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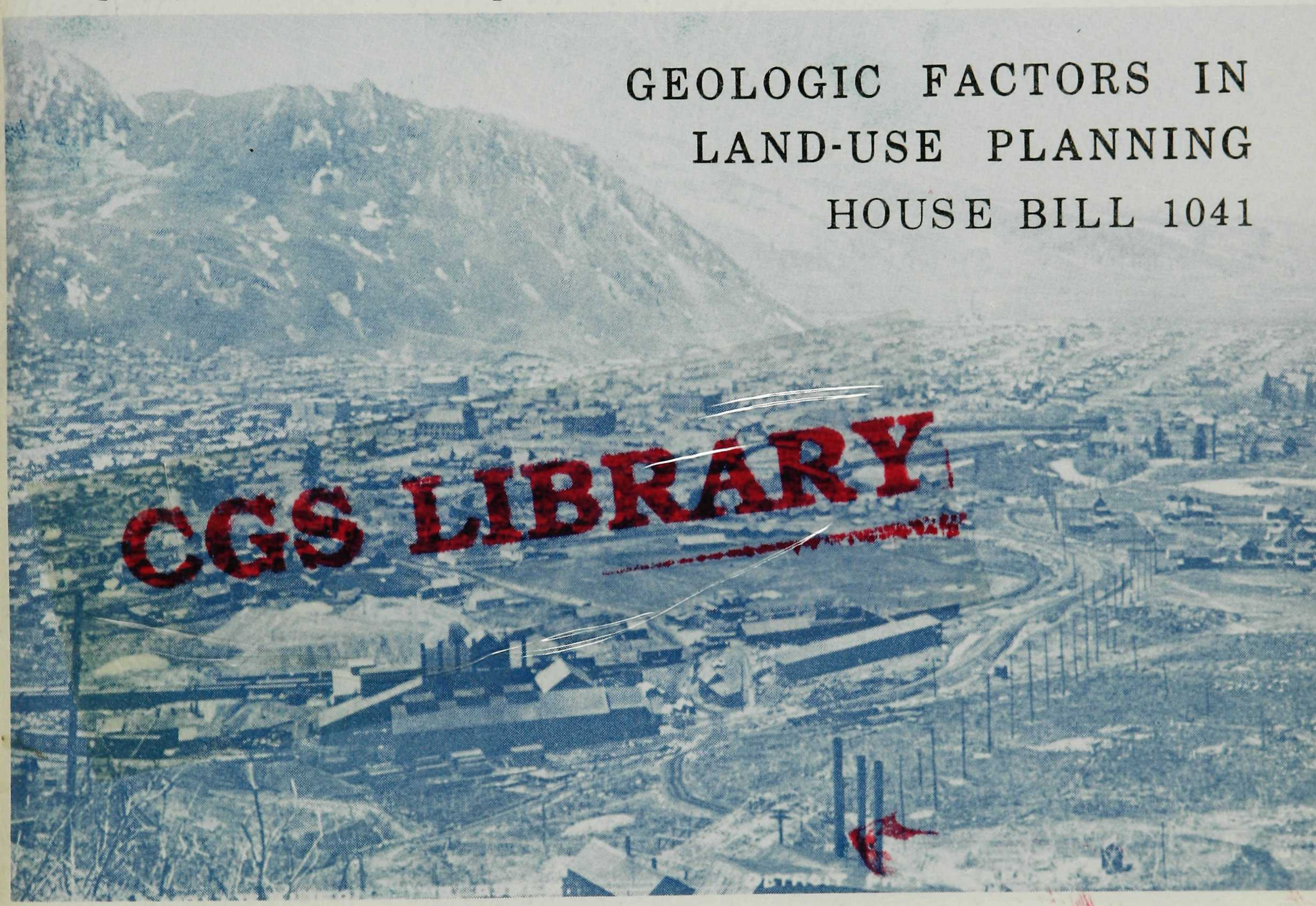
GOVERNOR'S THIRD CONFERENCE ON ENVIRONMENTAL GEOLOGY

Aspen, Colorado September 25-26, 1975

GEOLOGIC FACTORS IN LAND-USE PLANNING
HOUSE BILL 1041



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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO
1977
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Cover: Aspen, Colorado during the heyday of mining (Mollie Gibson Mine in foreground). This photo, taken in the late 1800's, indicates that land-use planning problems are not new in Colorado. (Courtesy Colorado State Historical Society)

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PREFACE

As Colorado's population and the attendant construction activities increase, the interaction between geologic processes and man's activities intensifies. A major area of potential conflict is related to geologic processes that, when not recognized, become hazards to and increase the costs to the citizens of Colorado and their governments. The increasing awareness of this problem led to the passage of H.B. 1041 (see note below) by the 1974 Colorado Legislature.

The Governor's Third Conference on Environmental Geology was convened September 25-26, 1975, to bring state and local officials and consultants together. Governor Richard D. Lamm, and the cosponsors, Association of Engineering Geologists (Denver Section), Association of Professional Geological Scientists (Denver Section), and the Colorado Geological Survey, all strongly believed that communication among these groups was essential to the understanding and success in attaining the goals of H.B. 1041.

Publication of these proceedings is a continuation of that effort to increase the awareness of the people of Colorado of geologic processes as they affect land-use planning. The papers presented here are as the authors submitted, with only minor editorial changes. One paper presented at the Governor's Second Conference on Environmental Geology has been included in these proceedings because of its relevance.

I express my gratitude to all the contributing authors for their time and effort in the preparation of the manuscripts. In addition, I acknowledge and thank Stephen Schwochow for his able editing assistance.

D. C. Shelton

Note: For those readers who wish to refer to the Colorado Statutes as the authors cite specific land-use related laws, the following legal citations will assist:

H.B. 1034: C.R.S. 1973, 29-20-101, et. seq.
H.B. 1041: C.R.S. 1973, 24-65.1-101, et. seq.
H.B. 1529: C.R.S. 1973, 34-1-301, et. seq.
H.B. 1574: C.R.S. 1973, 34-1-20, et. seq.
S.B. 35: C.R.S. 1973, 30-28-101,110 (3)-(5), 133-137

CONTENTS

SLOPE FAILURE AS A GEOLOGIC HAZARD AND LAND-USE PLANNING PROBLEM IN COLORADO

JAMES SOULE

Colorado Geological Survey

GENERAL

Sloping ground is probably the simplest and most widespread element of landscape. Most of the mountain, foothill, and tableland regions of Colorado contain extensive areas of moderately to steeply sloping land. Until recent years, people tended to avoid these slopes as they were typically difficult to traverse and to construct buildings on, and were commonly associated with the more severe aspects of Colorado's climate. Nowadays slopes have become associated with scenic views and natural beauty, recreational opportunities, and escape from urban life. Consequently slopes have become desirable development sites, even though they are frequently difficult and occasionally hazardous places on which to build. Accordingly, regional and local land-use planning efforts must address the geologic hazards associated with slopes, the most common hazard being mass movement downslope of earth materials (slope failure).

NATURE OF SLOPE FAILURE

Movement of earth materials downslope results when gravitational stress exceeds cohesion and/or friction, or when fluvial (running water) or eolian (wind) processes carry material away, usually downslope. Mass movement can involve merely a few inches to tens of feet of surficial material or, in the case of some of the largest landslides, displace entire moutainsides. Movement can be so slow as to be nearly undetectable or so fast as to be catastrophic. Most slope failures are slow events that produce distinctive physiography, which can in turn be used as evidence for the particular slope-failure process.

Numerous natural and man-caused factors can greatly affect the rate and likelihood of slope failure. Among the more important factors that increase the possibility of slope movement are natural and artificial increases in ground moisture, undercutting of slopes by streams and roads, devegetation (especially clear-cutting of timber, forest fires, and some land-development practices), artificial oversteepening of slope-forming materials, excessive overloading by buildings, and seismicity. Colorado's more common slope-failure types are soil creep, rotational and translational landslides, earthflows, mudflows, rockfalls, and debris avalanches and flows. Soil creep is a widespread phenomenon whereby a few feet of soil and surficial material migrate slowly downslope. Soil creep commonly indicates areas that are metastable with respect to other types of slope failures. Landslides are mass failures along shear surface(s) involving relatively large amounts of material moving downslope as an integrated mass. Earthflows and mudflows are caused by increased moisture in the moving mass of material resulting in increased fluidity and flowage. Rockfalls result typically from removal of support or dislodging of large to small blocks of rock from cliffs. Accumulations of colluvium, such as rockfall-talus and other debris, can themselves move rapidly under certain conditions, resulting in debris avalanches and debris flows.

Slope failure-prone areas are widespread in Colorado. They include steeper mountain and foothill areas underlain by poorly consolidated bedrock, colluvium and residuum. These places are particularly susceptible to soil creep, landsliding, and earthflows. Rockfalls often occur near barren cliffs which are common in many parts of the state. Mud and debris flows are particularly common in drainages where material can accumulate on slideslopes and then, during occasional periods of high runoff, is moved into streamcourses. Debris avalanches are frequently found where moderately thick, oversteepened accumulations of colluvium occur; these hazard areas include many places adjacent to tableland mesas and buttes and some mountain areas where anomalously thick surficial deposits are on steep unstable slopes.

SLOPE-FAILURE HAZARDS

The simplest and perhaps the most serious aspect of slope failure as a hazard is that moving ground interferes with either man-made structures or man's activities. Slow slope movements can cause severe damage to building foundations, dams, and numerous other rigid structures, causing, at best, added maintenance costs and, at worst, complete loss of structures. Rapid slope movements, like rockfalls and debris avalanches, can impact structures and inhabited areas and can destroy structures or cause loss of life nearly instantaneously. Intermediate rates of slope movement, especially those that are dependent on climate, can vary greatly on both a yearly and a seasonal basis; they are most typical and, in terms of estimating the degree of hazard, are the most problematical. The recurrence or recurrence interval of these slope movements can be impossible to estimate. Thus, places with demonstrable slope-failure physiography can be dormant for years, then suddenly experience rapid movement.

Such unexpected failures commonly result from variation in the weather; man's activities and their specific effects on slope movement are probably even less predictable. One consequence of this difficulty in predicting amount of slope movement associated with slope failure is that the degree or amount of hazard is nearly impossible to quantify precisely.

IDENTIFICATION OF SLOPE-FAILURE HAZARD AREAS

Identification of slope-failure hazard areas is essential to planning for land use(s) in places where there is a reasonable likelihood that slope failure could adversely affect human activities. Generally speaking, there are three classes of slope-failure hazard areas: (1) Areas of naturally active slope-failure processes; (2) areas of slope-failure physiography where current activity is nonexistent or uncertain; and, (3) areas where conditions are favorable for slope failure, but where there is no evidence for current or past slope-failure activity. Identification of the first two classes of hazard areas is typically a straightforward matter of scientific investigation. These investigations are usually highly dependent on such basic data as aerial photographs and other types of remote sensing imagery and topographic maps, in addition to as much detailed field study as is deemed necessary. On most resulting slope-failure maps, these two classes are usually represented by morphogenetic map units defined by empirically observable physical features and processes. The hazard potential of the third class of slope-failure hazard area cannot empirically be precisely determined. Thus, mapping units for this class must necessarily be "signals" indicating a hazard that may or may not exist or be a problem for a particular land use.

Because gravity operates on all earth materials on slopes by eventually moving them downslope (mass wasting and erosion are, after all, taking place in all degrading places on the land surface of the earth), all slopes have some propensity to fail, however insignificant the slope failure might be. Thus, indicating that all sloping ground has a potential to fail makes sense logically, although it might not tell the user of the map much about what he should plan for. The other extreme--quantifying potential for failure--makes sense too, but for different reasons, is probably equally unworkable. Because no one is clairvoyant, including geologists, and potential for failure is highly dependent on particular land-surface modifications and uses, as well as on all the natural variables mentioned earlier, the practicality of making this kind of map is highly doubtful. It would seem, then, that a compromise between these two extremes should be possible and useful for planning land use. An approach being used in my Colorado Geological Survey geologic hazards investigation/identification projects is to map areas with some potential for slope failure as carefully as time and basic data permit. Then, in the particular map explanation, or directly on the map itself, the slope stability problems that could most reasonably be expected are discussed. If a detailed study of a site within one of these areas is then made, for whatever reason, that investigator knows generally what he should look for. In this way possible hazards are pointed out, and at the same time a map user knows that exact determination of the hazards has not been made and may be necessary, depending on the planned use for his study.

The result of this approach is that I do not spend an inordinate amount of time (and money) attempting to precisely identify hazards in areas where time-consuming, high-accuracy field mapping would be necessary, but I do point out places where hazardous conditions for some land uses could exist.

LAND-USE PLANNING IN SLOPE-FAILURE HAZARD AREAS

If maps showing areas of current, past, and potential slope failures are available to land-use planning authorities, these data should be considered in planning for future land use in those areas. Locations where slope-failure processes are active are usually the most definitive on maps. Current knowledge of geologic hazards and mapping techniques (photogeology supplemented by detailed field work) are developed to the extent that most active slope-failure areas can be identified reliably enough that specific regulations of land use based on such determinations are possible. The emphasis of these regulations should be to ensure either that the hazard is of no consequence to a proposed land use or that the proponent of a land-use change understands how to mitigate the adverse effects of the hazard and is committed to incorporating these mitigation procedures into his development plans. Because all those concerned can usually be convinced of the nature and severity of the problem, an active slope failure is probably the easiest to deal with administratively. Areas of past or potential slope failure present different problems. In the case of past and apparently stabilized slope failures, plans for land use should ensure that this stability is not disturbed or, if it is, that it is of no consequence to the land use being considered.

Areas of potential slope failure should be carefully investigated to determine if possible, the potential slope failures to be caused by the anticipated land use. Very often misunderstanding or disagreement results when a land-use regulatory authority, such as a County Planning Commission in Colorado functioning under Senate Bill 35, confronts a subdivision developer with legally enforcible requests for detailed site investigations and evaluations of geologic hazards. Confusion may result on both sides when the potential for slope failure is not obvious or is possibly minimal in the context of, for example, a proposed low-density residential project. Hazard potential is not an absolute, dependent entirely on natural conditions. Rather, it is the result of several interrelated factors, including specific site plans, building density, types of structures, and even sewage-disposal and site-drainage methods. Because of time and costs involved in detailed site studies related to slope failure and other geologic hazards, especially for subdivisions, the present tendency is to provide the absolute minimum of detailed information that the law requires. Typically, such studies do little to assist developers or counties in evaluating the feasibility of site plans. Usually the information is presented with disclaimers, and these disclaimers may be justified for many slope-failure areas. The price of detailed prediction of natural hazards, in terms of liability for adverse natural events, can be very high indeed. However, the value to both developers and planners of appropriately detailed site studies for individual projects should not be underestimated. The Colorado Geological Survey knows of many cases where knowledge of slope failure and other geologic hazards early in the site planning has saved money far in excess of the cost of the detailed hazards investigations.

The problem seems to be one of determining the severity of the hazard, if any, and, in turn, calculating an acceptable level of risk for particular land uses or human activities. In view of this, planning officials should inform landowners and the public at large of the extent to which government agencies will regulate or otherwise become involved controlling land use in such areas.

FIGURE 1: Soil ripples. This distinctive form of microtopography is indicative of slopes that are prone to fail by landsliding and earthflowage.

FIGURE 2. Curved trunks of trees like those in the foreground often indicate that a slope is moving relatively rapidly. Water on the road to the right of the slope accumulates after leakage from landslide material.

FIGURE 3. This entire mountainside is a complex of landslides. Note the most recent landslide on the left.

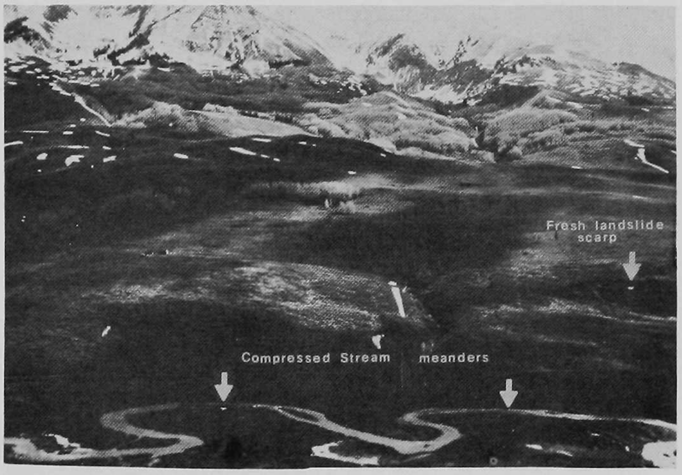


FIGURE 4. Note the well-defined main scarp (arrow) and compressed stream meanders (arrows) that have resulted from large-scale landsliding.

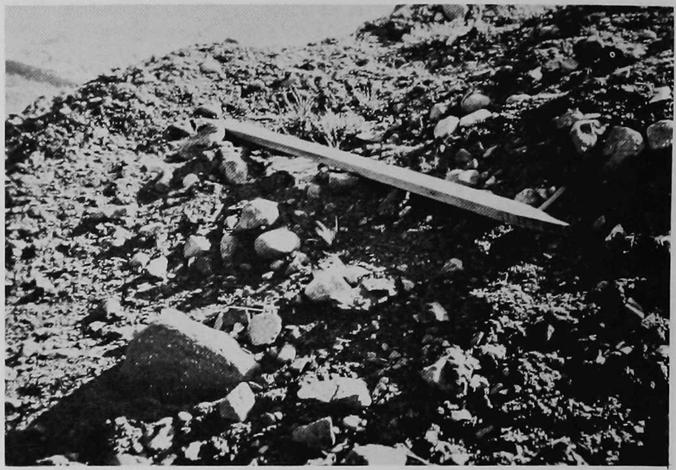


FIGURE 6. Close-up view of some typical unstable slope-forming materials. Lumber in photograph gives the approximate scale.

FIGURE 5. This failure of a roadcut resulted from oversteepening unstable slope-forming materials.

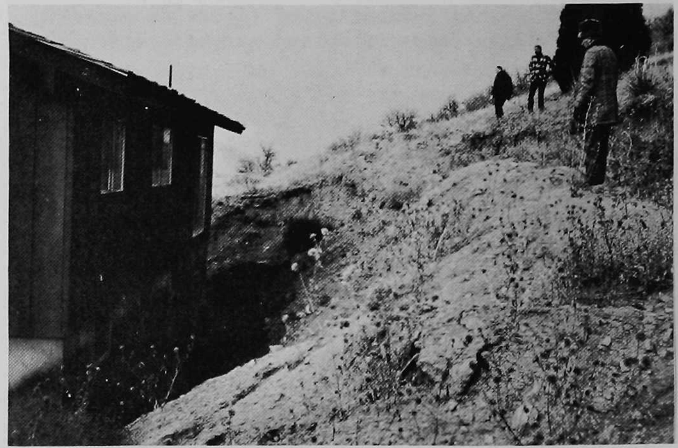


FIGURE 7. The excavation for this house foundation was made in unstable colluvium. The material on which the man in the foreground is standing has slid downslope and is causing distress in the rigid concrete foundation walls.

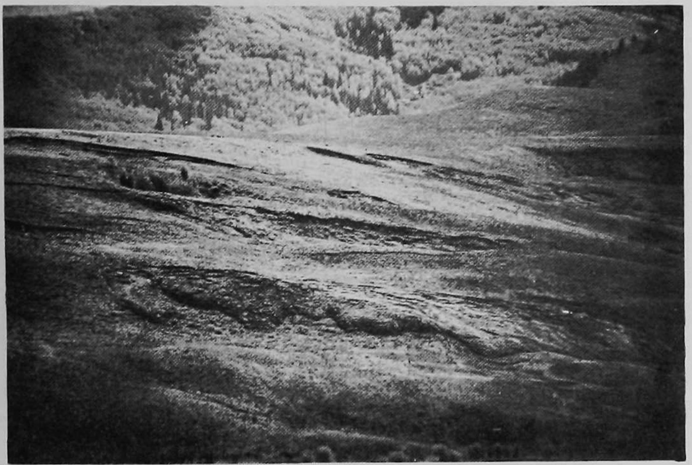


FIGURE 8. These earthflows are caused by leakage from irrigation ditches that are on top of the hill in the near distance.

FIGURE 10. These buildings are on a modern debris fan. The source of much of the debris is the receding cliff (arrow) in the upper reaches of the drainage basin.

FIGURE 9. These condominiums are built on active earthflows.

FIGURE 11. Typical appearance and composition of fresh mud, debris-flow material.

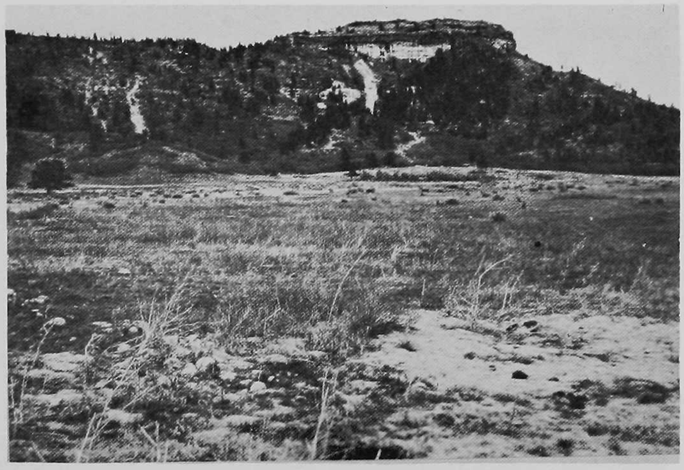


FIGURE 12. The mud, debris-flow deposits in the foreground whose source is on the butte in the background indicate that slope-failure hazards can extend some distance away from contiguous steeper-slope areas.

FIGURE 14. Larger rocks commonly bound out onto nearly level ground adjacent to their steep-cliff sources.

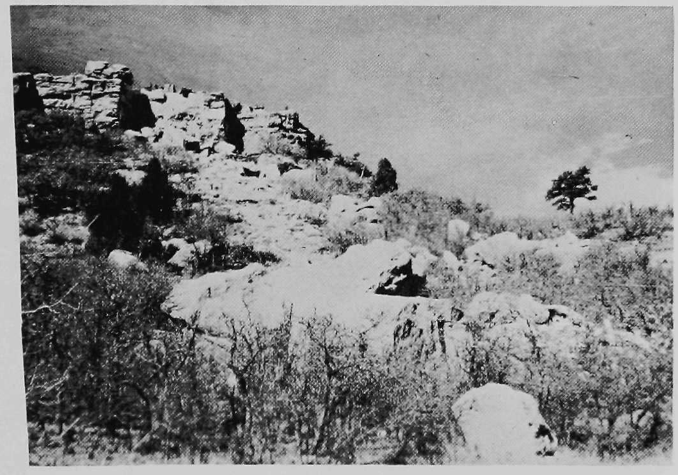


FIGURE 13. This rockfall occurred during a heavy rainstorm. The rocks rolled and bounded down onto an occupied building site in a platted subdivision.

MITIGATION OF UNSTABLE SLOPE HAZARDS

MICHAL BUKOVANSKY

Geological Engineer, Dames & Moore

INTRODUCTION

Unstable areas and slopes, frequently covered by old or recent landslides, are a common feature in mountainous regions. Human activity, construction and development, often extend into these potentially dangerous areas. Many well documented cases exist where construction triggered deformations or landslides. Individual sites had to be treated, often at very high costs; some had to be abandoned. On the other hand, with adequate knowledge of geotechnical conditions and commensurate engineering, many unstable areas have been successfully developed.

The recognition of the fact that we deal with an unstable slope is probably the most important step. Once we realize the potential danger, various methods of mitigation can be applied and, in most cases, the site can be successfully used for the design purpose.

SAFETY FACTOR

In an engineering assessment of the stability, the term "safety factor" is frequently used. Its meaning is shown in Figure 1. Safety factor of a slope or of a slide, as shown on this figure, is defined as a ratio of the resisting forces to the driving forces. In a landslide, driving forces tend to force the slide downward, over the resistance of the lower portion of the slide. Depending on the ratio of the driving and resisting forces, we can distinguish three cases:

1. When resisting forces are higher than driving forces, the safety factor is higher than one, and the slide is stable.
2. When resisting forces are lower than driving forces, the safety factor drops below unity, and the slide is unstable. Deformations or a catastrophic displacement will occur.
3. When resisting forces are equal to driving forces, the safety factor equals one. This situation is common at numerous old landslides and natural slopes. A small change in either resisting or driving forces such as the human activity or a change in the overall environmental conditions can easily trigger new deformations.

CHANGING STABILITY CONDITIONS

Human activity can very effectively influence the stability or the safety factor of a slide. Figure 2 shows three basic methods to increase the stability. If we build a buttress, or in other words, we load the toe of the slide, we are certainly increasing the safety factor. If we excavate the upper portion of the slide, we are reducing the driving forces and the effect is the same. The third very effective method of stability improving is the drainage. Installing horizontal subdrains in a water saturated landslide will result in increased resisting forces and, possibly, in stable conditions.

Unfortunately, these basic guidelines are not always followed. Many times, the construction follows just opposite rules and, in most cases, stability problems are encountered. Three typical cases of how to decrease the stability of a slide are illustrated in Figure 3. The excavation of the toe of a slide would very probably result in a failure since we have reduced the resisting forces and decreased the available safety factor. Increasing the amount of water in the slope or the slide will have a very similar effect. Homeowners in some portions of California have learned that just watering their lawns may bring about stability problems. Finally, loading the upper portion of a slide will increase the driving forces and reduce the safety factor as well. A water reservoir, as shown in Figure 3, frequently comprises a typical unfortunate solution. It is located on a slide because ground water is frequently found in landslides. It loads the upper portion of the slide and, in addition, frequently leaks and thus deteriorates the hydrologic conditions.

SIZE OF A LANDSLIDE

To evaluate the size of an existing or potential landslide is a very important item. Slides can vary in size from several cubic yards to tens or hundreds of millions of cubic yards. Generally, the smaller the slide, the easier the remedial measures. With increasing yardage of a landslide, mitigation becomes less economically viable.

Two cases on Figure 4 document well this relation. The first case is a large landslide from Czechoslovakia, in Tertiary claystone. The slide is nearly a mile long, with yardage of about a hundred million cubic yards. The toe of the slide has been eroded by a large river, and deformations on the order of 1 ft/yr could be detected on the surface. The slide was to be crossed by a large channel. With regard to the size of the slide, any stabilization method was economically not viable, and the project had to be abandoned.

The second example, a landslide in glacial till, is from Breckenridge, Colorado. The slide is of a limited extent--several hundred feet long. Remedial measures for a slide of this type are economically very feasible. In fact, the lower slide portion has been already developed without any appreciable decrease of the stability.

CORRECTIVE MEASURES

In Figure 5, typical corrective measures for unstable slopes and landslides are listed. They are divided into four groups: change of the slope shape, drainage, retaining forces, and special treatment.

The change of the slope shape may include a total excavation of the slide, a partial excavation of the upper slide portion, loading the slide toe or a combination of both. Excavation is typically an economic and safe way to treat unstable areas. It becomes difficult and expensive with the increasing size of the area.

Drainage, very effective and frequently used, is limited to cases where ground water exists within the area. Surface drainage is efficient in only a few cases of small slides; usually, subsurface drainage is required. It can be achieved with the help of trenches filled with pervious gravel, horizontal drainage holes, drainage wells, and, in extreme cases, subsurface drainage tunnels.

Retaining forces include buttresses, piles, retaining walls of various types, bolts and anchors. Their applications are limited to slides or areas of a limited extent. Buttresses are by far the most popular method because of low costs and simple installation.

Special treatment methods include freezing, thermal methods, grouting, electro-osmosis and blasting. All of these methods have been used in special cases where more common methods were not feasible. They are expensive and of limited applicability for common stability problems.

CASE HISTORIES

Figure 6 shows the treatment of a failure of a highway cut. The failure is a toppling type in thinly laminated sedimentary rocks (sandstones, shales, and marls), dipping favorably into the cut slope. The failure was triggered by the excavation of the cut. After the depth of the failure plane was estimated and the yardage of the failure evaluated (some 30,000 yd^3), it became evident that the excavation of the slide comprised the most economical means of stabilization. The slide was excavated to the depth of the failure plane. Three inclinometers were installed in the cut slope to monitor future stability of the area.

