landslides within a unit area. The map was constructed by displaying landslides on 1:24000 scale topographic maps and using a method developed by the U.S. Geologic Survey. Landslide data sources were 1976/1:15840 scale and 1983/1:40000 scale aerial photographs. Specific details of the method are described in Wright (1974, p.483-485).

LANDSLIDE SUSCEPTIBILITY

Landslide susceptibility isopleth maps identify potential problem areas during the initial environmental assessment phase. The method quantifies slope stability cconditions and identifies where site specific studies should be conducted for further evaluation.

The final product of the isopleth map shows three levels of landslide susceptibility. The three levels of landslide susceptibility and their general management considerations are as follows:

Low - Percent of landslide disturbed terrain ranges from 0 to 10%. Landslides are unlikely to pose a concern to proposed management. Localized problems readily handled in design may be present.

Moderate - Percent of landslide-disturbed terrain ranges from 10 to 30%. Landslides may require limited modification to proposed management involving changes to slope shape or decreases in surface soil moisture. Geologic review needed to establish effective mitigation criteria.

High - Percent of landslide-disturbed terrain ranges from 30 to 50%. Landslide may require moderate to extensive modification to proposed management involving changes to slope shape or decreases in surface soil moisture. Geologic study is necessary to establish degree of risk and effective mitigation criteria.

Landslide-susceptibility isopleth maps have certain limitations. Those limitations include the factors used to determine landslide susceptibility and interpretation of the isopleth map. Using the isopleth method, quantification is based solely on the density of existing landslides within a unit area that are visible on an aerial photo. The effects of other factors are not considered independently but rather in combination where existing unstable slopes are the result of one or more factors. Interpretation of the isopleth map should include the physical characteristics of landslide-susceptibility zones. For example, zones of high landslide-susceptibility may be within a range of slope gradient/aspect or may be associated with faults or certain soil/bedrock types. These characteristics could then be used to prognosticate events outside the landslide-susceptibility zones.

SLOPE STABILITY CONDITIONS

Slope stability conditions have been evaluated by analyzing the isopleth map and comparing characteristics of known unstable areas to those of unknown unstable areas. The following is a summarization of characteristics in known landslide areas based on landslide-susceptibility zones.

High landslide-susceptibility zones in the study area are characterized as having multiple nested, small (1-5 acres), shallow, debris flows, that occur on northwest, southwest, and west facing slopes (see LS 1 and 2, Map 1). The flows are located on ridge slopes from ridge crest to channel bottoms and along a major fault zone. The landslide material contains clay rich soils derived from the west dipping North Horn Formation. The direct causes in mobilizing the landslides were saturated soil conditions below a sandstone/ shale contact and daylighting strata on western facing slopes (see Table 1).

Moderate landslide-susceptibility zones in the study area occur as buffer zones surrounding high landslide-susceptibility zones and as zones adjacent to isolated landslides (see LS 3 and 4, Map 1). The landslide type that occurs in this zone is predominately small (5-10 acres), shallow, debris flows. The flows usually are located in small southwest and northeast facing draws. The landslide material consists of clay rich soils derived from the westerly dipping North Horn Formation. The immediate cause in mobilizing the landslides was saturated soil conditions in small draws (see Table 1).

Low landslide susceptibility zones in the study area occur as buffer zones surrounding moderate landslide-susceptibility zones and as zones adjacent to the existing location of the pipeline (see LS 5, Map 1). The landslide type that occurs in this zone is predominately isolated, small (1-5 acres), shallow debris flows associated with the existing pipeline and stream channels. The landslide material consists of clay rich soils derived from the west dipping North Horn Formation. The immediate cause in mobilizing the landslides was slope configuration changes caused by channel erosion and the cut and fill construction along the existing pipeline. This activity results in reducing the slope support above the cut (see Table 1).

AFFECTED ENVIRONMENT/EFFECTS OF IMPLEMENTATION

Proposed Realignment Route

The proposed pipeline route follows the ridge crest of Haystack Ridge for approximately 2.3 miles. The route crosses approximately 2400 feet of known low and moderate landslide-susceptibility zones (see Sec. 3, Map 1). Based on general management considerations landslides may require limited modification involving changes to slope shape or decreases in surface soil moisture. Geologic review needed to establish effective mitigation criteria. Anticipated problems include small, shallow, debris flows (1-2 acres) forming along the route where it crosses the moderate and low landslide-susceptibility zones. These slides could possible form in the spring or after the construction disturbance. The affects of a landslide, on a southwest facing slope, could become a minor problem to the proposed pipeline (see LS 6, Map 1). The formation of the landslide has reduced the slope support above the landslide and will probably result in continued growth as headscarp retrogression developes.

