EXPLANATION
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GEOLOGIC HAZARDS IN DOUGLAS COUNTY, COLORADO

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1978

GENERAL

Geologic hazards are natural geologic conditions that if unrecognized or inadequately planned for can result in loss of life, damage to structures, or high maintenance costs, especially for homes, roads, and utilities. The mapping units used on this map are a combination of genetically related features, processes, and/or conditions that could cause problems for human activities. Where appropriate, mapping units and their definitions conform to the terminology and definitions given in Colorado House Bill 1041 and the Colorado Geological Survey's Guidelines and Criteria for Identification and Land Use Controls in Geologic Hazard and Mineral Resource Areas (Rogers and others, 1974). In addition, hazard areas may include geologic hazards that vary greatly in degree depending on natural variation within the area and on various man-caused changes that may occur in the future. Because most of Douglas County is presently in the natural state or is being used for low-intensity uses like agriculture and grazing, most of the mapped hazards cause no difficulties for existing human activities. No detailed quantification of geologic hazards is made in this study other than the table below which relates the degree of hazard to certain types of land use. In short, the actual degree of hazard depends as much, if not more, on human decisions affecting land use as it does on geologic factors.

SUGGESTIONS TO MAP USERS

This map should be used as an indicator of locations where a particular geologic hazard may adversely affect certain land uses. It is not intended to supplant detailed field investigations of individual sites, but rather to signal places where the indicated geologic conditions can be expected and should be specifically addressed in advance of any land-use change. If this map is used to designate geologic-hazard areas as specified by H.B. 1041 (Rogers and others, 1974, p. 120-121), then it is suggested that this map serve as a basis for further investigation of individual sites. Detailed investigation and evaluation may serve as the basis for actual designs, or such studies might indicate that for economic or safety reasons the particular activity is not feasible. Land-use decisions in these areas should be based on technical reviews and planning evaluation of detailed studies and specific site plans.

EXPLANATION

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SUBSIDENCE AREA: Area where collapse of underground mining excavations can cause general lowering or severe differential settlement of the ground surface. Precise delineation of these subsidence areas is difficult and requires drilling or geophysical investigations because the mining excavations are concealed beneath the ground surface and in most localities poor or no records of mining or maps of mines are available. Moreover, because surface subsidence is caused by surfaceward migration of collapsing mine voids, subsidence effects can occur without warning or be sporadic. Subsidence commonly is intermittent, can vary greatly in rate, and can occur suddenly with little prior warning. Consequently, hazard zones with indefinite boundaries only are shown on this map.

Hazards in mine-subsidence areas are usually related to buckling, spreading, or cracking of rigid structures such as buildings, bridges, or roads; disruption of drainage and utilities; or in some instances, loss of structures that fall into subsidence pits.

In addition to subsidence caused by mining, some areas with certain surficial materials may settle or collapse if loaded or wetted. Most commonly, these materials are soil and eolian deposits (loess and sand) located at or near the south or southeast. These subsidence areas are not mapped because of their simple association with drainages, their number, and the necessity for site-specific engineering-soils test to determine related hazard for a specific land use.

SLOPE-FAILURE AREA: Area where landsliding, earthflowage and/or accelerated creep are taking place. Evidence for slope failure includes hummocky topography with distinctive abrupt changes in slope near the main scarps of landslides, vegetation or man-made works disrupted by slope movements, anomalous slope reversal(s), ground-moisture conditions indicative of slope movement, and microtopographic features such as soil ripples and ground cracks.

Slope-failure areas are mapped only where ground-movement can be demonstrated unequivocally. Other slope failures undoubtedly exist, but have not been recognized as such. Most of these slope failures probably are included under unstable or potentially unstable slopes.

Slope failure areas are hazardous because slope movements can damage or destroy buildings and/or their foundations and utilities.

ROCKFALL-ROCKSLIDE/DEBRIS AVALANCHE AREA: Area subject to falling, sliding, and/or avalanching of individual blocks of rock, accumulations of blocky material, or heterogeneous, granular colluvium. Includes areas with deposits of talus and debris contiguous to their sources. Areas mapped as this unit are characterized by very rapid to nearly instantaneous slope movements that occur during heavy rainstorms. Because of this association with periods of rapid water runoff, water-flooding and debris-flow hazards are common locally in some parts of these areas. Lesser slopes do not usually indicate a lessening of susceptibility to these hazardous processes. Rockfalls occur on or near cliffs. Debris avalanches and rockslides usually are initiated on rock-rubble and debris-strewn slopes ranging from 20 to 45-degrees (36 to 100-percent) inclination. Materials mobilized by these types of slope failures can continue to move downward and outward as slurry-like flows that move away from their sources over gentler slopes.

Hazards in these areas result from possibility of impact to structures by rapidly moving rocks and debris. These mass movements occur so rapidly that little, if any, warning of their impending occurrence is possible. Safe, intensive land uses such as residential development in these areas are rarely possible. Other less intensive land uses may be safe, especially if occasional cleaning up of debris and/or partial to complete destruction of structures is acceptable.

UNSTABLE OR POTENTIALLY UNSTABLE SLOPE: Slope with evidence for past slope movements or geologic conditions favorable for slope failure. These slopes are characterized by physiography produced by landsliding soil creep, earthflowage and/or by moderately to steeply sloping, poorly consolidated colluvium, alluvium or deeply weathered bedrock. Potential for slope movement varies with slope inclination and aspect, local ground-moisture conditions, permeability of surficial materials and man-made modifications of the ground surface, especially those that affect drainage and steepness of slope.

Unstable or potentially unstable slopes commonly coincide with moderate-to-high erosion-potential areas. This coincidence appears to be related to changes in natural drainage usually made for road construction, agricultural management or from damage to or removal of natural vegetation by people and grazing animals. In many places modern accelerated gully and sheet erosion has removed considerable amounts of material decreasing the stability of slopes. Lesser slopes included in this mapping unit are usually less likely to fail than steeper slopes although lateral spreads may occur where the ground has become water-saturated and is deeply incised by gullies.

Unstable or potentially unstable slopes are hazardous because man-caused changes in the land surface can cause unexpected slope movements. Frequently this can result in considerable expense for many kinds of land developments or land uses.

LOW EROSION-SUSCEPTIBILITY AREA: Area where modern erosion is minimal because surficial materials are thin, well indurated, or composed of exposures of resistant bedrock. These areas usually are underlain by caprock that forms mesas and buttes, or are underlain by thin pediment gravels composed predominantly of cobble to boulder-size clasts indurated by caliche, or are exposures of resistant bedrock. In many locations stream bottomlands are aggraded by deposition of sediment produced by accelerated modern erosion in uplands. This aggradation locally raises stream base level. Extensive stream-bottomland areas are indicated by the marshland symbol.

Many low erosion-susceptibility areas are characterized by materials that are difficult to excavate and by poorly defined surface drainage. These factors result in added expense for construction, drainage control, and sewage disposal. Additionally, low-lying areas near streams are usually not difficult to excavate but they are subject to occasional flooding and deposition of sediment. Flooding can damage buildings and roads and accumulations of sediment can divert flood water locally, interrupt or damage drainage-control structures, and damage or destroy roads and utilities.

MODERN ACCELERATED-EROSION AREA: Area undergoing gullying or sheet erosion that appears to be accelerated or aggravated presently by overgrazing, poor construction practices, vegetation removal or disturbance, or dams and other man-made changes in surface drainage. This erosional condition may be attributed to one or a combination of these causative factors. Erosion tends to be most pronounced on slopes where surficial materials consist of 1 to 5 m of poorly consolidated, sparsely vegetated soil and weathered-rock material(regolith), colluvium or alluvium derived from the sandy, arkosic, poorly indurated rocks of the Dawson Formation. Susceptibility to erosion apparently is not directly dependent on slope. However, gully erosion is more common on steeper slopes or adjacent to or in drainage courses; sheet erosion is usually restricted to gently sloping areas where grass cover is sparse. Gullies are shown on the map as open (patternless) areas that nearly always coincide with places where drainage is poorly developed.

Hazards in modern-erosion areas result from excessive removal or deposition of sand, silt, and clay. These materials can clog or block (siltate) drainage-control structures, damage or destroy vegetation cover, or be responsible for excessive maintenance cost for buildings, utilities, and roads. Erosional effect can severely damage the land surface necessitating costly rehabilitation work prior to use of the land for agriculture or residential development. Moreover, intensive land uses such as residential development can aggravate or increase erosion such that lessening of its effects on adjacent land may be difficult or impossible. Gullies frequently undercut unstable or potentially unstable slopes causing local small slope failures. This condition of slope instability is so common in most areas that any slope directly above a modern gully should be considered suspect with respect to its slope stability.

MODERATE-TO-HIGH EROSION-SUSCEPTIBILITY AREA: Area where potential for erosion to occur is moderate to high because of slope, composition (arkosic grit, sandstone, claystone, and surficial deposits derived from these rocks), or poor consolidation of surficial materials, sparse vegetation cover, and proximity and similarity to areas already undergoing accelerated modern erosion. Many parts of the mapped areas are in a state of imminent accelerated erosion because of widespread overgrazing, extensive areas of small-scale surficial slope failure (soil creep), surface modification by roads and drainage-diversion or impoundment structures (dams), and vegetation damage caused by off-road vehicles and other intensive human activities.

Prediction of the amount or degree of erosion-related damage that may occur in a given area is not implied in the definition of this mapping unit. The map boundaries for areas so mapped are generalized because the degree of erosion susceptibility in a given area is as dependent on effects of man-made land-surface modifications as on natural conditions. In many areas, susceptibility to erosion lessens with decreased slope, increased distance from drainage courses, and increased degree of consolidation of surficial materials.

The coincidence of moderate-to-high erosion-susceptibility areas with unstable or potentially unstable slopes is due, in part, to increases in permeability caused by ground cracks resulting from slope movement and decreases in compaction of surficial materials. In many places it is apparent that erosion and slope movement(s) are related processes and one may be the initiating process that activates the other.

The most important hazard-related factors in these areas are erosion and deposition of sediment, damage to vegetation, and increased maintenance costs of roads, drainage-control structures, buildings, and utilities. Erosion can be a severe esthetic and feasibility problem for planning many kinds of developments.

DEBRIS-FLOW AREA: Area susceptible to occasional rapid movement of slurry-like mixtures of soil and rocks, incorporated woody debris, and water. Debris movement initiates typically as rockfalls, rockslides, and/or debris avalanches and debris slides. These slope movements are coincident with intense rainstorms that occur during the late spring and summer. This rapidly moving debris is typically capable of moving considerable distances downward and outward onto adjacent moderately to gently sloping areas (20 to 0-percent slopes). Depending primarily on the drainage development in the debris-flow area, debris flows can either be confined to drainage channels or spread out over relatively large areas before debris movement ceases. Debris movement during a given debris-flow event is very difficult to predict because of minor topographic irregularities, variable amounts of debris mobilized during a rainstorm, and diversion of debris flow(s) by variations in channel geometry and/or effects of material already present in channels. Additionally, man-made land-surface changes can significantly alter the potential for debris flowage in some areas. Debris-flow deposits of various ages occur in the mapped debris-flow hazard areas. The age of these debris-flow events ranges from occurrences during this century and the past two decades to some that probably occurred a few thousand years ago. All of these areas are underlain by deposits of unquestionably debris-flow origin or have physiography clearly indicative of such deposits.

Hazards in debris-flow areas result from sudden impact by moving debris that injures people and damages or destroys buildings, utilities, and roads. In some cases defense structures or other measures can reduce hazards considerably, possibly to acceptable levels.

NOTE: Other hazards and discussion of individual hazard areas are indicated by notes on the map.

Reference

Rogers, W. P., and others, 1974, Guideline and criteria for identification and land-use controls of geologic hazard and mineral resource areas; Colorado Geol. Survey Spec. Pub. 6, 146 p.