Stabilization of a slide by partial excavation of the upper slide portion is illustrated in Figure 7. A highway cut, designed and excavated in hard shales along bedding planes, failed during the excavation. A vertical fault striking parallel with the cut face was the reason for the failure (a slab of rock became loose and started to slide down, acting as an active wedge against the portion below the fault). Sliding was at a very slow rate of inches per day. Since the yardage of the loosened rock mass was up to 100,000 yd^3, a total excavation of the sliding mass would have been very expensive. Simple analysis showed that a partial excavation of the upper slide portion would be sufficient to stabilize the loosened rock mass.

Figure 8 shows the commonly used methods of surface and subsurface drainage. Drainage trenches are a very simple, fast and inexpensive method of stabilization of small and shallow slides where trenches can be excavated with a backhoe and immediately filled with some free-draining, high-friction material, such as gravel. These trenches, which have to be excavated safely below the shear plane, drain the slide mass and effectively increase the shearing resistance along the shear plane.

The drainage method with horizontal drainage holes is frequently used to treat deep-seated slides and unstable areas. The number of drainage holes required is usually high, and many of them are frequently ineffective.

The last example of subsurface drainage with a tunnel and subdrains drilled from the tunnel is the most expensive but absolutely reliable method. It has been applied in cases where all other drainage methods failed.

Stabilization of a landslide in soft shales interbedded with sand lenses by means of gravel-filled trenches, parallel with the direction of the movement, is shown in Figure 9. The depth of the shear plane was estimated with the help of three borings. An analysis showed that the slide could be stabilized with three trenches filled with gravel. Additional increase of the safety factor was achieved by flattening the upper slide portion and by installing a reliable surface drainage system.

Figure 10 shows various retaining forces used to stabilize landslides or unstable slopes. A buttress is the most popular means of support. Retaining walls, anchored piles or anchors are expensive, and their application is limited strictly to slides of a small extent.

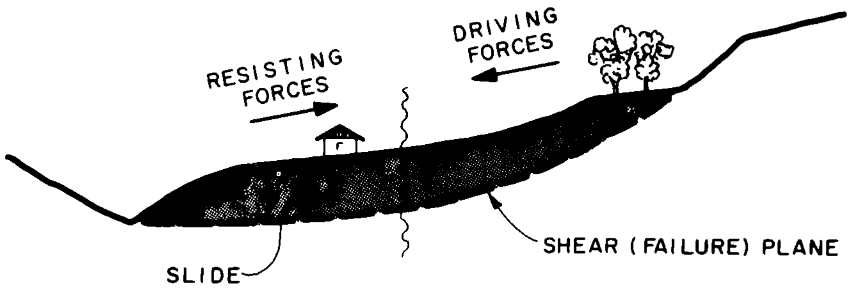
Stabilization of a large old landslide, deformations of which were renewed by the highway cut excavation at the toe, is illustrated in Figure 11. The slide was in badly weathered sedimentary rocks (sandstones and shales). The highway cut excavation caused a considerable deformation of the slide, reaching up to several feet and badly damaging a house located in the middle of the slide. Three borings were drilled to estimate the depth of the slide. The analysis showed that the slide could be stabilized by a rockfill buttress, which would replace the toe of the slide. Both the draining effect and the increase in friction were taken into account.

Because the buttress had to be located inside the slide and prior to its placement, it was necessary to excavate the toe of the slide. The safety factor of the slide was further decreased during the short construction period. To decrease the danger of further deformations, excavation was carried out in sections rather than for the total width of the slide.

Figure 12 lists special corrective measures, rarely used in engineering. It lists also methods of the slope deformation control, which should be mentioned briefly.

Slope deformation control methods, whether they use simple surveying or more sophisticated devices such as inclinometers, extensometers, shear strips, piezometers or microseismics, are extremely valuable tools in stability problems. They can be used to evaluate whether deformations can be traced in potentially unstable areas. They comprise an excellent tool to verify the effectiveness of remedial measures on existing landslides or unstable areas. Up-to-date soil and rock mechanics provide many advanced analytical methods to evaluate the stability conditions. The accuracy of these methods largely depends on the accuracy of the input data, which is usually much lower. Deformation control helps to verify analytical results and to monitor the safety of the area for many years.

SAFETY FACTOR OF A SLIDE
(STABILITY)



$$\text{SAFETY FACTOR SF} = \frac{\text{RESISTING FORCES}}{\text{DRIVING FORCES}}$$

SF > 1 .... SLIDE IS STABLE

SF < 1 .... SLIDE IS UNSTABLE

SF = 1 .... EQUILIBRIUM

FIGURE 1.

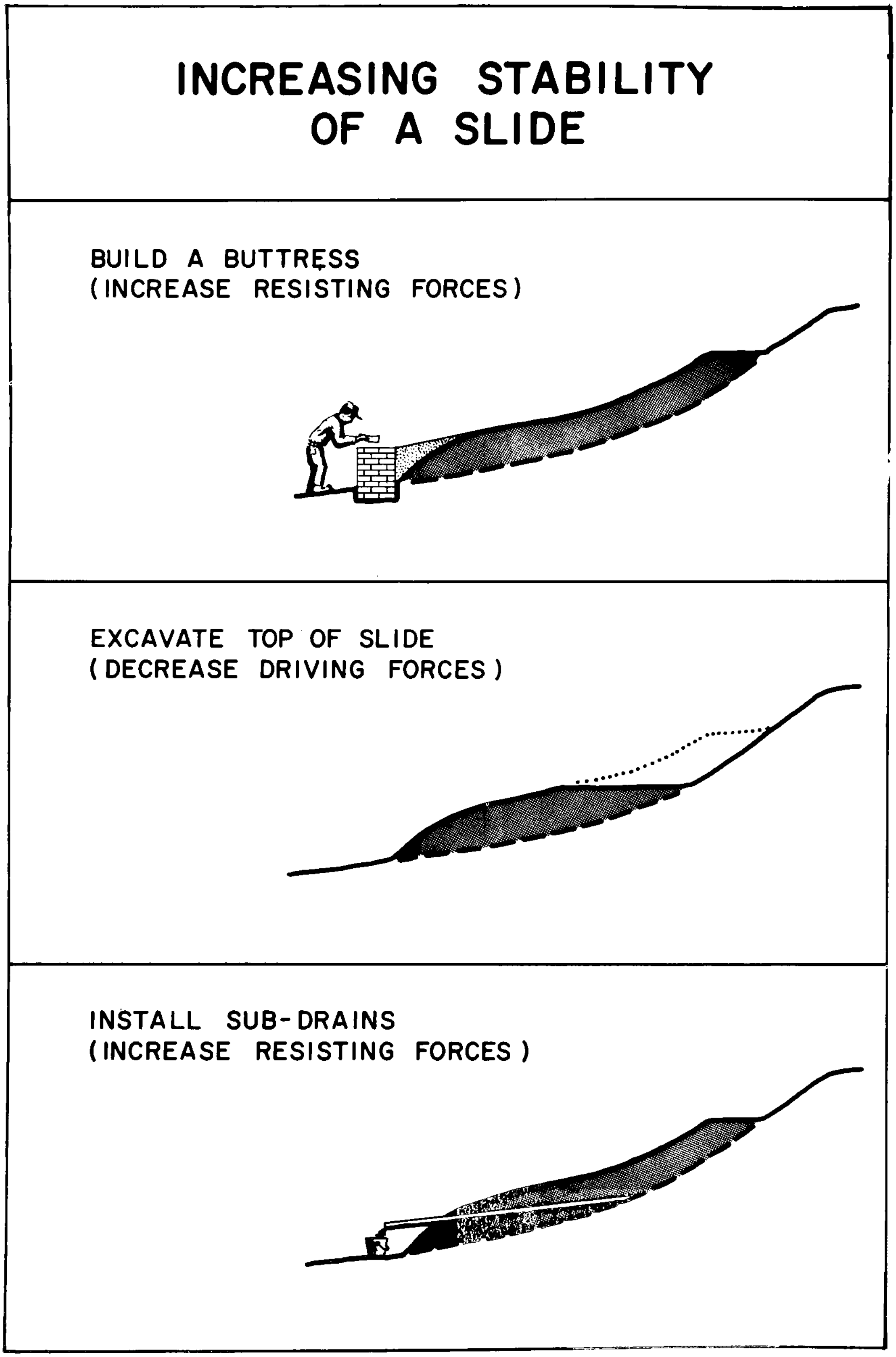

INCREASING STABILITY OF A SLIDE
BUILD A BUTTRESS
(INCREASE RESISTING FORCES)
EXCAVATE TOP OF SLIDE
(DECREASE DRIVING FORCES)
INSTALL SUB-DRAINS
(INCREASE RESISTING FORCES)

FIGURE 2.

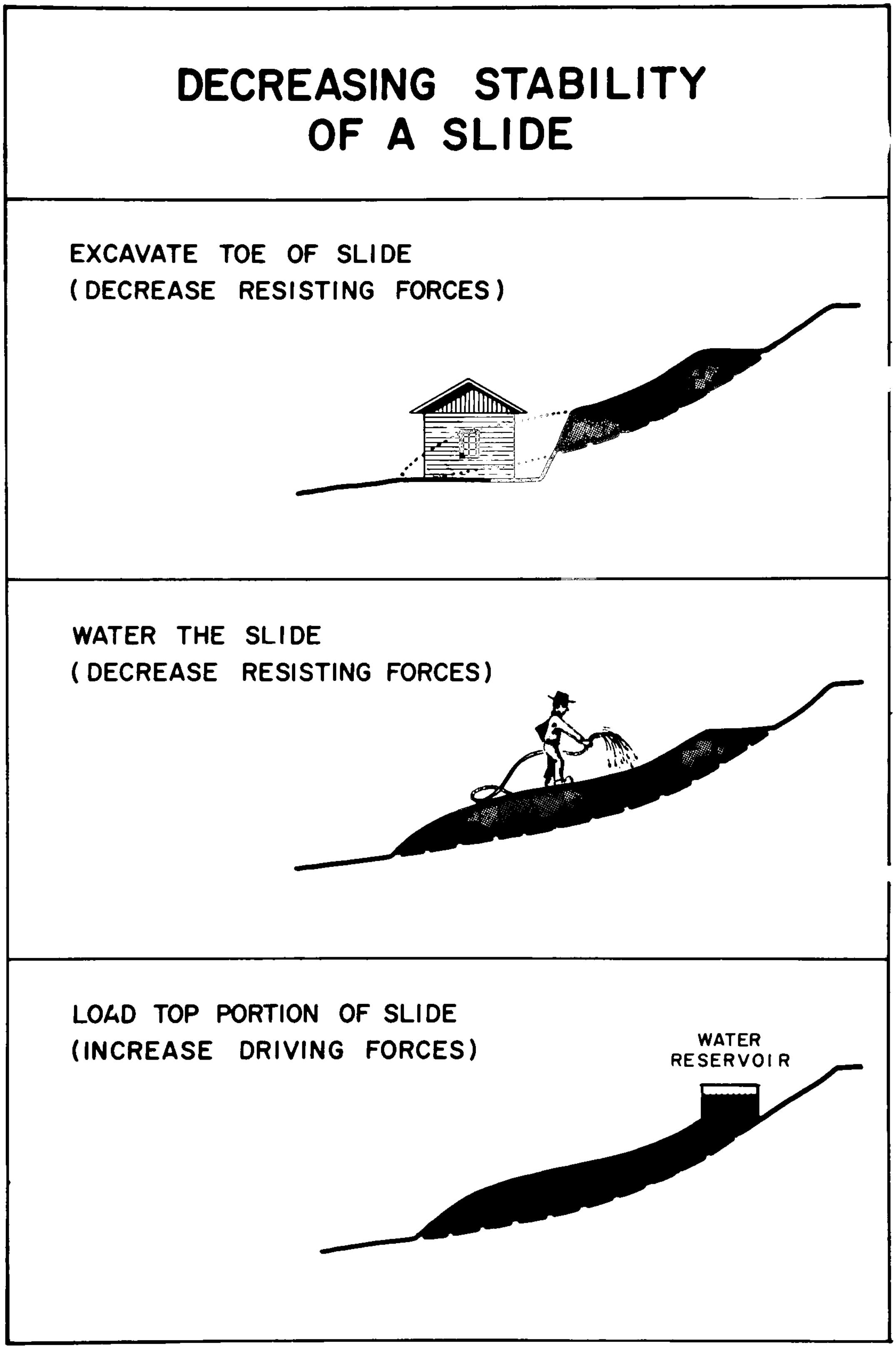
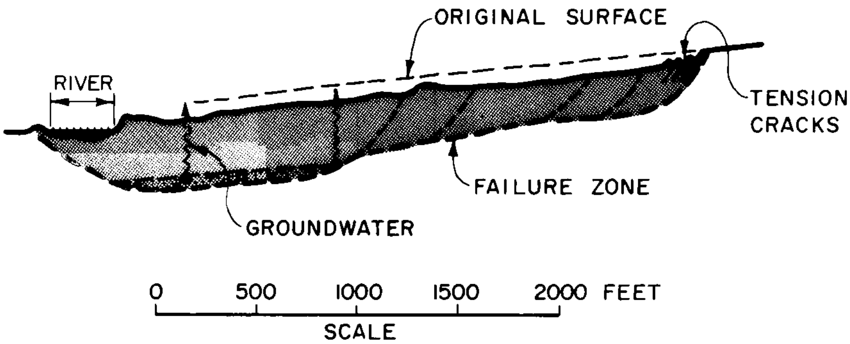

DECREASING STABILITY OF A SLIDE
EXCAVATE TOE OF SLIDE
(DECREASE RESISTING FORCES)
WATER THE SLIDE
(DECREASE RESISTING FORCES)
LOAD TOP PORTION OF SLIDE
(INCREASE DRIVING FORCES)
WATER RESERVOIR

FIGURE 3.

LARGE LANDSLIDES

LANDSLIDE - SUCANY (CZECHOSLOVAKIA)

A recent landslide with low stability (SF < 1)



LANDSLIDE - BRECKENRIDGE (COLORADO)

An old, fairly stable landslide (SF ≧ 1)

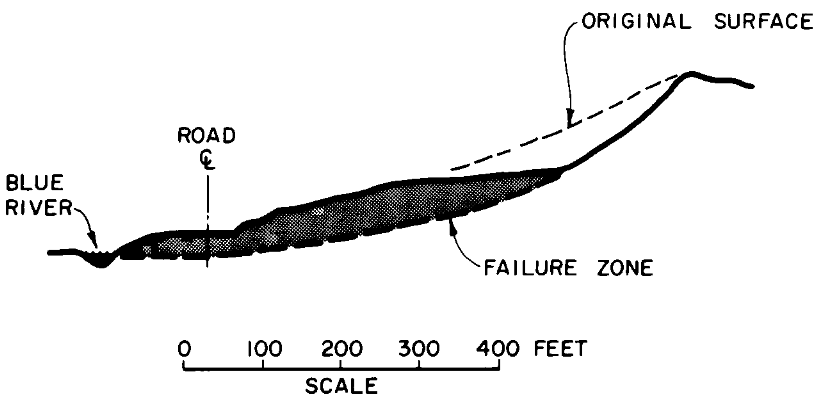


FIGURE 4.

CORRECTIVE MEASURES

CHANGE OF SLOPE SHAPE	• EXCAVATE THE SLIDE • EXCAVATE UPPER PORTION • LOAD LOWER PORTION • COMBINE EXCAVATION AND LOADING
DRAINAGE	• SURFACE DRAINAGE • SUB-SURFACE DRAINAGE (TRENCHES) • SUB-SURFACE DRAINAGE (BORINGS) • SUB-SURFACE DRAINAGE (WELLS) • SUB-SURFACE DRAINAGE (GALLERIES)
RETAINING FORCES	• BUTTRESS • PILES • WALLS • ANCHORS
SPECIAL TREATMENT	• FREEZING • THERMAL METHODS • GROUTING • ELECTROOSMOSIS • BLASTING

E

FIGURE 5.

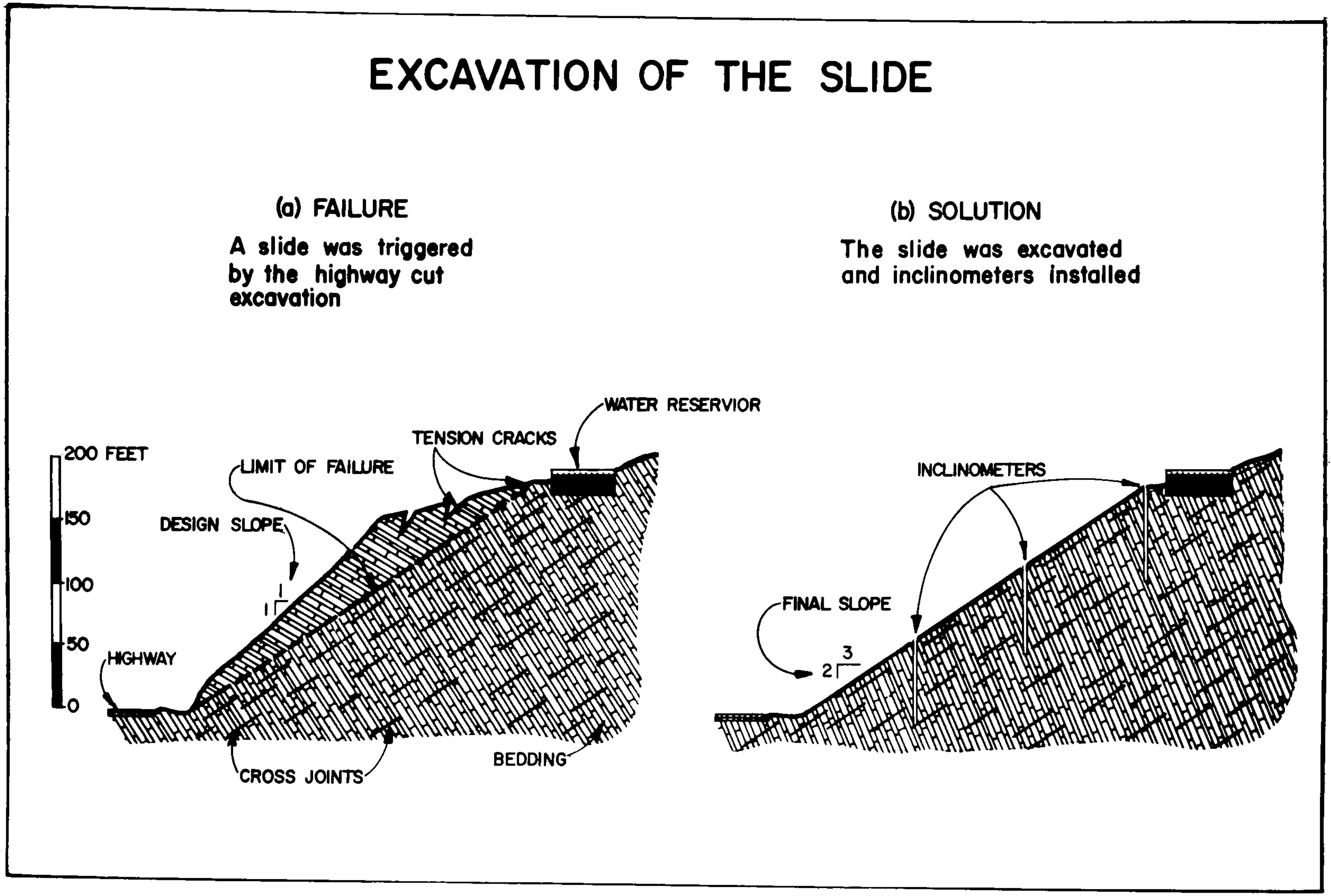

EXCAVATION OF THE SLIDE
(a) FAILURE
A slide was triggered by the highway cut excavation
(b) SOLUTION
The slide was excavated and inclinometers installed
200 FEET
150
100
50
0
HIGHWAY
DESIGN SLOPE
LIMIT OF FAILURE
TENSION CRACKS
WATER RESERVIOR
CROSS JOINTS
BEDDING
INCLINOMETERS
FINAL SLOPE
1
1
3
2

FIGURE 6.

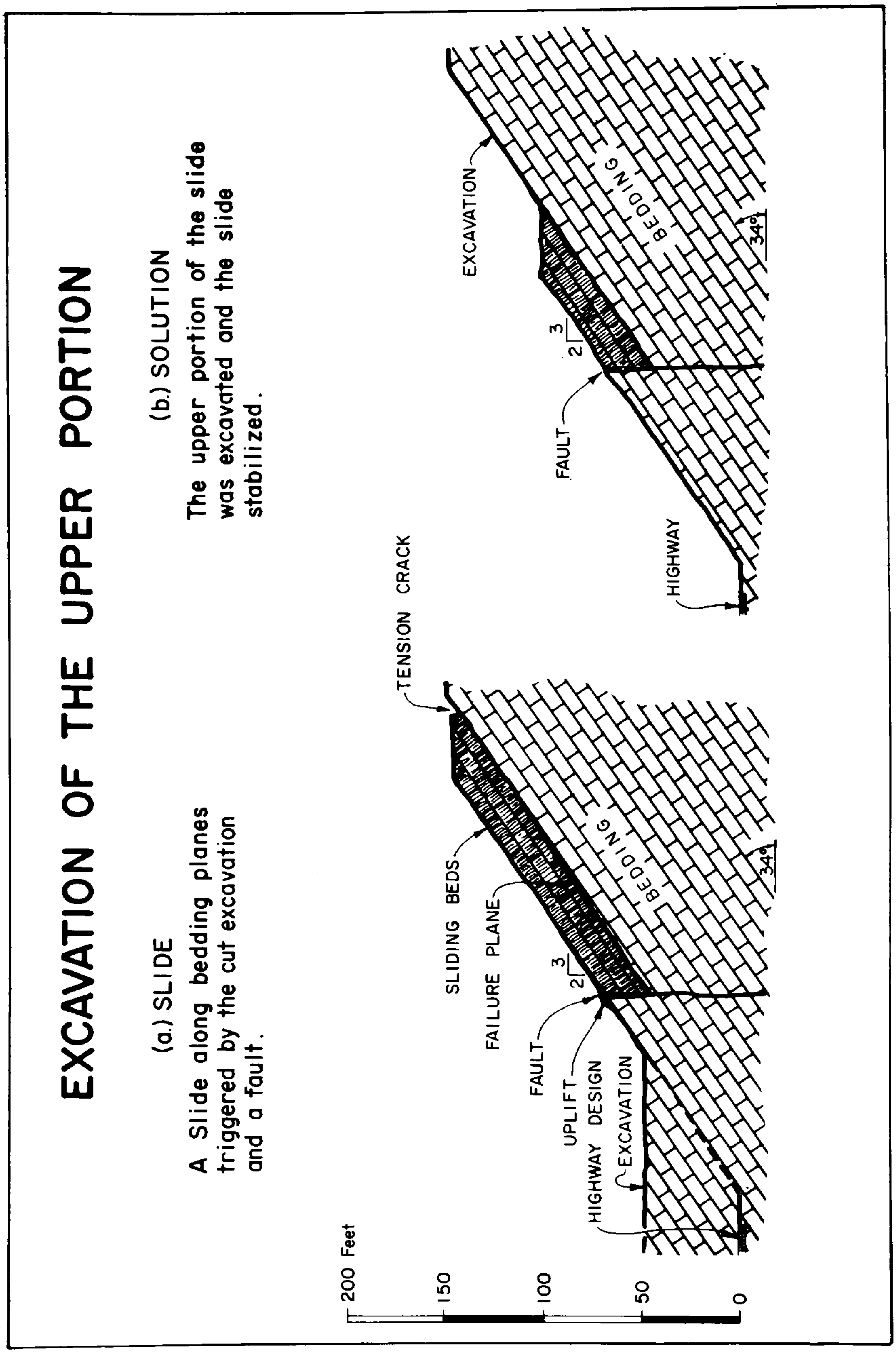

EXCAVATION OF THE UPPER PORTION
(a.) SLIDE
A Slide along bedding planes triggered by the cut excavation and a fault.
(b.) SOLUTION
The upper portion of the slide was excavated and the slide stabilized.
TENSION CRACK
SLIDING BEDS
FAILURE PLANE
FAULT
UPLIFT
HIGHWAY DESIGN
EXCAVATION
BEDDING
34°
3
2
EXCAVATION
FAULT
HIGHWAY
BEDDING
34°
3
2
200 Feet
150
100
50
0

FIGURE 7.

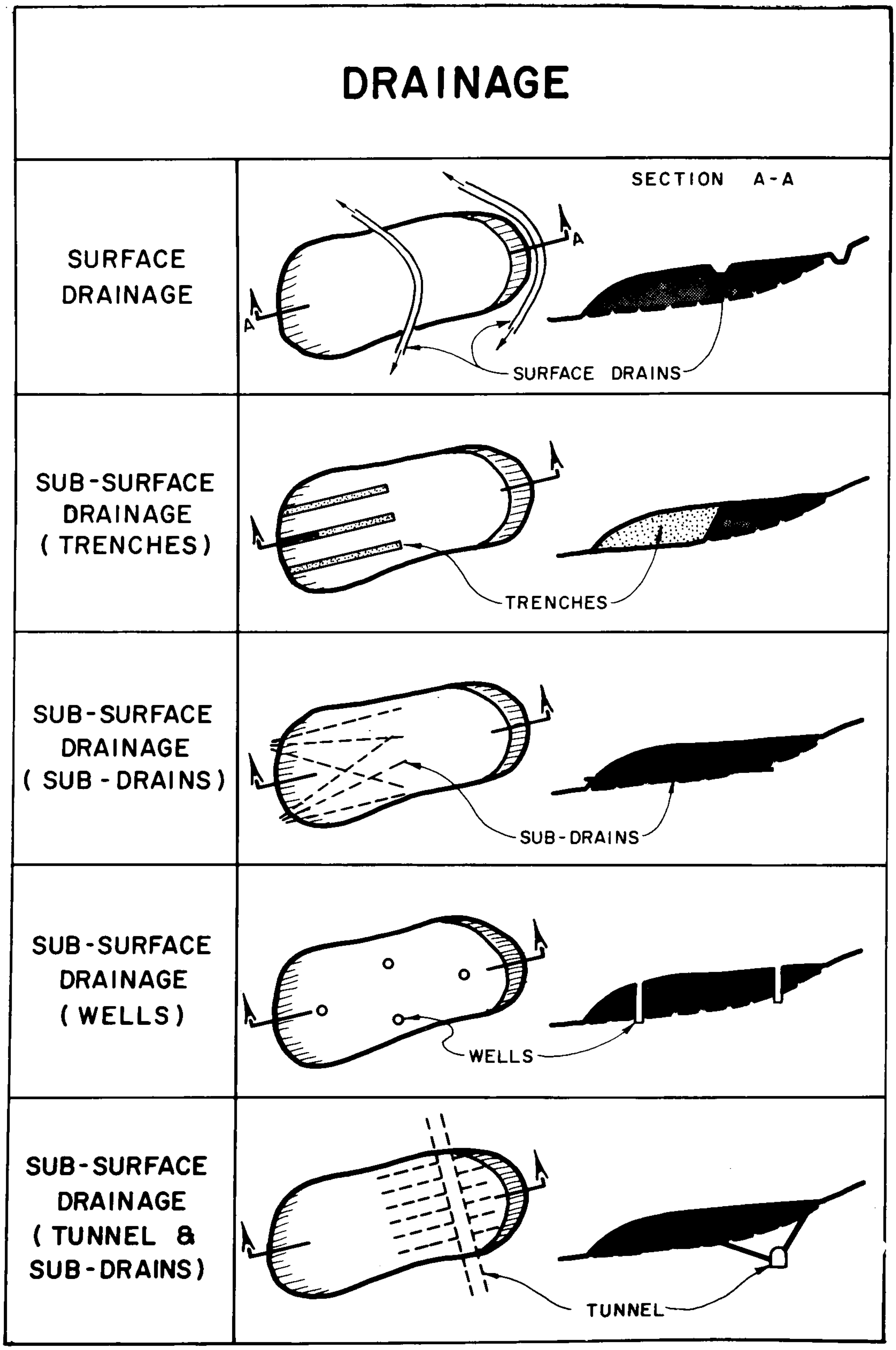

DRAINAGE
SURFACE DRAINAGE
SECTION A-A
A
A
SURFACE DRAINS
SUB-SURFACE DRAINAGE (TRENCHES)
TRENCHES
SUB-SURFACE DRAINAGE (SUB-DRAINS)
SUB-DRAINS
SUB-SURFACE DRAINAGE (WELLS)
WELLS
SUB-SURFACE DRAINAGE (TUNNEL & SUB-DRAINS)
TUNNEL

FIGURE 8.