Other sections of the proposed realignment route are located in unknown landslide-susceptibility zones. The probability of landslides forming in these areas is smaller than in areas of known landslide-susceptibility, but the possibility exists. Based on characteristics of known landslide-susceptibility, prognostication is possible in unknown areas.

Section 2, Map 1, has similar characteristics to a high landslide-susceptibility zone. The area is on a western facing slope with a slope gradient of 50%. The slope is located along a major fault zone where the strata is dipping to the west and daylighting. The area is underlain by the North Horn Formation and probably has a sandstone/shale contact within the section. Geologic review is needed to determine effective mitigation criteria.

All other sections are located on the ridge crest of Haystack Ridge. According to characteristics in known landslide-susceptibility zones, the ridge crest is a good location for the pipeline. Bedrock is closer to the surface, soils are shallower, groundwater recharge area is less and the emplacement of the pipeline will not require cutting across steep slopes. Landslide problems are not anticipated in these sections.

Alternative Route

The alternative route follows an unnamed ridge south of South Fork Thistle Creek. The route branches into two secondary routes. The western secondary route crosses approximately 6000 feet of known high, moderate, and low landslide-susceptibility zones (see Map 1). The eastern secondary route crosses approximately 4000 feet of known moderate and low landslide-susceptibility zones. Based on general management considerations emplacement of the pipeline in high and moderate landslide-susceptibility zones may require limited to extensive modification to the area involving changes to slope shape or decreases in surface soil moisture. Emplacement of the pipeline in the low zone poses a minor concern to management. Localized problems may be encountered and should be adequately handled in design when encountered. Geologic study is necessary to determine effective mitigation criteria. Anticipated problems include initiation of new landslides and aggravation of existing landslides.

Other sections of the alternate route are located in unknown landslide-susceptibility zones. The probability of landslides forming in these area is smaller than in areas of known landslide-susceptibility, but the possibility exists. Based on characteristics of known landslide-susceptibility, prognostication is possible in unknown areas.

Sections 2a and 3a, Map 1 have similar characteristics to a low and moderate landslide-susceptibility zone (see LS6 and LS3, Map 1). These sections traverse a narrow ridge with a minor stream channel between them. The areas of concern are north and west facing slopes with slope gradients of 50%. The area is underlain by the westerly dipping North Horn Formation which daylights the west and north facing slopes. Geologic review is needed to determine effective mitigation criteria.

Section la, Map 1, is located on the ridge west of the unnamed ridge. According to characteristics in known landslide susceptibility zones, the ridge crest is a good location for the pipeline. Bedrock is closer to the surface, soils are shallower, groundwater recharge area is less and the emplacement of the pipeline will not require cutting across steep slopes. Landslide problems are not anticipated in this section.

CONCLUSION

Comparison of the proposed and alternate pipline realignment routes concludes that the proposed route is the most suitable from the slope stability aspect. The alternate route traverses more unstable ground then the proposed route and does not avoid all unstable areas along the existing route (see LS7, Map 1).

Comparison of the existing route and the proposed realignment route concludes that the proposed route would be the most suitable location for the pipeline. The existing location of the pipeline crosses steep slopes where existing slope stability conditions are hazardous to the pipeline. Known landslide susceptibility ratings range from moderate to low and increased landslide activity is expected.