GEOLOGIC HAZARDS FOR COMMON LAND USES

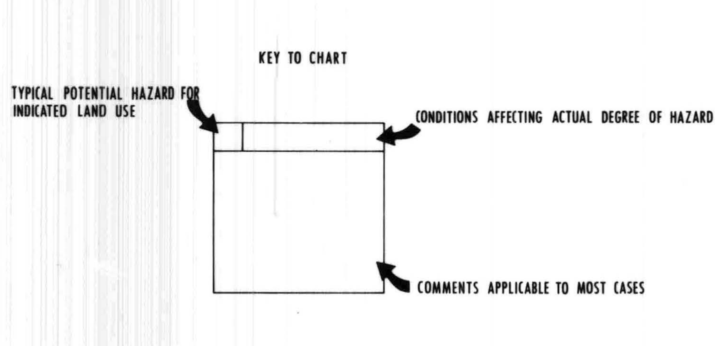
LAND-USE ACTIVITY

HAZARDS MAP UNIT	Road construction	Road maintenance	Utilities -- installation & maintenance	Low-density single-family residential development (< 1 d.u./5 acres)	Medium-density single-family residential development (1 d.u./5 acres to 1 d.u./1 acre)	High-density single-family residential development (> 1 d.u./acre)	Multi-family housing (townhouses & apartments)
Landslide area	4 ABCDEFHIJKN — INCREASED DESIGN AND CONSTRUCTION COSTS. POSSIBLE DAMAGE TO ROADS OR CONSTRUCTION EQUIPMENT.	4 CEFHIL — INCREASED COSTS. EXISTENCE OF ROAD CAN AGGRAVATE HAZARD GREATLY FOR OTHER LAND USES.	3 CEFHLN — IN MANY CASES, INCREASED DESIGN AND DEVELOPMENT COSTS. OCCASIONAL DISRUPTION OF UTILITIES BECAUSE OF LINE BREAKAGE. CAREFUL ATTENTION SHOULD BE GIVEN TO COMPACTION OF BACKFILL AND RESTORATION OF SURFACE DRAINAGE.	3 ABCDEFHIJKN — IN MOST CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS. IN SOME CASES THIS TYPE OF DEVELOPMENT MAY NOT BE FEASIBLE.	5 ABCDEFHIJKN — IN SOME CASES CAREFUL ENGINEERED DESIGNS FOR BUILDINGS CAN REDUCE ADVERSE EFFECTS. IN MANY CASES THIS TYPE OF DEVELOPMENT WILL NOT BE FEASIBLE. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.	5 ABCDFHIJKN — LANDSLIDING OR LANDSLIDE POTENTIAL MAY BE INCREASED GREATLY BY THIS TYPE OF DEVELOPMENT. IN MANY CASES THIS TYPE OF DEVELOPMENT WILL NOT BE FEASIBLE. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.	5 ABCDFHIJKN — LANDSLIDING OR LANDSLIDE POTENTIAL MAY BE INCREASED GREATLY BY THIS TYPE OF DEVELOPMENT. IN MANY CASES THIS TYPE OF DEVELOPMENT WILL NOT BE FEASIBLE. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.
Unstable or potentially unstable slope	3 ABCDEFHILN — POSSIBLY INCREASED DESIGN AND CONSTRUCTION COSTS.	2 CDEFHI — POSSIBLY INCREASED COSTS. EXISTENCE OF ROAD CAN AGGRAVATE HAZARDS FOR OTHER LAND USES.	2 CEFHLN — IN SOME CASES, INCREASED DESIGN AND DEVELOPMENT COSTS. CAREFUL ATTENTION SHOULD BE GIVEN TO COMPACTION OF BACKFILL AND RESTORATION OF SURFACE DRAINAGE.	2 ABCDEFHIJLN — IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.	2 ABCDEFHIJKN — IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.	3 ABCDEFHIJKN — IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.	3 ABCDEFHIJKN — IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.
Rockfall-rockslide debris-avalanche area	2 ACEFGKN — THESE AREAS ARE STEEPLY SLOPING MAKING THEM EXPENSIVE TO CONSTRUCT ROADS ON. CUTS MAY CAUSE SUDDEN MOVEMENT OF ROCK AND DEBRIS.	3 CFG — OCCASIONAL CLEAN UP OF ROCKS AND DEBRIS WILL BE NECESSARY.	4 CFGN — OCCASIONAL REPLACEMENT OF UTILITY LINES WILL BE NECESSARY. OCCASIONAL DISRUPTION OF SERVICE BECAUSE OF LINE BREAKAGE.	4 ABCEFGKN — CAREFUL SITING OF STRUCTURES, ROADS AND UTILITIES MAY RESULT IN REDUCTION OF DANGER TO AN ACCEPTABLE LEVEL.	4 ABCEFGKN — CAREFUL SITING OF STRUCTURES, ROADS, AND UTILITIES MAY, IN SOME INSTANCES, RESULT IN REDUCTION OF DANGER TO AN ACCEPTABLE LEVEL.	5 ABCEFGKN — IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS.	5 ABCEFGKN — IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS.
Mudflow-debris flow area	1 DFGLN — EXCEPT DURING INFREQUENT MUDFLOW, DEBRIS-FLOW EVENTS, THESE AREAS PRESENT LITTLE PROBLEM FOR ROAD CONSTRUCTION.	2 DFG — OCCASIONAL CLEANUP OF MUD, ROCKS, AND DEBRIS WILL BE NECESSARY.	2 DFGLN — OCCASIONAL REPAIR OR REPLACEMENT OF UTILITY LINES WILL BE NECESSARY.	4 FGKLN — CAREFUL SITING OF STRUCTURES, ROADS AND UTILITIES MAY RESULT IN REDUCTION OF DANGER TO AN ACCEPTABLE LEVEL.	4 FGKLN — IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS UNLESS ELABORATE HAZARD-MITIGATION MEASURES ARE EMPLOYED.	5 FGKLN — IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS UNLESS ELABORATE HAZARD-MITIGATION MEASURES ARE EMPLOYED.	5 FGKLN — IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS UNLESS ELABORATE HAZARD-MITIGATION MEASURES ARE EMPLOYED.
Subsidence area	2 L — MAY RESULT IN UNEXPECTEDLY HIGH REMEDIAL-ENGINEERING AND CONSTRUCTION COSTS.	2 L — MAY RESULT IN UNEXPECTEDLY HIGH MAINTENANCE COSTS.	2 L — MAY RESULT IN HIGH REMEDIAL-ENGINEERING AND CONSTRUCTION COSTS.	4 L — CAREFUL SITING OF STRUCTURES COMBINED WITH SOME DETAILED ENGINEERING GEOLOGIC STUDIES USUALLY CAN MINIMIZE HAZARD.	4 K — CAREFUL SITING OF STRUCTURES COMBINED WITH DETAILED ENGINEERING-GEOLOGIC STUDIES CAN MINIMIZE HAZARDS.	5 K — USUALLY A HIGH HAZARD EVEN IF DETAILED ENGINEERING GEOLOGIC STUDIES MADE AND GEOLOGICAL ENGINEERING RECOMMENDATIONS CARRIED OUT.	5 K — USUALLY A HIGH HAZARD EVEN IF DETAILED ENGINEERING GEOLOGIC STUDIES ARE MADE AND GEOLOGICAL ENGINEERING RECOMMENDATIONS ARE CARRIED OUT.
Modern accelerated erosion area	3 ABCDFGKM — REMEDIAL AND/OR MITIGATION MEASURES MAY BE NECESSARY.	3 BCDFGM — MAY RESULT IN HIGH MAINTENANCE COSTS.	3 ABCDFGKM — MAY RESULT IN HIGH MAINTENANCE COSTS.	2 ABCDFGKM — MINOR SURFACE-DRAINAGE MODIFICATIONS OR OTHER CORRECTIVE MEASURES CAN REDUCE THE HAZARD CONSIDERABLY.	4 ABCDFGKM — SURFACE-DRAINAGE MODIFICATIONS, REMEDIAL MEASURES TO DECREASE GULLYING POTENTIAL AND CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO DRAINAGE CAN REDUCE THE HAZARD CONSIDERABLY.	4 ABCDFGKM — SURFACE-DRAINAGE MODIFICATIONS, REMEDIAL MEASURES TO DECREASE GULLYING POTENTIAL, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE CAN REDUCE HAZARD CONSIDERABLY.	4 ABCDFGKM — SURFACE-DRAINAGE MODIFICATIONS, REMEDIAL MEASURES TO DECREASE GULLYING POTENTIAL, AND CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE CAN REDUCE THE HAZARD CONSIDERABLY.
Moderate-to-high erosion potential area	2 ABCDFGKM — REMEDIAL AND/OR CORRECTIVE MEASURES MAY BE NECESSARY IF ROAD IS NOT CAREFULLY DESIGNED. AN EROSION-CONTROL PLAN SHOULD BE DEVELOPED PRIOR TO CONSTRUCTION.	2 BCDFGM — REMEDIAL AND/OR CORRECTIVE MEASURES MAY BE NECESSARY IF ROAD IS NOT CAREFULLY MAINTAINED, ESPECIALLY MAINTENANCE AFFECTING DRAINAGE OR DRAINAGE-CONTROL STRUCTURES.	2 ABCDFGKM — IF EXCAVATIONS OR CUTS AND FILLS ARE CAREFULLY DESIGNED AND EXECUTED, MOST UTILITIES WILL NOT ACCELERATE EROSION.	2 ABCDFGKM — MINOR SURFACE-DRAINAGE MODIFICATIONS OR OTHER CORRECTIVE MEASURES CAN MINIMIZE EROSION HAZARD.	2 ABCDFGKM — SURFACE-DRAINAGE MODIFICATIONS, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE, AND MINIMAL DISTURBANCE OF NATURAL VEGETATION CAN MINIMIZE EROSION HAZARD.	2 ABCDFGKM — SURFACE-DRAINAGE MODIFICATIONS, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE, AND MINIMAL DISTURBANCE OF NATURAL VEGETATION CAN MINIMIZE EROSION HAZARD.	2 ABCDFGKM — SURFACE-DRAINAGE MODIFICATIONS, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE AND MINIMAL DISTURBANCE TO VEGETATION CAN MINIMIZE EROSION HAZARD.
Low erosion potential area	3 DF — MAY BE DIFFICULT AND/OR EXPENSIVE TO BUILD ROADS IN AREAS WHERE BEDROCK IS NEAR THE SURFACE.	1 D — ROADS ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	3 DK — MAY BE DIFFICULT OR EXPENSIVE TO MAKE CUTS IN AREAS WHERE BEDROCK IS NEAR THE SURFACE. UTILITIES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	3 DL — MAY BE DIFFICULT OR EXPENSIVE TO EXCAVATE FOR FOUNDATIONS OR INSTALLATION OF UTILITIES. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	2 DK — MAY BE DIFFICULT OR EXPENSIVE TO EXCAVATE FOR FOUNDATIONS OR INSTALLATION OF UTILITIES. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	2 DK — MAY BE DIFFICULT OR EXPENSIVE TO EXCAVATE FOR FOUNDATIONS OR INSTALLATION OF UTILITIES. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	2 DK — MAY BE DIFFICULT AND EXPENSIVE TO EXCAVATE FOR FOUNDATIONS. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.

HAZARDS MAP UNIT	Industrial and commercial development	Agriculture and grazing	Subsurface-fluid extraction (water and oil and gas)	Mining and quarrying	Septic sewage disposal	Solid-waste disposal
Landslide area	4 ABCDFHIJKN — REMEDIAL ENGINEERING AND/OR LANDSLIDE STABILIZATION MAY, IN SOME CASES, MAKE THIS TYPE OF DEVELOPMENT FEASIBLE.	1 BCDFHLN — POSSIBLE DAMAGE TO FENCES, BUILDINGS AND IRRIGATION DITCHES AND SOME TYPES OF DRAINAGE MODIFICATIONS.	1 IJL — POSSIBLE DAMAGE TO WELL CASINGS AND RARELY DRILLING AND PRODUCTION EQUIPMENT.	2 ABCDFHL — MAY CAUSE TECHNICAL DIFFICULTIES ASSOCIATED WITH REMOVAL OF SOIL AND ROCK. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	3 ABCDFHK — LANDSLIDING MIGHT CAUSE DAMAGE TO TANKS OR LEACH LINES. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.	2 BCDEFHK — CUT SLOPES IN SOME LANDFILLS MAY FAIL CAUSING INCREASED OPERATING COSTS.
Unstable or potentially unstable slope	2 ABCDFHIJKN — REMEDIAL ENGINEERING WILL IN MANY CASES MAKE THIS TYPE OF DEVELOPMENT FEASIBLE.	0 BCDFHLN — OCCASIONAL DAMAGE TO FENCES, BUILDING AND IRRIGATION DITCHES.	1 IJL — INFREQUENT DAMAGE TO WELL CASINGS AND PRODUCTION EQUIPMENT.	1 ABCDF — OCCASIONALLY MAY CAUSE DIFFICULTIES FOR REMOVAL OF SOIL AND ROCK. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	2 ABCDFHL — SLOPE MOVEMENT MIGHT CAUSE DAMAGE TO TANKS OR LEACH LINES. INCREASED GROUND MOISTURE COULD CAUSE SLOPE INSTABILITY.	1 BCDEFHL — CUT SLOPES IN SOME LANDFILLS MAY FAIL CAUSING INCREASED OPERATING COSTS.
Rockfall-rockslide debris-avalanche area	5 ABCEFGKN — WITH CONSIDERABLE REMEDIAL ENGINEERING SOME TYPES OF INDUSTRIAL OR COMMERCIAL DEVELOPMENT MAY BE TECHNICALLY FEASIBLE.	0 BCEFGN — OCCASIONAL DAMAGE TO FENCES, BUILDINGS AND IRRIGATION DITCHES.	2 CG — SOME OCCASIONAL DIFFICULTIES FOR DRILLING AND PRODUCTION EQUIPMENT.	1 ACG — SOME OCCASIONAL DIFFICULTIES FOR EQUIPMENT AND OPERATIONS. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	4 K — PERCOLATION RATES ARE TYPICALLY MUCH TOO HIGH FOR SEPTIC SEWAGE DISPOSAL.	2 K — MOST OF THESE AREAS ARE TOO STEEP FOR PRACTICAL LANDFILL SITES.
Mudflow-debris flow area	4 FGKLN — WITH INSTALLATION OF DEFENSE STRUCTURES AND ENGINEERED MITIGATION MEASURES SOME TYPES OF INDUSTRIAL AND COMMERCIAL DEVELOPMENT MAY BE FEASIBLE.	1 FGN — EXCEPT DURING INFREQUENT MUDFLOW DEBRIS-FLOW EVENTS, THESE AREAS PRESENT ESSENTIALLY NO PROBLEM FOR AGRICULTURE.	1 FG — INFREQUENT DAMAGE TO DRILLING AND PRODUCTION EQUIPMENT.	1 FG — INFREQUENT DISRUPTION OF MINING OR QUARRYING ACTIVITY. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	4 FG — POSSIBLE INFREQUENT DAMAGE TO OR DESTRUCTION OF SYSTEM.	4 K — POSSIBLE INFREQUENT DISRUPTION BY LANDFILL ACTIVITY. MUDFLOW-DEBRIS-FLOW DEPOSITS ARE TYPICALLY TOO PERMEABLE TO MAKE GOOD LANDFILL SITES.
Subsidence area	5 K — WITH EXTENSIVE REMEDIAL ENGINEERING WORK THIS TYPS OF DEVELOPMENT MAY BE SAFE AND COMMERCIALLY FEASIBLE.	1 — POSSIBLE DAMAGE TO IRRIGATION DITCHES AND BUILDINGS.	2 L — POSSIBLE DAMAGE TO PRODUCTION EQUIPMENT. POSSIBLY PROBLEMS FOR DRILLING, CASING, OR CEMENTING OPERATIONS.	1 — COLLAPSE OF GROUND SURFACE COULD DAMAGE EQUIPMENT OR DISRUPT OPERATIONS.	2 K — SUBSIDENCE MAY DAMAGE TANKS OR DISRUPT LEACH LINES.	1 L
Modern accelerated erosion area	3 ABCDFGKM — REMEDIAL AND/OR CORRECTIVE MEASURES WILL BE NECESSARY AND MAY BE EXPENSIVE.	2 BCDFGM — CORRECTIVE MEASURES MAY INCREASE AGRICULTURAL PRODUCTIVITY OF LAND.	1 CDFGLM — MIGHT CAUSE DIFFICULTIES FOR ACCESS ROADS AND PRODUCTION EQUIPMENT.	1 CFGLM — MAY CAUSE MINOR DIFFICULTIES FOR ACCESS ROADS DURING HEAVY RAINSTORMS.	1 M — MIGHT CAUSE MINOR DIFFICULTIES FOR LEACH FIELDS.	1 M — MINOR DIFFICULTIES IN MOST CASES WHERE CAREFULLY PLANNED.
Moderate-to-high erosion potential area	2 ABCDFGKM — REMEDIAL AND/OR CORRECTIVE MEASURES WILL BE NECESSARY.	2 BCDFGM — CORRECTIVE MEASURES MAY INSURE OR INCREASE AGRICULTURAL PRODUCTIVITY OF LAND.	1 CDFGM — MAY ADD TO THE COST OF INSTALLATION AND MAINTENANCE OF PRODUCTION EQUIPMENT.	1 CFGM — CONSTRUCTION AND MAINTENANCE OF ACCESS ROADS MAY BE AFFECTED SEVERELY BY HEAVY RAINSTORMS.	1 M — INCREASED GROUND MOISTURE FROM LEACHFIELDS MAY CAUSE OR ACCELERATE EROSION.	1 KM — MINOR DIFFICULTIES IN MOST CASES WHERE EXCAVATIONS ARE CAREFULLY PLANNED WITH RESPECT TO NATURAL DRAINAGE.
Low erosion potential area	2 DK — CONSTRUCTION COSTS MAY INCREASE CONSIDERABLY. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	0 L — AGRICULTURAL STRUCTURES ADJACENT, TO MAJOR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	1 L — SOME DIFFICULTIES FOR INSTALLATION OF PRODUCTION EQUIPMENT. STRUCTURES ADJACENT TO MAJOR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	1 L — CONSTRUCTION OF ACCESS ROADS MAY BE DIFFICULT. MINES AND QUARRIES NEAR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	4 DK — TYPICALLY, PERCOLATION RATES ARE TOO LOW (BEDROCK NEAR SURFACE) OR TOO HIGH (NEAR MAJOR DRAINAGES) FOR LEACH FIELDS TO WORK PROPERLY. EXCAVATIONS TYPICALLY DIFFICULT AND EXPENSIVE IN SHALLOW BEDROCK AREAS. AREAS NEAR MAJOR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	4 DK — EXCAVATION DIFFICULT IN SHALLOW DEPTH-TO-BEDROCK AREAS. OCCASIONAL FLOODING IN AREAS ADJACENT TO MAJOR DRAINAGES CAN DISRUPT OPERATIONS. PERCOLATION OF LEACHATE CONTAMINATING GROUND WATER MAY OCCUR IN AREAS NEAR MAJOR DRAINAGES.