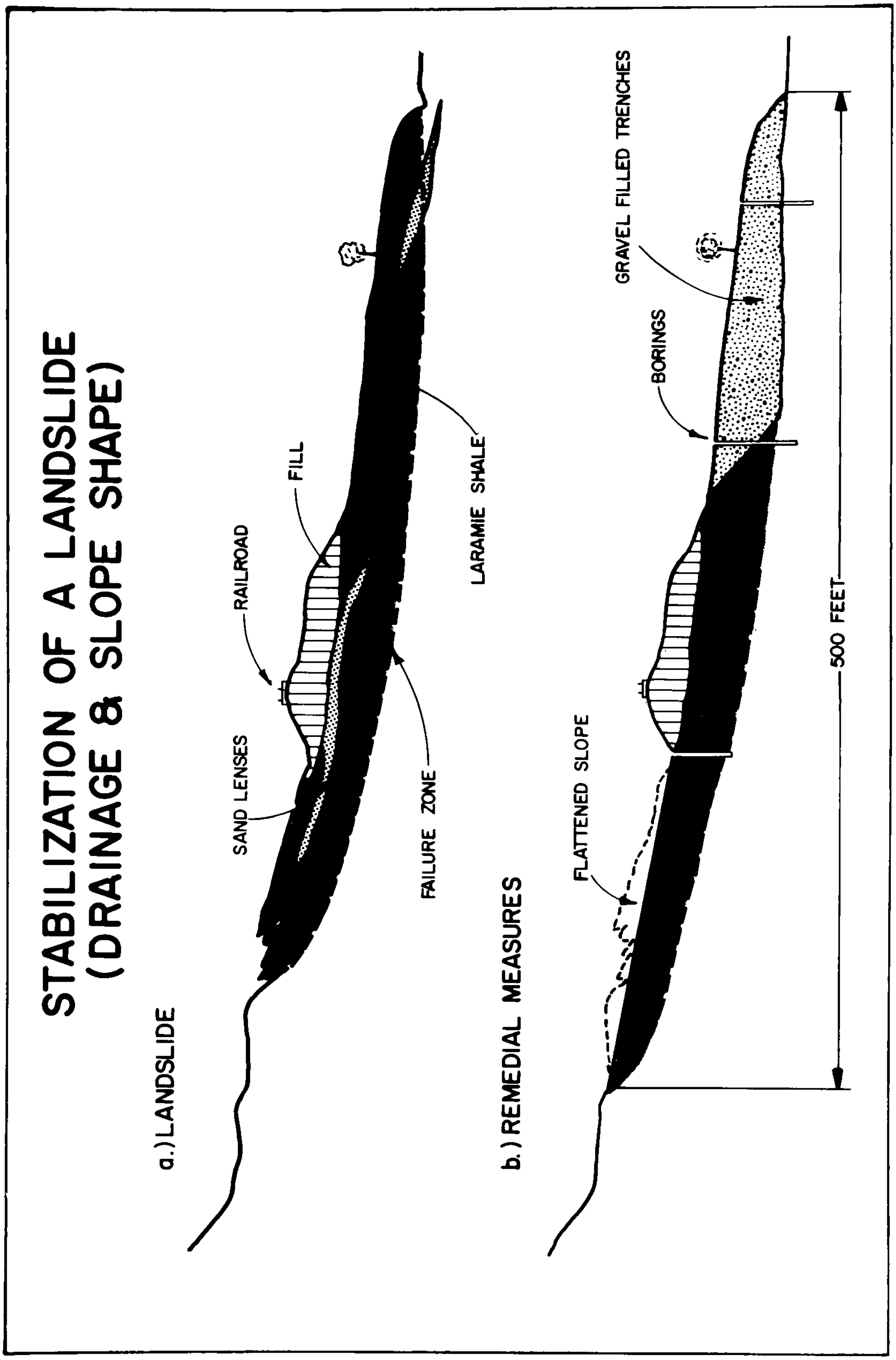

STABILIZATION OF A LANDSLIDE
(DRAINAGE & SLOPE SHAPE)
a.) LANDSLIDE
RAILROAD
FILL
SAND LENSES
FAILURE ZONE
LARAMIE SHALE
b.) REMEDIAL MEASURES
FLATTENED SLOPE
BORINGS
GRAVEL FILLED TRENCHES
500 FEET

FIGURE 9.

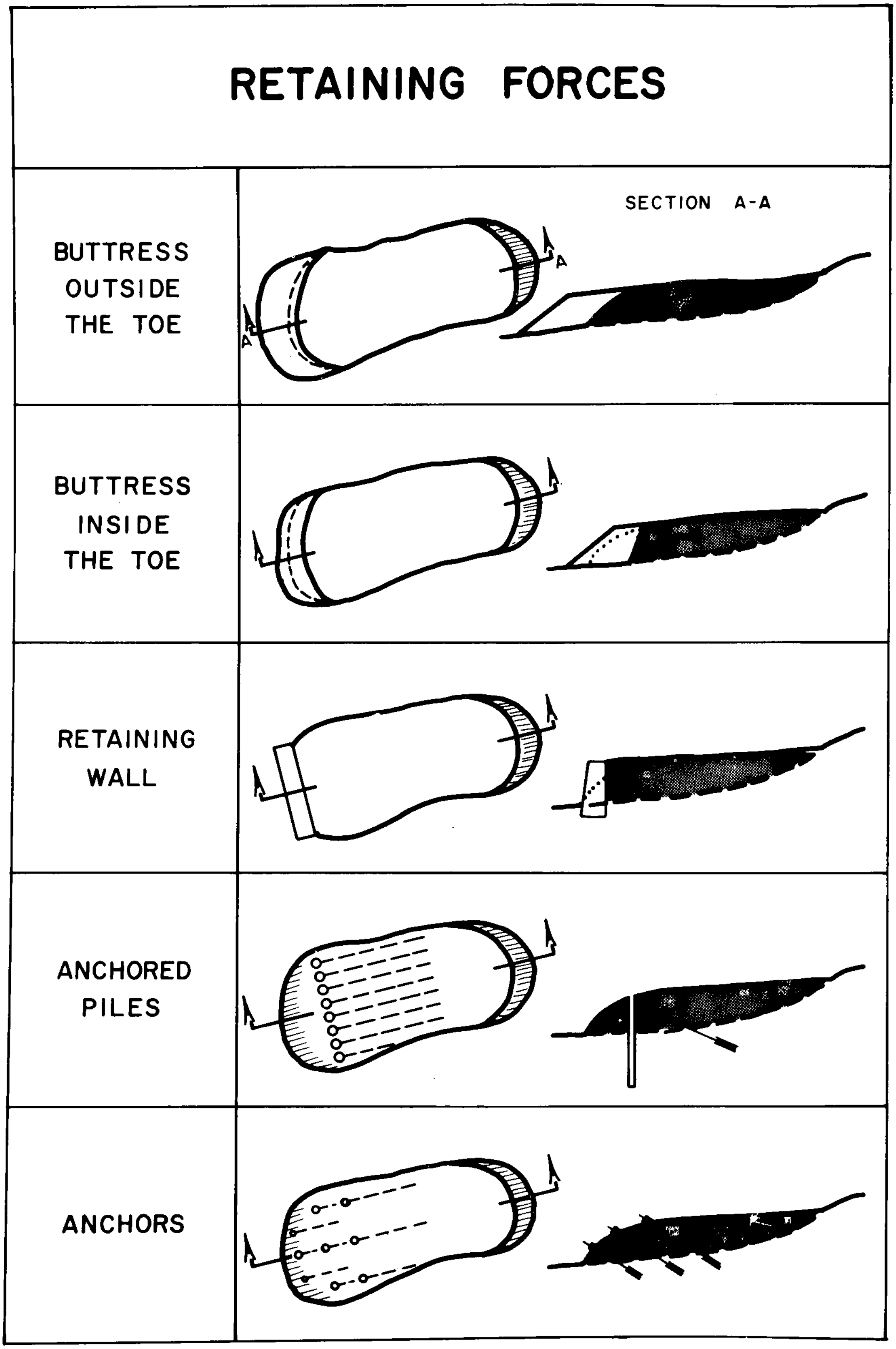

RETAINING FORCES
BUTTRESS OUTSIDE THE TOE
SECTION A-A
A
A
BUTTRESS INSIDE THE TOE
RETAINING WALL
ANCHORED PILES
ANCHORS

FIGURE 10.

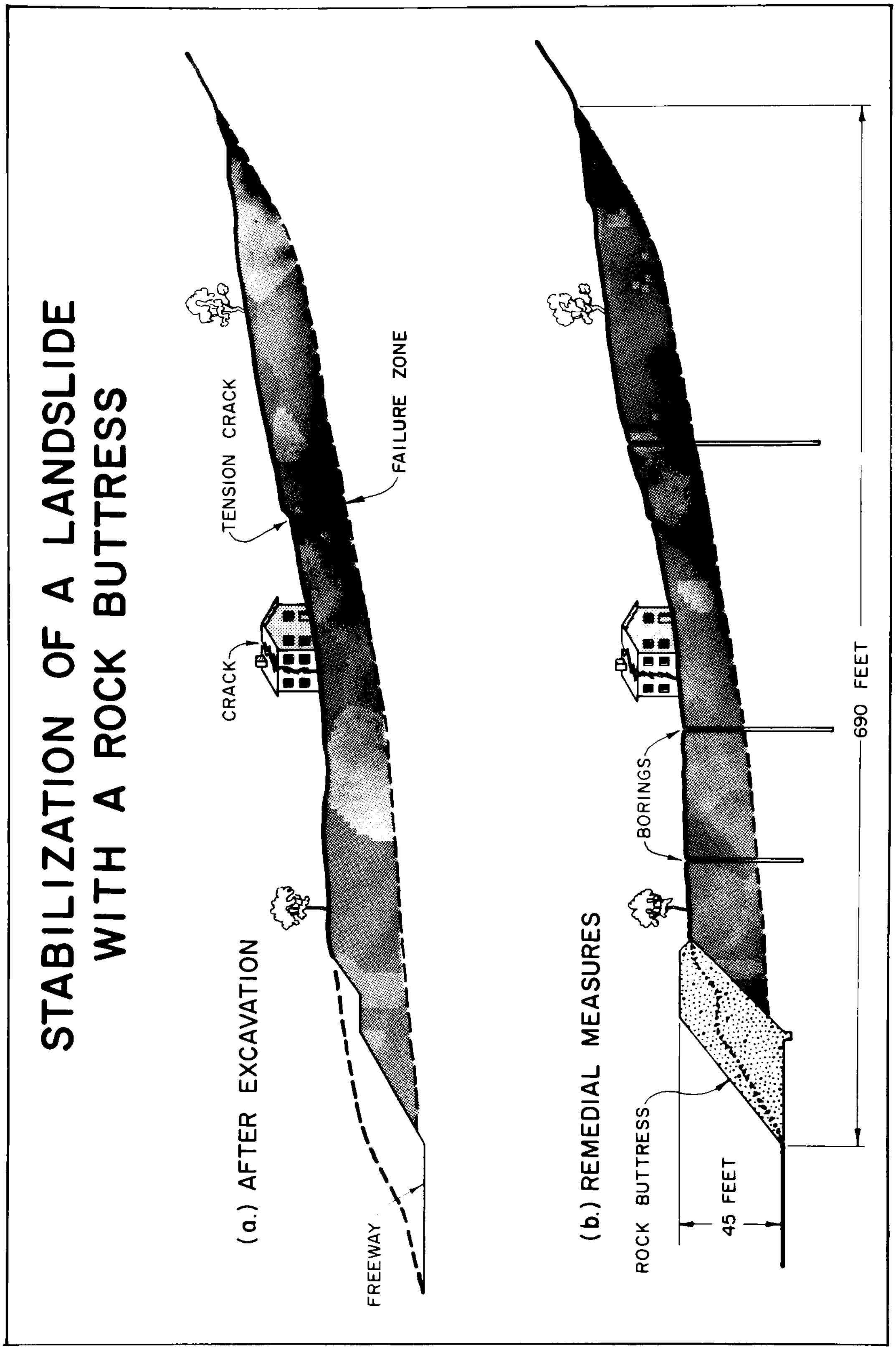

STABILIZATION OF A LANDSLIDE
WITH A ROCK BUTTRESS
(a.) AFTER EXCAVATION
TENSION CRACK
FAILURE ZONE
CRACK
FREEWAY
(b.) REMEDIAL MEASURES
BORINGS
ROCK BUTTRESS
45 FEET
690 FEET

FIGURE 11.

SPECIAL CORRECTIVE MEASURES

- GROUTING
- FREEZING
- THERMAL METHODS
- CONSOLIDATION BY BLASTING
- ELECTROOSMOSIS

SLOPE DEFORMATION CONTROL

- SURFACE MONITORING
- INCLINOMETERS
- EXTENSOMETERS
- SHEAR STRIPS
- PIEZOMETERS
- MICROSEISMICS

FIGURE 12.

SNOW AVALANCHE HAZARD IDENTIFICATION AND DELINEATION

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INTRODUCTION

Thousands of snow avalanches fall throughout the Colorado mountains each year, the potential existing wherever the combination of steep slopes and adequate snowfall occurs. Because the majority of these avalanches take place in remote mountain areas, and do not affect man, it is necessary to distinguish between avalanche "hazard" and avalanche "danger".

A hazard exists wherever there is a potential avalanche. However, the degree of danger to man depends on both the frequency of avalanche occurrence and man's length of exposure to the hazard. Three types of problems are recognized when man enters avalanche hazard zones.

The first problem occurs because of increased winter recreational use of the back country by cross-country skiers, snowshoers, and snowmobilers. These people often travel through avalanche hazard zones, but because of their short time of exposure to the hazard, accidents are relatively rare. However, as the number of winter backcountry users increases, the number of avalanche victims also increases. This can be attributed to both an increased total exposure time and because an increasing proportion of these people are unfamiliar with the hazards and safety precautions necessary for safe recreational use of the mountains in winter. Mapping of major hazard zones does little to reduce the problem because the victims are most often caught in small snowslides triggered by themselves (Williams, 1975).

A second type of problem is encountered on steep slopes of commercial ski areas and on highways or railroads built through avalanche hazard zones. In this case the total exposure time may be quite high. However, it is possible for affected ski slopes and transportation arteries to be closed during avalanche control operations. Consequently the danger to man from these hazards can be significantly reduced. Nevertheless, this has been the largest single cause of avalanche accidents in the U.S. in recent years (Williams, 1975).

A third type of problem is caused by the construction of buildings in runout zones which are reached by avalanches only rarely. In this case the time of exposure may be very long. The difficulty in such cases is the determination of the <u>extent</u>, <u>type</u>, <u>destructive force</u>, and <u>frequency</u> of avalanches at the locations of the proposed buildings. These are the necessary elements of avalanche hazard evaluation. Once determined, they provide quantitative guidelines for land use in avalanche hazard zones which, in turn, dictate the acceptable level of danger to residents of these zones.

This paper discusses the elements of avalanche hazard evaluation necessary in the detailed delineation of avalanche paths, and suggests general approaches which can be used in their determination.

OBTAINING THE NECESSARY DESIGN ELEMENTS

Avalanche Terrain and the Interrelatedness of Design Elements

An avalanche <u>path</u> (Figure 1) may commonly be divided into 1) a <u>starting zone</u> where avalanches start, gain mass, and accelerate, 2) a <u>track</u> in which avalanche velocity is maintained, and 3) a <u>runout zone</u> where large avalanches decelerate, stop, and deposit most of the mass which has fallen from higher in the path. The starting zone usually consists of slopes steeper than 30° (62%) and, as a result, avalanches in this region may be quite common, occurring as small slides or sluffs during and after snowstorms. These small slides may occur several times in a winter. Larger and deeper releases of snow from the starting zone may reach and traverse part or all of the avalanche track. These "full track" avalanches are less common than the smaller slides discussed above because the conditions producing them do not occur as often as those producing the small slides.

During exceptional conditions large volumes of snow will release from the starting zone, encounter favorable conditions in the track, and flow long distances into the runout zone. It is here, within the runout zone, that the avalanches may encounter man and his works. Therefore it becomes of practical importance to be able to delineate the probable runout zone of the exceptionally large avalanche.

Both avalanche size and avalanche frequency have been considered in previous paragraphs. Specification of one is meaningless without knowledge of the other. In a given avalanche path progressively larger avalanche events are associated with progressively smaller frequencies or longer "return periods". Hence, delineation of an avalanche runout zone without specifying the frequency of the event does not describe the hazard. At some point within the runout zone the probability of an avalanche reaching

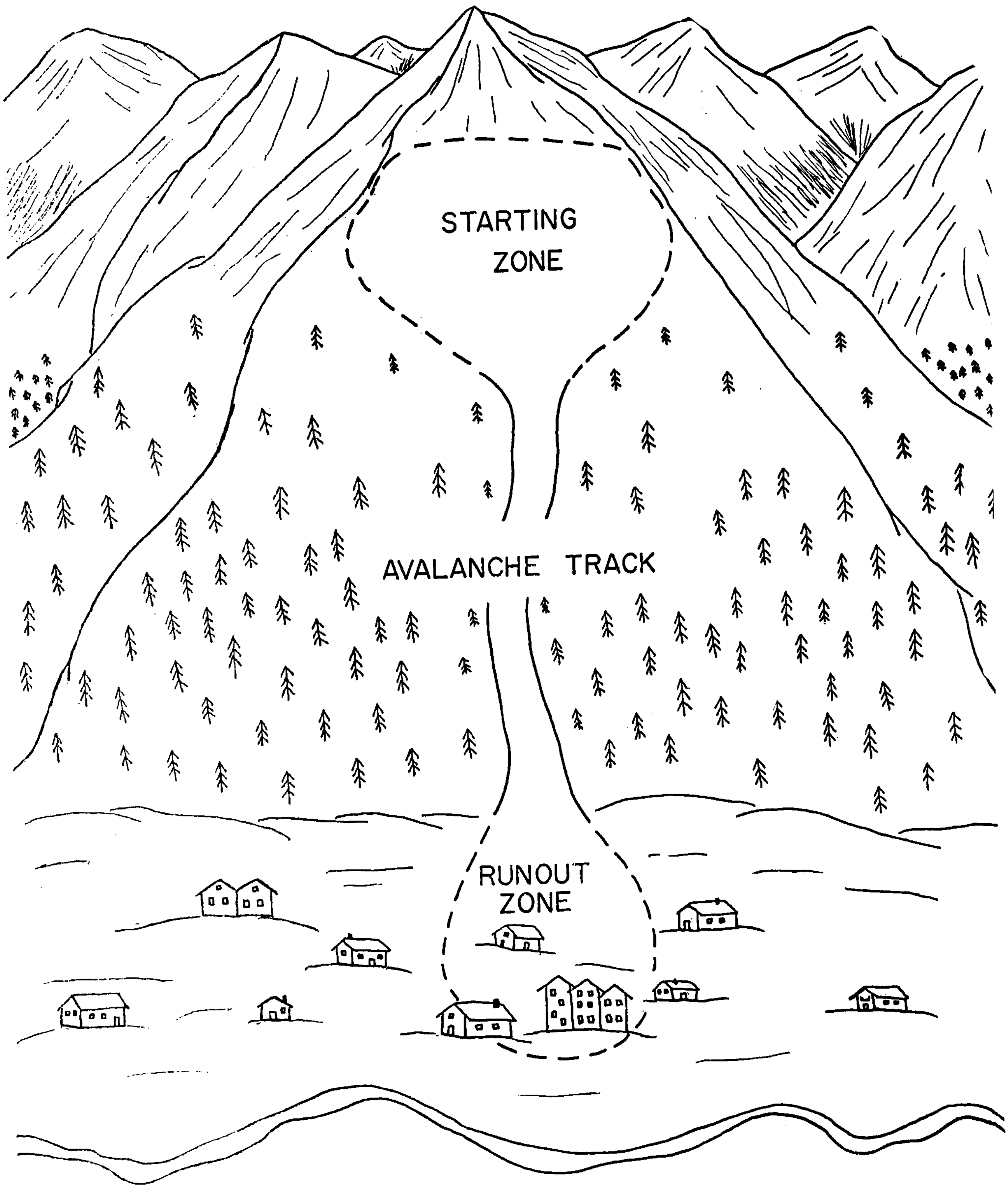

FIGURE 1. Schematic drawing of an avalanche path showing the runout zone of the design avalanche.

that point becomes so small it can be disregarded. It is desirable to define such a point in terms of avalanche "return period" in much the same way as flood hazards are defined. An area might be defined as "safe", for example, if avalanches with return periods of 100 to 200 years are incapable of reaching it. Such an avalanche has an annual probability of 0.5% to 1.0%.

The determination of the sizes of avalanches with such long return periods is very difficult because they are rare events which have almost never been observed during the short history of modern mountain towns. When such avalanches have been observed good data on their extent are usually lacking. Smaller avalanches in a given path may have been observed because they occur more often, but they do not provide good information for planning. Instead, these smaller avalanches are often misinterpreted by proponents of land-use change as representing the maximum extent of avalanches which must be planned for. It is important to recognize that detailed data on the avalanche or snowpack conditions collected over a short time period (5 to 10 years, for example) usually do little to provide information about the large, rare event. Such data, regardless of detail, are useless for planning purposes unless it is known that the rare event happened, by chance to occur during the short period of observation. As pointed out by LaChapelle (1966), the probability that the "100" year avalanche will occur during any given 10 year period is only 9.6%. Furthermore, there is no reliable method of extrapolating short-term records to a long time period.

This lack of good, long records in Colorado forces the avalanche analyst to adopt indirect methods in analyses of avalanche hazard areas. Two different approaches to such analyses are discussed below: 1) The indirect determination of the sizes of large large events of the past, and 2) The use of dynamic equations to reconstruct the "design avalanche". Both approaches have certain advantages and limitations which are discussed below.

Determination of the Sizes of Past Events

This approach is most familiar to geologists and other earth scientists who typically observe features, collect data, and make interpretations. Its main advantage is that the imprint of large avalanches of the past, if interpreted through forest destruction, is the result of the large events which have occurred over a long time period. Such a long, imperfect record is generally superior to a short, detailed record.

The 100-to 200-year return period of the avalanches which should be considered for land planning is roughly the same as the ages of large mature specimens of certain species of trees which commonly border avalanche paths in alpine areas. Careful study of mature trees at the lateral limits of avalanche tracks (Figure 2) and runout zones will sometimes reveal trees which have withstood the large avalanches more than once. The interval between successive large events may be established in this way. Younger trees of approximately equal age within the track and runout zone indicate the minimum length of time since the last large event. Careful study of many locations in the avalanche path, particularly at locations which would only be reached by big avalanches, can be used to estimate the intervals between events. The details of tree-ring analysis (dendrochronology) as applied to avalanche frequency is discussed in detail by Smith (1973).

The outer limits of the destructive effects of past avalanches in the track, which have occurred during the lifetime of the forest, can sometimes be determined by field inspection. The dimensions of the destructive cross section in the track (Figure 3), can be observed and measured in the field. In this way flow depths of maximum avalanches of the past can be estimated from field data. Estimates of the destructive force of such avalanches can sometimes also be made through analysis of broken trees (Mears, 1975).

The outer limits of the runout zones may also be inferred through interpretation of forest destruction and the location of dead logs and other debris carried by avalanches. Such interpretation is very valuable if estimates of the ages of trees which stand just beyond the runout limits observed can be made. This establishes a length of time in which avalanches of a force sufficient to destroy such trees did not occur. However, it must be remembered that avalanches sometimes flow through trees without destroying them but may cause impact pressure sufficient to destroy buildings.

Airphoto interpretation of avalanche paths in forested areas is often very helpful in estimates of the sizes of potential avalanches. Such photos enable the entire path to be viewed at a distance, revealing the interrelatedness of starting zone size, track gradient and shape, and runout extent. Such perspective is seldom gained from the valley floor.

The interpretative methods discussed above require that the avalanche path be studied and visited during snow-free conditions. Much more can be learned about the large events of the past when a deep snow cover, which usually obscures useful data, is not present. Attempts to collect such information during mid-winter conditions are usually ineffective and, in some cases may be dangerous. In contrast, when it is necessary to obtain data on "average" or annual snow and avalanche conditions, winter observations are essential. The location of the starting zones of the common avalanches, which may affect roads or ski area facilities often, can best be determined by winter observations. It is important to recognize the differences between the objectives of these two types of studies, and to employ field methods most suitable for each.

The field determination of the sizes of past events as an indication of future avalanche hazard has certain disadvantages. The methods apply best to forested locations. However, runout zones are often located on treeless meadows and floodplains. In these cases the effects of past avalanches cannot be determined and other methods, as discussed below, must be applied. Even within forested avalanche paths, where estimates of runout distances can be made, estimates of the destructive force of avalanches

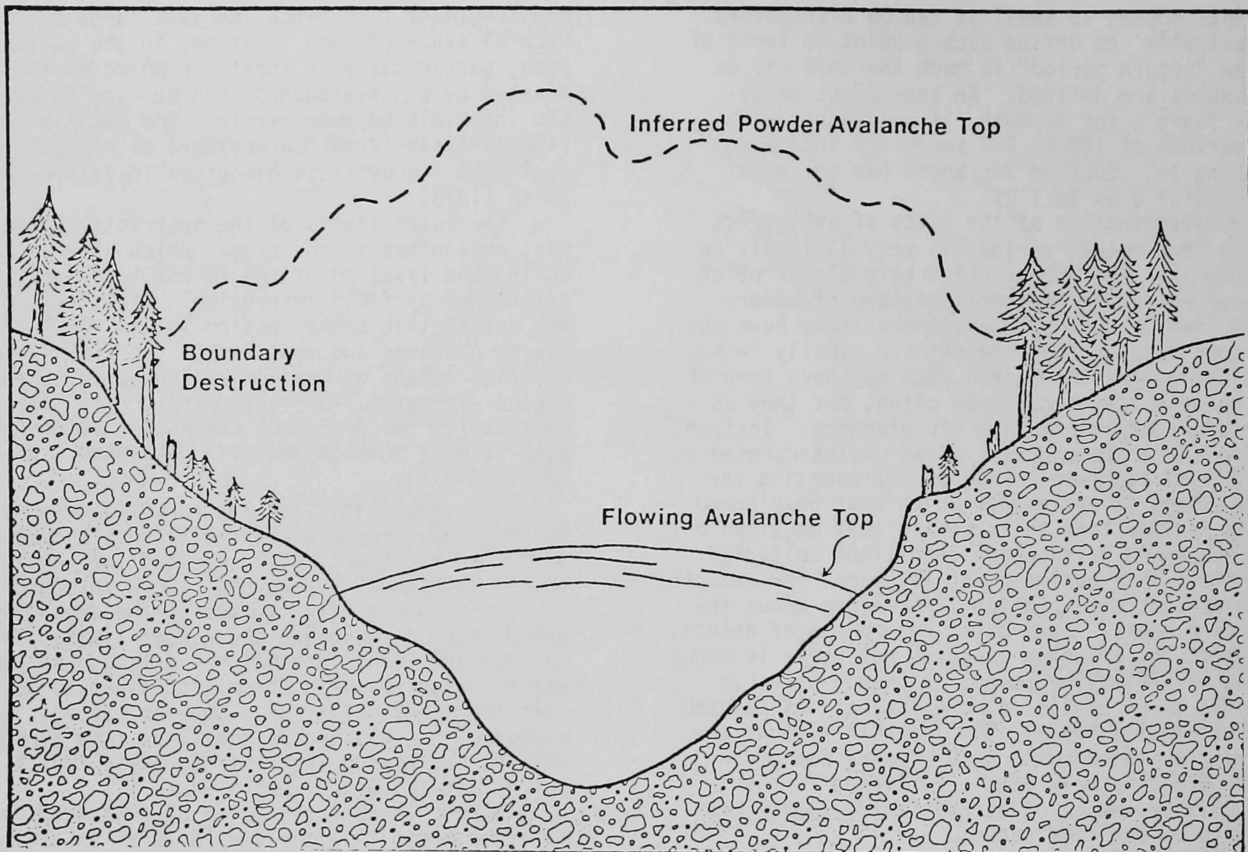

FIGURE 2. Schematic drawing of destruction in a large, channeled, avalanche path. The location of the tops of flowing and powder avalanches are shown for comparison.