RECOMMENDATIONS

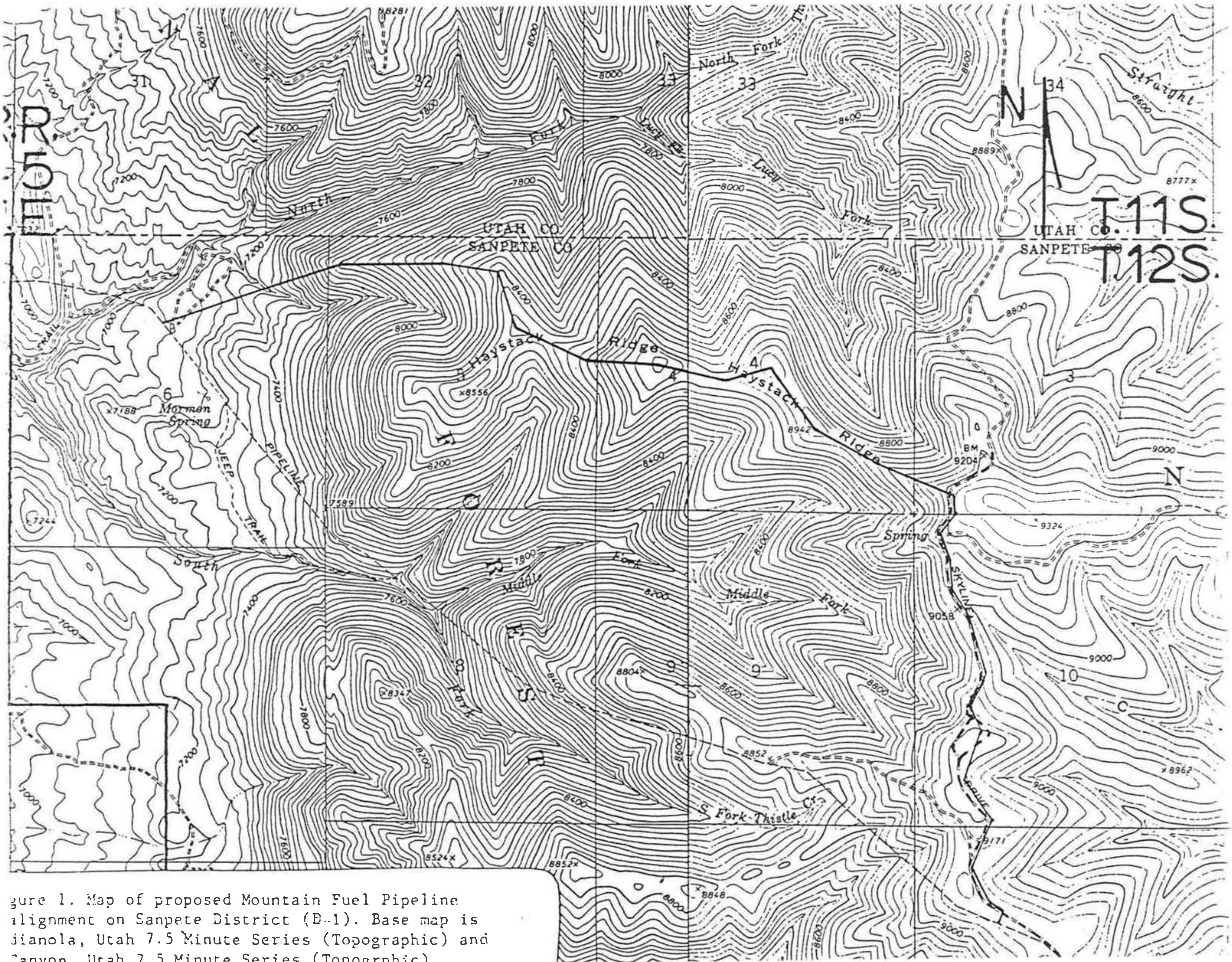
The proposed realignment route is the most suitable location for the pipeline from the slope stability aspect. Some minor problems exist but they are considerably less than the problems of the existing line. Geologic review is necessary to determine specific mitigation criteria. Avoiding the area where the proposed line crosses through the landslide-susceptibility zones, minimizing cuts, 100% rehabilitation and drainage control should adequately mitigate concerns for increased slope stability associated with the proposed project.

Alan J. Gallegos

ALAN J. GALLEGOS
Geologist

Reviewed by:

EARL OLSEN
Regional Environmental Geologist



gure 1. Map of proposed Mountain Fuel Pipeline
alignment on Sanpete District (D-1). Base map is
Jianola, Utah 7.5 Minute Series (Topographic) and
Canyon, Utah 7.5 Minute Series (Topogrphic)

TABLE 1

CHARACTERISTICS OF LANDSLIDE-SUSCEPTIBILITY ZONES
SOUTH FORK THISTLE CREEK AREA

ANDSLIDE - SCEPTIBILITY RATING	SLOPE GRADIENT	ASPECT	ASSOCIATED LANDFORM	GEOLOGIC FACTORS	LANDSLIDE TYPE	DIRECT CAUSE of INSTABILIT
HIGH	50-60%	1) NW; 2) S: 3) W	1) Ridge sideslopes from ridgecrest to channel bottom; 2) Fault scarp slopes	1) Westerly dipping strata daylighting N and NW facing slopes 2) North Horn Form. (clay soils) 3) Sandstone/shale contact	Multiple nested slide large (50 ac), shallow (1-10 ft), debris flows.	Saturated soi below a sand-stone/shale contact.
MOD	30-60%	1) SW	1) Small draws on NE and SW facing slopes	1) Westerly dipping strata 2) North Horn Form.	Isolated, small (5-10 acres), shallow (1-15 ft), debris flows.	Saturated soi in small draw
LOW	30-50%	1) SW 2) W	1) Stream channels 2) Man-made cut and fill structure	1) Westerly dipping strata daylighting western facing slopes 2) North Horn Form. (clay soils)	Isolated, small (1-5 acres), shallow (1-10 ft), debris flows.	1) Undercutti of slope by channel erosi 2) Undercutti of slope by c and fill cons ruction