Explanation of Chart Symbols

KEY TO CHART



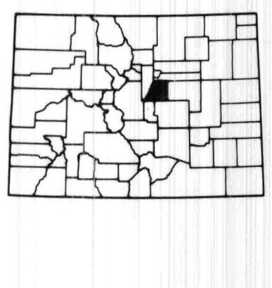
DEGREE OF HAZARD

- 0 IN ALL CASES ESSENTIALLY NO GEOLOGIC HAZARDS WILL BE CREATED - LITTLE, IF ANY, HAZARD
- 1 TYPICALLY MINOR PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - LOW HAZARD
- 2 IN SOME CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - MODERATE HAZARD
- 3 IN MANY CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - MODERATE TO HIGH HAZARD
- 4 IN MOST CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - HIGH HAZARD
- 5 IN ESSENTIALLY ALL CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - VERY HIGH TO EXTREME(SEVERE) HAZARD

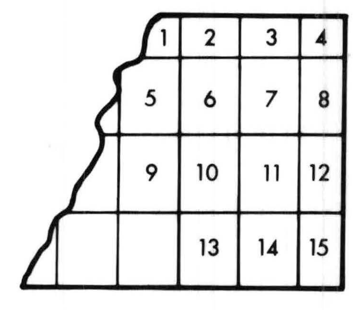
CONDITIONS AFFECTING HAZARD

- A IMPROPERLY DESIGNED CUTS OR FILLS CAN INCREASE THE HAZARD GREATLY
- B STREAM REROUTING OR INADEQUATE DRAINAGE CONTROL STRUCTURES CAN INCREASE THE HAZARD GREATLY
- C DISRUPTION OR REMOVAL OF NATURAL VEGETATION CAN INCREASE THE HAZARD GREATLY
- D OCCASIONAL FLASH FLOODING IN SMALL DRAWS CAN BE A SEVERE HAZARD
- E HAZARD DECREASES CONSIDERABLY WITH DECREASING SLOPE
- F HAZARD OR LIKELIHOOD OF OCCURRENCE OF THIS HAZARDOUS PROCESS VARIES SEASONALLY
- G NEARLY ALL HAZARDOUS EVENTS OCCUR RAPIDLY DURING HEAVY RAINSTORMS
- H SLOPE MOVEMENT(S) DEPENDENT ON VARIATIONS IN WEATHER, GROUND MOISTURE, COMPOSITION OF SURFICIAL MATERIALS, AND MAN-MADE SURFACE MODIFICATIONS
- I SWELLING (EXPANSIVE) SOILS MAY OCCUR LOCALLY
- J SETTLING SOILS MAY OCCUR LOCALLY
- K DETAILED ENGINEERING-GEOLOGY STUDIES NECESSARY DURING PRE-PLANNING PHASES OF DEVELOPMENT
- L GEOLOGIC CONDITIONS SHOULD BE CONSIDERED SERIOUSLY IN DEVELOPMENT PLANS
- M MAY INCREASE INSTABILITY OF AN UNSTABLE OR POTENTIALLY UNSTABLE SLOPE
- N MAY INCREASE LIKELIHOOD OF ACCELERATED EROSION IN A MODERATE-TO-HIGH EROSION-POTENTIAL AREA

Colorado



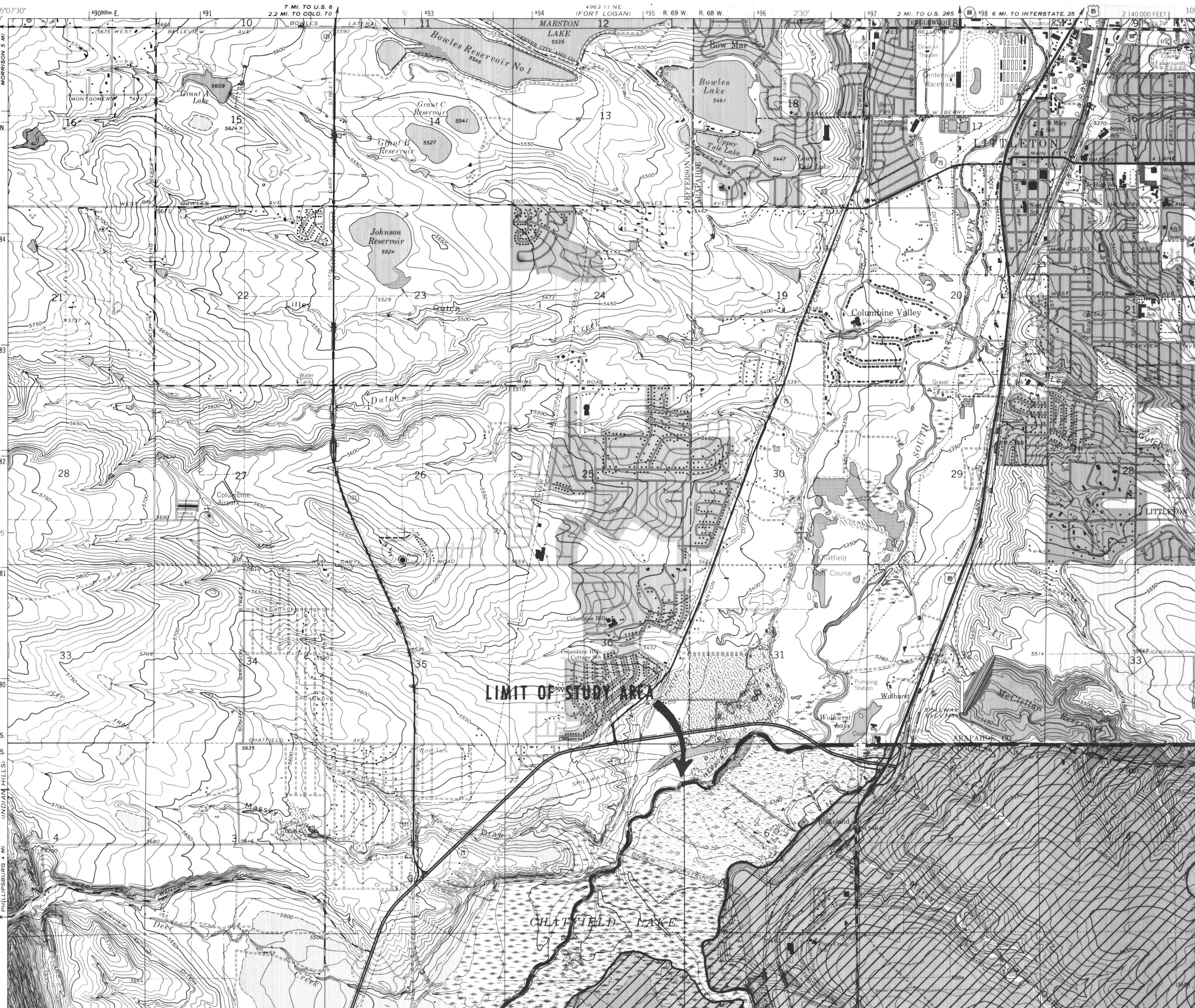
Index of 7½′ Quadrangle Sheets in Douglas County



1 Littleton
2 Highlands Ranch
3 Parker
4 Piney Creek
5 Kassler
6 Sedalia
7 Castle Rock North
8 Ponderosa Park
9 Devils Head
10 Dawson Butte
11 Castle Rock South
12 Russelville Gulch
13 Larkspur
14 Greenland
15 Cherry Valley School

PLATE 16 of 16

Drafted by: Susan J. Soukup



Base from U.S. Geological Survey
7 ½-minute quadrangle.

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Purple tint indicates extension of urban areas

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

CGS-OF-78-5

PLATE 1 OF 16

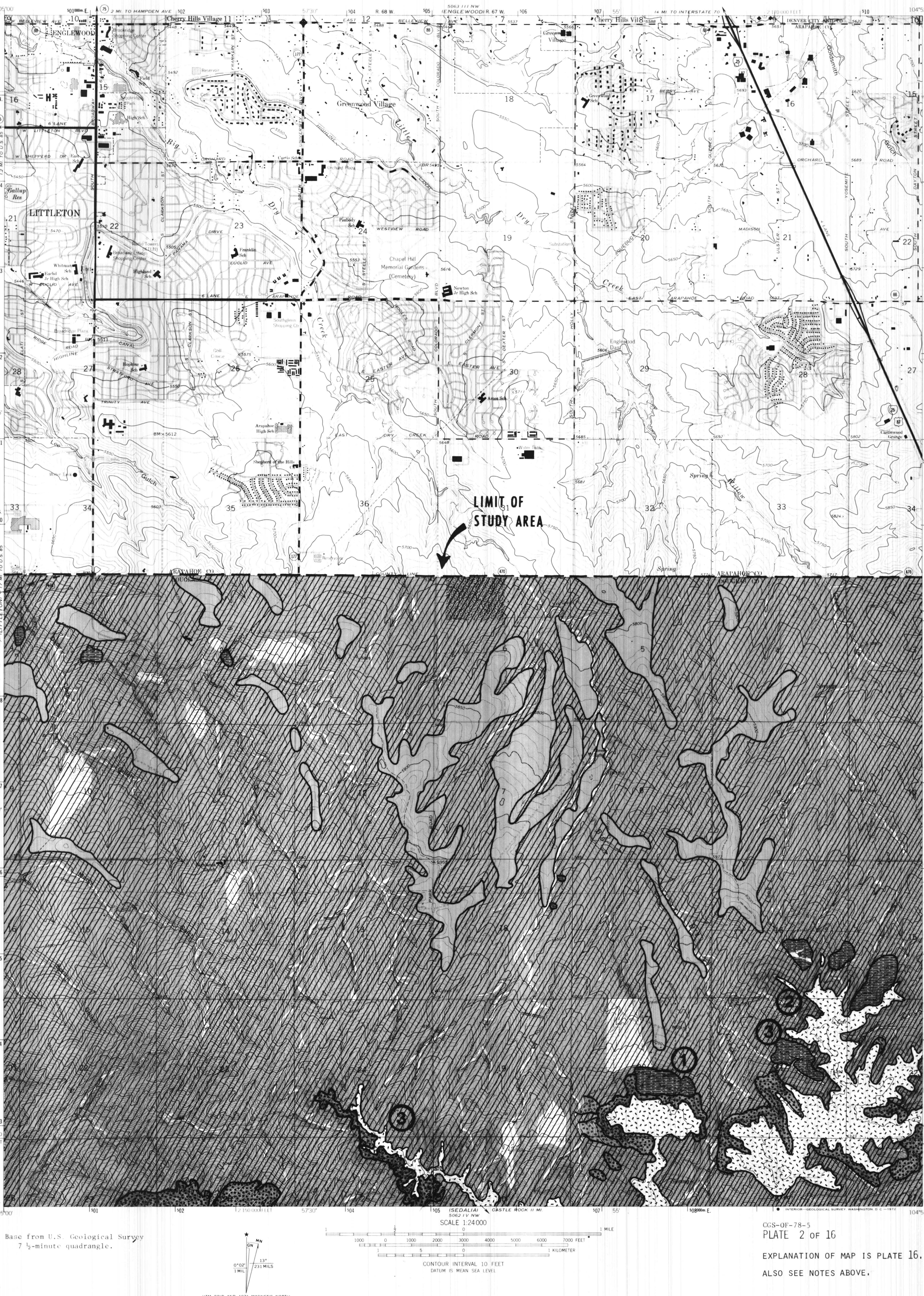
EXPLANATION OF MAP IS PLATE 16.

GEOLOGIC HAZARDS MAP OF THE LITTLETON QUADRANGLE

BY

JAMES M. SOULE

1978



NOTES

① This large landslide appears to be inactive. Intensive residential development of this feature could reactivate its movements.

② There are many small areas of accelerated creep and small-scale landsliding on steeper mesa sideslopes in this area.

③ Most small drainageways adjacent to mesa slideslopes are localized small debris-flow areas.

Base from U.S. Geological Survey
7 ½-minute quadrangle.

UTM GRID AND 1971 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

CGS-OF-78-5
PLATE 2 OF 16

EXPLANATION OF MAP IS PLATE 16.

ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE HIGHLANDS RANCH QUADRANGLE

BY

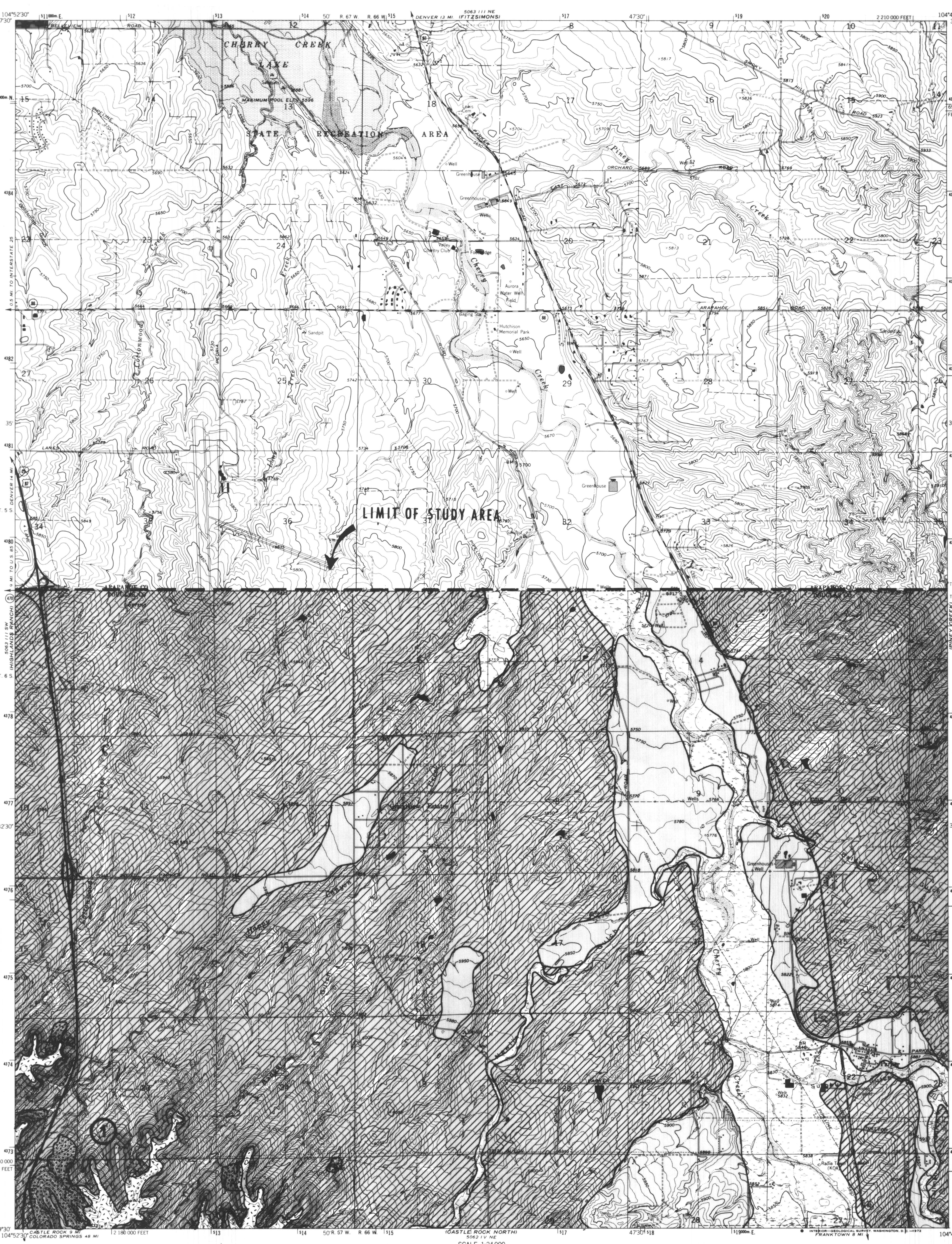
JAMES M. SOULE

1978

REFERENCES

Maberry, J.O. and Lindvall, R. M., 1974, Geologic map and engineering data for the Highlands Ranch Quadrangle, Arapahoe and Douglas Counties, Colorado: U.S. Geol. Survey Map MF-631.

________________, 1977, Geologic map of the Highlands Ranch Quadrangle, Arapahoe and Douglas Counties, Colorado: U.S. Geol. Survey Map GQ-1413.



NOTE

(1) Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rock-slide areas.

Base from U.S. Geological Survey 7 ½-minute quadrangle.

SCALE 1:24000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CGS-OF-78-5

PLATE 3 OF 16

EXPLANATION OF MAP IS PLATE 16.

ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE PARKER QUADRANGLE

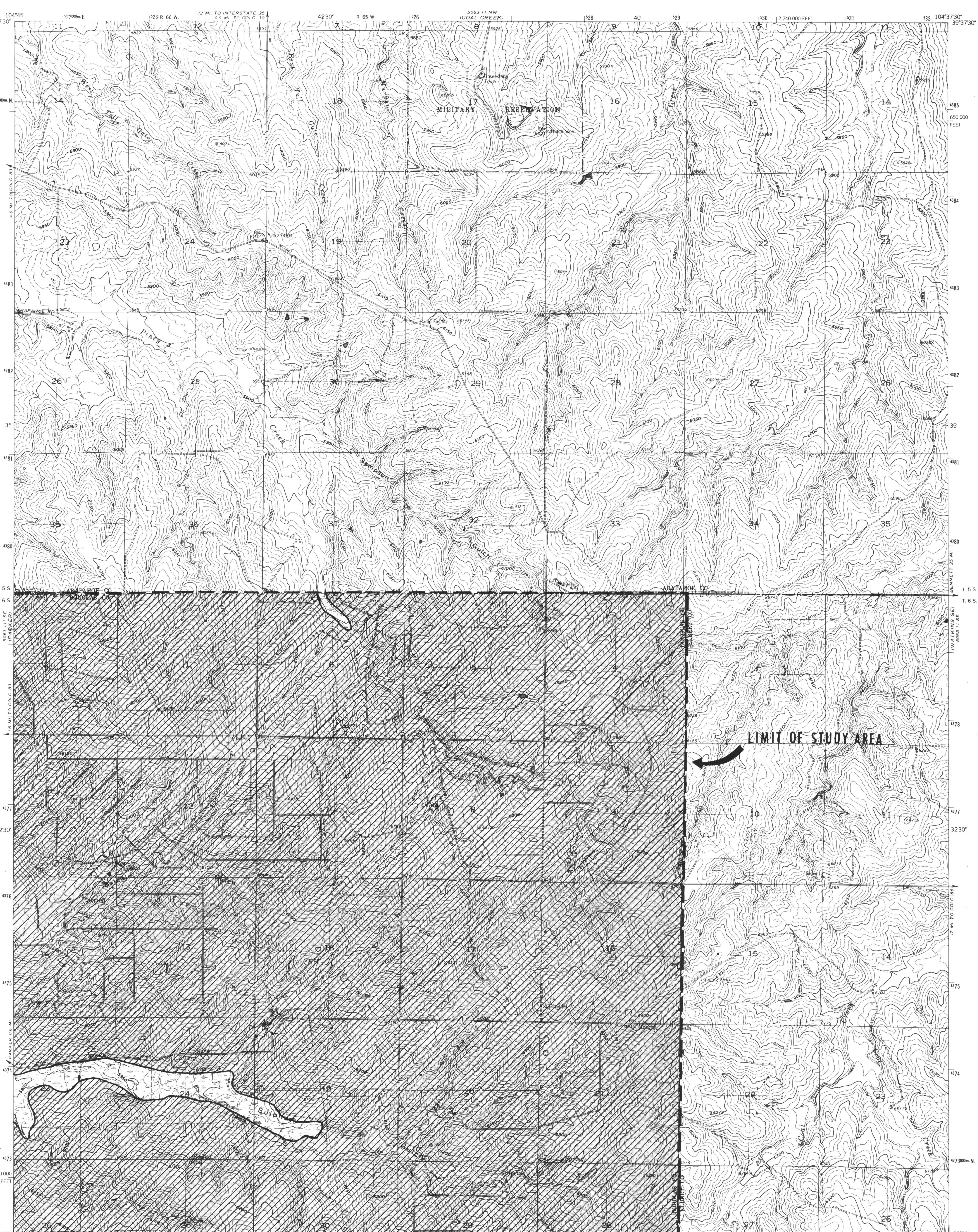
BY

JAMES M. SOULE

1978

REFERENCES

Maberry, J. O. and Lindvall, R. M., Folio of the Parker Quadrangle, Douglas and Arapahoe Counties, Colorado: U.S. Geol. Survey Maps I-770-A to I-770-N.



Base from U.S. Geological Survey
7 ½-minute quadrangle.

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1971 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

CGS-OF-78-5

PLATE 4 OF 16

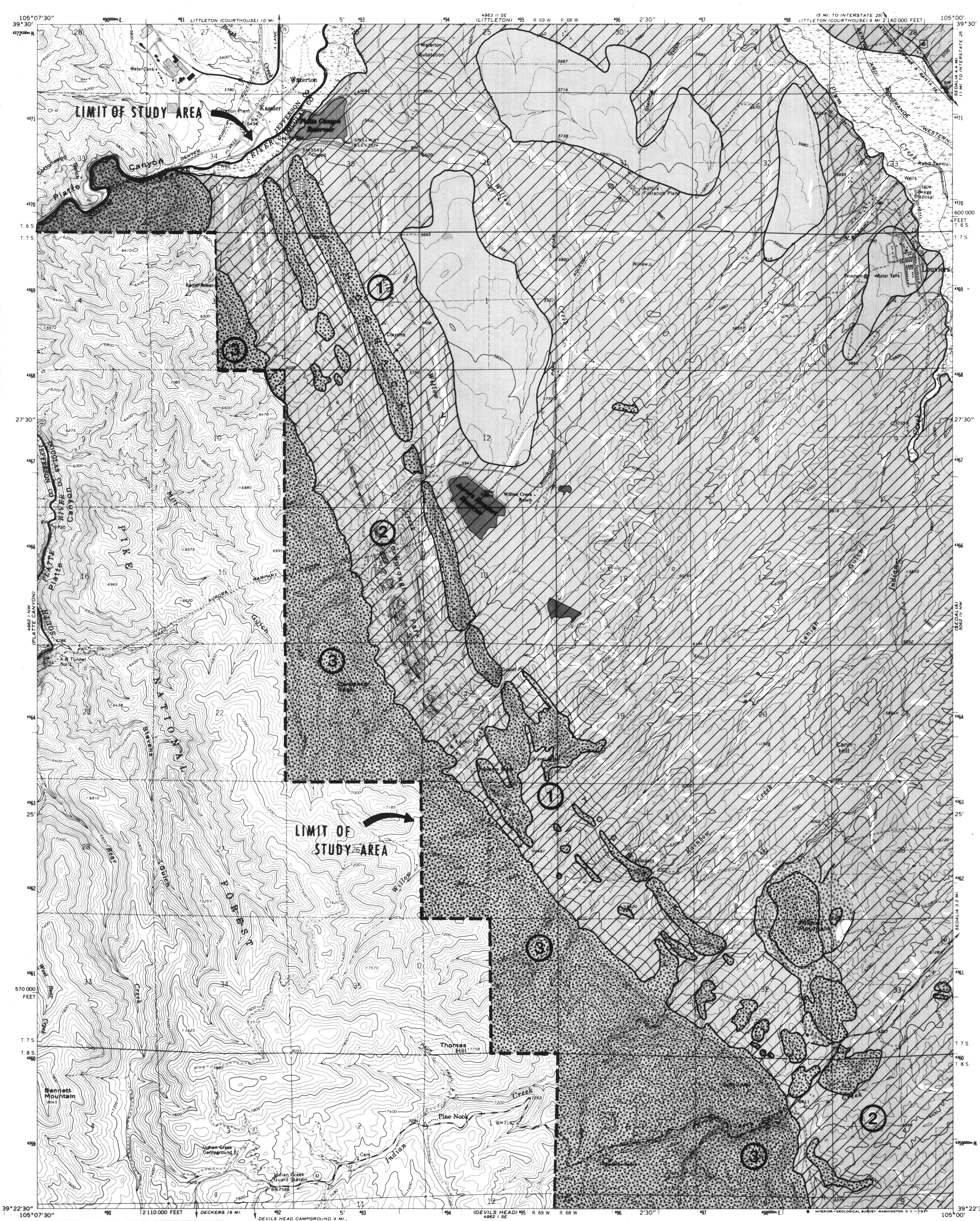
EXPLANATION OF MAP IS PLATE 16.

GEOLOGIC HAZARDS MAP OF THE
PINEY CREEK QUADRANGLE

BY

JAMES M. SOULE

1978



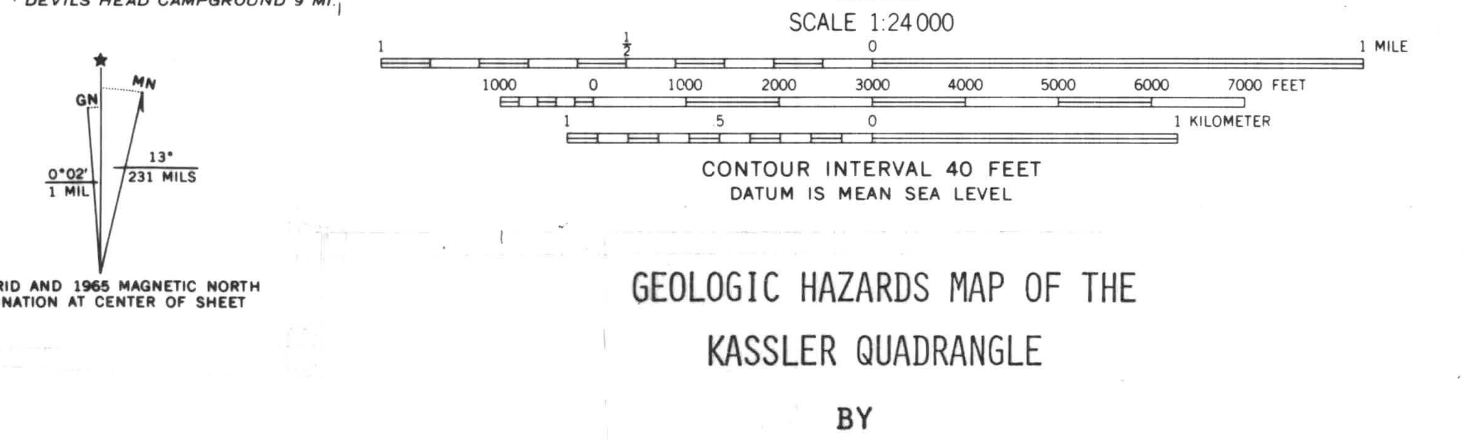
NOTES

① Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rockslide areas.

② Many pinnacles in the vicinity of Roxborough Park may present moderate to severe rockfall hazards in their immediate vicinity.

③ All canyons along the mountain front are highly flash-flood prone and can produce large amounts of mobilized debris during heavy rainstorms. Hazardous debris fans are formed at the mouths of most of these canyons.

Base from U.S. Geological Survey 7 ½-minute quadrangle.



CGS-OF-78-5

PLATE 5 OF 16

EXPLANATION OF MAP IS PLATE 16.

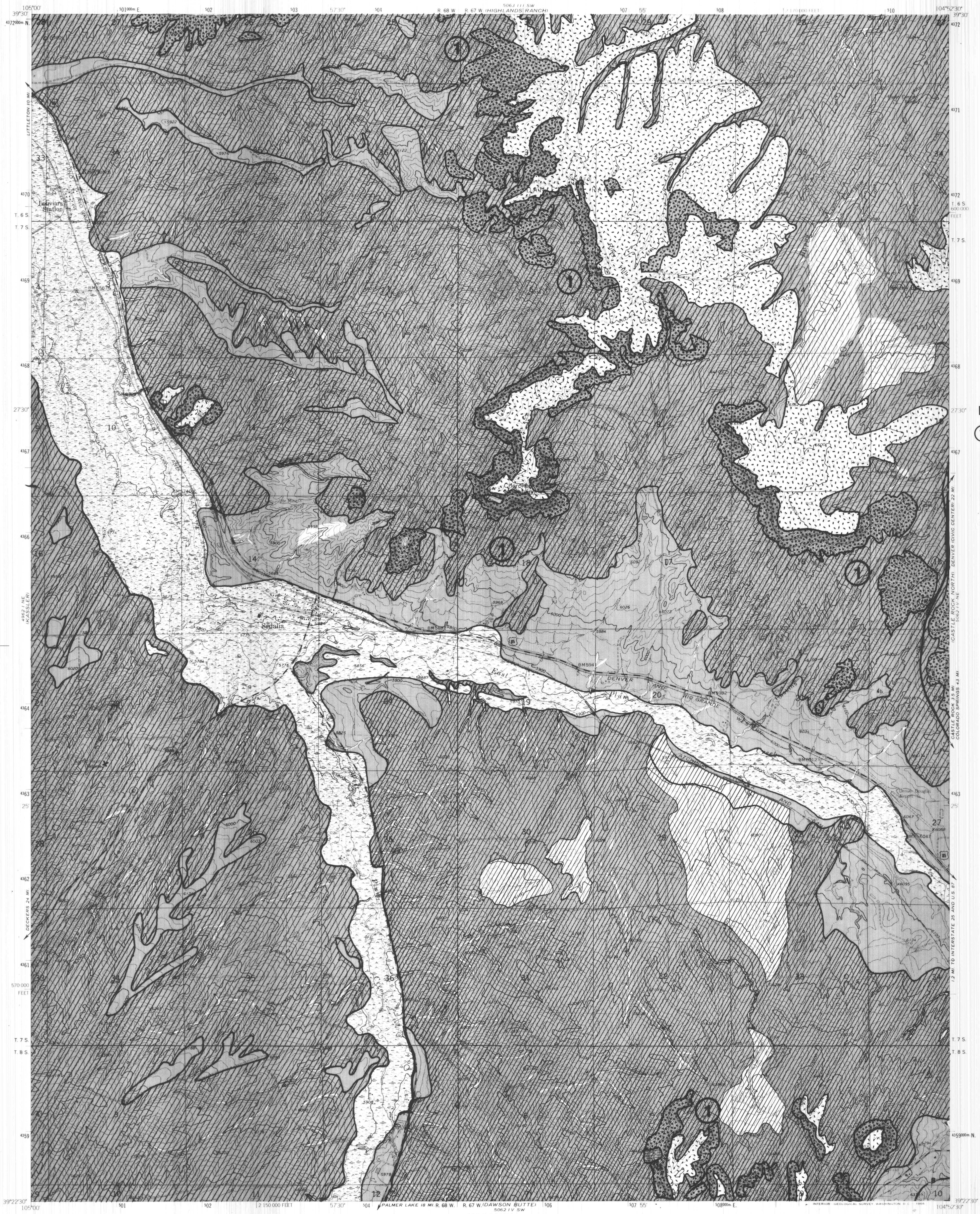
ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE KASSLER QUADRANGLE

BY

JAMES M. SOULE

1978



NOTE

(1) Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rock-slide areas.

Base from U.S. Geological Survey 7 ½-minute quadrangle.

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

CGS-OF-78-5

PLATE 6 OF 16

EXPLANATION OF MAP IS PLATE 16.

ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE SEDALIA QUADRANGLE

BY

JAMES M. SOULE

1978

NOTES

①

These landslides consist of large areas of deep accelerated creep. Slope movements appear to occur only during the late winter and spring months of especially wet years.

②

Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rockslide areas.

Base from U.S. Geological Survey 7 ½-minute quadrangle.

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

GN MN 0°07' 2 MILS 13° 231 MILS

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

CGS-OF-78-5
PLATE 7 OF 16

EXPLANATION OF MAP IS PLATE 16.

ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE CASTLE ROCK NORTH QUADRANGLE

BY

JAMES M. SOULE

1978

Base from U.S. Geological Survey 7 ½-minute quadrangle.