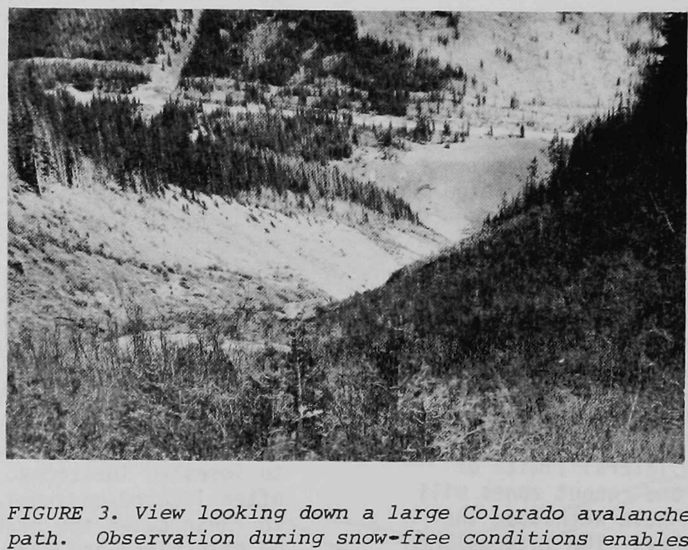

FIGURE 3. View looking down a large Colorado avalanche path. Observation during snow-free conditions enables assessment of the destructive effects of large avalanches of the past. The runout zone is devoid of trees and extends past the highway on the adverse slope.

may also be necessary if special design is planned to mitigate the hazard. For such estimates avalanche dynamic equations need to be applied. Finally, as suggested earlier, the specification of the size of the runout zone does not define the hazard without knowledge of an associated avalanche frequency. Knowledge of the area alone does no more than say an avalanche has occurred; it does not answer the question, "How likely is an avalanche of this size"? Such information is best obtained by study of the historical record where available, and careful study of the vegetation in and adjacent to avalanche paths.

Use of Avalanche Equations

A hazard analysis of an avalanche path through use of dynamic equations is an approach more familiar to engineers than to geologists. The results of such an analysis depend upon assumptions about the avalanche flow parameters of boundary and internal friction, flow depth, and discharge rate which are discussed below. These assumptions are dependent upon assumptions about the amount and type of snow released from the starting zone. The advantage of the use of dynamic equations over the methods of the previous section, is that design criteria such as velocity, flow depth, discharge, and impact pressure, which are essential for safe design of structures can be established. These design criteria are also important if avalanche flow is to be diverted, arrested, or dissipated so that it will not reach structures.

The fluid dynamic basis of avalanche motion was outlined some twenty years ago by Voellmy (1964, in translation). In deriving the equations he assumed that an avalanche, flowing at terminal velocity behaves as a fluid, and that a modified form of the Chezy equation, long used by hydraulic engineers in open channel-fluid mechanics problems, can be applied to avalanche dynamics problems. Three equations he derived which are highly relevant to land planning in avalanche paths are for avalanche velocity, runout distance, and impact pressure. These equations are discussed below because they illustrate some of the difficulties with their use, not because they summarize the field of avalanche dynamics.

The velocity, U, of an avalanche flowing at terminal velocity on a slope of inclination a is

$$u = [Eh' (\sin a - f\cos a)]^{1/2} \qquad (1)$$

where E is a turbulent friction coefficient, h' is the depth of flow, and f is a coefficient of kinetic friction. The slope angle a may be measured in the field or scaled from topographic maps and it is generally agreed that 0.1 f 0.3, (Salm, 1975). However, practical use of equation 1 is still hampered by its sensitivity to E and h'. According to Schaerer (1974), E may vary by a factor of two on a given type of terrain. Likewise, h' must also be estimated for a given location, possibly also varying by a factor of two. Thus, the product Eh' may vary by a factor of 4, and U, which is proportional to $(Eh')^{1/2}$, by a factor of two.

The velocity and flow depth determined and used in equation 1 are also important in the determination of the avalanche runout distance, S, which is of obvious importance in land planning. Runout distance may be calculated as

$$S = \frac{U^2}{2g(f\cos B - \tan B + U^2/2Eh')} \qquad (2)$$

where g is the gravitational acceleration, B is the slope of the runout zone, and other terms are as defined above. Equations 1 and 2 should be applied only to "flowing" avalanches, where the motion is largely on the ground, but cannot be used for analysis of powder avalanches. In powder avalanches part of the avalanche is transported by turbulent suspension, and great flow depths and velocities are sometimes attained. Although impact pressures from powder avalanches are less than those caused by flowing avalanches, they can be very destructive and should also be considered in land planning. Techniques for the evaluation of powder avalanches are presently being researched (Mears, in press).

Avalanche impact pressure, P, is calculated through

$$P = k\frac{L}{g}U^2 \qquad (3)$$

where L is the specific weight of the flowing snow, k varies between 0.1 and 1.0, depending on the size and shape of the object and the type of avalanche, and other terms are as defined above. Since velocity appears as a squared term in equation 3, its determination is obviously important in hazard analysis. Velocity, however, is also subject to a wide range of uncertainty, as mentioned in the discussion of equation 1.

Over the past two decades experience has been gained by Swiss workers as Voellmy's equations were applied to analyses of avalanche paths on different types of terrain. During this time very little similar experience has been gained in the United States because there has not been much demand for avalanche analysis as related to land-use problems. This lack of experience has led to wide differences in the results of investigators as they used the equations even in analyses of the same avalanche path. It is not unusual for experts to disagree, but the science of avalanche dynamics has not progressed far enough in this country to develop "engineering judgement".

Although the use of the equations of avalanche flow is beset by many difficulties, at present, it is the only means by which design parameters may be obtained. It is also superior to subjective estimates of avalanche path extent because it provides some basis by which the assumptions of various investigators may be compared. Independent methods by which avalanche velocities, forces, and runout distances may be calculated are presently being developed (Mears, 1975; Bovis and Mears, in press).

CONCLUSIONS

Two basically different approaches to the analysis of an avalanche path have been briefly discussed in this paper. Each is found to have its advantages and limitations and neither is sufficient to provide all the necessary information about avalanche hazard.

Of the necessary elements discussed in the Introduction, it appears that avalanche extent and frequency can best be estimated by field and air-photo reconstruction of past avalanche events. This method is applicable only in locations at which avalanche paths are bounded by forests.

Avalanche velocities, flow depths, discharges, and destructive force must be calculated through the analytical methods of avalanche dynamics, which at present, are subject to wide ranges of uncertainties.

The type of avalanche likely to constitute the design case at a given location must be decided prior to analysis.

In view of the uncertainties and limitations of the presently available methods of avalanche analysis, it appears foolhardy to depend on one method of analysis alone. Instead, several methods, each depending on different sets of assumptions, should be employed in an attempt to see if the derived results converge. It must be remembered that the consequences of underdesign which may result from an improperly conducted study may be serious.

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DEBRIS FLOWS AND DEBRIS FANS

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INTRODUCTION

Two of the types of "Specific Geologic Hazards" that were identified in Colorado House Bill 1041 and described in Colorado Geological Survey Special Publication No. 6 (Rogers and others, 1974) are mudflows and debris fans. In the usage of Special Publication No. 6, mudflow is a collective term that encompasses a variety of types of flows ranging from very wet, fluid mixtures of fine-grained sediment and water to relatively dry mixtures of granular solids, water, and/or air. Debris flow is that aspect of mudflow whereby relatively dry mixtures of granular solids, water, and/or air move readily on low slopes. A debris fan is the accumulated deposit resulting from mudflows and streamflows. The size of a debris fan is usually very large relative to the volume of debris in a single debris-flow episode, indicating that a fan is the product of many flow episodes over a prolonged period of time. The debris fans are typically triangular or fan-shaped in plan view, with the apex of the triangle or fan located at an abrupt change in gradient of the drainageway, especially at the intersection of the mouth of a drainageway with a larger valley.

Figure 1, which shows a small debris fan near Climax, Colo., illustrates several of the features as they occur in the field. The fan has been built by intermittent debris flows that originated in the bowl-shaped source area in the upper left part of the photograph (Area A). A recent debris flow (Area D) has mobilized in the new highway embankment (Area C) part way up the slope and traveled down the left side of the fan (Area E).

Because a debris fan topographically forms a relatively smooth, broad area higher than the flood plain in the larger valley that it intersects, it makes a deceptively attractive site for building. Marble, Colo., which is built on a debris fan, has been severely damaged by several debris-flow episodes over the last century. The old mining town of Brownsville, Colo., located about one mile (2 km) west of Silver Plume, was buried by a debris flow in 1912 (Brown, 1973). As land development proceeds in the mountainous areas of Colorado, pressure to utilize sites that are subject to debris flows will almost certainly increase.

The hazards from debris flows are common in many parts of the country, and damage to persons and pro-

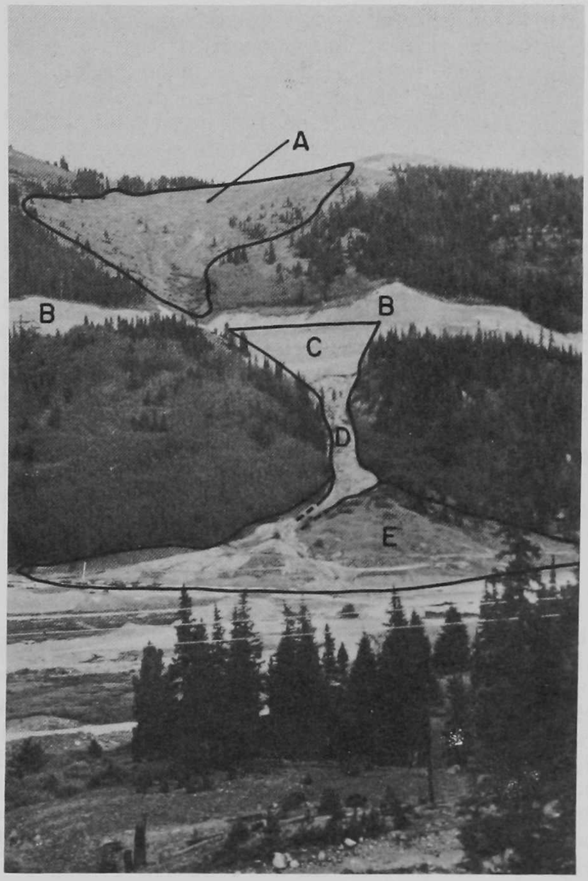

FIGURE 1. View looking west of debris-flow and fan about 10 km north of Climax, Colo. Area A is the source area for debris flows that traveled down the drainageway to construct the debris fan (Area E). A new road constructed across the drainageway has modified the natural system. Area B is a roadcut and Area C is an embankment. Part of the embankment (Area D) mobilized into a debris flow and traveled over the left side of the debris fan.

perty has been extensive. For example, debris flows caused by a single storm in the Santa Monica Mountains (Calif.) in 1969, killed 12 people and caused millions of dollars in property damage. In all, 23 people were killed by debris flows in southern California during the years 1962-1971 (Campbell, 1975). The 150 people killed in central Virginia during Hurricane Camille in August, 1969 died as a result of impact from debris avalanches and debris flows (Williams and Guy, 1973). Other examples could be cited from many parts of the United States, including Washington, Oregon, Utah, Nevada, Ohio, New Hampshire, and large parts of the Appalachians, and from many locations around the world.

Planners, developers, architects, engineers, and others responsible for the safety and welfare of citizens and property are most interested in precisely where and when, or under what conditions, debris flows may develop and in the consequences of mobilization of the process. At present (1976), a large technological gap exists between the needs of these people and our ability to supply information in a form that satisfies those needs. Some progress has been made, and several methods have been proposed that could be of great value in predicting the time and place of debris-flow activity.

At present, relative susceptibility to the debris-flow hazard is usually based on empirical observations derived from careful study of materials and topography. Geologic materials on slopes that have produced debris flows in the past are considered susceptible to future problems. The size and frequency of past flows generally are good indicators of the present degree of hazard.

The conditions necessary for debris-flow mobilization, the characteristics of flows and their deposits, and some of the methods for predicting the time and place of occurence are summarized below.

MOBILIZATION OF DEBRIS FLOWS

Mobilization of a debris flow is a process whereby intact slope materials are transformed into a fluid-like mass of granular solids, water, and/or air. Processes leading to mobilization of debris flows have been discussed by Johnson and Rahn (1970), Campbell (1975), Rodine (1974), and Swanston (1970). The conditions that promote development of debris flows are abundant water, unconsolidated materials having a limited range of properties, and sufficiently steep slopes. Each of these conditions is discussed separately.

A dense cover of vegetation can retard mobilization, but debris flows do originate on densely vegetated slopes. However, debris flows are more commonly formed on slopes where vegetation is sparse or absent (see Area A, Figure 1) or has been removed by fire, forest clearcutting, or other means.

Role of Water

An abundant supply of water can be obtained in at least five ways (Rodine, 1974). The first and most common source is direct, intense rainfall. Other sources of more local importance are snowmelt, springs, interstitial or pore water, and catastrophic events such as volcanic eruptions.

Most debris flows are mobilized in unconsolidated deposits that overlie bedrock. The first step in the mobilization process is the failure of the unconsolidated material by landsliding. The mechanism of failure is apparently related to excess pore pressures and seepage forces provided by one of the water sources mentioned above. The role of pore water in initiation of the landsliding has been discussed by Swanston (1970) and Campbell (1975). During landsliding, the materials dilate and are remolded, allowing incorporation of additional water, which results in a debris flow. Rodine (1974) has shown that debris flows can also be initiated by sluicing or jetting with a stream of water, which accomplishes the same remolding and dilation of the material as landsliding.

Materials

Materials that are susceptible to mobilization into a debris flow appear at first glance to be a mixture of a wide variety of sizes of blocks of rock, sand grains, silt, and clay. One way to look at the materials in a debris flow is to consider them as containing two components: (1) a clay-and-water slurry, and (2) other materials, including silt, sand, gravel, boulders, and miscellaneous items such as wood, tin cans, automobiles, etc. The clay-and-water slurry is the source of transport. The other materials can be transported in the slurry in varying amounts, so long as they do not interlock and strengthen the mass. Rodine (1974) determined, experimentally, that as much as 45 to 55 percent by volume of a single particle size, e.g., fine sand, can be contained in a clay-water slurry without interlocking. Larger grains and fragments can exist if they are of different sizes.

The ability to flow is governed by the slurry. The density and strength of the slurry provide the cohesive medium that transports fine-grained particles without interlocking. The combined clay-water slurry and fine-grained particles provide the buoyancy and strength to support larger particles. In this way, the materials in the debris flow are pyramided to larger and larger fragments until the entire mass is supported in a virtually frictionless position because of the lack of interlocking and the strength and buoyancy provided by the finer fraction.

Hampton (1972) has shown, theoretically, that as little as 10 percent clay in the total weight of solids is adequate to completely support the sand-sized material in a debris flow. Rodine (1974) reported a range of 1 to 20 percent in the percentage of clay by volume from a number of debris flows in Utah and California. Measured clay fractions (particles less than 2 microns) from debris-flow material in Colorado reported by Curry (1966), Sharpe (1974), and Fleming (unpub. data from Douglas County, Colo.) range from 5 to 11 percent by weight.

Debris flows in Colorado are most commonly associated with torrential rainstorms. These conditions are analagous to those reported by Campbell (1975) in southern California and Williams and Guy (1973) for Hurricane Camille in Virginia. In both cases it appears that debris-flow initiation depended on a significant amount of moisture in the unconsolidated materials prior to an intense storm. The actual initiation of the debris flows requires a high-intensity storm at the time of failure. Campbell (1975) has tentatively determined the necessary rainfall conditions for greatest debris-flow hazard in the Santa Monica Mountains. About 10 inches (25 cm) of antecedent rainfall followed by a storm with a minimum intensity of 0.25 inches per hour (0.6 cm/hr) appears sufficient to trigger many flows. Similar studies are needed to determine the susceptibility of materials to debris-flow activity in various parts of Colorado.

Slope

In addition to abundant water and unconsolidated material, the third factor necessary to produce debris flows is an appropriate slope inclination. If a slope is very steep, about 45° or more, it is unlikely that unconsolidated material can accumulate to any significant thickness. Bare exposures of bedrock are more common on steeper slopes and less material is available for mobilization into a debris flow. For relatively flat slopes of 10° or less, landslides in unconsolidated material are uncommon. If they do occur, mobilization to yield rapid flows is unlikely. In a more complete discussion of the effect of slope on the occurrence of debris flows, Campbell (1975) reported that most soil slips (landslides) characterized by subsequent debris flows in the Santa Monica Mountains were on slopes ranging in inclination from about 25° to 45°.

The debris flows that occurred in Virginia during Hurricane Camille were on slopes ranging in inclination from about 15° to 40° (Williams and Guy, 1971). In that case, slopes of similar geological characteristics that faced north, northeast, or east experienced several times more failures than slopes facing in other directions. The debris flows appeared to begin in small topographic swales or valleys on otherwise smooth slopes. The tendency for debris flows to form in topographic swales has been observed in many other parts of the country.

While it is true that most debris flows originate on steep slopes, once in motion the flows have the ability to travel great distances over relatively flat slopes. For example, a debris flow in Douglas County, Colo., that initiated on a slope of about 30° traveled more than 7,000 feet (2,100 m) on a slope slightly steeper than 3°.

DEBRIS FLOWS AND THEIR DEPOSITS

Initiation of a debris flow is associated with a rapid slope failure, usually accompanied by a noise that resembles thunder. Flows tend to occur in channels or chutes and, as debris flows travel onto a fan, they build their own channel rather than spread over the fan surface. Figure 2 shows two debris-flow paths on a debris fan on Cement Creek in Colorado. The flows originated in the basin shown in the upper left of the photograph and traveled down the small drainageway to the top of the debris fan. From that point downslope, no channel existed for the debris flow and it formed a channel by depositing flow material along the margins to produce features that resemble levees. Because a debris flow forms its own channel on a fan surface, virtually any part of the entire fan surface may be overrun during a flow episode. A summary of eyewitness accounts of debris-flow episodes has been prepared by Rodine (1974).

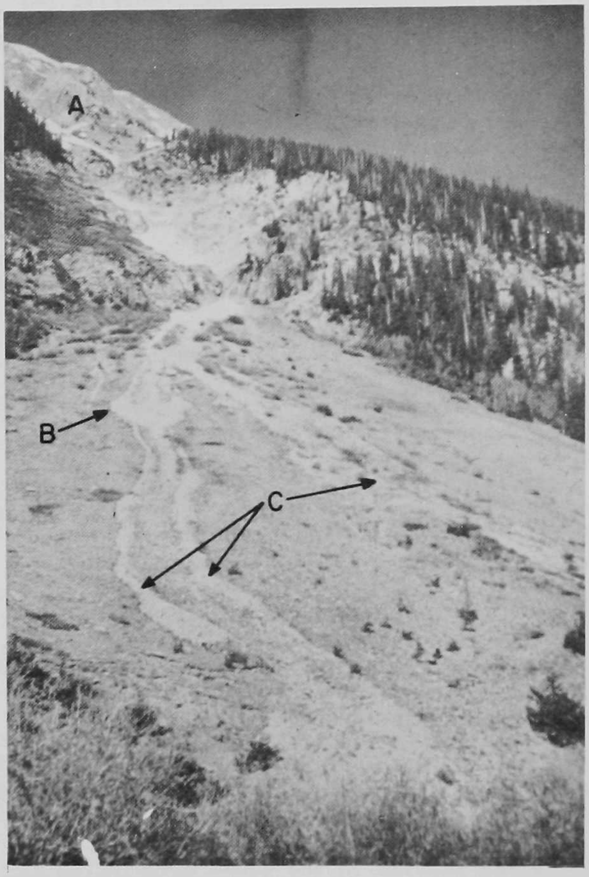

FIGURE 2. Two recent debris-flow paths on a debris fan at Howards Fork, San Juan County, Colo. Features marked on the photograph are the source area (A), a wave of debris that stopped part way down the fan (Point B) and levees (Point C) constructed by a debris flow as it traveled down the fan. (Colorado Geological Survey photo).

Debris flows of various sizes and types occurred over a period of about 10 days during the spring of 1969 in Wrightwood, Calif. Johnson (1970, p. 439) summarized the characteristics of the Wrightwood flows as follows:

> *A stream of muddy melt water, a few inches deep and three to four feet wide, flowed nearly continuously in the channel. About every ten to twenty minutes, the muddy water gradually became deeper and carried noticeably more and more sediment. A few moments after we noticed the deepening of the muddy water, we would begin to hear a low rumble, signaling the appearance of another debris wave. Then the muddy water usually dwindled to a trickle,*

apparently when the debris wave became arrested temporarily at a construction in the channel. Suddenly the debris wave would appear around a bend in the channel, about ten meters upstream. . . The rumble, the clanking of boulders rumbling over the snout, and the sloshing and slopping of the mud drowned the sound of our gleeful shouts as we attempted to alert the whole world to the remarkable event unfolding before our eyes. The front of the typical debris wave consisted largely of boulders, usually six inches to two feet but occasionally three or four feet in diameter. . . The foremost boulders sometimes tumbled over the front and were pushed along the channel but they usually seemed to move along more or less together, slowly shifting position. The boulders visible on top of the flow moved ahead and tumbled over the front as though they were on top of the tread of a caterpillar tractor. The snout and top of the flow, extending ten to thirty feet behind the snout, typically were armoured with boulders. . .

Behind the bouldery front, the surfaces of the flows exposed more of the finer-grained mud and the boulders appeared to be more widely separated than they were in the frontal region. . .

The part of the debris wave that contained boulders commonly was several tens of feet and sometimes may have been 100 meters long. Gradually, the number of boulders decreased and the debris became charged with pebble-sized fragments. . Following this debris was material that appeared to have a lower percentage of pebbles. . .

Gradually, the flow of finer-grained debris became more and more diluted with water until it returned to its normal condition as muddy water.

A wave of debris that stopped part way down the fan is visible in the channel on the left side of Figure 2 (point B). This debris wave contains many of the characteristics implied in the above description by Johnson (1970). The snout has a lobate form and contains coarser rock fragments than the uphill parts of the flow. The materials are very poorly sorted, and stratification is absent except at boundaries between separate flow episodes.

The velocity of a debris flow can vary from 2 to more than 15 miles per hour (1-7 meters/second). The flows described by Johnson (1970) were traveling about 2 mph. Williams and Guy (1973) reported a velocity of about 15 mph for flows during Hurricane Camille. The flows witnessed by Curry (1966) in the Ten Mile Range of Colorado traveled about 6 mph.

Debris fans represent the accumulations of many debris flows, and the materials in the fan should contain a wide range of gradation with large rock fragments scattered over the surface and in the subsurface. Clean, well-sorted sand, gravel, and cobbles in a debris fan are uncommon and, where present, represent either deposition by flowing water or reworking of debris-flow material by running water.

METHODS FOR PREDICTING TIME AND PLACE OF OCCURRENCE

Debris-flow source areas, debris-flow channels, and debris fans can be identified and mapped on the basis of topographic form, character of vegetation, and nature of the existing deposits. These constitute areas that are considered to be susceptible to future debris-flow activity.

The prediction of debris-flow occurrence and the assignment of a geologic-hazard designation to a specific area are currently subjective processes. Three approaches to prediction will improve hazard designation in the future. These are predictive models based on (1) climatic events, (2) prehistoric and historic records of past debris-flow events, and (3) properties of the unconsolidated materials in the source area.

Models based on climatic events offer a method to generate warnings of debris-flow initiation. Campbell's (1975) tentative model, which combines the requirements of antecedent rainfall conditions with the necessary rainfall intensity to trigger activity, can form the basis for such a warning in the Santa Monica Mountains. Oberste-Lehn (1976) has developed a similar model for earthflow activity for an area near Hollister, Calif. Cruder models can be developed from the probability of a past storm that triggered debris-flow events occurring again. The storms cited by Curry (1966) in the Ten Mile Range and those in 1965 in Douglas County, Colo., were unusual storms that could be assigned a recurrence probability.

Prehistoric and historic records of debris flows permit estimation of the frequency of future events. Data covering at least the past 100 years are available for much of the United States in the form of newspaper accounts, diaries or published histories, aerial-photograph comparisons, and personal interviews. This relatively short time base can be extended for specific debris-flow deposits through other dating methods, including lichenometry, tree-ring and radiocarbon dating, and various stratigraphic techniques.

Various techniques have been applied in order to develop a frequency of debris-flow activity for specific areas. Curry (1966) estimated, on the basis of lichenometry, that the large mudflows in the Ten Mile Range in Colorado occur about once every 150-400 years. Johnson (1970) has estimated that the frequency of debris flows in semiarid areas of the Western United States is 30-100 years. Sharpe (1974) discussed several of these estimates and suggested that debris-flow recurrence in the San Juan Mountains in Colorado is 30-125 years for any given site and 20-60 years for flow activity in a topographic basin.

A more basic approach to predictive techniques for debris-flow activity has been developed by Rodine (1974). He examined the characteristics of the deposits, including the strength and unit weight. Combining the material characteristics with the slope angle and the geometry of the flow channel, Rodine defined a "Mobility Index" for source materials. The Mobility Index is simply the ratio of water content of the source materials at mobilization to the water content at field capacity. The water content of source materials at mobilization is obtained from laboratory tests of strength and unit weight as a function of water content and from an equation for the dimensions of the channel that could contain the flow. The technique assumes that sufficient water is available to saturate the materials. To date, the method has been applied to only a few sites in Utah and California. The preliminary results are encouraging, but additional measurements are needed to develop the method into a practical predictive technique.

In summary, predictive methods that determine where, when, and how large a specific debris flow will be are primitive, but predictions will improve as more information is collected from various parts of the world. In the meantime, maps that identify areas of past debris-flow activity and, hence, susceptibility to future debris flows provide the best basis for designation of geologic hazard areas. Maps that show areas of debris-flow hazard for several parts of Colorado have been prepared by the Colorado Geological Survey; see, for example, Soule (1976, in press).

If research efforts are successful and techniques are improved to the point that we can accurately predict debris-flow activity, the problem that will remain is the determination of acceptable levels of risk. The large debris flows in the Ten Mile Range apparently occur about once every 150-400 years (Curry, 1966). Does this level of recurrence constitute a sufficient hazard to regulate land use and development? Answers to questions such as this are being sought in flood-plain management and will surely be faced for debris-flow hazards in the future.

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GROUND SUBSIDENCE AS A GEOLOGIC HAZARD IN COLORADO

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INTRODUCTION

The original title of this paper was "Ground Subsidence as a Geologic Hazard in Colorado, or Did HB 1041 Give You That Sinking Feeling?". It seemed that this might offend the sensibilities of some of those who were instrumental in getting the law drafted; hence, the title was reduced somewhat, perhaps without changing the feeling.

It is appropriate to start with a quotation from Robert Legget's recent book, Cities and Geology (Legget, 1973):

> "As Francis Bacon said so percipiently almost 400 years ago, 'Nature, to be commanded, must be obeyed'. Obedience to nature could well be the motto of every planning agency".

There is another maxim that perhaps was lost in antiquity and which may very well have eluded the extensive research of Dr. Legget as he wrote his book. This maxim has recently surfaced in a somewhat modified form in a common television ad which you may recognize as you ponder the following words by an obscure (i.e. unknown) philosopher:

> "Oh frail mortal, seek not to deceive Mother Nature for in so doing, know, oh little man, that more often than not, the would-be screwor becomes the unwitting screwee".

In a more serious vein, damage to or loss of personal property in its ultimate effect is relative to the financial status of the owner. The individual usually can ill-afford the economic loss if his property is damaged. If public property is damaged or lost, the taxpayer loses. Since we all individually or collectively seem to be subject to some form of economic strangulation, anything which tends to tighten the noose is of concern to us, and so it is with the potential losses due to ground subsidence, whether viewed from the standpoint of an individual or as the public.