SCALE 1:24 000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CGS-OF-78-5

PLATE 8 OF 16

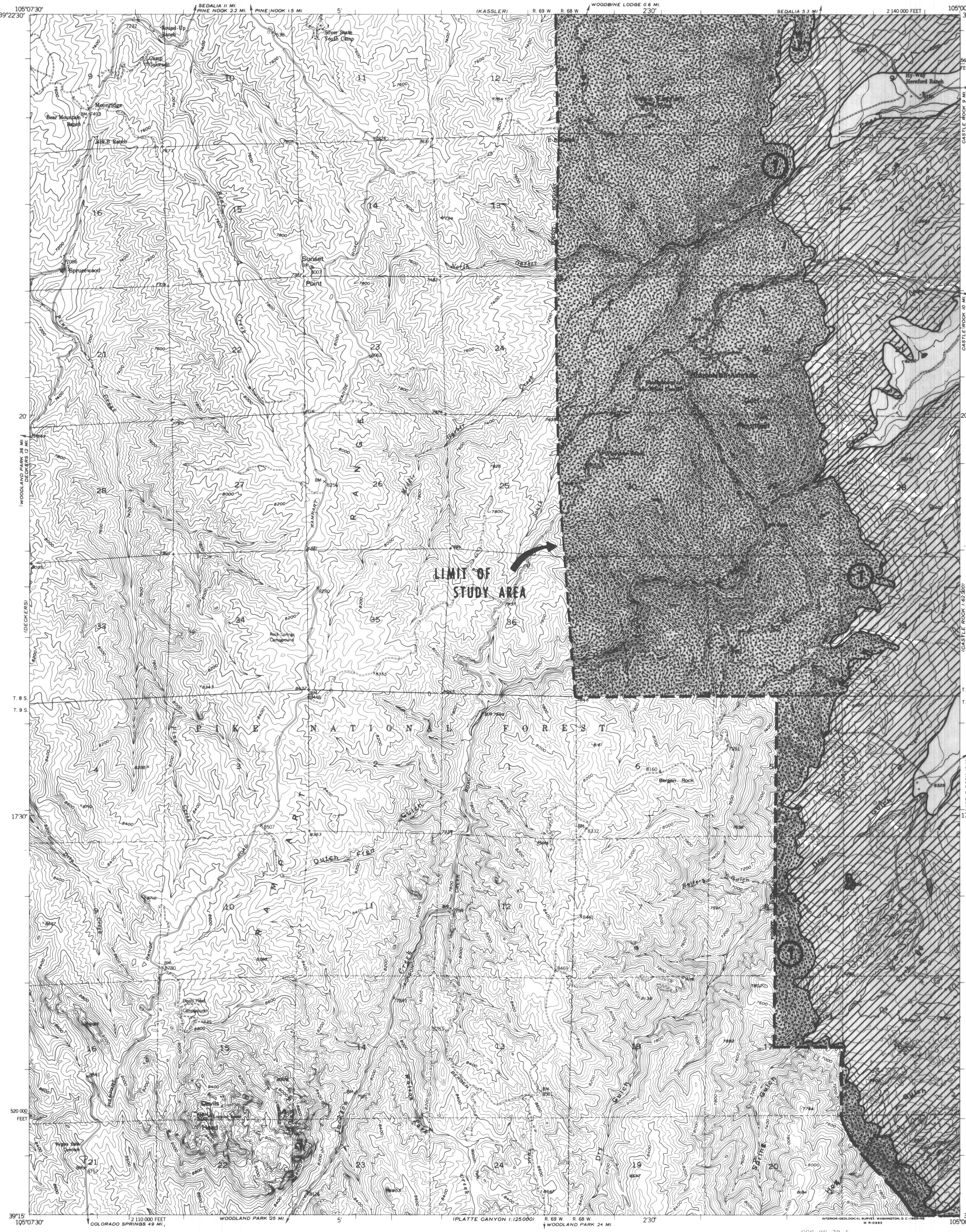
EXPLANATION OF MAP IS PLATE 16.

GEOLOGIC HAZARDS MAP OF THE PONDEROSA PARK QUADRANGLE

BY

JAMES M. SOULE

1978



NOTE

① All canyons along the mountain front are highly flash flood prone and can produce large amounts of mobilizied debris during heavy rainstorms. Hazardous debris fans are formed at the mouths of most of these canyons.

Base from U.S. Geological Survey 7 ½-minute quadrangle.

SCALE 1:24 000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

14°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1954

CGS-OF-78-5

PLATE 9 OF 16

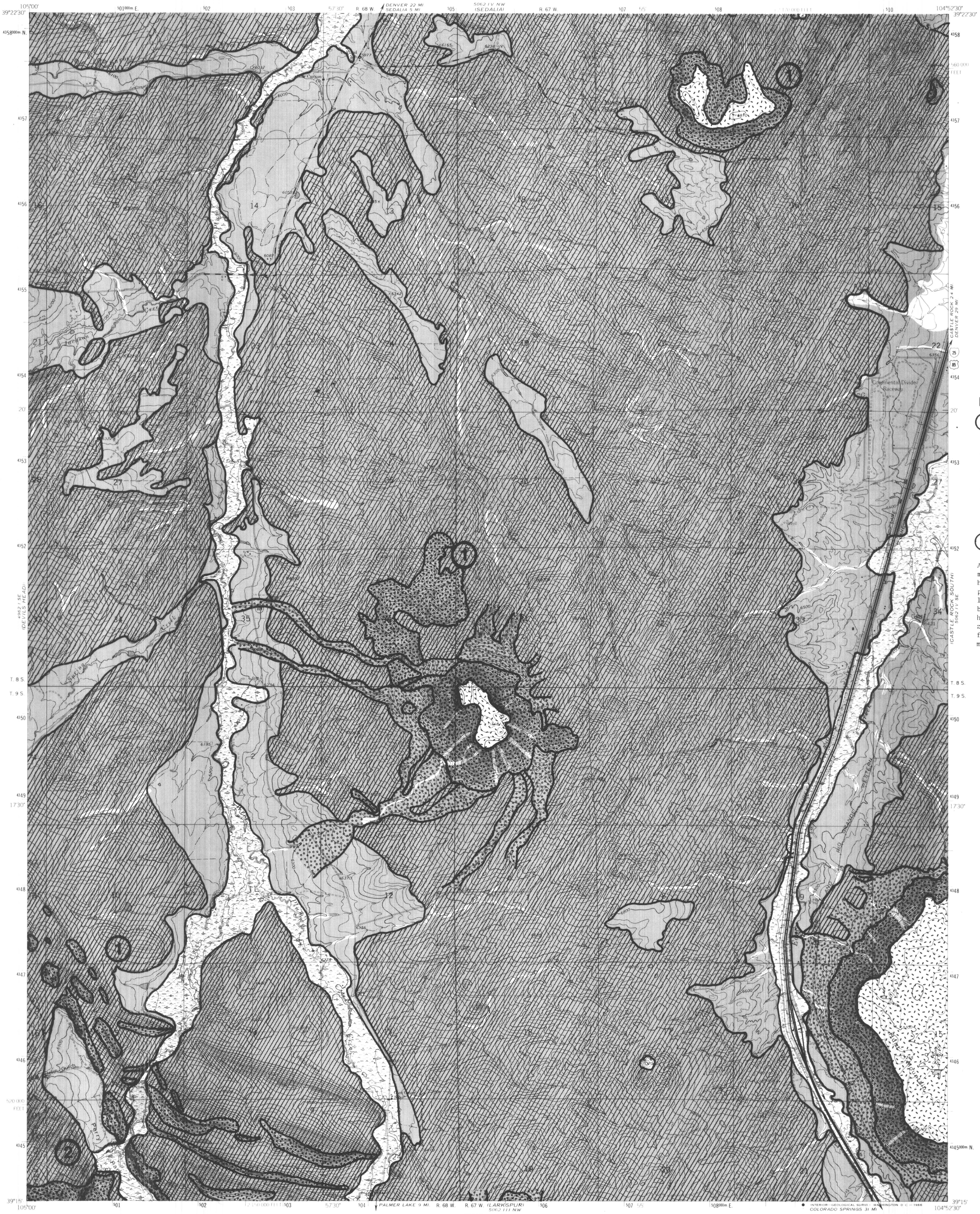
EXPLANATION OF MAP IS PLATE 16.
ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE DEVILS HEAD QUADRANGLE

BY

JAMES M. SOULE

1978



NOTES

① Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rockslide areas.

② All canyons along the mountain front are highly flash flood prone and can produce large amounts of mobilized debris during heavy rainstorms. Hazardous debris fans are formed at the mouths of most of these canyons.

Base from U. S. Geological Survey
7 ½-minute quadrangle.

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CGS-OF-78-5

PLATE 10 OF 16

EXPLANATION OF MAP IS PLATE 16.

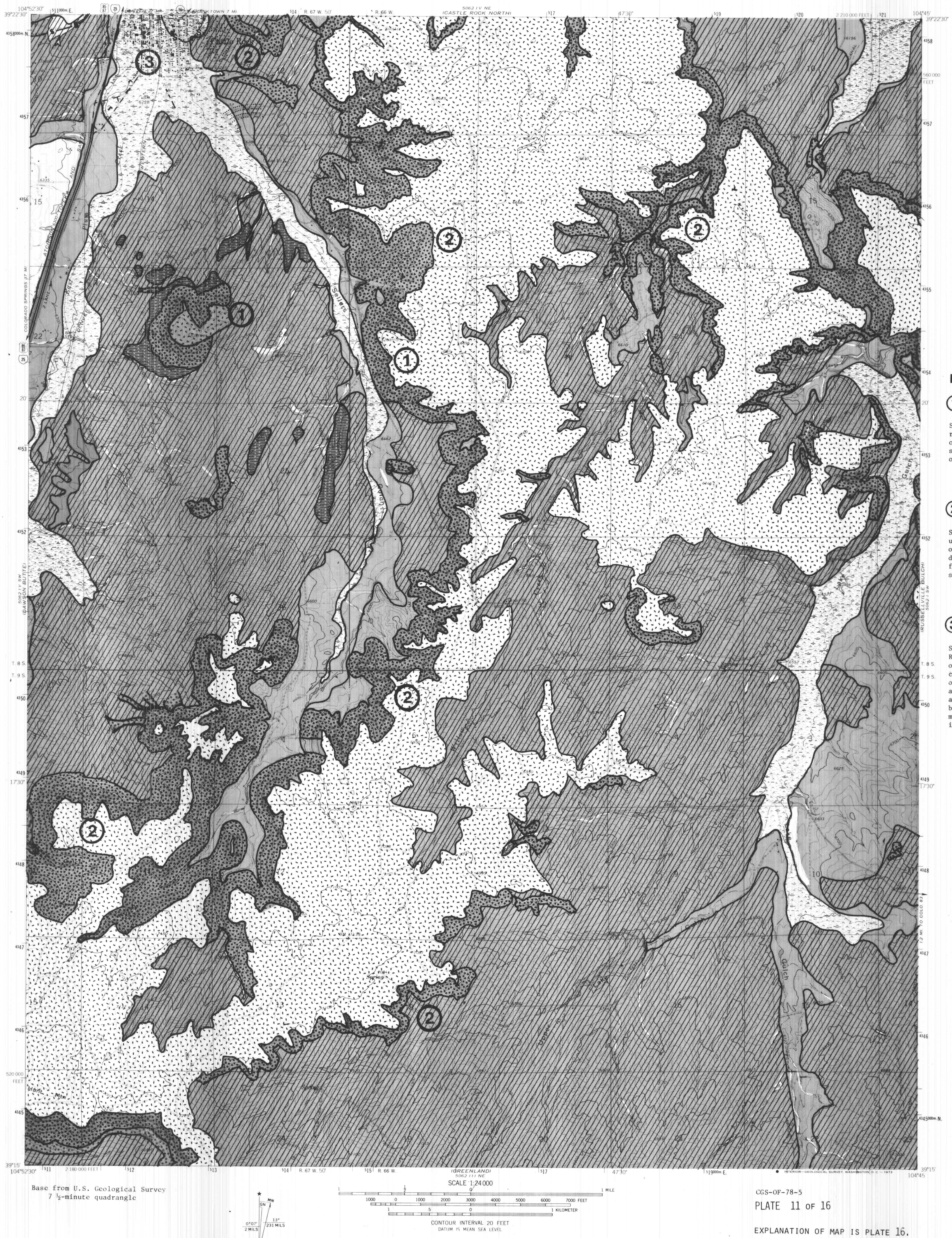
ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE
DAWSON BUTTE QUADRANGLE

BY

JAMES M. SOULE

1978



NOTES

① Small areas of rockfall-rockslide and unstable or potentially unstable slope exist near or in quarries.

② Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rockslide areas.

③ Subsidence near Castle Rock is caused by collapse of abandoned underground clay mines. As records of the exact location(s) and extent of this mining are not available the boundaries shown on this map should be considered indefinite.

Base from U.S. Geological Survey
7 ½-minute quadrangle

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CGS-OF-78-5

PLATE 11 OF 16

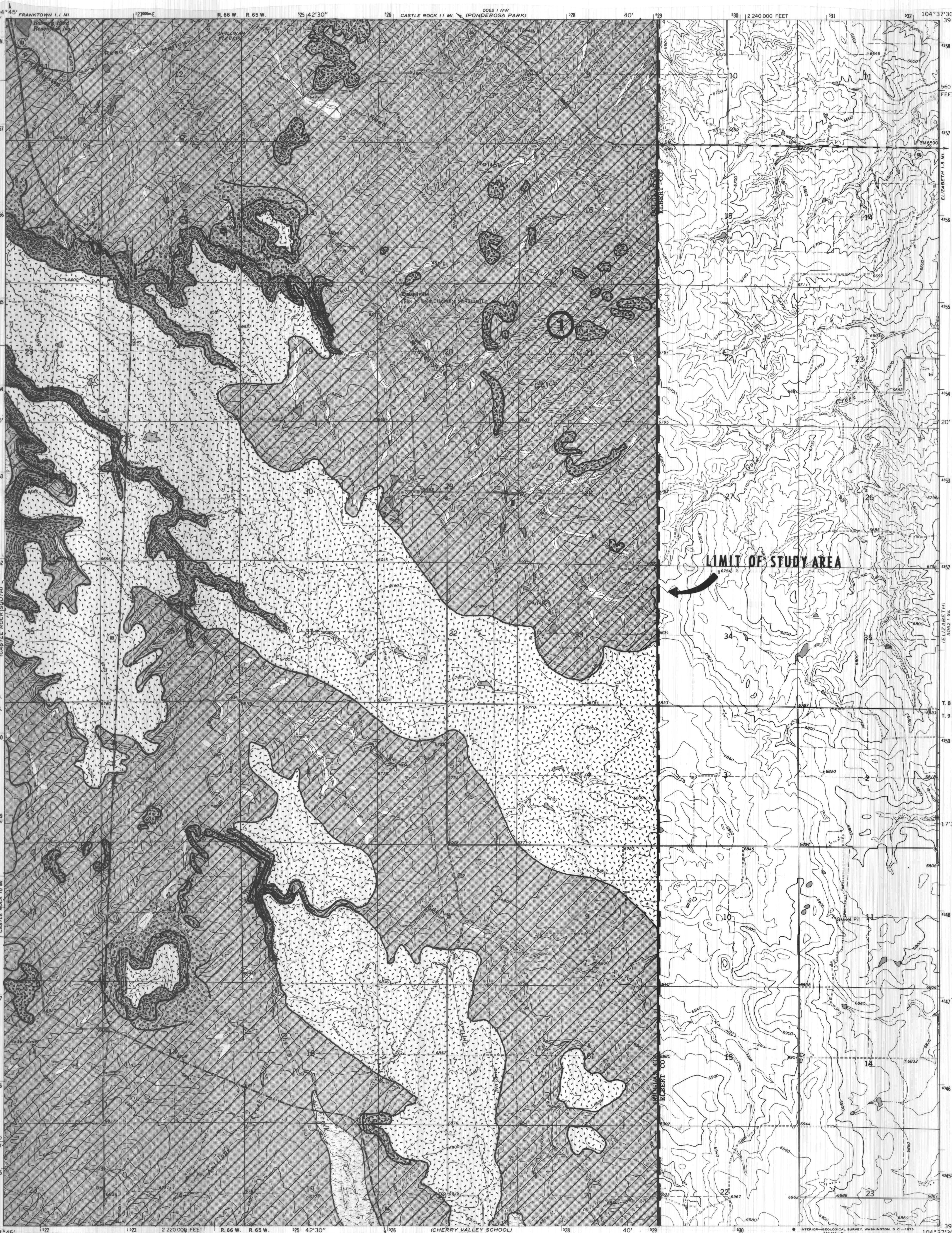
EXPLANATION OF MAP IS PLATE 16.
ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE CASTLE ROCK SOUTH QUADRANGLE

BY

JAMES M. SOULE

1978



NOTE

①

Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rock-slide areas.

Base from U.S. Geological Survey 7 ½-minute quadrangle.