Basically, if you refer to HB 1041 and to commonly accepted definitions, types of subsidence include natural consolidation or hydrocompaction, dissolution of soluble rock or soils, fluid withdrawal and removal of ground support by underground mining. I shall briefly touch on the first three and spend a little more time on underground mining which is of more immediate interest to us in Colorado.

Consolidation and dissolution are natural phenomena; fluid withdrawal and underground mining are results of man's activity. It should be noted that consolidation and dissolution, although they are basically natural, can be caused, or at least aggravated, by human activity. Generally, subsidence resulting from man-made causes is more predictable than that which results from natural phenomena.

CONSOLIDATION OR HYDROCOMPACTION OF GRANULAR MATERIALS

Hydrocompaction is a process observed mainly in loosely compacted granular materials such as loess or wind-deposited silt, and fine-grained colluvial soil. These deposits are reduced in bulk as water is introduced into or passes through them. Subsidence occurs as a result of the natural compaction and the reduction in volume of the wetted material. Examples of this phenomenon are found in a number of places throughout the western United States. In Colorado areas underlain by loess in some of our east-slope counties are susceptible to this type of subsidence.

The potential for hydrocompaction also exists in alluvial valleys where extensive irrigation is practiced. The San Luis Valley is the area which probably has the greatest potential for this type of subsidence in Colorado. An interesting aspect of this area is that subsidence here could result both from hydrocompaction as a result of irrigation, and also from pumping of ground water resources, or fluid withdrawal.

Another aspect of hydrocompaction is that it can occur in artificial fills or embankments if the materials have not been compacted to an optimum density during construction. Examples of this are common in random fills where cracks have developed and ground slumping has developed as a result of either watering or from natural moisture.

DISSOLUTION OF SOLUBLE MATERIALS

Dissolution can occur in limestone, dolomite, gypsum, anhydrite, sodium chloride (common salt), dawsonite and nahcolite, all of which are soluble materials. The rates at which these minerals pass into solution and the conditions under which solution occurs are variable. Where these materials are the bedrock formations, natural subsidence will occur if groundwater has dissolved cavities to the extent that overlying rock or soil is unable to support its own weight. This condition is aggravated by man-made or artificial loads placed on or in the ground above the cavity.

Artificial subsidence occurs as a result of man-caused activity, such as intensive pumping of ground water, development of drainage channels, water impoundment, irrigation, solution mining, and other factors which can change the hydrologic regime. Limestone deposits are found in many places throughout the United States in beds of sedimentary rocks. In some areas such as Alabama and Florida, rather dramatic instances of subsidence, or collapse, of the ground surface have occurred. Occasionally, a cow or some other equally valuable animal is lost. The potential for this type of occurrence in Colorado is more limited, but less dramatic subsidence effects can be felt in any area where limestone and (or) dolomite are found at or near the surface. In limestone terrain the cause of subsidence can sometimes be traced to overpumping of limestone aquifers. The excessive extraction of groundwater effectively removes buoyant support from bedrock and (or) soil overlying the cavity containing the water. If the remaining arch of rock or soil is unable to support its own weight, subsidence occurs. The process is aggravated if an artificial load such as a building, a road, a cow, etc. is superimposed on the land surface.

The natural dissolution of any soluble material follows the pattern just described. The solution rates may vary, but the magnitude of subsidence and its effects also will depend on other factors, including depth to the water table, groundwater chemistry, purity of soluble material, and other considerations. A small depression in an open field may be an agricultural inconvenience; the same depression at the corner of a private house may be a homeowner's nightmare. Dissolution of materials may go on for years under some conditions with no real hint of the problems to come. The problem may arrive overnight or very suddenly.

Gypsum, which occurs in many parts of Colorado (Figure 1), is one of the most soluble salts which we find. The most prominent occurrences in Colorado are in Garfield and Eagle Counties. In Figure 1 areas of halite and potash also are shown. These minerals are sodium chloride and salts of potassium which generally are more soluble than carbonates and sulfates. Halite has been mined by solution in various parts of the country. Deposits of nahcolite and dawsonite occur in the Piceance Basin, and are associated with oil shale at relatively deep levels.

Obviously the planner and engineer will look closely at any area which is known to be underlain by soluble salts. If geological conditions indicate potential danger of subsidence, a compatible surface use must be established. A complicating factor in areas underlain by soluble salts is that the limits of natural and man-made solution cavities generally are not controllable.

Salt deposits are known to occur in large areas in northeastern, southeastern and southwestern parts of Colorado. In Montezuma County brine has been mined by solution methods. In the northeastern and southeastern parts of the State there has been no mining; these are relatively deeply buried deposits. The potential for subsidence will be nil in these areas until it can be proved that these deposits are of sufficient volume and grade to be commercial.

WITHDRAWAL OF UNDERGROUND FLUIDS

Numerous areas in the United States have suffered subsidence due to removal of underground fluids such as groundwater, oil, and even natural gas. In Colorado the most likely possibility for subsidence due to fluid withdrawal is in the San Luis Valley, which was mentioned previously, and in other smaller intermontane valleys where large-scale irrigation is practiced. Overpumping of aquifers which consists of unconsolidated or poorly consolidated granular deposits, removes support and the land surface subsides.

SUBSIDENCE AS A RESULT OF UNDERGROUND MINING

Underground mining is the most important cause of subsidence in Colorado today. The mining process creates void spaces at varying depths. The weight of overlying rocks, residual tectonic stresses and other factors which tend to weaken rocks, generally work to close these voids. Depending on the void geometry, depth of mining and a number of other factors, there may be ground subsidence at the surface above the mined area.

The magnitude of subsidence can be measured from fractions of an inch to feet. The effects of subsidence are depressions, cracks, and slumping or tilting of the ground surface. These effects, if manifested where man-made structures have been built, can cause foundation adjustments that range from minor to catastrophic. Examples are changes in direction of flow of canals, adjustments in road grades, change in direction and amount of pipeline (water, sewer) grades; disruption of the water table; heaved, sunken, cracked and warped pavements; awe, and occasionally, terror. In extreme cases, loss of life can occur. Loss or damage to equipment is not uncommon.

Underground mining in Colorado generally includes vein mining in the igneous and metamorphic host rocks of the mountains, where metallic minerals are largely produced, and room-and-pillar mining, or some modification of it, in bedded sedimentary rocks where nonmetallic minerals are extracted. Solution mining, as mentioned above, has been practiced only in a limited area of southwestern Colorado. The main hazard around vein mining properties is old shafts, which have been covered over and may cave. Shallow workings such as near-surface stopes also may cave either as a result of man's activity or with the passage of time. Sometimes a covered shaft can be identified as such by a slight depression at the surface. Shallow workings are more difficult to recognize since there may be little or no surface evidence for them until subsidence occurs suddenly. Room-and-pillar mining is generally used to extract coal and oil shale from flat-lying or gently dipping sedimentary host rocks. A modification of this type of mining also has been

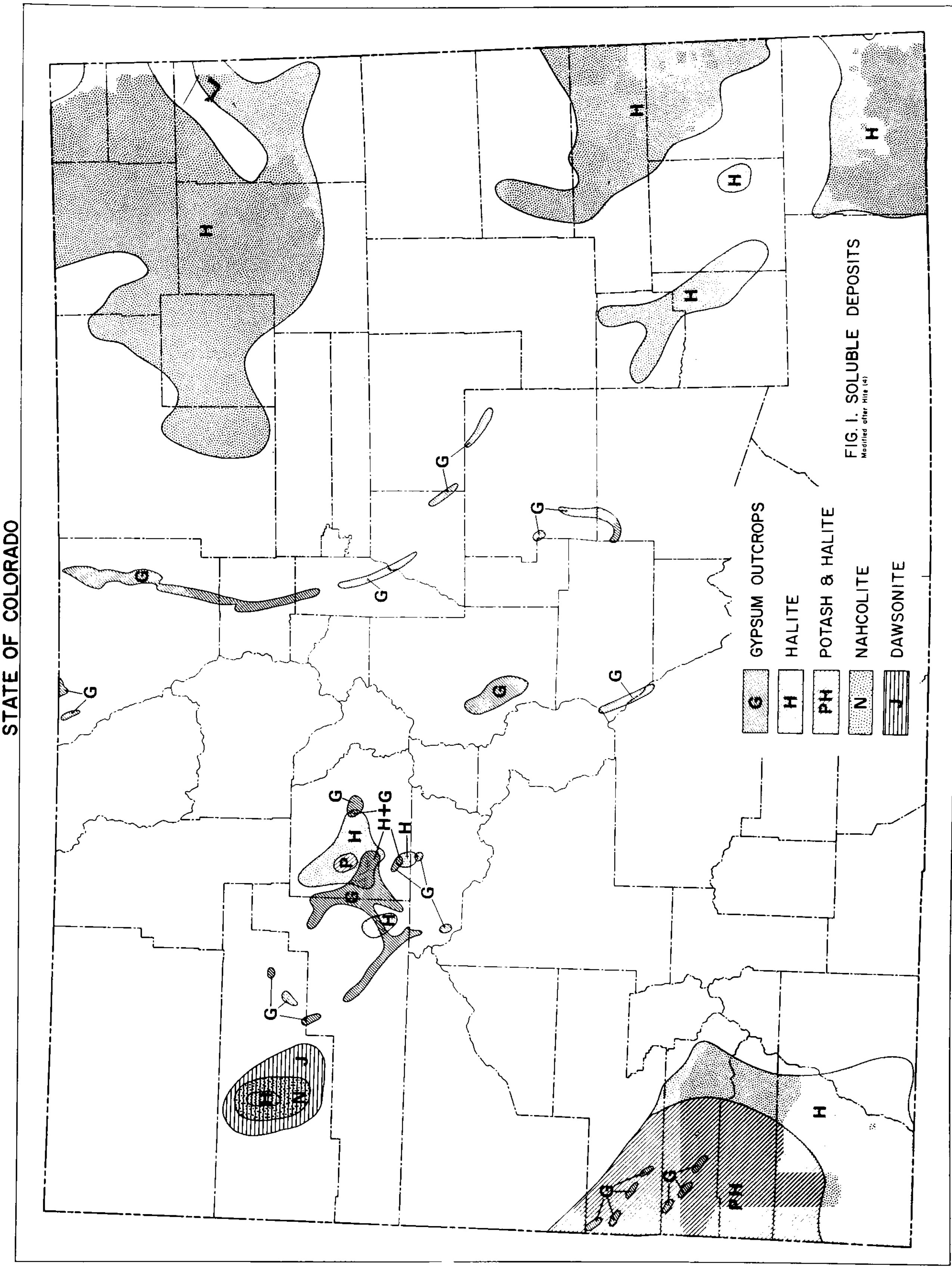

FIG. 1. SOLUBLE DEPOSITS
Modified after Hite (4)

STATE OF COLORADO

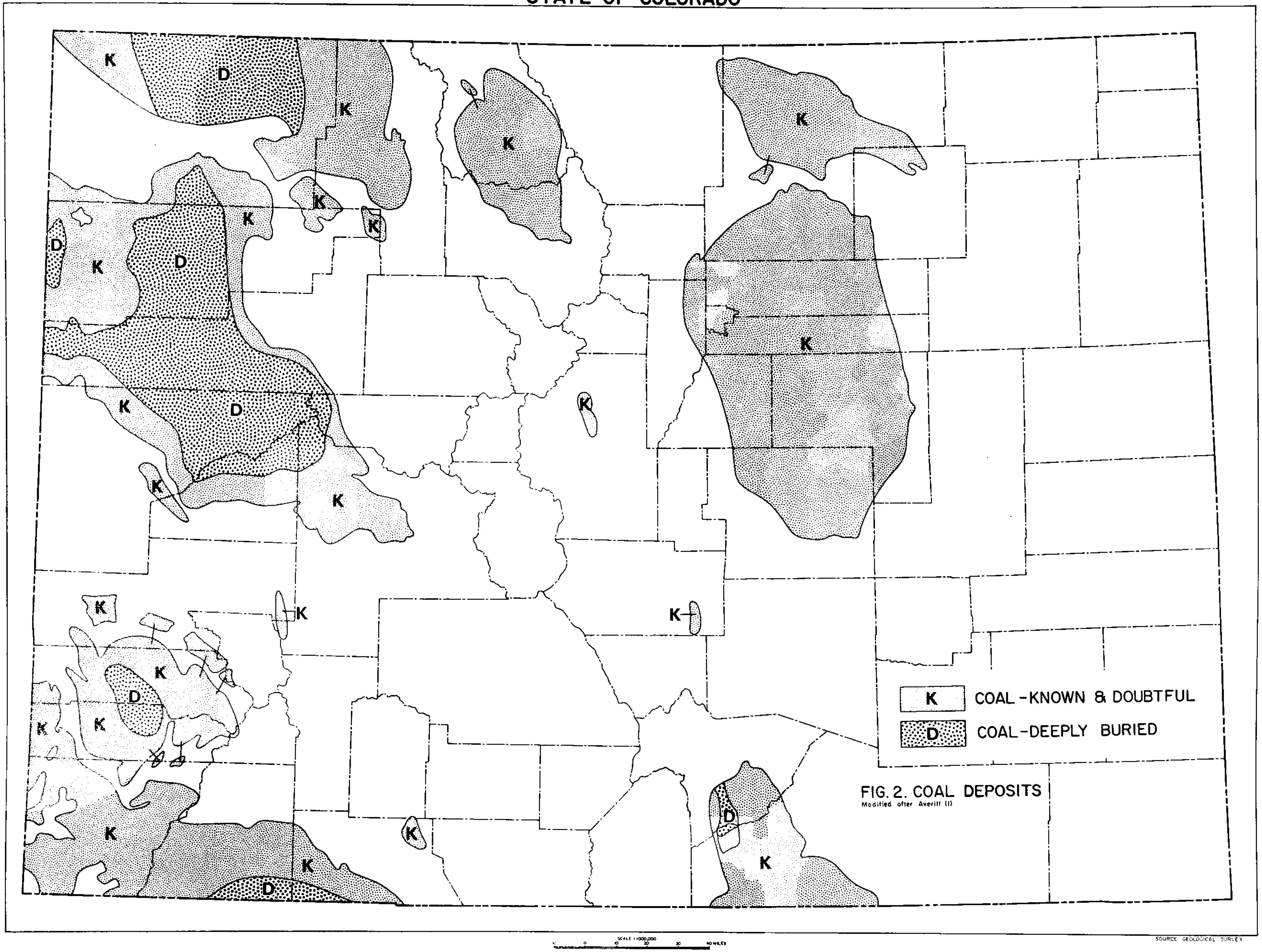

FIG. 2. COAL DEPOSITS
Modified after Averill (1)

used to extract clay in the Castle Rock area of Douglas County (James Soule, personal communication, September 23, 1975).

Because of the current and potential future emphasis on coal mining our attention should focus on this segment of the industry as representing the greatest potential for ground subsidence. Many of the lessons we have learned from subsidence related to coal mines can be applied to subsidence related to other causes. Most people concerned with land development are less interested in the cause than in the effect.

Figure 2 illustrates the distribution of coal deposits throughout the State. These deposits are mainly in the western two-thirds of the State. Relatively shallow and reasonably well-known deposits, and deeper, less well-defined deposits are shown. In both cases there are some areas where the economic feasibility of coal mining has not been determined. Also included in this diagram are areas which are subject both to open-cut and to underground mining.

Recently an extensive study of ground subsidence was made in the Boulder-Weld coalfield (Myers and others, 1975). From this study some of the effects of subsidence that have been mentioned can be seen. We can also gain some idea of the severity and of the range of problems associated with subsidence, particularly the environmental effects, i.e. the socioeconomic effects.

Seven coal beds which are thick enough to be mined occur at various places in this field. In most parts of the coalfield only one bed was mined, but in some places, coal was taken from two beds. The direction of mine development and the limits of mining have been determined to a significant extent by a system of faults which defines a series of horsts and grabens with a predominant northeast-southwest orientation. The depth of underground mining ranges from less than 50 ft to over 600 ft.

SUBSIDENCE THEORY IN THE BOULDER-WELD COALFIELD

Theories which relate underground coal mining to ground subsidence at the surface, have been developed largely in Europe where the mining method is different than that used in the Boulder-Weld coalfield. With qualification, however, some of the theory can be used to suggest explanations for evidence of subsidence here. This discussion will not dwell at length on subsidence theory, but it will demonstrate matters of interest to the planner and engineer.

Perhaps the most important factor to be aware of in planning any surface structure above an underground mine is that the surface area potentially affected by subsidence is larger in extent than the area from which material has been extracted in the subsurface. This is illustrated in Figure 3, a simple subsidence diagram. As the coal is mined from one side to the other, surface subsidence will form a shallow depression. This depression or trough will advance with the direction of mining. The maximum subsidence in flat-lying beds will occur on the surface above the midpoint of mining, which is indicated by S_{max}. Subsidence will diminish to zero in either direction from the maximum. Note that the zero points of subsidence (a and a') at the surface are beyond the limits of underground mining. The angle between the vertical line drawn to the surface from the mining limit and a line drawn from that limit to the zero point at the surface is called the angle of draw. However, the maximum amount of subsidence will not exceed the thickness of the coal mined and usually will not exceed 90 percent of that thickness. In any case, maximum subsidence is not reached until a critical width of mining is attained. Figure 3 is a simple diagrammatic illustration. The subsidence problem can be greatly complicated by more steeply dipping rocks, by faults and folds, and by multiple mining zones.

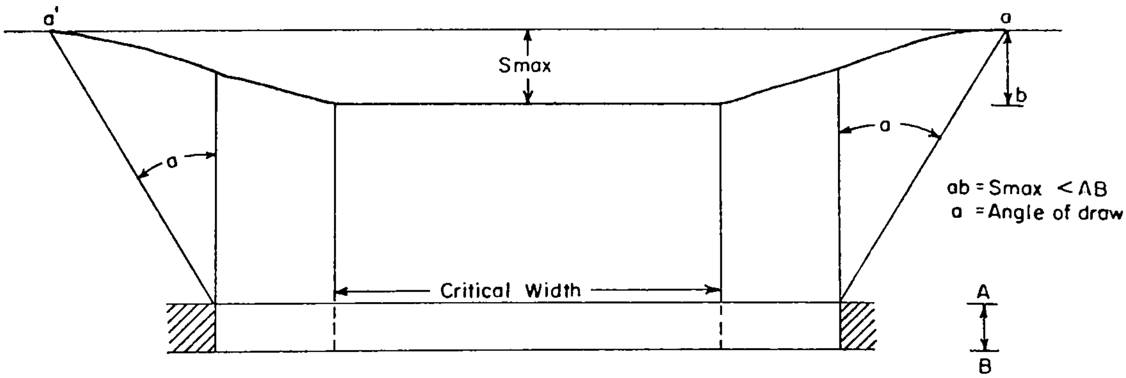

FIGURE 3. Diagrammatic Relationship - Mining and Subsidence. As the mine face advances in coal bed A-B, ab and angle a will increase until a "critical width" of the mine opening is reached. At this point the amount of vertical subsidence, ab, reaches a maximum value, S_{max}*. Further enlargement of the mine opening will subject a larger and larger area at the surface to maximum subsidence though* S_{max} *itself will not increase. Modified after Myers and others (1975).*

To accomplish the objectives of the report (Myers and others, 1975) referred to above in relating mining activity and surface subsidence in the Boulder-Weld coalfield, a series of six maps was made. The maps illustrate extent of mining, depth of cover, mine pillars, probable thickness of extracted coal, and subsidence inventory. The sixth map is a derivative of the other five and is the subsidence hazard map.

The main factors affecting subsidence are the depth of cover to the mining zone, the thickness of the coal seams mined, and the distribution of pillars left in the mine. Having investigated these factors, a subsidence inventory was made in the field in order to establish, where possible, a direct correlation between mining factors and surface subsidence. This inventory included not only observation of the land surface but extensive interviews with people. Although our geologists made conscious efforts to be objective, reports from people interviewed were subjective.

An obvious problem in an area like this is that the number of people who were involved in the mining is constantly diminishing. Hence we are losing one of our best sources of information, although admittedly its value may be clouded by subjectivity. Much of the information we need for analysis was never consciously observed or recorded formally. All of the data was gathered in order to prepare the last map of the series, the subsidence hazard map. This is the so-called red-, yellow-, green-map, signifying severe, moderate and low potential for subsidence. Some of the effects of subsidence are seen in Figures 4 thru 12, which were taken from Myers and others (1975). Figures 11 and 12 illustrate very well the complexity and lack of predictability regarding development of subsidence phenomena.

The determination of the potential for subsidence in areas of previous mining is difficult mainly because the necessary geologic data base is incomplete. Records of significant features and events were not formalized, and in some cases reporting of evidence for subsidence was suppressed. The net result is that any party considering development of land in this coalfield may be faced with the possibility of extensive, costly geologic studies. Considering the present state of the art, it is extremely unlikely that such studies will provide absolute answers; there will always be an element of risk. Figures 11 and 12 illustrate very well the complexity and lack of predictability regarding development of subsidence phenomena.

FIGURE 4. Collapse over room of Lewis No. 1 mine. Pit is about 10 ft by 15 ft and is 3 ft deep. From 5 to 10 ft of coal was extracted at a depth of approximately 50 ft. Flume carrying irrigation water in middle background must be periodically reset because underground mine fires in this area are causing continued subsidence.

FIGURE 5. Recent subsidence over Lewis No. 1 and No. 2 mines brought on by underground fire. Note three puffs of grayish-white smoke. Mine is less than 50 ft deep and is above water table. Collapse and fracturing of overlying beds permits circulation of air for continued combustion.

FIGURE 6. Collapse over room of Marshall No. 1 mine. The collapse area is approximately 15 ft by 30 ft and is about 3 ft deep. From 5 to 10 ft of coal were extracted from this area at a depth of about 50 ft.

FIGURE 8. Subsidence over Strathmore mine, South Longmont Street, Lafayette. The most recent damage to the street has not yet been fully repaired. Note unpaved section of street and sagging sidewalk. The coal seam in this area of the Strathmore mine was quite thick, and the probable thickness of coal extracted was 20 to 25 ft. Depth of mining was 100 to 125 ft.

FIGURE 7. Large, well-developed subsidence pits over rooms of the Shanahan mine. Pits are 8 to 10 ft deep and are 15 to 25 ft across. The coal seam at this mine was unusually thick (10 to 15 ft), which accounts for the large amount of vertical subsidence. The mining depth was less than 50 ft.

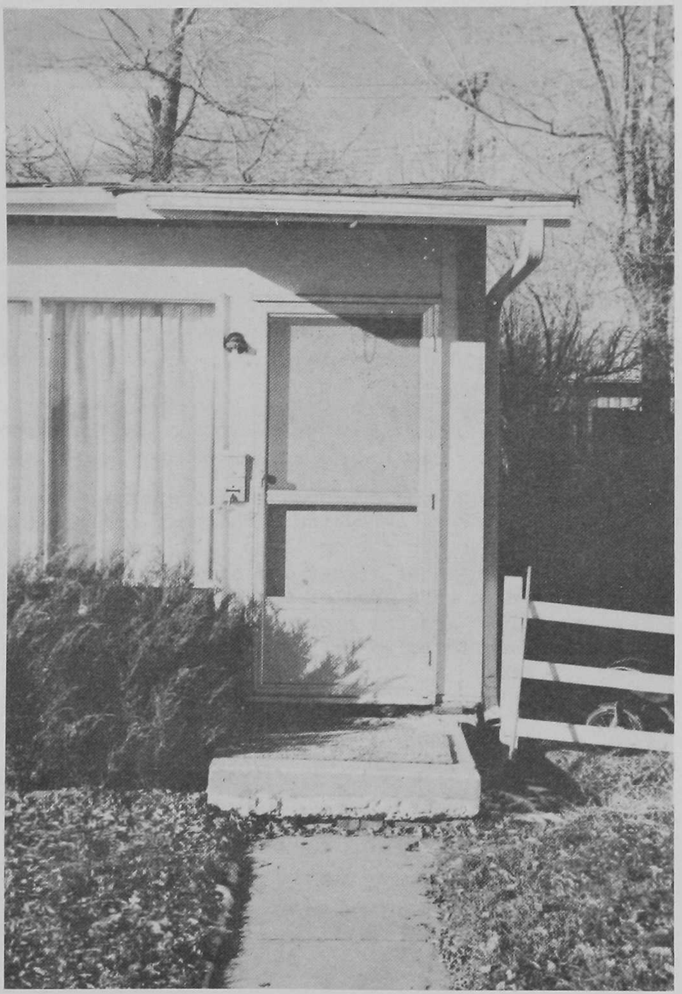

FIGURE 9. Front stoop of house to the right in Figure 8. This house is immediately south of home shown in Figure 10. The walk was pulled away from the stoop and it in turn has pulled away from the house. Bricks have been jammed beneath the house and beneath the stoop for temporary support.

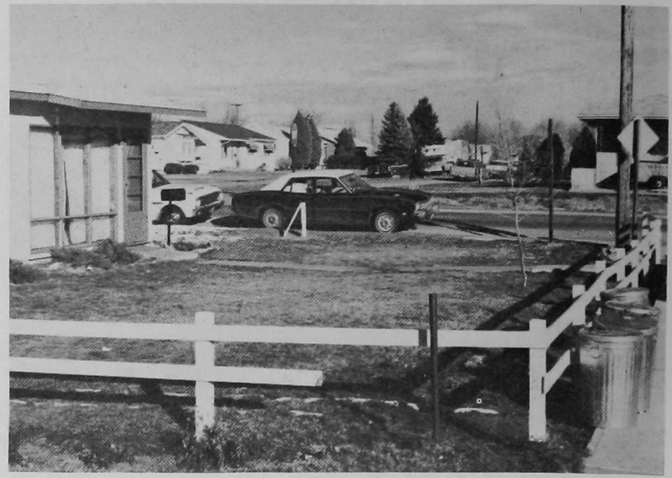

FIGURE 10. Subsidence over Strathmore mine, South Longmont Street, Lafayette. The low sag in the front lawn and the front walk are subsidence related. This "subsidence" is actually the result of compaction of trash and rubble used to fill a true subsidence pit which formed in 1956 (Denver Post, May 27, 1956). There was rapid collapse and overnight development of a hole 40 ft deep and 15 to 20 ft square.

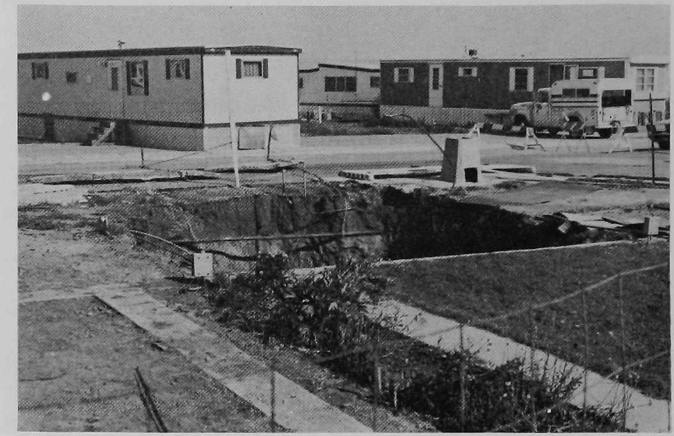

FIGURE 11. Subsidence pit at a trailer court in Lafayette. Ground began caving in the early morning of August 29, 1974, and continued to enlarge until noon. Final dimensions of the subsidence pit were 24 by 18 by 15 ft. The subsidence occurred in a vacant area, and only minor damage to utility lines was sustained. Had one of the large "mobile" homes shown in the background of this figure been parked on top of the subsidence area, it is doubtful that it could have been moved quickly enough to save it. This recent event is a dramatic example of continuing subsidence problems in an area where mining ceased over half a century ago.

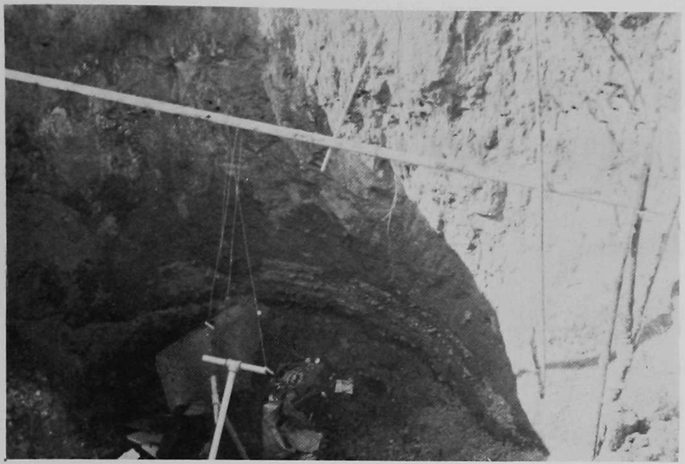

FIGURE 12. Detail of subsidence pit at trailer court in Lafayette. The upper 12 ft of the subsidence pit walls are composed of sand- and silt-size material; the lower 3 ft of the pit consist of bedded, angular gravel. The subsidence occurred over the Strathmore mine which lies at a depth of 100 to 150 ft and was last worked in 1919. Normally only one level was worked in this mine, but in the area of the trailer court two levels were mined, and it is estimated that a total void space of 20 to 25 ft was created.

SUMMARY

Subsidence is both a natural and a man-made phenomenon. Subsidence in areas underlain by soluble rocks generally is less predictable than in areas where underground mining of bedded sedimentary rocks has taken place. In many cases man and nature have worked together, usually inadvertently, to cause subsidence. The mechanisms of subsidence are complex rather than simple. In some areas, such as the Boulder-Weld coalfield, care must be taken to distinguish between phenomena which can be evidence for subsidence and those which may be due to some other cause. The study of subsidence in the coalfield illustrates very well the frustration of working with old, often incomplete and questionable data that usually raise more questions than they answer. All of these negative factors make necessary more intensive study than might otherwise be the case where land development is contemplated. Thus, the answers to subsidence problems will not be simple; they will be relatively costly as a rule, and they probably will not be 100 percent correct. Hence, there will be an element of risk inherent in surface developments in most areas which are subject to subsidence. Our best approach is to become aware of those areas in which natural and man-made subsidence has occurred and has the potential to occur in the future. If it is infeasible to plan around these areas, and if they must be used, then we must accept whatever added burdens of cost and anxiety may accrue. The best hope of success will come from a multidisciplinary effort among land developers, planners, engineers, geologists, and politicians.

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GEOLOGIC ASPECTS OF SOLID WASTE DISPOSAL IN THE URBAN ENVIRONMENT

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INTRODUCTION

Solid waste disposal is a national problem that is growing exponentially and most acutely in urban areas. A study by the Office of Science and Technology (1969) indicated that, as long ago as 1968, the nation was generating almost 1.5 billion pounds of urban solid waste per day, at a handling and disposal cost of about $4 billion per year. The figure of $4 billion per year, which I am sure would be much larger today, does not include such things as environmental degradation; reduction of the visual amenity; and air, water and ground pollution.

Figure 1 is a view from one of the approaches to the Queen City of the Plains. In fairness to Denver, it could be repeated nationwide around the peripheries of just about all our major cities. Chaotic piles of solid waste, moreover, litter the cores of most major cities in the United States, and many smaller communities as well. Some waste dumps in the Greater Denver Area violate all rules of propriety--massive open dumps that attract vermin, pollute the air and water, and degrade the surroundings with wind-blown rubbish. One open dump that comes to mind is encroaching into the hydrologic regimen by dispersing its pollutants directly into the surface and ground water of a major drainage, and is encroaching onto the flood plain in a way that will, in future floods, inhibit the free flow of the runoff. Figure 2, on the other hand, has some merit. A certain amount of visual blight is evident, not all of it because of the car dump, but car dumps of this sort are a source of some encouragement because they show that an attempt is being made to recycle a finite natural resource. The Office of Science and Technology report (1969, p. 12) estimated that the value of a single car body in 1968, with its components separated out, was around $65.00. The cost of handling the material itself, of course, must be subtracted.

My main topic is the geologic aspects of solid waste, but to understand and really get into the problem, we have to know something about what solid waste consists of, where it is generated, and how it is best dealt with and handled. Solid waste does not occur in nature. It results from the varied activities of humans and domestic animals. It is unwanted, discarded material. It can readily be classified into four main categories (Table 1).

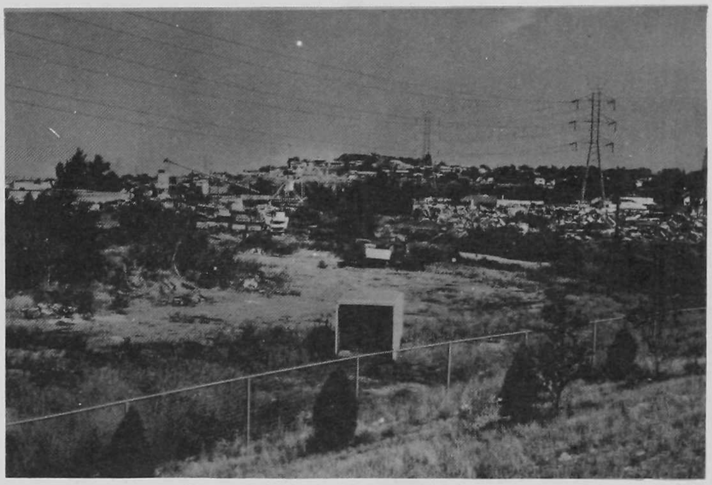

FIGURE 1. Solid-waste dump at outskirts of Denver, Colorado. Similar dumps greet the traveler at the peripheries of most large American cities.

FIGURE 2. Automobile salvage dump, Denver, Colorado. Nonrenewable resources are being recycled for further use.

*TABLE 1. MAJOR SOURCES OF SOLID WASTE IN 1967**

	lbs/day/capita	megatons/yr
URBAN		
domestic	3.5	128
municipal	1.2	44
commercial	2.3	84
subtotal	7.0	256
INDUSTRIAL	4.2	153
AGRICULTURAL		
vegetable	15.0	552
animal	43.0	1563
subtotal	58.0	2115
MINERAL	30.8	1126
TOTAL	100.0	3650

**From Office of Science and Technology, 1969, p. 7.*

FIGURE 3. Typical urban refuse in an Adams County, Colorado sanitary landfill. Note preponderance of waste paper. Photograph by James M. Soule.

*TABLE 2. CATEGORIES OF URBAN SOLID WASTE**

DOMESTIC - Household

COMMERCIAL
Hospitals, hotels, restaurants, stores, offices, markets, construction, and demolition

MUNICIPAL
Street refuse, dead animals
Abandoned cars
Incinerator refuse
Sewage treatment residues

**From Office of Science and Technology, 1969, p. 10.*

*TABLE 3. PRINCIPAL CLASSES OF HOUSEHOLD REFUSE**

COMPOSITION	APPROX. PERCENTAGE
Paper	54
Garbage	8
Yard trimmings, wood	3
Metals	7
Glass	7
Miscellaneous Rags, plastic, dirt, rubber, old shoes, paint moisture	21
TOTAL	100

**Modified from Office of Science and Technology, 1969, p. 12-18.*

URBAN SOLID WASTE

Urban solid waste, which is the primary concern of this report, can be further subdivided (Table 2), and treatment should vary accordingly. Commercial waste, for example, includes mostly such things as paper cartons and various kinds of waste paper. Hospital waste includes some things that are pathogenic or are very toxic and must have rather special treatment. Household refuse which, because of its volume, is a main concern in most communities, includes a great variety of things that end up on the dump (Figure 3). Many of these products have the potential of being recycled, but most of them are not actually being recycled at the present time. The technology is available, but the process is not yet generally economical. By far the greatest part of household refuse consists of waste paper, which includes newpapers and magazines, paper cartons, cardboard boxes, and paper bags from the supermarket (Table 3).

DISPOSAL METHODS

Most solid waste is disposed of in one of five general ways: in open dumps, by incineration, by on-site methods, by recycling, and in sanitary landfills.

The open dump is a problem because it is an attraction for vermin, insects, and other disease-carrying organisms. It causes visual blight and is a source of pollution, off-site, to the environment. Many cities, large and small, now have regulations that prohibit open dumps, but compliance is difficult to enforce.

Incineration is coming into the fore, partly because sites for sanitary landfills are becoming harder to find. Methods of incineration vary greatly, and nowadays power is even being generated as a by-product. Depending on the efficiency of the incinerator system, the waste can be reduced by as much as 90 percent by volume or as little as 40 percent. In either event, the residue still has to be rehandled (Office of Science and Technology, 1969, p. 50).

On-site disposal is largely limited to industry, but much garbage and some combustible waste are now handled in the home. But in-home disposal only passes the problem on to somebody else, because the residue is just flushed down the drain and sent elsewhere for further processing.

Recycling is still somewhat utopian, but in a modest way it has been going on for a long time. A great deal of garbage, for example, has been fed to hogs in the past and is being fed to them today. Feeding garbage to hogs, however, carries a real danger of spreading disease, and legislation in the past few years has tended to require that edible refuse be boiled or cooked before being fed to the animals. Composting is another useful but statistically insignificant form of recycling.

The sanitary landfill, at the present time, is the most satisfactory widespread method of disposal, but it presents many problems.

PROBLEMS OF LANDFILLS

Geology plays a key role in the proper location and design of sanitary landfills, especially with respect to ground-water movement, and therefore, to off-site pollution. Figure 4 is a logarithmic scale showing permeability of tight, unweathered clay on the one hand, and clean gravel on the other, with gradations between. Permeability rates, of course, are much higher for clean gravel than for clay, and it is ironic that most of our landfills are located in areas near the lefthand side of the Figure--in sands and gravels. These are the areas where cyclic land use has resulted in the removal of gravel and sand for other purposes and has left convenient holes in the ground where we tend to dump our waste and where we have the greatest problems with ground-water contamination. In the simplest case, Figure 5, the water table follows the slope of the land; ground-water moves down a gradient which, in general, is parallel to the slope. The landfill in the upper lefthand corner is releasing leachates that travel vertically downward through the soil until they reach the water table; they then move in the direction of the ground-water gradient with virtually no dispersion upstream.

Figure 6 depicts the very simple but very common condition in which solid waste is dumped into an exhausted gravel pit; the leachates go directly into the ground-water and disperse downstream. Even if the fill is normally above the water table, a seasonal rise of the water table would induce a reaction between the ground-water and the waste material, and even a qualified organic chemist could not predict all the possible chemical combinations that would result. Microbial and chemical decompositions of the waste material generate various gases. One of the more common reactions in an aerobic environment is the production of carbon dioxide from the breakdown of the cellulose. The CO_2, in the presence of water, produces carbonic acid which reacts with many components of the dump, which in turn tends to raise the hardness of the water and increase the biochemical oxygen demand (Schneider, 1970, p. F4). Anaerobic decomposition leads to the production of methane, ammonia, and hydrogen sulfide. All these reaction products make their way into the hydrologic regimen or escape to the atmosphere.

Figure 7 illustrates another fairly simple example that is very prevalent in the mountain communities of Colorado, the case in which leachate travels down directly to the water table. Shortly below, a zone of fractured bedrock provides ideal channelways for the long-distance migration of leachates. In the rare but more nearly ideal case, the solid waste is deposited in an environment of very low permeability and porosity and essentially is contained within the waste disposal site iteself. Prior geologic studies can help find such settings.

THE SANITARY LANDFILL

Just what is meant by a sanitary landfill? The study by the Office of Science and Technology (1969, p. 59) reviewed more than 6,000 landfills throughout the United States and found that only about 6 percent of them were, indeed, sanitary. The intent of the sanitary landfill procedure is to confine the leachates--the waste byproducts--essentially to the landfill site; to cover the site daily so as to discourage the proliferation of vermin and minimize offensive odors and visual blight; and, finally, to restore a ground surface that can be used for other purposes after the landfill is completed.

In Pits

Oftentimes the fill is emplaced in three separate lifts for better control (Figure 8). Common practice is to emplace about four feet, or four units, of compacted fill to one unit of cover material per day. Finally, a minimum soil cover about two feet thick is used to top the completed landfill. In an actual example in the Denver area, a gravel pit was worked right down to a claystone bottom. The same claystone was used to provide an impervious membrane on the walls of the pit, to cover each individual lift, and finally, to restore the surface with a final cover. A "plumbing system" was devised to carry away seepage and rainwater. Demolition waste, which usually lacks many of the undesirable characteristics of ordinary landfill refuse, was not

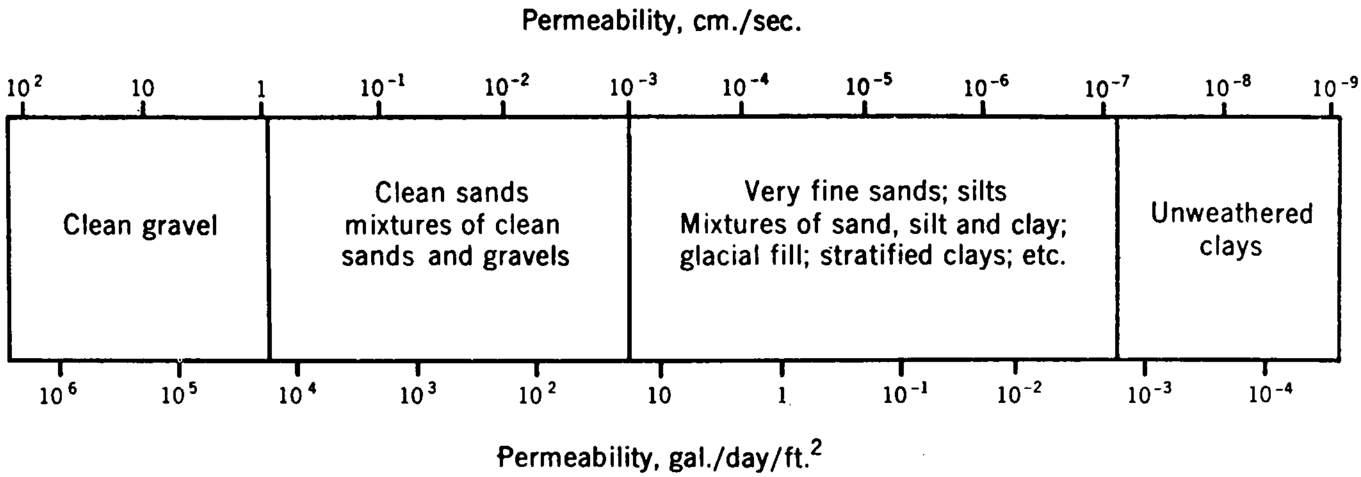

FIGURE 4. Permeability ranges of different soil classes (Hughes and others, 1971; modified from Todd, 1959, p. 53

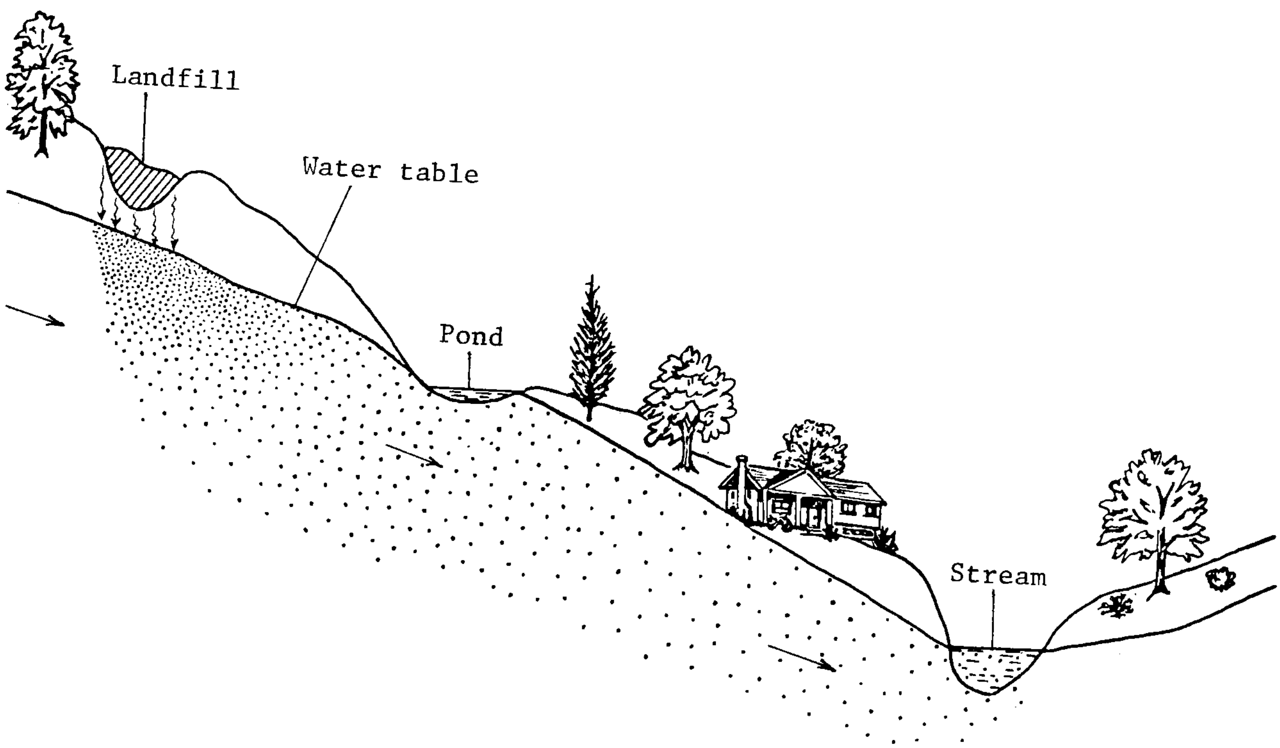

FIGURE 5. Generalized movement of leachate through the land phase of the hydrologic cycle (from Schneider, 1970, p. F6). Arrows show flow of ground-water; dots show dispersion of leachate.

covered daily because daily coverage was not deemed necessary. It should be emphasized that in seeking a site for a sanitary landfill, the planner must be mindful of the need for a ready supply of suitable cover material in order to carry out the sanitary concept.

Trench Method

Another approach to sanitary landfilling is the trench method, used where no pre-existing pit is available. Figure 9 illustrates an example from Derry Township, Pennsylvania (Foose, 1972, p. 15). A trench about 40 feet wide at the top was excavated to a depth of about 10 feet. At the outset, the topsoil was stockpiled for later use in the reclamation phase of the landfill. Then, as the trench was being filled with waste, an adjacent trench was being excavated, and the material being excavated was dumped daily on the accumulated refuse. Finally after the entire filling operation was complete, the stockpiled topsoil was used to regrade the surface.

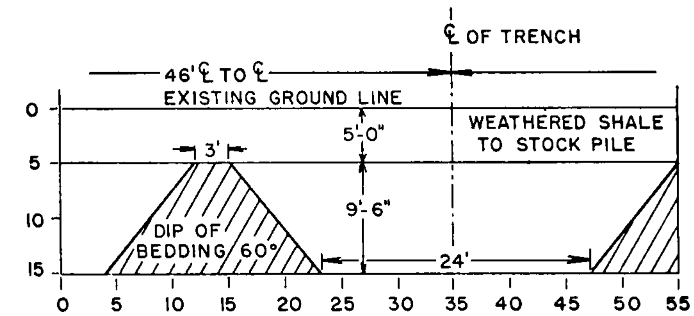

FIGURE 9. Cross section showing details of a trench-type landfill design (from Foose, 1972, p. 15).

In Gulleys

If landfills are placed in gulleys or ravines, special precautions are necessary. First, surface drainage has to be diverted around the landfill to minimize the generation of leachates. Second, a plumbing system should be devised to collect the leachate for further treatment, in a manner similar to the treatment of sewage. In Sonoma, California, impervious barriers or "buffer zones" have been constructed downstream from the landfills to trap leachate that may have escaped from the fill and to prevent its passage downstream into natural drainage (McCollough and Pacey, 1972, p. 45). Figure 10 shows the procedure that was used. First, the valley bottom was graded to 2-4 percent minimum to ensure drainage to the leachate subdrain. The subdrain consists of a perforated pipe enclosed in permeable gravel to allow for good infiltration and also to protect the pipe from compaction of the overlying dump material. A minimum of 10 feet of earth was retained between the dump itself and a permeable stratum below.

Figure 11 shows the design of the buffer zone. After the permeable materials were completely excavated, an impervious core, very much like a dam, was faced with more-or-less pervious protective flanking fills. Next, an observation water well was placed upstream of the fill to monitor potential pollution. Piezometers were installed to detect any buildup of hydraulic pressure and, finally, detection wells were installed to monitor any gas such as methane, that might be generated by the landfill.

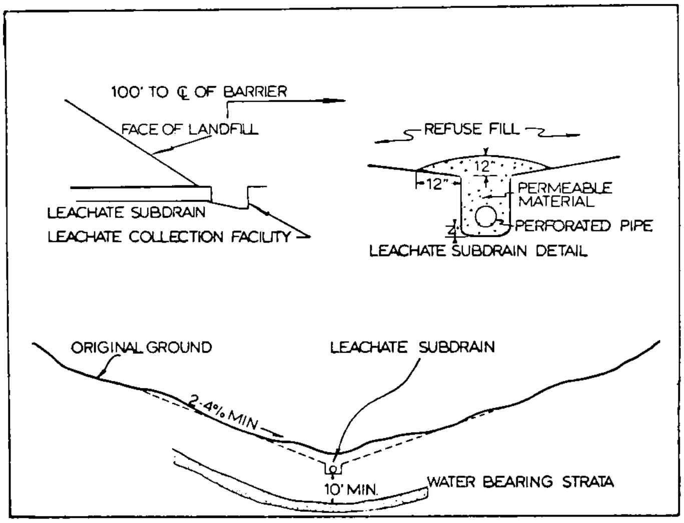

FIGURE 10. Design details of a sanitary landfill in Sonoma County, California (from McCollough and Pacey, 1971, p. 52).

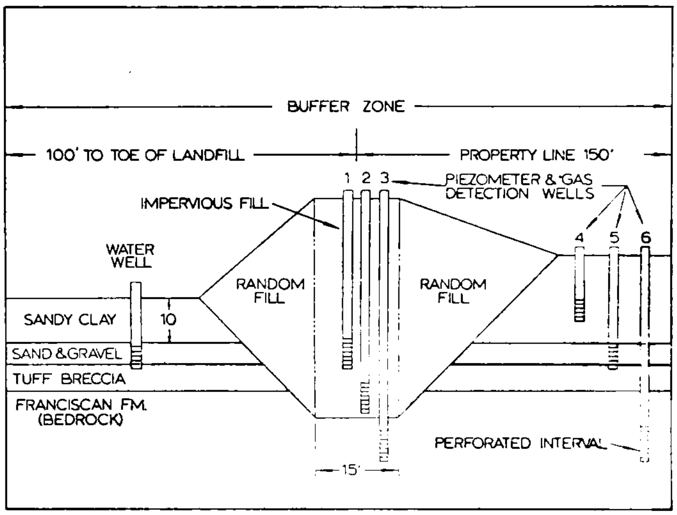

FIGURE 11. Diagrammatic cross section of an impervious fill barrier and monitoring facilities in Sonoma County, California (from McCollough and Pacey, 1971, p. 55).

Controlling Ground Water

With ingenuity and the right set of circumstances it is possible to devise a landfill that directs the flow of ground water toward rather than away from the fill, one of the main considerations being to avoid siting the fill in an infiltration area. Figure 12 shows how the water table can be intercepted and how a ditch or a drain can be used to extract the leachate. This procedure produces a cone of depression that causes the groundwater to flow to the fill rather than away from it. Parenthetically, in much of Colorado where we have low local rainfall--say about 10 inches of rainfall or less annually--a fill probably would not generate any leachate at all, unless it had direct access to surface or ground-water (A.M. Spieker, oral commun., 1975).

Another possibility for directing ground-water flow toward rather than from a fill is to center a pumping well in such a position that the cone of depression pulls the ground-water toward the landfill. Of course, this procedure implies the long-term pumping of the well, because leachates tend to remain for great lengths of time, and slow decomposition might take place over a period of many years (Schneider, 1970, p. F7).

It is also possible nowadays, given sufficient money, to locate a sanitary landfill just about any place in the world. For example, a landfill can be sited in a pervious gravel area by using an impermeable vinyl membrane for containment. After the excavation is graded, a layer of compacted sand is set in place to support the membrane; compacted sand is then also placed on top of the membrane to prevent the landfill debris from perforating the vinyl and breaking the seal.

MULTIPLE SEQUENTIAL LAND USE

In selecting sites for landfills one should plan for multiple sequential land use. Colorado law, in fact, now requires a bonded reclamation plan. To the extent that an exhausted pit can be rehabilitated for other use, the pit is an asset to the community, rather than a liability. Perhaps a tract of agricultural land will be excavated for sand and gravel, will then be backfilled with refuse, and finally will be zoned industrially. Some of Denver's most valuable real estate has had such a history. Shopping centers and municipal facilities occupy high-value reclaimed lands that support the economic base of the community. But sometimes other methods of reclaiming the land should be considered by the planner. The wisdom of backfilling on floodplains, for example, is questionable unless such sites are reclaimed for uses that will tolerate intermittent flooding. If the topsoil is saved, high-value agricultural land can sometimes be returned to productivity after the gravel is extracted and the topsoil is restored. The community may find it advantageous to use a site for water-oriented open space, particularly if backfilling might cause ground-water pollution. Reclaimed landscaped urban ponds or lakes can greatly increase the value of adjacent real estate (Rickert and Spieker, 1971, p. G2) and enhance the visual amenity.

Exhausted clay pits along the Front Range are ideally suited for the construction of sanitary landfills (Figure 13). Percolation is very low, surface drainage is negligible, and the pollution potential is minimal. One problem in utilizing pits that are long and very narrow, however, is the difficulty of maneuvering compaction machinery. Even well-compacted fills commonly subside for many years as the refuse slowly decomposes. Unless optimum compaction is assured, sequential use might be directed toward open space rather than toward higher value construction.

FEDERAL HELP

In summary, the purpose of urban solid waste disposal should be to contain pollution at the disposal site, to protect and enhance environmental quality at the same time, and where possible, to reuse and conserve natural resources. To this end the Congress, in 1965, passed the solid waste disposal act, Public Law 89-272. Under Public Law 89-272 the Federal Mission is to "conduct, and encourage, cooperate with, and render financial and other assistance to appropriate public (whether federal, state, interstate, or local) authorities, agencies, and institutions, private agencies and institutions, and individuals in the conduct of, and promote the coordination of, research, investigation experiments, training, demonstrations, surveys, and studies relating to the operation and financing of solid-waste disposal programs, the development and application of new and improved methods of solid-waste disposal (including devices and facilities therefor), and the reduction of the amount of such waste and unsalvageable waste materials".

Several federal agencies have been directed under this act to help out in solving the problem of solid waste disposal at the national, state, county, and community levels. Among these agencies are the Bureau of Solid Waste Management in the Department of Health, Education and Welfare, the Bureau of Mines and the Federal Water Quality Administration in the Department of the Interior, the Model Cities program in the Department of Housing and Urban Development, and the Farmers Home Administration in the Department of Agriculture. Planners or community leaders who face problems in solid waste management should be able to count on grants or cooperative fundings from one or more of these agencies, in the areas of research, development, and demonstration projects (U.S. Dept. of Health, Education and Welfare, 1971, p. 32).

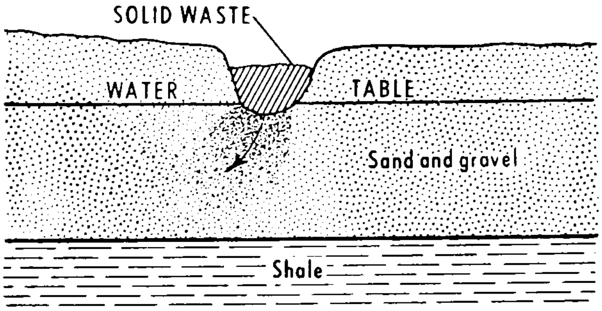

FIGURE 6. Effect on ground-water resource of solid waste disposal in a permeable environment (from Schneider, 1970, p. F8).

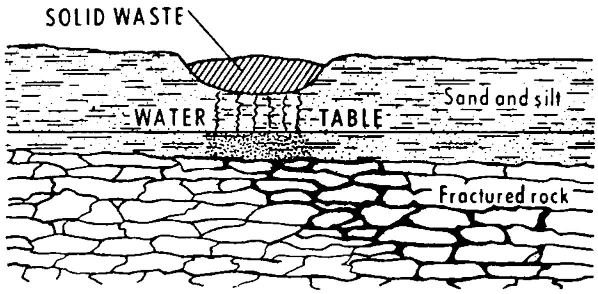

FIGURE 7. Effect on ground-water resource of solid-waste disposal at a site underlain by fractured bed-rock (from Schneider, 1970, p. F9).