SCALE 1:24 000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CGS-OF-78-5

PLATE 12 OF 16

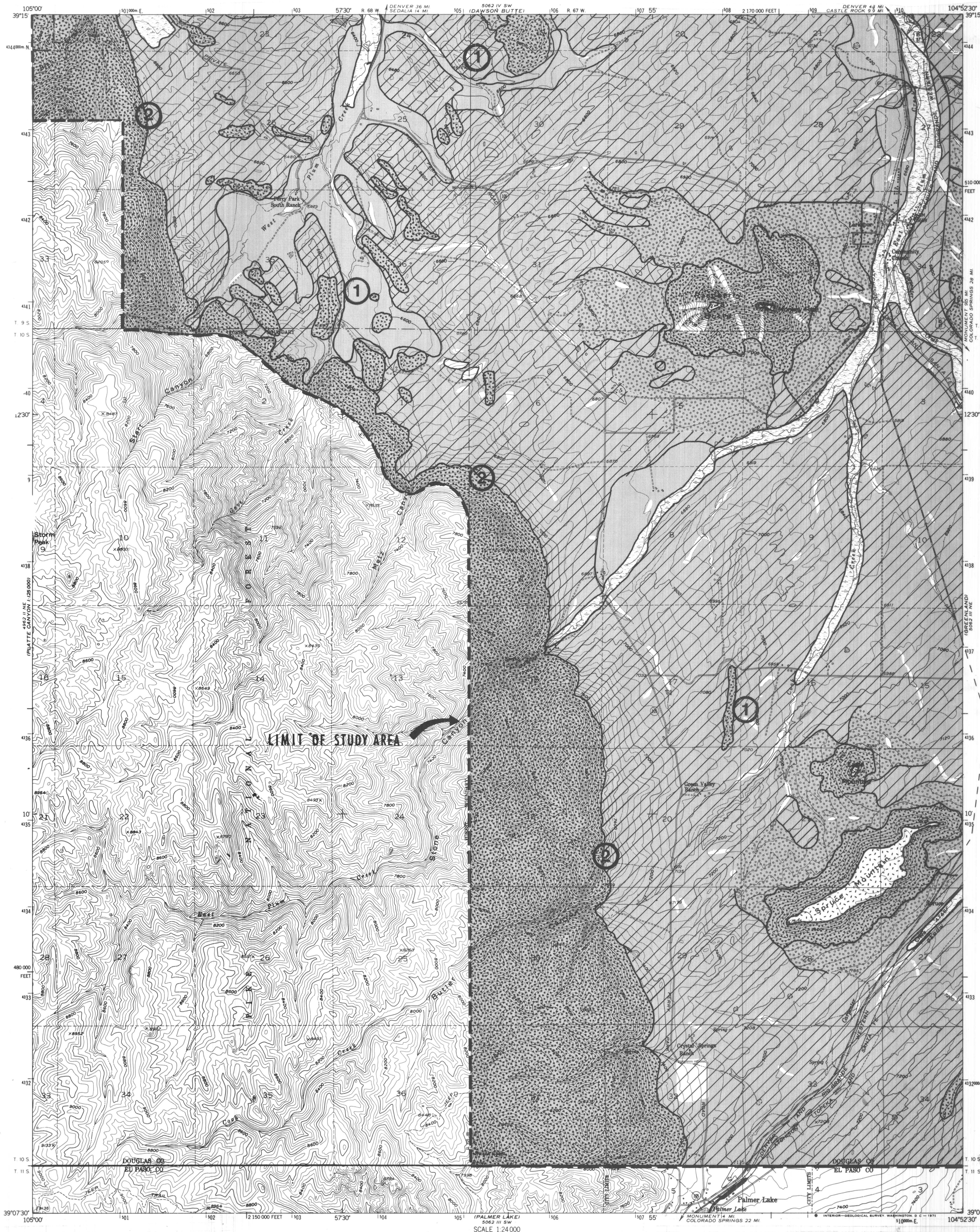
EXPLANATION OF MAP IS PLATE 16.
ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE RUSSELLVILLE GULCH QUADRANGLE

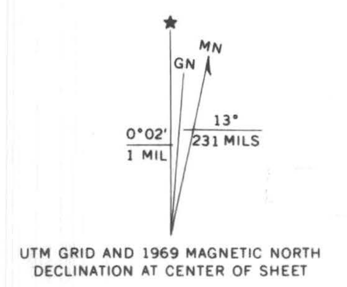
BY

JAMES M. SOULE

1978



Base from U.S. Geological Survey
7 ½-minute quadrangle.



SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

NOTES

① Small debris-flow areas, usually 20 to 5 acres or less, exist in or near drainageways downslope from most rockfall-rock-slide areas.

② All canyons along the mountain front are highly flash flood prone and can produce large amounts of mobilized debris during heavy rainstorms. Hazardous debris fans are formed at the mouths of most of these canyons.

CGS-OF-78-5

PLATE 13 OF 16

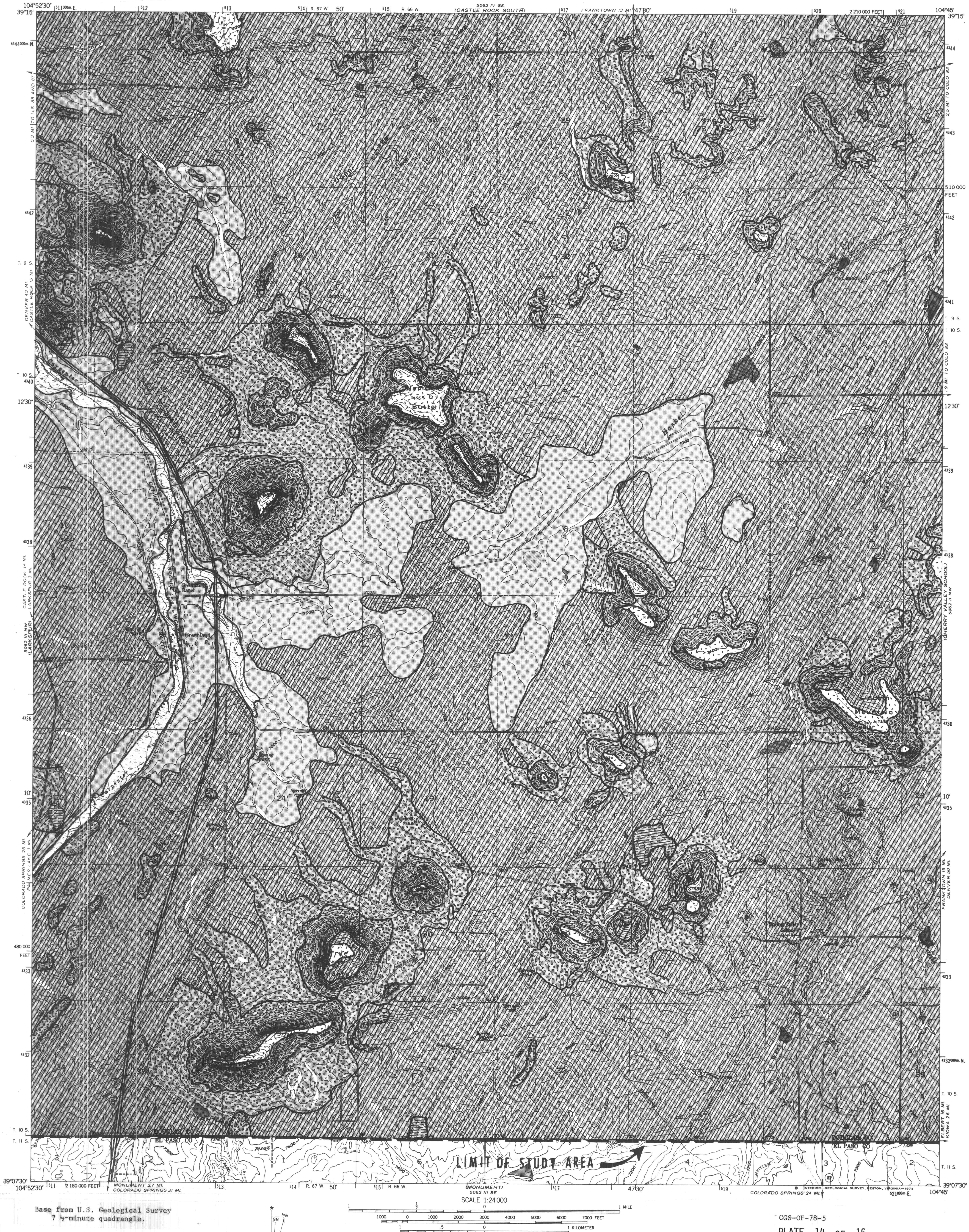
EXPLANATION OF MAP IS PLATE 16.
ALSO SEE NOTES ABOVE.

GEOLOGIC HAZARDS MAP OF THE LARKSPUR QUADRANGLE

BY

JAMES M. SOULE

1978



Base from U.S. Geological Survey
7 ½-minute quadrangle.

CGS-OF-78-5

PLATE 14 OF 16

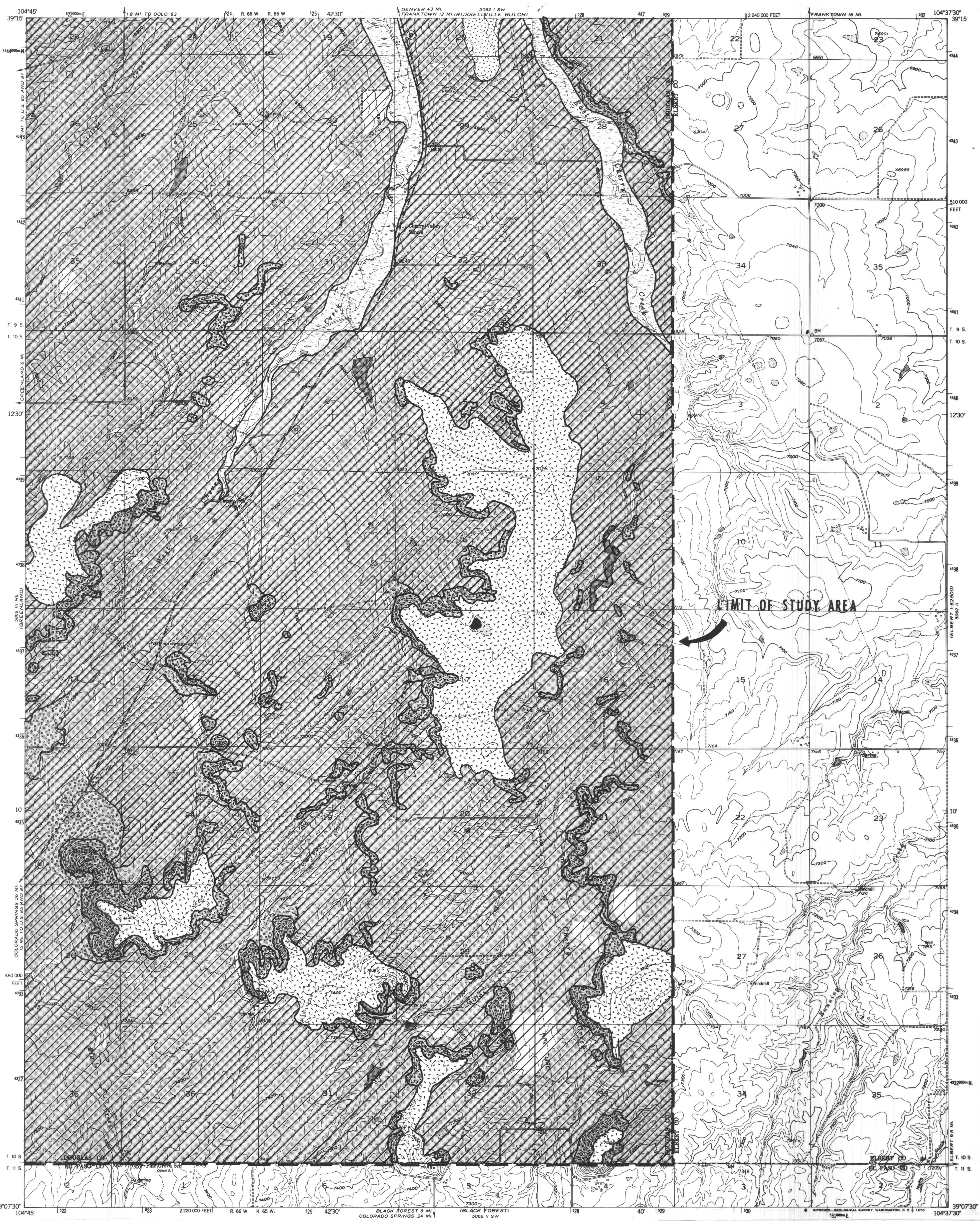
EXPLANATION OF MAP IS PLATE 16.

GEOLOGIC HAZARDS MAP OF THE
GREENLAND QUADRANGLE

BY

JAMES M. SOULE

1978



Base from U.S. Geological Survey
7 ½-minute quadrangle.

UTM GRID AND 1969 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

CGS-OF-78-5

PLATE 15 OF 16

EXPLANATION OF MAP IS PLATE 16.

GEOLOGIC HAZARDS MAP OF THE CHERRY VALLEY SCHOOL QUADRANGLE

BY

JAMES M. SOULE

1978

EXPLANATION
Colorado Geological Survey
Open-File Report
CGS-OF-78-5

GEOLOGIC HAZARDS IN DOUGLAS COUNTY, COLORADO

by JAMES M. SOULE
1978

GENERAL

Geologic hazards are natural geologic conditions that if unrecognized or inadequately planned for can result in loss of life, damage to structures, or high maintenance costs, especially for homes, roads, and utilities. The mapping units used on this map are a combination of genetically related features, processes, and/or conditions that could cause problems for human activities. Where appropriate, mapping units and their definitions conform to the terminology and definitions given in Colorado House Bill 1041 and the Colorado Geological Survey's Guidelines and Criteria for Identification and Land Use Controls in Geologic Hazard and Mineral Resource Areas (Rogers and others, 1974). In addition, hazard areas may include geologic hazards that vary greatly in degree depending on natural variation within the area and on various man-caused changes that may occur in the future. Because most of Douglas County is presently in the natural state or is being used for low-intensity uses like agriculture and grazing, most of the mapped hazards cause no difficulties for existing human activities. No detailed quantification of geologic hazards is made in this study other than the table below which relates the degree of hazard to certain types of land use. In short, the actual degree of hazard depends as much, if not more, on human decisions affecting land use as it does on geologic factors.

SUGGESTIONS TO MAP USERS

This map should be used as an indicator of locations where a particular geologic hazard may adversely affect certain land uses. It is not intended to supplant detailed field investigations of individual sites, but rather to signal places where the indicated geologic conditions can be expected and should be specifically addressed in advance of any land-use change. If this map is used to designate geologic-hazard areas as specified by H.B. 1041 (Rogers and others, 1974, p. 120-121), then it is suggested that this map serve as a basis for further investigation of individual sites. Detailed investigation and evaluation may serve as the basis for actual designs, or such studies might indicate that for economic or safety reasons the particular activity is not feasible. Land-use decisions in these areas should be based on technical reviews and planning evaluation of detailed studies and specific site plans.

EXPLANATION

S—
S—

SUBSIDENCE AREA: Area where collapse of underground mining excavations can cause general lowering or severe differential settlement of the ground surface. Precise delineation of these subsidence areas is difficult and requires drilling or geophysical investigations because the mining excavations are concealed beneath the ground surface and in most localities poor or no records of mining or maps of mines are available. Moreover, because surface subsidence is caused by surfaceward migration of collapsing mine voids, subsidence effects can occur without warning or be sporadic. Subsidence commonly is intermittent, can vary greatly in rate, and can occur suddenly with little prior warning. Consequently, hazard zones with indefinite boundaries only are shown on this map.

Hazards in mine-subsidence areas are usually related to buckling, spreading, or cracking of rigid structures such as buildings, bridges, or roads; disruption of drainage and utilities; or in some instances, loss of structures that fall into subsidence pits.

In addition to subsidence caused by mining, some areas with certain surficial materials may settle or collapse if loaded or wetted. Most commonly, these materials are soil and eolian deposits (loess and sand) located at or near the south or southeast. These subsidence areas are not mapped because of their simple association with drainages, their number, and the necessity for site-specific engineering-soils test to determine related hazard for a specific land use.