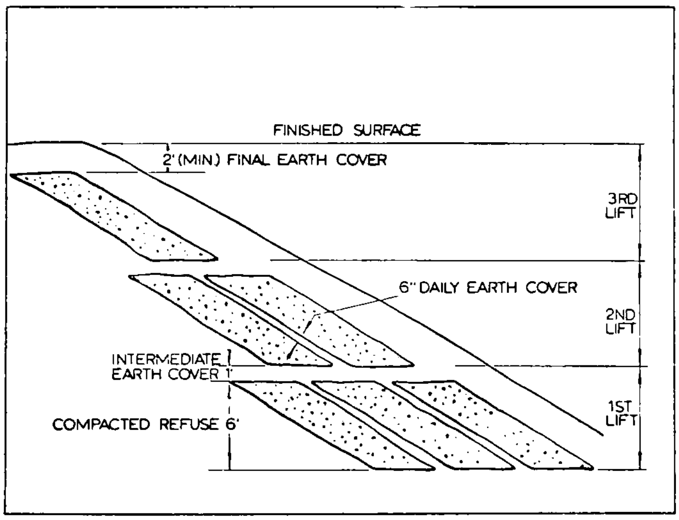

FIGURE 8. Diagrammatic cross section of a three-lift sanitary landfill (from McCollough and Pacey, 1971, p. 54).

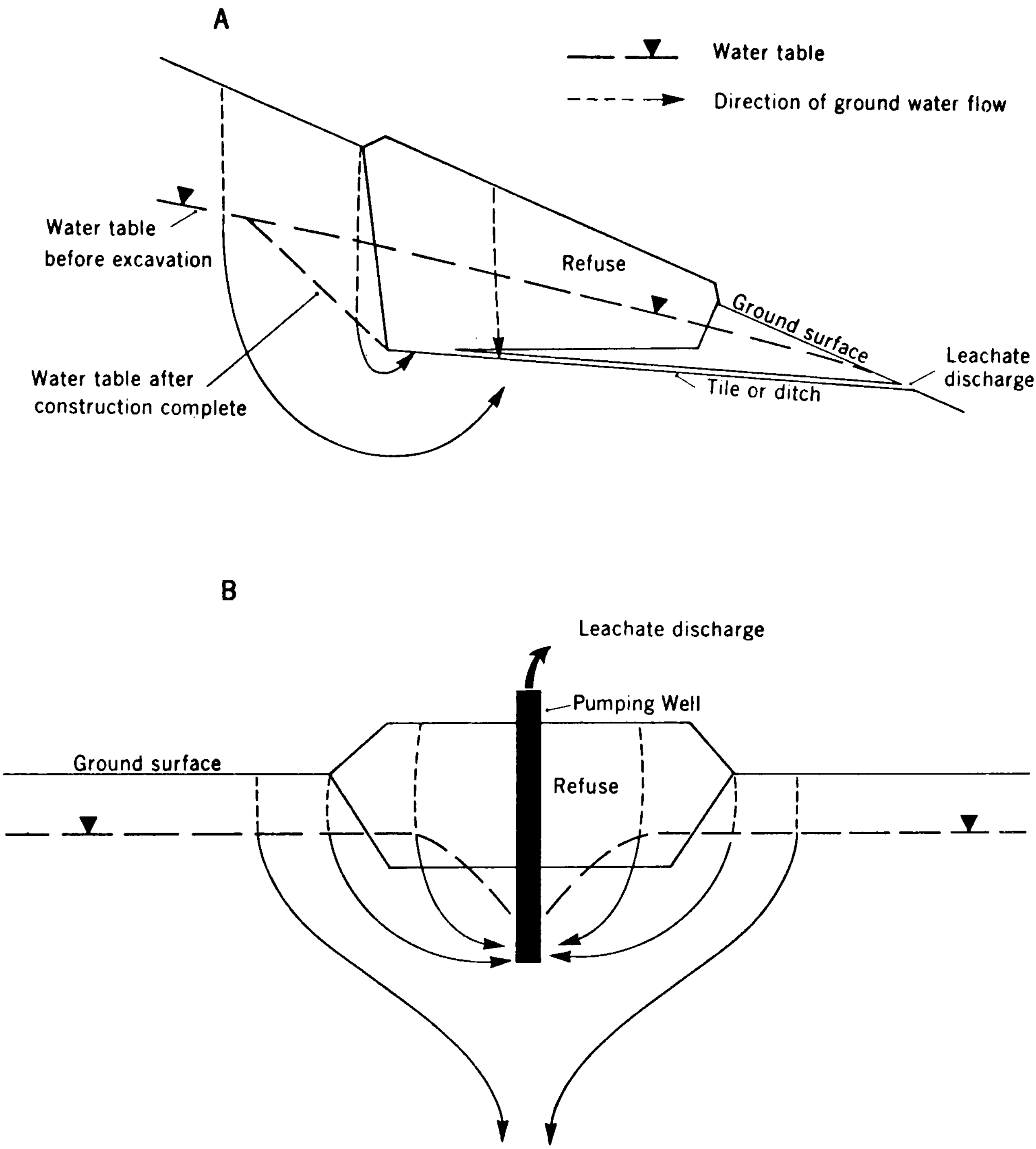

FIGURE 12. Leachate confined to landfill sites by maintaining ground-water gradients toward the fill by (A) gravity drainage and (B) a pumping well (from Hughes and others, 1971, p. 60).

FIGURE 13. Clay pits in the Laramie Formation, Golden, Colorado. Pits such as these are possible sites for sanitary landfills. U.S.G.S. photographs by R.L. Parker, R.B. Taylor, and W.R. Hansen, 1974.

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HYDROLOGIC PROBLEMS IN LAND DEVELOPMENT PLANNING

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INTRODUCTION

The urban developer faces a wide variety of geologic and hydrologic problems, such as flooding, erosion, landslides, mud flows, avalanches, and subsurface water seepage. Unplanned development usually accentuates these problems, having a detrimental effect on the land, water or natural resources (Figure 1).

The objective of this paper is to point out some of the surface and subsurface water problems that have been encountered in land developments in Colorado. Many of these problems may be commonplace, but too many of the factors precipitating these problems are frequently overlooked during the planning stages of a development where they could be properly evaluated and remedied. In short, this paper discusses one segment of the geoplanning concept, the underlying theme of this conference.

FIGURE 1. Landslide damage resulting from ground water seepage into highly fractured shale.

SURFACE WATER

Flooding

In Colorado, streams are part of a relatively youthful geomorphic age; consequently, stream valleys and flood plains are nonexistent in mountainous areas or narrow through the plains region. Flooding is confined to a ribbonlike area paralleling stream channels. Natural diking along the streambanks, common to geomorphically old streams, is generally not present, therefore even small amounts of storm runoff can cause localized flooding.

Many sectors of the Colorado Front Range were inundated by floods in 1965, 1969, and 1973. The 1965 flood was the result of a 100-year rain storm, whereas the others were reported to be from 20- to 50-year storms.

The problems and resultant damage associated with these floods have been well documented and range from total loss of buildings to collapsed bridges and washed-out roads. Even after repeated economic loss to many of the facilities lining these major streams, the owners of those structures have elected to clean up and rebuild their facilities.

Even though flood risk along major streams is high, that risk, even from a 100-year event, apparently is acceptable to many of the owners of large structures. To these individuals the expense of repairing damaged property is less than the cost of facility relocation. By comparison, high flood-risk areas are generally not acceptable to an individual homeowner, who does not have the financial backing to reconstruct after a flood.

Determining flood risk along major rivers is easily accomplished. The existence of a flood plain in itself, places the flood risk at a high level. Assessing flood risk for small youthful streams with no or limited flood plains is not as easy. Small streams such as Turkey Creek, Bear Creek, and South Saint Vrain Creek, flow through narrow stream valleys with little evidence of flooding. Small stream valleys, particularly on the eastern slope of the Rockies, occupy steeply graded, sparsely vegetated drainage area; consequently runoff is rapid. The frequency of intense storms sufficient to cause high stream flows in these small creeks is generally low, but when flooding does occur, damage associated with flooding is usually extensive, as experienced in the 1965 flood along Plum Creek (Figure 2) and the 1969 Jamestown and Turkey Creek floods.

Any modification of the land surface or change of surface drainage must be carefully planned, properly constructed and maintained to insure small surface water problems are not magnified into high economic losses. Several good examples of such problems have taken place this past year.

On April 12, 1973, the Lower Lathrop Reservoir, located near Greeley, Colorado, full from the abundance of winter precipitation was surcharged by quick spring runoff. The reservoir embankment failed, and water spilled from the reservoir, quickly inundating the small stream valley below the dam and eventually the town of Kersey, about 5 miles downstream. The factors contributing to this disaster are admittedly complex. The dam impounding the reservoir was old; thus the spillway could have been improperly sized, or the reservoir level may not have been properly maintained. Further embankment failure may have resulted from malfunction or lack of embankment drainage systems.

In Denver, the May rainstorms this year created similar conditions with substantial economic losses. During the intense storms, water in the irrigation lake on the Wilshire Golf Course overflowed the embankment and flooded a downslope urban area. Lake water was fed by the Highline Canal that apparently acted as a storm drain for the upslope urbanized area.

To predict the possible occurrence of these conditions would take a considerable amount of hydrologic foresight. However, a surface-water hydrologist should be able to identify potential surface-water hazards and flood susceptibility in advance of development so that such remedial measures as greenbelts to lessen the flood lossses, or channelization of the streams to remove flood water safely, could be planned.

FIGURE 2. Washed-out service road adjacent to I-25 at Castle Rock as a result of 1965 flood. Note collapsed bridge in background.

Erosion

Like stream flooding, erosion is a natural hazard of concern to individuals responsible for land development. The ability of a stream to erode a land mass is a function of stream gradient and water velocity. Urbanization, particularly in hilly or mountainous terrain usually creates steeper land surfaces and consequently erosion increases. Further, protective vegetation is commonly removed exposing loose erosion-susceptible soil.

It has been the author's experience that little attention is given to grading of individual building sites to protect the sites and adjacent areas from erosion and deposition of eroded debris. Surface runoff from individual building pads seldom is diverted to paved roadways or culverts, and generally water from one building pad flows down cut or fill slopes unabated. In Colorado, building codes have not evolved sufficiently to require the developer to provide building pad drainage or to install slope drainage terraces on high cuts and fills. Further, there are no requirements for planting man-made slopes to slow erosion of soils.

In the judgement of the author, proper identification of potential erosion problems backed by minimum standards set by grading codes are absolutely necessary to the safe development of hilly or mountainous terrain.

GROUND WATER

Wet Basements

Ground water is really of little concern to a developer until the facility he constructs intercepts the ground-water table. The most common problem in the Colorado area is that of wet basements. This problem probably represents more grief to the homeowner and developer in this area than any other condition. The first, and most common cause of wet basements results from poorly graded lot surfaces that allow surface water and eave drainage to collect around the building, eventually to percolate through the soil into basement areas. Percolation is usually rapid immediately next to basement walls where basement excavation back fill has been poorly compacted. As most surficial deposits at one time or another are saturated, the opportunity for wet basements is widespread, as shown in Figure 3.

The second type of wet basement is caused by a fluctuating ground-water table. A problem at a large industrial plant in Jefferson County illustrates this condition extremely well. The foundation investigation for the plant, that is sited on an old river terrace just north of Clear Creek, was conducted by a reputable soil and foundation engineering firm in early spring of 1970. Test borings, drilled for that investigation intercepted water-bearing terrace sands and gravels in only one of the 9 borings. The water surface was well below proposed basement levels at that time. Lacking expertise in the ground-water field, the investigator did not consider the possibility that the water could rise significantly to intercept the basement level. During basement excavation the following fall, ground water was still not encountered. However, in the spring and summer of 1971, water began seeping into the basement affecting facilities housed there.

A series of test holes drilled by the author in 1972 indicated the ground-water table was well above the basement grade shown in Figure 4. The test holes also indicated the terrace sands and gravels were deposited in an old drainage swale eroded into the claystone bedrock. Water was apparently funneled into this buried swale from surface water seeping from an irrigation ditch and from several small plots of irrigated acreage north of the plant. In this instance, about 10 ft of ground-water table fluctuations were apparently common.

Based on the results of this investigation, the author designed a horizontal collection drain to intercept the southward movement of ground water along the northern perimeter of the plant. The cost of this installation was perhaps 2-3 times the cost of a peripheral drain, which should have been installed around the basement during its construction.

A similar ground-water fluctuation problem exists in a localized area of Aurora. The development is underlain by a thin alluvial aquifer in which the water table was well below ground surface. As water in the aquifer was recharged from surface percolation, the addition of 40 in. of water annually from lawn irrigation raised the water table to within a few feet of the ground surface. Homeowners thus created their own wet basements and have had to install sump pumps to lower the water table.

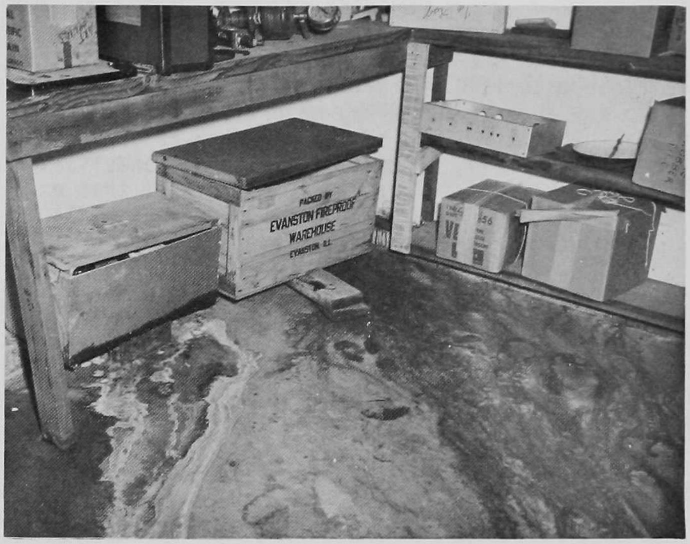

Figure 3. Water seepage flowing across basement floor in a Lookout Mountain area home near Golden, Colorado. The home is founded on crystalline rocks.

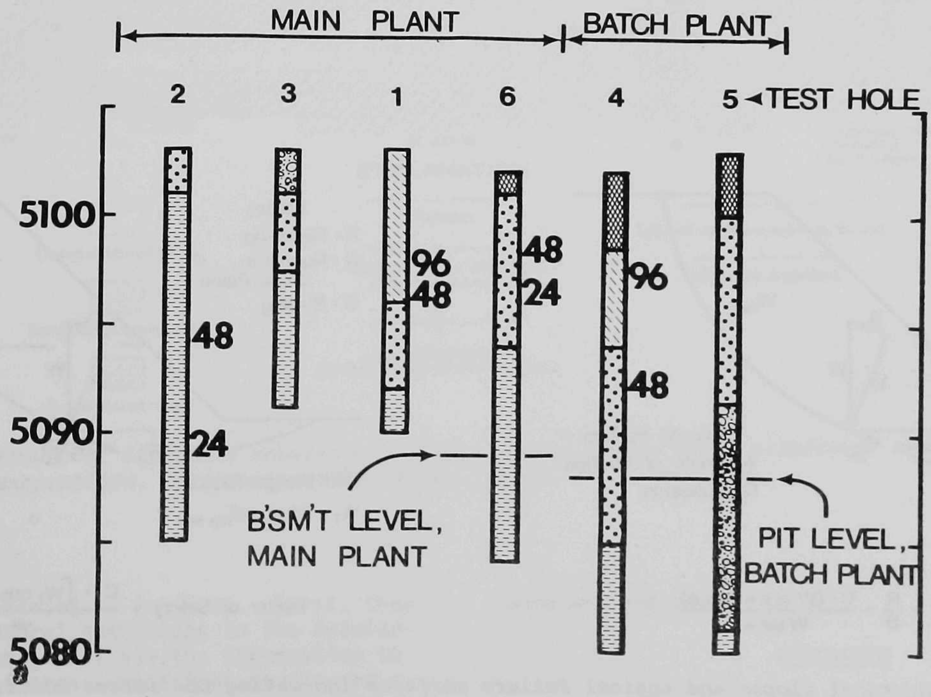

FIGURE 4. Summary test hole logs drilled immediately upslope of plant, indicating surficial deposits overlying claystone bedrock. Water levels are at the elevations adjacent numbers 24, 48, and 96. These represent hour after drilling that measurement was taken.

Landslides

Excavations are particularly vulnerable to sliding when earth materials are saturated. It is probably safe to say that nearly every major landslide in Colorado has been influenced by the presence of ground water. Fortunately, property losses from landslides in Colorado has not reached the magnitude of that experienced in California during the 1950's, as hillside construction is thus far limited.

The influence that water has on slope stability has commonly been misconceived. Many view water as a lubricating agent where in actuality there is really no such thing. It is true that some materials, particularly bentonite, lose shear strength when wetted, and this could influence slope stability. To display how ground water affects the safety of a slope, a typical cutslope and a failure surface are shown on Figure 5, along with vector diagrams demonstrating the forces affecting failure along the slip-circle.

Factor of safety, the indicator of slope stability, is defined as the ratio of resisting forces to sliding forces. A factor of less than 1.0 is indicative of failure. Sliding forces are basically the weight component of the earth materials resolved tangentially to the slip-circle. Resisting forces incorporate cohesion and friction along the slide plane. The presence of water seeping out of a slope cut affects primarily friction. The normal force (N) is reduced by pore-water pressure (PP), acting in an opposite direction. Consequently, the normal force and the resisting force is reduced and thus the overall factor of safety is lowered. The factor of safety of a slope without ground water may be of the order of 1.5 to 2.0, whereas the same slope with saturated soil may have a factor of safety of 1.0 to 1.5.

In the planning stages of a development preliminary knowledge of water-table elevation and proposed grading plans would allow the engineering geologist and soil engineer an opportunity to assess potential stability problems and recommend remedial measures for hazardous areas.

Subsidence

Finally, a problem that to date has gone unnoticed in Colorado, but one that may be experienced as development of alluvial basins takes place, is subsidence of land surface, the result of ground water pumping.

In California the U.S. Geological Survey has correlated the rate of land subsidence with water table decline associated with aquifer overpumping. One such area is located near Bakersfield, California (Figure 6). In this study area, 4 ft of subsidence monitored in a 2- to 3-sq-mi area over a 9-yr period was caused by a water level decline of about 40 ft.

Such ground water movement would cause catastrophic problems to land use. In residential developments, maintenance of drainage patterns, building foundation stability and utility operation would be difficult. As Colorado development growns into the major alluvial basin areas, such as the San Luis Valley, this type of problem should be expected.

In conclusion, the ground-water geologist, engineering geologist and surface-water hydrologist have two vital roles to play in solving hydrologic and geo-

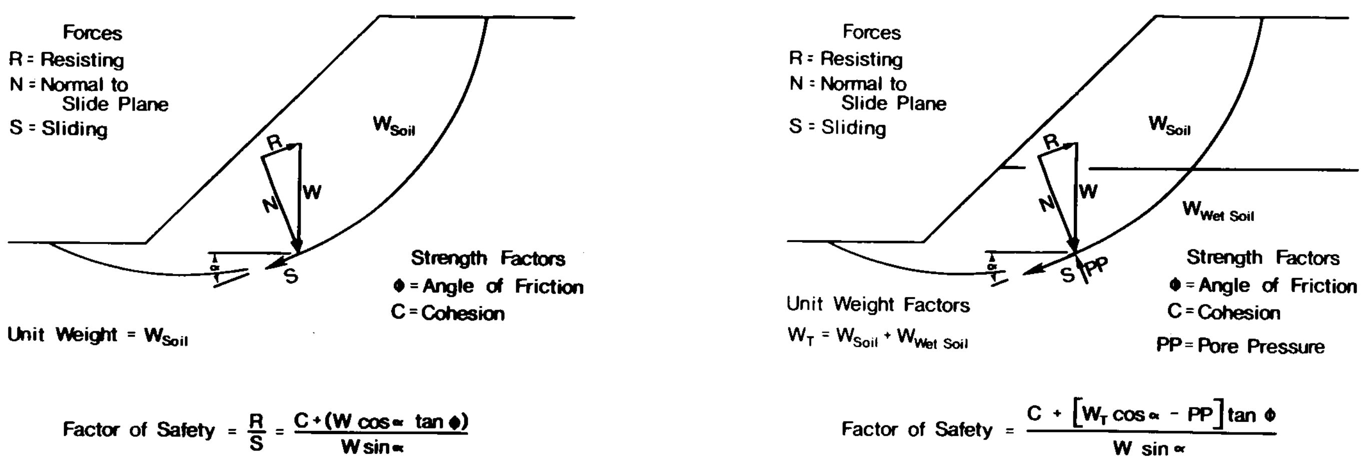

FIGURE 5. Sketch of identical slopes and typical failure surfaces indicating the forces contributing to the factor of safety of the slope.

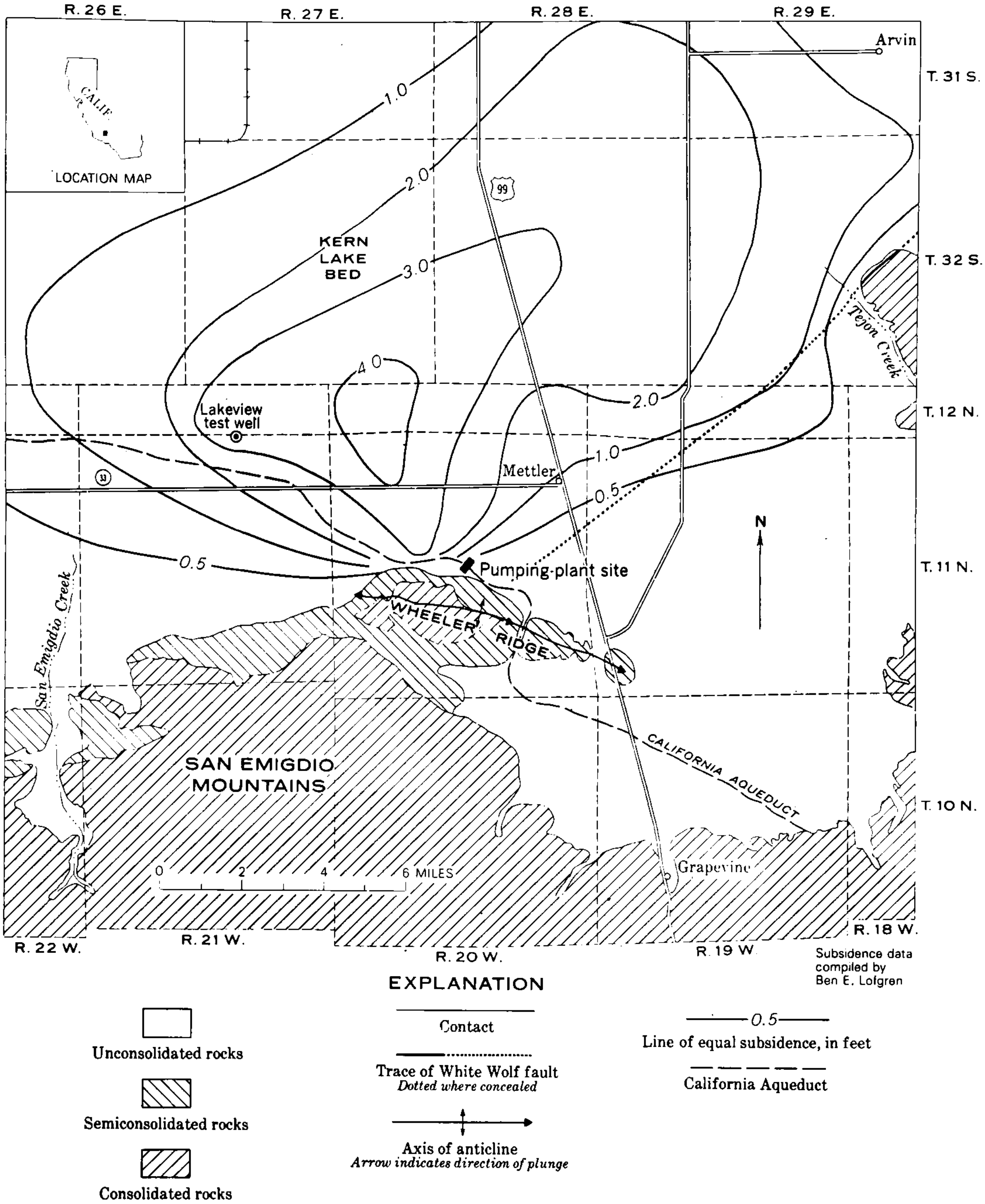

FIGURE 6. Indicates subsidence resulting from grouna water withdrawal near Bakersfield, California (after Riley, 1970).

hydrologic problems created by land use. First, they must delineate the natural conditions in the development area. Second, they must use the information to predict the effects of those conditions on the proposed development, and recommend solutions to potentially hazardous conditions. Further, they should review proposed plans and inspect construction of the facilities to assure that the potential hazard is adequately remedied.

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IDENTIFICATION AND DESIGNATION OF MINERAL RESOURCE AREAS -- PROBLEMS AND PRACTICALITIES

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In House Bill 1041 the Colorado Geological Survey was charged with two responsibilities: 1) to prepare guidelines for the identification of mineral resource areas, and 2) to provide local governments with the technical assistance that they needed to identify and designate such areas. This presentation will review the Survey's work with this bill and identify some of the problems that have been encountered in some areas.

In part 1 of the bill, a "mineral" is defined as:

> "...an inanimate constituent of the earth, in either solid, liquid, or gaseous state which when extracted from the earth, is usable in its natural form or is capable of conversion into usable form as a metal, metallic compound, a chemical, an energy source, a raw material for manufacturing, or construction material".

A "mineral resource area" is then defined as:

> "...an area in which minerals are located in sufficient concentration in veins, deposits, bodies, beds, seams, fields, pools, or otherwise, as to be capable of economic recovery. The term includes but is not limited to any area in which there has been significant mining activity in the past, there is significant mining activity in the present, mining development is planned or in progress, or mineral rights are held by mineral patent or valid mining claim with the intention of mining".

For convenience, a House Bill 1041 mineral resource area will be referred to as a "MRA".

First let us see how important our mineral resources are and what they have contributed to the development of the state. In 1974 the Colorado Division of Mines reported a total of nearly $700 million worth of mineral production in the state (Figure 1a). Of this total, metallics accounted for 31.4 percent, nonmetallics for 10.4 percent, and mineral fuels for 58.2 percent. Including the value of several commodities refined and concentrated in the state but not mined or produced in the state, the 1974 total exceeds $776 million. The 50-percent increase in production value since 1973 is attributed to increased production and price of mineral fuel commodities. Figure 1b, cumulative values of mineral commodities, shows, for the period between 1959 and 1973, a relatively constant rate of increase in total value, attributable to constant rates of increase in fuels and nonmetallics. As in Figure 1a, the increase in total value after 1973 is attributed to the increased value of mineral fuels.

In addition to the contribution of revenue, taxes, and jobs, the industry has developed new technologies over the years and has contributed significantly to the state's history, culture, and tourist industry.

Before we can identify or designate an MRA as an area of state interest, we must have a classification scheme for the various minerals and deposits. The classification system proposed in the Survey's Guidelines is twofold. The first group is the "Vein-Lode and Disseminated Deposits", which are essentially the metallic ores that primarily occur in the mountainous areas. The second group is the "Bedded and Tabular Deposits", which includes aggregates and dimension stone, mineral fuels (coal, oil and gas, oil shale, and uranium), clays, and evaporites. These minerals occur mainly in the sedimentary terrains, but some, such as the industrial minerals, for example, pyrite and fluorite, are associated with the ore and vein deposits.