SLOPE-FAILURE AREA: Area where landsliding, earthflowage and/or accelerated creep are taking place. Evidence for slope failure includes hummocky topography with distinctive abrupt changes in slope near the main scarps of landslides, vegetation or man-made works disrupted by slope movements, anomalous slope reversal(s), ground-moisture conditions indicative of slope movement, and microtopographic features such as soil ripples and ground cracks.

Slope-failure areas are mapped only where ground-movement can be demonstrated unequivocally. Other slope failures undoubtedly exist, but have not been recognized as such. Most of these slope failures probably are included under unstable or potentially unstable slope.

Slope failure areas are hazardous because slope movements can damage or destroy buildings and/or their foundations and utilities.

ROCKFALL-ROCKSLIDE/DEBRIS AVALANCHE AREA: Area subject to falling, sliding, and/or avalanching of individual blocks of rock, accumulations of blocky material, or heterogeneous, granular colluvium. Includes areas with deposits of talus and debris contiguous to their sources. Areas mapped as this unit are characterized by very rapid to nearly instantaneous slope movements that occur during heavy rainstorms. Because of this association with periods of rapid water runoff, water-flooding and debris-flow hazards are common locally in some parts of these areas. Lesser slopes do not usually indicate a lessening of susceptibility to these hazardous processes. Rockfalls occur on or near cliffs. Debris avalanches and rockslides usually are initiated on rock-rubble and debris-strewn slopes ranging from 20 to 45-degrees (36 to 100-percent) inclination. Materials mobilized by these types of slope failures can continue to move downward and outward as slurry-like flows that move away from their sources over gentler slopes.

Hazards in these areas result from possibility of impact to structures by rapidly moving rocks and debris. These mass movements occur so rapidly that little, if any, warning of their impending occurrence is possible. Safe, intensive land uses such as residential development in these areas are rarely possible. Other less intensive land uses may be safe, especially if occasional cleaning up of debris and/or partial to complete destruction of structures is acceptable.

UNSTABLE OR POTENTIALLY UNSTABLE SLOPE: Slope with evidence for past slope movements or geologic conditions favorable for slope failure. These slopes are characterized by physiography produced by landsliding soil creep, earthflowage and/or by moderately to steeply sloping, poorly consolidated colluvium, alluvium or deeply weathered bedrock. Potential for slope movement varies with slope inclination and aspect, local ground-moisture conditions, permeability of surficial materials and man-made modifications of the ground surface, especially those that affect drainage and steepness of slope.

Unstable or potentially unstable slopes commonly coincide with moderate-to-high erosion-potential areas. This coincidence appears to be related to changes in natural drainage usually made for road construction, agricultural management or from damage to or removal of natural vegetation by people and grazing animals. In many places modern accelerated gully and sheet erosion has removed considerable amounts of material decreasing the stability of slopes. Lesser slopes included in this mapping unit are usually less likely to fail than steeper slopes although lateral spreads may occur where the ground has become water-saturated and is deeply incised by gullies.

Unstable or potentially unstable slopes are hazardous because man-caused changes in the land surface can cause unexpected slope movements. Frequently this can result in considerable expense for many kinds of land developments or land uses.

LOW EROSION-SUSCEPTIBILITY AREA: Area where modern erosion is minimal because surficial materials are thin, well indurated, or composed of exposures of resistant bedrock. These areas usually are underlain by caprock that forms mesas and buttes, or are underlain by thin pediment gravels composed predominantly of cobble to boulder-size clasts indurated by caliche, or are exposures of resistant bedrock. In many locations stream bottomlands are aggraded by deposition of sediment produced by accelerated modern erosion in uplands. This aggradation locally raises stream base level. Extensive stream-bottomland areas are indicated by the marshland symbol.

Many low erosion-susceptibility areas are characterized by materials that are difficult to excavate and by poorly defined surface drainage. These factors result in added expense for construction, drainage control, and sewage disposal. Additionally, low-lying areas near streams are usually not difficult to excavate but they are subject to occasional flooding and deposition of sediment. Flooding can damage buildings and roads and accumulations of sediment can divert flood water locally, interrupt or damage drainage-control structures, and damage or destroy roads and utilities.

MODERN ACCELERATED-EROSION AREA: Area undergoing gullying or sheet erosion that appears to be accelerated or aggravated presently by overgrazing, poor construction practices, vegetation removal or disturbance, or dams and other man-made changes in surface drainage. This erosional condition may be attributed to one or a combination of these causative factors. Erosion tends to be most pronounced on slopes where surficial materials consist of 1 to 5 m of poorly consolidated, sparsely vegetated soil and weathered-rock material(regolith), colluvium or alluvium derived from the sandy, arkosic, poorly indurated rocks of the Dawson Formation. Susceptibility to erosion apparently is not directly dependent on slope. However, gully erosion is more common on steeper slopes or adjacent to or in drainage courses; sheet erosion is usually restricted to gently sloping areas where grass cover is sparse. Gullies are shown on the map as open (patternless) areas that nearly always coincide with places where drainage is poorly developed.

Hazards in modern-erosion areas result from excessive removal or deposition of sand, silt, and clay. These materials can clog or block (siltate) drainage-control structures, damage or destroy vegetation cover, or be responsible for excessive maintenance cost for buildings, utilities, and roads. Erosional effect can severely damage the land surface necessitating costly rehabilitation work prior to use of the land for agriculture or residential development. Moreover, intensive land uses such as residential development can aggravate or increase erosion such that lessening of its affects on adjacent land may be difficult or impossible. Gullies frequently undercut unstable or potentially unstable slopes causing local small slope failures. This condition of slope instability is so common in most areas that any slope directly above a modern gully should be considered suspect with respect to its slope stability.

MODERATE-TO-HIGH EROSION-SUSCEPTIBILITY AREA: Area where potential for erosion to occur is moderate to high because of slope, composition (arkosic grit, sandstone, claystone, and surficial deposits derived from these rocks), or poor consolidation of surficial materials, sparse vegetation cover, and proximity and similarity to areas already undergoing accelerated modern erosion. Many parts of the mapped areas are in a state of imminent accelerated erosion because of widespread overgrazing, extensive areas of small-scale surficial slope failure (soil creep), surface modification by roads and drainage-diversion or impoundment structures (dams), and vegetation damage caused by off-road vehicles and other intensive human activities.

Prediction of the amount or degree of erosion-related damage that may occur in a given area is not implied in the definition of this mapping unit. The map boundaries for areas so mapped are generalized because the degree of erosion susceptibility in a given area is as dependent on effects of man-made land-surface modifications as it is on natural conditions. In many areas, susceptibility to erosion lessens with decreased slope, increased distance from drainage courses, and increased degree of consolidation of surficial materials.

The coincidence of moderate-to-high erosion-susceptibility areas with unstable or potentially unstable slopes is due, in part, to increases in permeability caused by ground cracks resulting from slope movement and decreases in compaction of surficial materials. In many places it is apparent that erosion and slope movement(s) are related processes and one may be the initiating process that activates the other.

The most important hazard-related factors in these areas are erosion and deposition of sediment, damage to vegetation, and increased maintenance costs of roads, drainage-control structures, buildings, and utilities. Erosion can be a severe esthetic and feasibility problem for planning many kinds of developments.

DEBRIS-FLOW AREA: Area susceptible to occasional rapid movement of slurry-like mixtures of soil and rocks, incorporated woody debris, and water. Debris movement initiates typically as rockfalls, rockslides, and/or debris avalanches and debris slides. These slope movements are coincident with intense rainstorms that occur during the late spring and summer. This rapidly moving debris is typically capable of moving considerable distances downward and outward onto adjacent moderately to gently sloping areas (20 to 0-percent slopes). Depending primarily on the drainage development in the debris-flow area, debris flows can either be confined to drainage channels or spread out over relatively large areas before debris movement ceases. Debris movement during a given debris-flow event is very difficult to predict because of minor topographic irregularities, variable amounts of debris mobilized during a rainstorm, and diversion of debris flow(s) by variations in channel geometry and/or effects of material already present in channels. Additionally, man-made land-surface changes can significantly alter the potential for debris flowage in some areas. Debris-flow deposits of various ages occur in the mapped debris-flow hazard areas. The age of these debris-flow events ranges from occurrences during this century and the past two decades to some that probably occurred a few thousand years ago. All of these areas are underlain by deposits of unquestionably debris-flow origin or have physiography clearly indicative of such deposits.

Hazards in debris-flow areas result from sudden impact by moving debris that injures people and damages or destroys buildings, utilities, and roads. In some cases defense structures or other measures can reduce hazards considerably, possibly to acceptable levels.

NOTE: Other hazards and discussion of individual hazard areas are indicated by notes on the map.

Reference

Rogers, W. P., and others, 1974, Guideline and criteria for identification and land-use controls of geologic hazard and mineral resource areas; Colorado Geol. Survey Spec. Pub. 6, 146 p.

GEOLOGIC HAZARDS FOR COMMON LAND USES

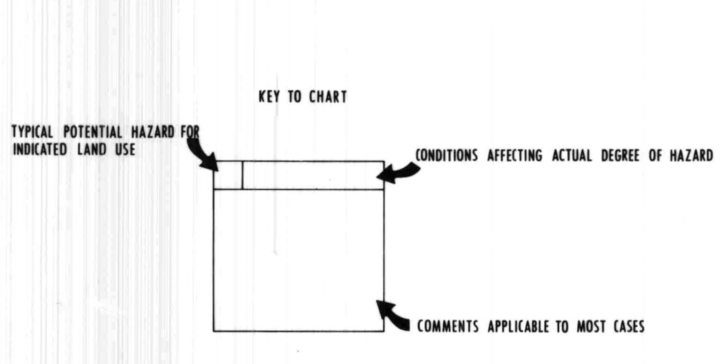
LAND-USE ACTIVITY (Hazards map unit)

Hazards map unit	Road construction	Road maintenance	Utilities -- installation & maintenance	Low-density single-family residential development (< 1 d.u./5 acres)	Medium-density single-family residential development (1 d.u./5 acres to 1 d.u./1 acre)	High-density single-family residential development (> 1 d.u./acre)
Landslide area	4 ABCDEFHIJKN: INCREASED DESIGN AND CONSTRUCTION COSTS. POSSIBLE DAMAGE TO ROADS OR CONSTRUCTION EQUIPMENT.	4 CEFHIL: INCREASED COSTS. EXISTENCE OF ROAD CAN AGGRAVATE HAZARD GREATLY FOR OTHER LAND USES.	3 CEFHLN: IN MANY CASES, INCREASED DESIGN AND DEVELOPMENT COSTS. OCCASIONAL DISRUPTION OF UTILITIES BECAUSE OF LINE BREAKAGE. CAREFUL ATTENTION SHOULD BE GIVEN TO COMPACTION OF BACKFILL AND RESTORATION OF SURFACE DRAINAGE.	3 ABCDEFHIJKN: IN MOST CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS. IN SOME CASES THIS TYPE OF DEVELOPMENT MAY NOT BE FEASIBLE.	5 ABCDEFHIJKN: IN SOME CASES CAREFUL ENGINEERED DESIGNS FOR BUILDINGS CAN REDUCE ADVERSE EFFECTS. IN MANY CASES THIS TYPE OF DEVELOPMENT WILL NOT BE FEASIBLE. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.	5 ABCDFHIJKN: LANDSLIDING OR LANDSLIDE POTENTIAL MAY BE INCREASED GREATLY BY THIS TYPE OF DEVELOPMENT. IN MANY CASES THIS TYPE OF DEVELOPMENT WILL NOT BE FEASIBLE. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.
Unstable or potentially unstable slope	3 ABCDEFHILN: POSSIBLY INCREASED DESIGN AND CONSTRUCTION COSTS.	2 CDEFHI: POSSIBLY INCREASED COSTS. EXISTENCE OF ROAD CAN AGGRAVATE HAZARDS FOR OTHER LAND USES.	2 CEFHLN: IN SOME CASES, INCREASED DESIGN AND DEVELOPMENT COSTS. CAREFUL ATTENTION SHOULD BE GIVEN TO COMPACTION OF BACKFILL AND RESTORATION OF SURFACE DRAINAGE.	2 ABCDEFHIJLN: IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.	2 ABCDEFHIJKN: IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.	3 ABCDEFHIJKN: IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.
Rockfall rockslide debris-avalanche area	2 ACEFGKN: THESE AREAS ARE STEEPLY SLOPING MAKING THEM EXPENSIVE TO CONSTRUCT ROADS ON. CUTS MAY CAUSE SUDDEN MOVEMENT OF ROCK AND DEBRIS.	3 CFG: OCCASIONAL CLEAN UP OF ROCKS AND DEBRIS WILL BE NECESSARY.	4 CFGN: OCCASIONAL REPLACEMENT OF UTILITY LINES WILL BE NECESSARY. OCCASIONAL DISRUPTION OF SERVICE BECAUSE OF LINE BREAKAGE.	4 ABCEFGKN: CAREFUL SITING OF STRUCTURES, ROADS AND UTILITIES MAY RESULT IN REDUCTION OF DANGER TO AN ACCEPTABLE LEVEL.	4 ABCEFGKN: CAREFUL SITING OF STRUCTURES, ROADS, AND UTILITIES MAY, IN SOME INSTANCES, RESULT IN REDUCTION OF DANGER TO AN ACCEPTABLE LEVEL.	5 ABCEFGKN: IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS.
Mudflow debris flow area	1 DFGLN: EXCEPT DURING INFREQUENT MUDFLOW, DEBRIS-FLOW EVENTS, THESE AREAS PRESENT LITTLE PROBLEM FOR ROAD CONSTRUCTION.	2 DFG: OCCASIONAL CLEANUP OF MUD, ROCKS, AND DEBRIS WILL BE NECESSARY.	2 DFGLN: OCCASIONAL REPAIR OR REPLACEMENT OF UTILITY LINES WILL BE NECESSARY.	4 FGKLN: CAREFUL SITING OF STRUCTURES, ROADS AND UTILITIES MAY RESULT IN REDUCTION OF DANGER TO AN ACCEPTABLE LEVEL.	4 FGKLN: IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS UNLESS ELABORATE HAZARD-MITIGATION MEASURES ARE EMPLOYED.	5 FGKLN: IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS UNLESS ELABORATE HAZARD-MITIGATION MEASURES ARE EMPLOYED.
Subsidence area	2 L: MAY RESULT IN UNEXPECTEDLY HIGH REMEDIAL-ENGINEERING AND CONSTRUCTION COSTS.	2 L: MAY RESULT IN UNEXPECTEDLY HIGH MAINTENANCE COSTS.	2 L: MAY RESULT IN HIGH REMEDIAL-ENGINEERING AND CONSTRUCTION COSTS.	4 L: CAREFUL SITING OF STRUCTURES COMBINED WITH SOME DETAILED ENGINEERING GEOLOGIC STUDIES USUALLY CAN MINIMIZE HAZARD.	4 K: CAREFUL SITING OF STRUCTURES COMBINED WITH DETAILED ENGINEERING-GEOLOGIC STUDIES CAN MINIMIZE HAZARDS.	5 K: USUALLY A HIGH HAZARD EVEN IF DETAILED ENGINEERING GEOLOGIC STUDIES MADE AND GEOLOGICAL ENGINEERING RECOMMENDATIONS CARRIED OUT.
Modern accelerated erosion area	3 ABCDFGKM: REMEDIAL AND/OR MITIGATION MEASURES MAY BE NECESSARY.	3 BCDFGM: MAY RESULT IN HIGH MAINTENANCE COSTS.	3 ABCDFGKM: MAY RESULT IN HIGH MAINTENANCE COSTS.	2 ABCDFGKM: MINOR SURFACE-DRAINAGE MODIFICATIONS OR OTHER CORRECTIVE MEASURES CAN REDUCE THE HAZARD CONSIDERABLY.	4 ABCDFGKM: SURFACE-DRAINAGE MODIFICATIONS, REMEDIAL MEASURES TO DECREASE GULLYING POTENTIAL AND CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO DRAINAGE CAN REDUCE THE HAZARD CONSIDERABLY.	4 ABCDFGKM: SURFACE-DRAINAGE MODIFICATIONS, REMEDIAL MEASURES TO DECREASE GULLYING POTENTIAL, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE CAN REDUCE HAZARD CONSIDERABLY.
Moderate-to-high erosion potential area	2 ABCDFGKM: REMEDIAL AND/OR CORRECTIVE MEASURES MAY BE NECESSARY IF ROAD IS NOT CAREFULLY DESIGNED. AN EROSION-CONTROL PLAN SHOULD BE DEVELOPED PRIOR TO CONSTRUCTION.	2 BCDFGM: REMEDIAL AND/OR CORRECTIVE MEASURES MAY BE NECESSARY IF ROAD IS NOT CAREFULLY MAINTAINED, ESPECIALLY MAINTENANCE AFFECTING DRAINAGE OR DRAINAGE-CONTROL STRUCTURES.	2 ABCDFGKM: IF EXCAVATIONS OR CUTS AND FILLS ARE CAREFULLY DESIGNED AND EXECUTED, MOST UTILITIES WILL NOT ACCELERATE EROSION.	2 ABCDFGKM: MINOR SURFACE-DRAINAGE MODIFICATIONS OR OTHER CORRECTIVE MEASURES CAN MINIMIZE EROSION HAZARD.	2 ABCDFGKM: SURFACE-DRAINAGE MODIFICATIONS, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE, AND MINIMAL DISTURBANCE OF NATURAL VEGETATION CAN MINIMIZE EROSION HAZARD.	2 ABCDFGKM: SURFACE-DRAINAGE MODIFICATIONS, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE, AND MINIMAL DISTURBANCE OF NATURAL VEGETATION CAN MINIMIZE EROSION HAZARD.
Low erosion potential area	3 DF: MAY BE DIFFICULT AND/OR EXPENSIVE TO BUILD ROADS IN AREAS WHERE BEDROCK IS NEAR THE SURFACE.	1 D: ROADS ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	3 DK: MAY BE DIFFICULT OR EXPENSIVE TO MAKE CUTS IN AREAS WHERE BEDROCK IS NEAR THE SURFACE. UTILITIES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	3 DL: MAY BE DIFFICULT OR EXPENSIVE TO EXCAVATE FOR FOUNDATIONS OR INSTALLATION OF UTILITIES. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	2 DK: MAY BE DIFFICULT OR EXPENSIVE TO EXCAVATE FOR FOUNDATIONS OR INSTALLATION OF UTILITIES. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	2 DK: MAY BE DIFFICULT OR EXPENSIVE TO EXCAVATE FOR FOUNDATIONS OR INSTALLATION OF UTILITIES. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.

Hazards map unit	Multi-family housing (townhouses & apartments)	Industrial and commercial development	Agriculture and grazing	Subsurface-fluid extraction (water and oil and gas)	Mining and quarrying	Septic sewage disposal	Solid-waste disposal
Landslide area	5 ABCDFHIJKN: LANDSLIDING OR LANDSLIDE POTENTIAL MAY BE INCREASED GREATLY BY THIS TYPE OF DEVELOPMENT. IN MANY CASES THIS TYPE OF DEVELOPMENT WILL NOT BE FEASIBLE. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.	4 ABCDFHIJKN: REMEDIAL ENGINEERING AND/OR LANDSLIDE STABILIZATION MAY, IN SOME CASES, MAKE THIS TYPE OF DEVELOPMENT FEASIBLE.	1 BCDFHLN: POSSIBLE DAMAGE TO FENCES, BUILDINGS AND IRRIGATION DITCHES AND SOME TYPES OF DRAINAGE MODIFICATIONS.	1 IJL: POSSIBLE DAMAGE TO WELL CASINGS AND RARELY DRILLING AND PRODUCTION EQUIPMENT.	2 ABCDFHL: MAY CAUSE TECHNICAL DIFFICULTIES ASSOCIATED WITH REMOVAL OF SOIL AND ROCK. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	3 ABCDFHK: LANDSLIDING MIGHT CAUSE DAMAGE TO TANKS OR LEACH LINES. HIGH MAINTENANCE COSTS SHOULD BE ANTICIPATED.	2 BCDEFHK: CUT SLOPES IN SOME LANDFILLS MAY FAIL CAUSING INCREASED OPERATING COSTS.
Unstable or potentially unstable slope	3 ABCDEFHIJKN: IN SOME CASES CAREFUL SITING OF AND/OR ENGINEERED DESIGNS FOR BUILDINGS CAN MINIMIZE ADVERSE EFFECTS.	2 ABCDFHIJKN: REMEDIAL ENGINEERING WILL IN MANY CASES MAKE THIS TYPE OF DEVELOPMENT FEASIBLE.	0 BCDFHLN: OCCASIONAL DAMAGE TO FENCES, BUILDING AND IRRIGATION DITCHES.	1 IJL: INFREQUENT DAMAGE TO WELL CASINGS AND PRODUCTION EQUIPMENT.	1 ABCDF: OCCASIONALLY MAY CAUSE DIFFICULTIES FOR REMOVAL OF SOIL AND ROCK. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	2 ABCDFHL: SLOPE MOVEMENT MIGHT CAUSE DAMAGE TO TANKS OR LEACH LINES. INCREASED GROUND MOISTURE COULD CAUSE SLOPE INSTABILITY.	1 BCDEFHL: CUT SLOPES IN SOME LANDFILLS MAY FAIL CAUSING INCREASED OPERATING COSTS.
Rockfall rockslide debris-avalanche area	5 ABCEFGKN: IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS.	5 ABCEFGKN: WITH CONSIDERABLE REMEDIAL ENGINEERING SOME TYPES OF INDUSTRIAL OR COMMERCIAL DEVELOPMENT MAY BE TECHNICALLY FEASIBLE.	0 BCEFGN: OCCASIONAL DAMAGE TO FENCES, BUILDINGS AND IRRIGATION DITCHES.	2 CG: SOME OCCASIONAL DIFFICULTIES FOR DRILLING AND PRODUCTION EQUIPMENT.	1 ACG: SOME OCCASIONAL DIFFICULTIES FOR EQUIPMENT AND OPERATIONS. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	4 K: PERCOLATION RATES ARE TYPICALLY MUCH TOO HIGH FOR SEPTIC SEWAGE DISPOSAL.	2 K: MOST OF THESE AREAS ARE TOO STEEP FOR PRACTICAL LANDFILL SITES.
Mudflow debris flow area	5 FGKLN: IN MOST CASES THIS LAND USE IS PROHIBITIVELY DANGEROUS UNLESS ELABORATE HAZARD-MITIGATION MEASURES ARE EMPLOYED.	4 FGKLN: WITH INSTALLATION OF DEFENSE STRUCTURES AND ENGINEERED MITIGATION MEASURES SOME TYPES OF INDUSTRIAL AND COMMERCIAL DEVELOPMENT MAY BE FEASIBLE.	1 FGN: EXCEPT DURING INFREQUENT MUDFLOW DEBRIS-FLOW EVENTS, THESE AREAS PRESENT ESSENTIALLY NO PROBLEM FOR AGRICULTURE.	1 FG: INFREQUENT DAMAGE TO DRILLING AND PRODUCTION EQUIPMENT.	1 FG: INFREQUENT DISRUPTION OF MINING OR QUARRYING ACTIVITY. MAY JEOPARDIZE THE SAFETY OF PERSONNEL.	4 FG: POSSIBLE INFREQUENT DAMAGE TO OR DESTRUCTION OF SYSTEM.	4 K: POSSIBLE INFREQUENT DISRUPTION BY LANDFILL ACTIVITY. MUDFLOW-DEBRIS-FLOW DEPOSITS ARE TYPICALLY TOO PERMEABLE TO MAKE GOOD LANDFILL SITES.
Subsidence area	5 K: USUALLY A HIGH HAZARD EVEN IF DETAILED ENGINEERING GEOLOGIC STUDIES ARE MADE AND GEOLOGICAL ENGINEERING RECOMMENDATIONS ARE CARRIED OUT.	5 K: WITH EXTENSIVE REMEDIAL ENGINEERING WORK THIS TYPS OF DEVELOPMENT MAY BE SAFE AND COMMERCIALLY FEASIBLE.	1: POSSIBLE DAMAGE TO IRRIGATION DITCHES AND BUILDINGS.	2 L: POSSIBLE DAMAGE TO PRODUCTION EQUIPMENT. POSSIBLY PROBLEMS FOR DRILLING, CASING, OR CEMENTING OPERATIONS.	1: COLLAPSE OF GROUND SURFACE COULD DAMAGE EQUIPMENT OR DISRUPT OPERATIONS.	2 K: SUBSIDENCE MAY DAMAGE TANKS OR DISRUPT LEACH LINES.	1 L
Modern accelerated erosion area	4 ABCDFGKM: SURFACE-DRAINAGE MODIFICATIONS, REMEDIAL MEASURES TO DECREASE GULLYING POTENTIAL, AND CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE CAN REDUCE THE HAZARD CONSIDERABLY.	3 ABCDFGKM: REMEDIAL AND/OR CORRECTIVE MEASURES WILL BE NECESSARY AND MAY BE EXPENSIVE.	2 BCDFGM: CORRECTIVE MEASURES MAY INCREASE AGRICULTURAL PRODUCTIVITY OF LAND.	1 CDFGLM: MIGHT CAUSE DIFFICULTIES FOR ACCESS ROADS AND PRODUCTION EQUIPMENT.	1 CFGLM: MAY CAUSE MINOR DIFFICULTIES FOR ACCESS ROADS DURING HEAVY RAINSTORMS.	1 M: MIGHT CAUSE MINOR DIFFICULTIES FOR LEACH FIELDS.	1 M: MINOR DIFFICULTIES IN MOST CASES WHERE CAREFULLY PLANNED.
Moderate-to-high erosion potential area	2 ABCDFGKM: SURFACE-DRAINAGE MODIFICATIONS, CAREFUL SUBDIVISION LAYOUT WITH RESPECT TO NATURAL DRAINAGE AND MINIMAL DISTURBANCE TO VEGETATION CAN MINIMIZE EROSION HAZARD.	2 ABCDFGKM: REMEDIAL AND/OR CORRECTIVE MEASURES WILL BE NECESSARY.	2 BCDFGM: CORRECTIVE MEASURES MAY INSURE OR INCREASE AGRICULTURAL PRODUCTIVITY OF LAND.	1 CDFGM: MAY ADD TO THE COST OF INSTALLATION AND MAINTENANCE OF PRODUCTION EQUIPMENT.	1 CFGM: CONSTRUCTION AND MAINTENANCE OF ACCESS ROADS MAY BE AFFECTED SEVERELY BY HEAVY RAINSTORMS.	1 M: INCREASED GROUND MOISTURE FROM LEACHFIELDS MAY CAUSE OR ACCELERATE EROSION.	1 KM: MINOR DIFFICULTIES IN MOST CASES WHERE EXCAVATIONS ARE CAREFULLY PLANNED WITH RESPECT TO NATURAL DRAINAGE.
Low erosion potential area	2 DK: MAY BE DIFFICULT AND EXPENSIVE TO EXCAVATE FOR FOUNDATIONS. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	2 DK: CONSTRUCTION COSTS MAY INCREASE CONSIDERABLY. STRUCTURES ADJACENT TO MAJOR DRAINAGEWAYS MAY BE SUBJECT TO OCCASIONAL FLOODING.	0 L: AGRICULTURAL STRUCTURES ADJACENT, TO MAJOR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	1 L: SOME DIFFICULTIES FOR INSTALLATION OF PRODUCTION EQUIPMENT. STRUCTURES ADJACENT TO MAJOR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	1 L: CONSTRUCTION OF ACCESS ROADS MAY BE DIFFICULT. MINES AND QUARRIES NEAR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	4 DK: TYPICALLY, PERCOLATION RATES ARE TOO LOW (BEDROCK NEAR SURFACE) OR TOO HIGH (NEAR MAJOR DRAINAGES) FOR LEACH FIELDS TO WORK PROPERLY. EXCAVATIONS TYPICALLY DIFFICULT AND EXPENSIVE IN SHALLOW BEDROCK AREAS. AREAS NEAR MAJOR DRAINAGES MAY BE SUBJECT TO OCCASIONAL FLOODING.	4 DK: EXCAVATION DIFFICULT IN SHALLOW DEPTH-TO-BEDROCK AREAS. OCCASIONAL FLOODING IN AREAS ADJACENT TO MAJOR DRAINAGES CAN DISRUPT OPERATIONS. PERCOLATION OF LEACHATE CONTAMINATING GROUND WATER MAY OCCUR IN AREAS NEAR MAJOR DRAINAGES.

Explanation of Chart Symbols

KEY TO CHART



DEGREE OF HAZARD

0 IN ALL CASES ESSENTIALLY NO GEOLOGIC HAZARDS WILL BE CREATED - LITTLE, IF ANY, HAZARD

1 TYPICALLY MINOR PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - LOW HAZARD

2 IN SOME CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - MODERATE HAZARD

3 IN MANY CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - MODERATE TO HIGH HAZARD

4 IN MOST CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - HIGH HAZARD

5 IN ESSENTIALLY ALL CASES SERIOUS PROBLEMS RELATED TO GEOLOGIC CONDITIONS WILL BE EXPERIENCED - VERY HIGH TO EXTREME(SEVERE) HAZARD

CONDITIONS AFFECTING HAZARD

A IMPROPERLY DESIGNED CUTS OR FILLS CAN INCREASE THE HAZARD GREATLY

B STREAM REROUTING OR INADEQUATE DRAINAGE CONTROL STRUCTURES CAN INCREASE THE HAZARD GREATLY

C DISRUPTION OR REMOVAL OF NATURAL VEGETATION CAN INCREASE THE HAZARD GREATLY

D OCCASIONAL FLASH FLOODING IN SMALL DRAWS CAN BE A SEVERE HAZARD

E HAZARD DECREASES CONSIDERABLY WITH DECREASING SLOPE

F HAZARD OR LIKELIHOOD OF OCCURRENCE OF THIS HAZARDOUS PROCESS VARIES SEASONALLY

G NEARLY ALL HAZARDOUS EVENTS OCCUR RAPIDLY DURING HEAVY RAINSTORMS

H SLOPE MOVEMENT(S) DEPENDENT ON VARIATIONS IN WEATHER, GROUND MOISTURE, COMPOSITION OF SURFICIAL MATERIALS, AND MAN-MADE SURFACE MODIFICATIONS

I SWELLING (EXPANSIVE) SOILS MAY OCCUR LOCALLY

J SETTLING SOILS MAY OCCUR LOCALLY

K DETAILED ENGINEERING-GEOLOGY STUDIES NECESSARY DURING PRE-PLANNING PHASES OF DEVELOPMENT

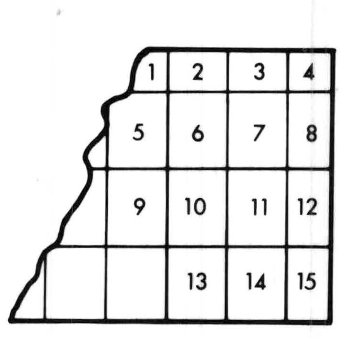
L GEOLOGIC CONDITIONS SHOULD BE CONSIDERED SERIOUSLY IN DEVELOPMENT PLANS

M MAY INCREASE INSTABILITY OF AN UNSTABLE OR POTENTIALLY UNSTABLE SLOPE

N MAY INCREASE LIKELIHOOD OF ACCELERATED EROSION IN A MODERATE-TO-HIGH EROSION-POTENTIAL AREA

Colorado

Index of 7½′ Quadrangle Sheets in Douglas County



1 Littleton
2 Highlands Ranch
3 Parker
4 Piney Creek
5 Kassler
6 Sedalia
7 Castle Rock North
8 Ponderosa Park
9 Devils Head
10 Dawson Butte
11 Castle Rock South
12 Russelville Gulch
13 Larkspur
14 Greenland
15 Cherry Valley School

PLATE 16 of 16

Drafted by: Susan J. Soukup