In the identification and evaluation of either of these groups of deposits, a number of basic items should be shown on the maps. 1) The deposits should be mapped on a suitable topographic base map at scales of 1:24,000, 1:62,500, 1:125,000, or 1:50,000. 2) The surface extent of the resource or resource-bearing rock unit can be represented by mapping formations, members, individual beds, or specific zones within a formation or member. 3) Because folds, faults, joints, and bedding are important in determining the surface and subsurface extent of a resource, any structural features directly affecting the rock unit should be shown. 4) The map should show the locations of existing prospects, adits, shafts, mines, pits, quarries,

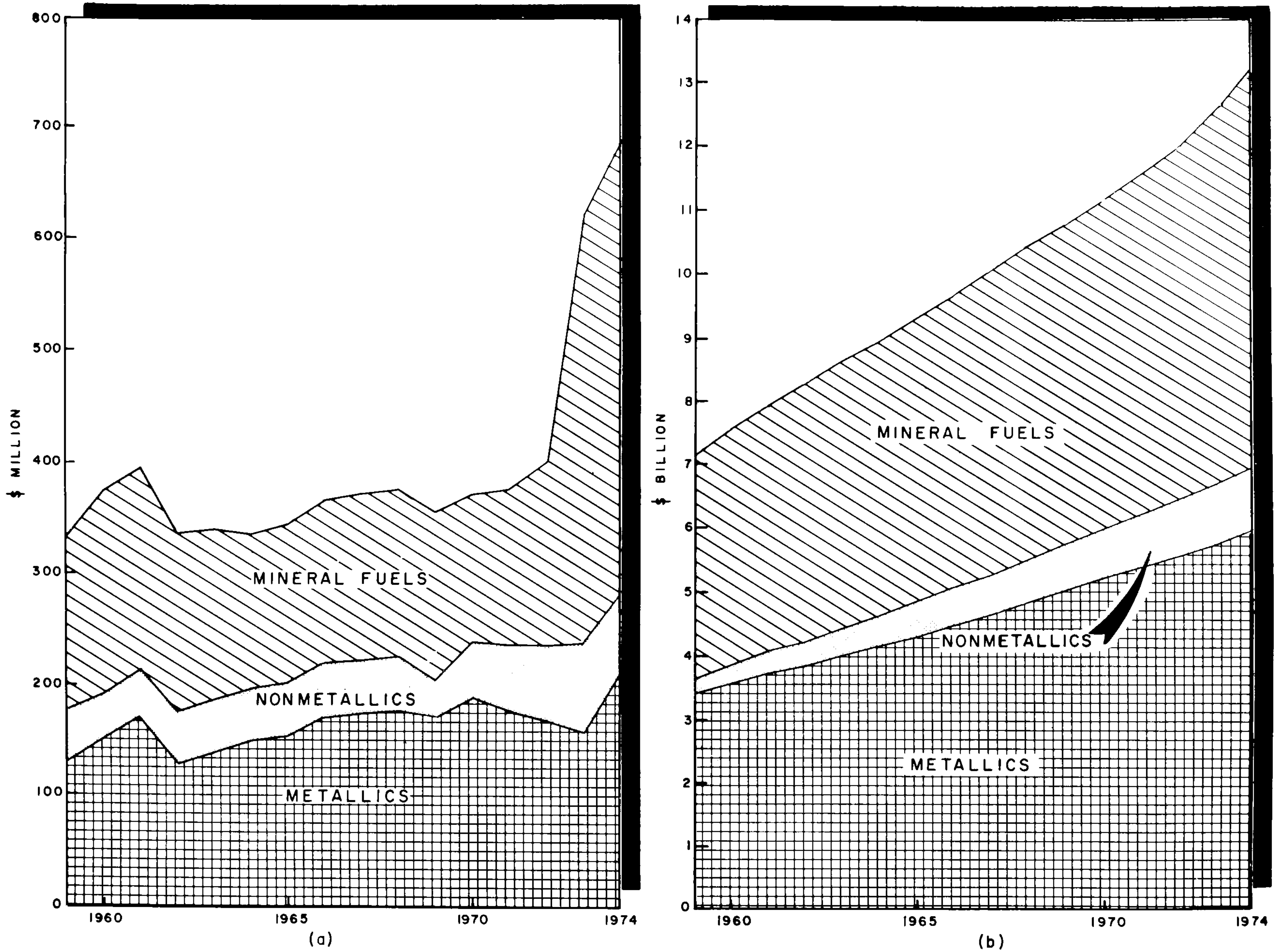

FIGURE 1. (a) Value of mineral production in Colorado, 1959 through 1974, by category. (b) Cumulative value of mineral production on Colorado, 1959 through 1974, by category. Source of information: Colorado Division of Mines annual report.

underground workings (if available), surface facilities, and waste disposal sites. An additional map can show the patented and, possibly, the unpatented mining claims. 5) Drill-hole and water-well information, in the form of abbreviated stratigraphic sections, is useful in determining the subsurface extent and character of some resources. 6) Because access, transportation routes and distances are important in a mining district or other MRA, the map should show the roads, rail lines, abandoned railway grades, and pipelines. At this point the author stresses the adoption and use of a statewide system of map symbols--letter abbreviations for elements, rock types, landforms, industrial minerals, and symbols for various exploration, mining and processing operations (Figure 2).

Au gold	**ra** rock asphalt	adit
Mo molybdenum	**He** helium	quarry
U uranium	**ha** salt	pit
ls limestone	**fd** feldspar	tailings
gn gneiss	**q** quartz	gas well
bs basalt	**fa** fly ash	mill
pg pegmatite	**tz** terrazzo	power plant

FIGURE 2. Examples of suggested map-unit abbreviations and symbols for mineral resources.

In evaluating the mapped resources, a variety of factors can be taken into account, some of which are more fully outlined in the Guidelines. If a particular MRA is an active or inactive mining district, it is helpful to present a picture of the district's or county's history and activity, including the years of operation, the primary and secondary commodities obtained, production tonnages and values, mining methods and the number and kinds of operators, markets and uses for the materials, and a list of references from the literature. Chemical and mechanical analyses help to determine the ore grade and potential uses for various deposits and to determine ore reserves. Resource thickness, overburden, structure, and other physical characteristics aid in determining limitations on mining feasibility, usable reserves, and potential uses. Other important factors include existing and possible transportation lines and access, surface and subsurface drainage, and availability of water.

All of the above factors taken together are aimed at the eventual calculation of reserves and at the analysis of the overall market conditions (supply and demand)--the primary factors that determine whether or not a particular mineral deposit can be economically worked with existing technology. In other words, a large or high-grade deposit might not be economically viable if access to it is difficult, or if there is no current or anticipated demand for it. A critical limitation in establishing exact identification and evaluation criteria is that such information is held by industry and, understandably, cannot be released.

The metallic group of mineral deposits is more difficult to delineate and evaluate for several reasons. First, in many of the mountain areas, the geology is quite complex, lithologically and structurally. Second, as the name implies, some ores tend to be disseminated throughout the country rock rather than concentrated in discrete veins or zones. Third, deeply buried ore bodies have little or no surface expression, and only careful geochemical and geophysical surveys and drilling programs can detect the subtle anomalies.

One way to proceed is to first outline the metallic occurrence areas in the state. Figure 3 shows the major metal-producing areas and those of abundant metallic occurrences. The region trending northeast to southwest through the center of the state is called the Colorado mineral belt. Drawing a boundary line closely around the mineral belt and broadly around the other occurrence areas would "identify" most of the known and possible mineralized areas. However, this would not be a "practical" way of identification because some counties would be entirely or nearly covered, even though this actually is the case. Some refinements in the boundary of the mineral belt or the most intensely mineralized areas can, however, be made on a county basis. The most obvious MRA's that can be readily identified include those districts currently operating and those that are inactive or abandoned. In the latter there is potential for renewed activity because of the low-grade ore left in the tailings and in the ground and the potential for undiscovered ore bodies in the district.

Our first attempt at identification in a metal-producing area involved the southeastern part of the Idaho Springs district in Clear Creek County (Figure 4). Fortunately a published geologic map of the district was available. On this geologic map we highlighted the ore-bearing veins and mine dumps and plotted the extent of underground workings from available mine maps. An area in which future mining would likely take place was delineated on the basis of 1) most intensive mineralization, 2) concentration of most economically important veins and most productive mines, 3) access to veins by existing tunnels, and 4) current mining interest and exploration. Included in the study were a gravel resources map and a summary text.

Another example of metallic resource identification (Figure 5) shows the general geology and metallic occurrences in a portion of the Uravan mineral belt, an annular belt of uranium and vanadium deposits in southwestern Colorado and southeastern Utah. The U.S. Geological Survey has fairly accurately defined the occurrence area, as shown in Figure 5a. Other important deposits occur, however, just east of the belt and to the west in the interior of the belt. Part of the interior area may be included in the MRA by selectively outlining groups of deposits in the Morrison Formation, which is the principal uranium-bearing rock unit in the region (Figure 5b). A more preferable approach, Figure 5c, involves the inclusion of the entire extent of the Morrison to adequately identify both the known

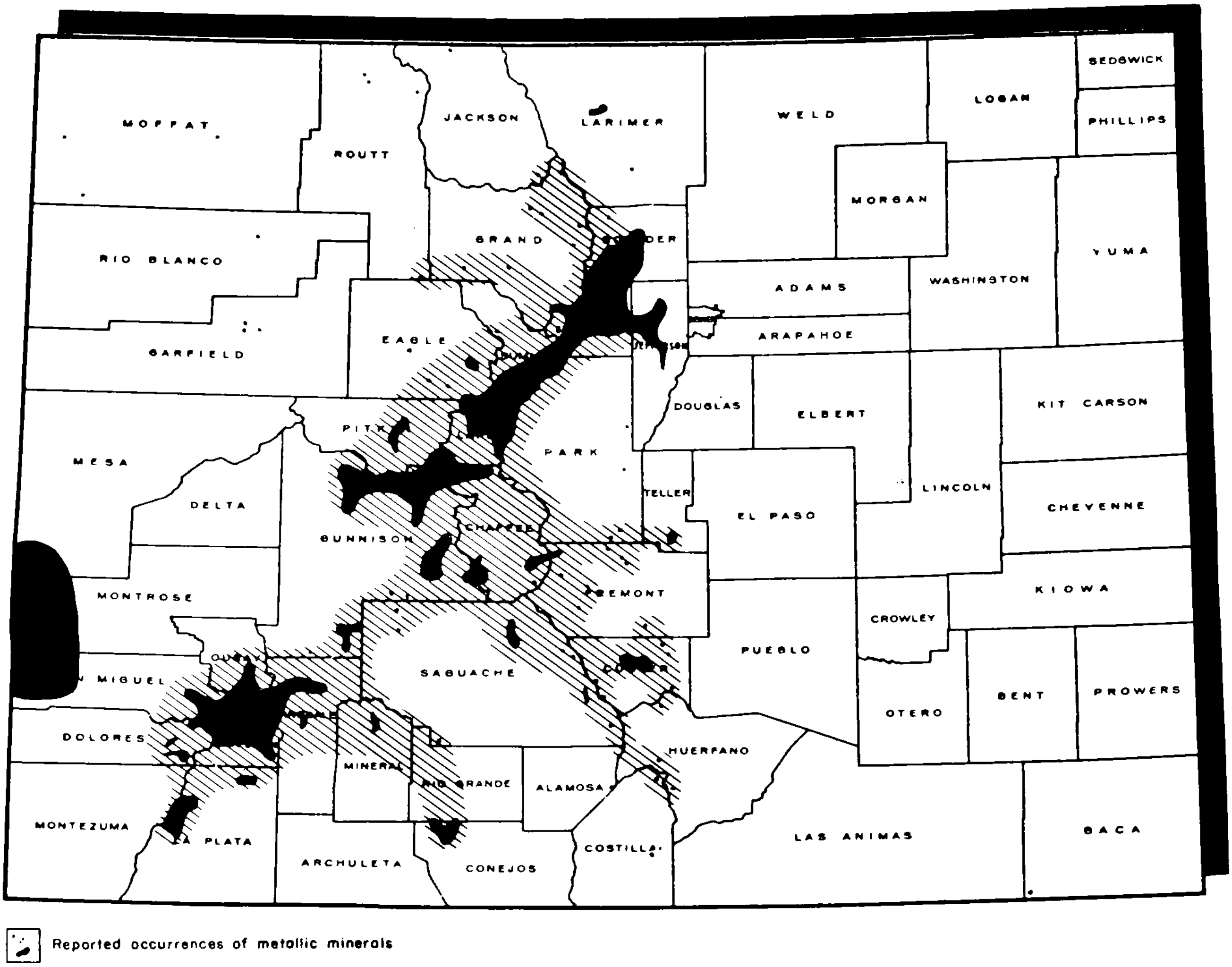

FIGURE 3. Metallic mineral occurrences in Colorado. The black pattern represents metallic mining districts and areas of intensive mineralization. The hachures represent the extent of possible mineralization and areas of other metalic occurrences (potential MRA's) adjacent to the Colorado mineral belt (after Henderson, 1926; Fischer and others, 1947; Eckel, 1961; U.S. Geological Survey, 1971; Marsh and Queen, 1974).

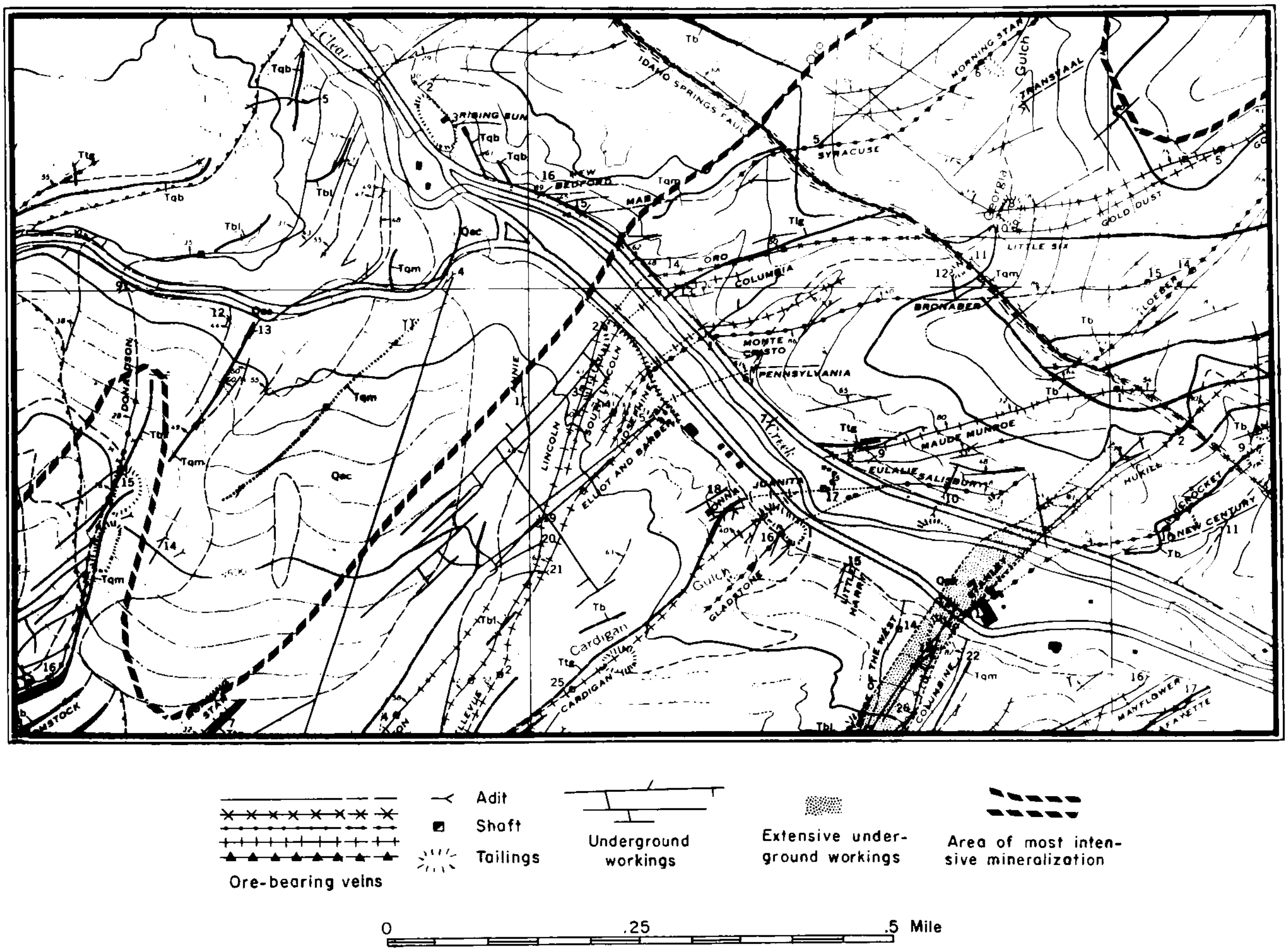

FIGURE 4. Example of identification of metallic resource area in north-central Colorado. The published USGS geologic map of the Idaho Springs district shows the ore-bearing veins, mines, adits, tunnels, and tailings. Available plans of underground workings were then plotted, to scale. The heavy dashed line is the northwestern boundary of the area of most intensive mineralization and in which future mining would most likely take place. (Base map and geology after Moench and Drake, 1966a. Mine workings plotted from Spurr and Garrey, 1908; Bastin and Hill, 1917; Moench and Drake, 1966b).

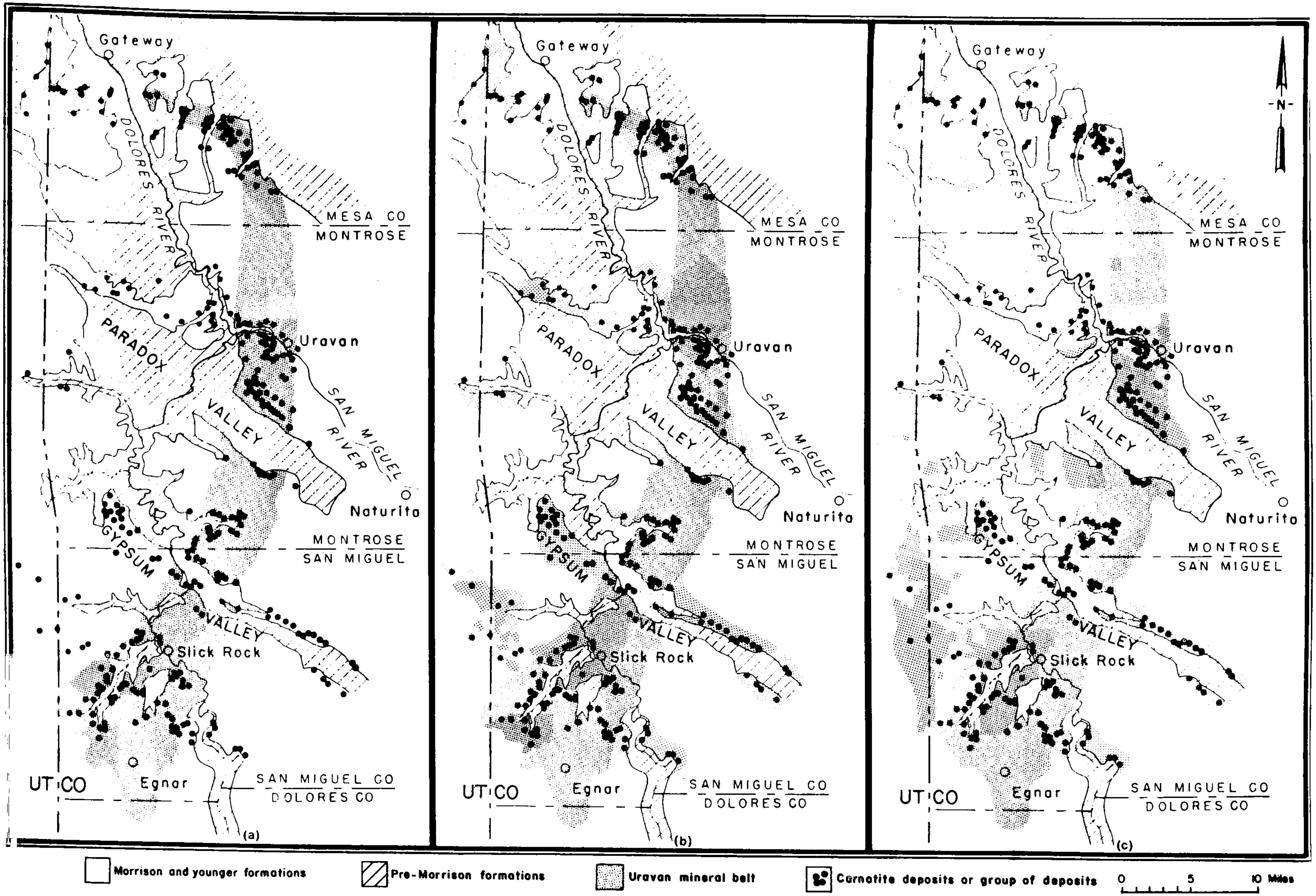

FIGURE 5. Example of identification of metallic mineral deposits (uranium) in western Colorado. (a) The fairly well-defined Uravan mineral belt can be delineated as an MRA. (b) Adjacent to the mineral belt, other small areas of uranium occurrences in the Morrison Formation can be broadly identified as MRA's. (c) To include all known and undiscovered uranium deposits in the Morrison Foundation within the principal mineralized area, the surface and subsurface extents of the Morrison are identified as MRA's. (Base map and geology from Fischer and Hilpert, 1952).

deposits and the undiscovered deposits that are likely present. This same procedure is applied in the same area but at a larger scale in Figure 6, a 1:125,000-scale geologic map of the Paradox Valley area. Here the boundary of the belt was drawn on the basis of the local concentration of known uranium deposits in the Morrison Formation and on the regional trend of the occurrences. To include both those known deposits adjacent to but outside (east of) the belt and those known and undiscovered deposits within the belt, the outcrops of the two principal ore-bearing members of the Morrison, the Brushy Basin and the Salt Wash, have been denoted as the MRA. In most cases, however, this procedure accounts for only those deposits at or near the surface. In the mineral belt and those areas where numerous deposits occur at the surface, it is advisable to include in the MRA those remnants of younger rocks (Kbc and Kd) that overlie the Morrison Formation and therefore conceal other possible uranium deposits.

To summarize, the basic problem with the metallic ores is first one of identification. The complex geology and occurrence of many ores prevent a straightforward circling of the area in most cases. We must look at both the areas that have produced and that are now producing, and the mineralized areas in and adjacent to the mining districts and the mineral belt, all as potential MRA's. The second problem is evaluation, which depends so heavily on economics --namely market conditions, supply and demand, and existing technology.

The bedded and tabular deposits tend to be somewhat easier to identify because the resources occur in definite formations, members, beds, or zones, complicated for the most part by local structure and lateral facies changes. Many of these units can be traced directly from existing geologic maps and from photointerpretation. Although it is difficult to determine what happens to the resource as the bed is projected into the subsurface, mapping the surface exposures and showing the underground projection of the unit at least defines or identifies an area initially and gives one a better idea of the total possible extent involved. Recalling that economics is still the underlying factor, one can say that a general evaluation of many bedded and tabular deposits can be made on a "formula" basis because many of the uses of these materials are governed by rigid specifications, which can be determined through field sampling and laboratory testing. Several examples will illustrate some of these points.

Figure 7 shows the general distribution of oil and natural gas, shallow coals, and oil shales in Colorado. Regarding oil and gas, although some large areas have been delineated, only a small portion of the total land is actually productive. Because of the relatively small surface facilities required and the fact that pipelines can be buried, designation of an oil and gas area will involve relatively small acreages, and such areas can, therefore, accomodate other land uses. Their identification, according to the bill, is conducted by the Colorado Oil and Gas Conservation Commission. Oil shales have been well studied, and the outcrops of the Green River Formation are accurately shown on various maps. The quality of oil shales can be determined with contour maps that show the yield of oil in intervals of gal oil/ton rock. Some areas in the oil shale country are also important potential sources of industrial minerals and evaporites.

With the current economic and energy situation and the tremendous pressure to develop surface-minable coal resources, our basic need in this area is for original, detailed, intrabasin analyses. Although a reasonable amount of data exists for some coal districts, there must be correlations of the individual coal beds from district to district and from mine to mine within each district to better assess the resource picture of the entire basin. Such correlation studies necessitate more drill-core data and more detailed descriptions on the outcrops and in the mines. Field observations should include stratigraphic position, attitude (strike and dip), thickness and lithologies of coal layers, partings, and impurities, notes on vitrain, fusain, and attrital coal, cleats or joints, mineral occurrences, and characteristics of the rock strata adjacent to the coal beds (mine floor and roof conditions). Chemical analyses of samples give heat values (Btu/lb) and the percentages of carbon, ash, volatiles, and impurities (mainly sulfur). Core holes determine overburden thickness and coal bed thickness, give clues as to the subsurface structure, help correlate coal beds, and provide samples for testing. The results of field mapping, drilling, and analyses are then portrayed on various maps, which include depth to individual coal beds (overburden isopachs), isopachs of individual coal beds or zones, carbon ratios, isocarbs, and isovols. The mapping system used in the recent Routt County mineral study (Miller, 1975) consisted of 5 overlapping categories based on stratigraphic position, commercial rank, and thickness of overburden. The Colorado Geological Survey now has two coal studies in progress, and one report on strippable coals is pending in the U.S. Bureau of Mines.

Figure 8 is a portion of an aggregate resources map that was compiled last year by the Colorado Geological Survey to fulfill the charges of House Bill 1529 (Preservation of Commercial Mineral Deposits). In this mapping project, we chose six simple landforms as the basic map units. Each landform was then assigned a number denoting a general category of quality, based on current or past production, field observations, physical characteristics, and other factors. This mapping style is somewhat unconventional but very practical because entire deposits are shown, in contrast to other maps that show only "point" occurrences. The maps, published at three different scales, also include pit and quarry locations, subsurface information, and field observations. By eliminating areas or deposits that are completely mined out, that are already lost to urbanization, that are unfavorably zoned (pre-HB 1529 zoning), and that are subject to higher land-use priorities, local planners may then determine those parts of the original total resource that are still available for extraction or, in other words, the reserves. These remaining areas constitute, therefore, the

Morrison formation { Jmb Brushy Basin member; Jsw Salt Wash member }

— — — Boundary of Uravan mineral belt

• ▲ uranium ore deposits

area underlain by uranium-bearing rocks of ore grade or less portions of the original MRA that should be considered for mineral conservation or, in the case of non-HB 1529 counties, designated.

Another study now in progress involves limestones and dolomites in the state. In this work, we will map individual formations and members at scales of 1:24,000 and 1:62,500, show all quarries and plants, compile production statistics, chemical analyses and references, and attempt to evaluate various deposits for potential uses, namely crushed-rock aggregate, cement rock, fluxstone, and sugar refining.

To conclude, I would like to offer several comments and recommendations. 1) In all categories of mineral resources, there is an obvious need for more basic geologic mapping, for exploration, and for analytical information. 2) The mining and manufacturing industries are in a favorable position to contribute to more of these governmental programs by furnishing whatever basic data, analyses, and evaluation criteria they can, by advising local governments on mining and reclamation concepts and operations, and by acquainting the public more with the importance of mineral resources and the products derived from them. Inasmuch as part of our job is to promote the economic development of the state's mineral resources, we hope that some of these projects will provide important new data, help to strengthen the state's existing mining industry, and encourage new mining and manufacturing opportunities. 3) The Colorado Geological Survey is working with local governments, industry, and consultants to establish convenient map-unit schemes for mineral resources and geologic hazards. We hope that all groups will use these schemes in their HB 1041 projects because maps covering different areas of the state but compiled on a common base will facilitate communication and understanding among all groups at each stage of a project--from preparation, through review, to the final decision. 4) To cope with the difficulty of identification and evaluation of metallic MRA's, the best attempt that can probably be made now is to outline the active and inactive mining districts because of present production from known ores, possible production from known low-grade but marginally economic ores, and the possibility of undiscovered ores. In addition areas of known occurrences and distinct mineralization can be broadly outlined if for no other reason than to "signal" the area until a more detailed evaluation can be done. 5) We feel that in any mineral resources mapping study, it is very important to show initially the entire areal occurrence. The local government can then "overlay" other factors and priorities on this base map and, by steps, reduce that total resource to the actual usable resource or reserve. In this way local government may determine what amount of resource it has to work with for designation purposes. 6) Because MRA boundaries do not recognize political boundaries, there is a great need for intercounty cooperation in the designation phase. The regional planning commissions and councils of governments are effective groups in coordinating such activities. 7) A county with a low population or low development pressures possibly could not afford a detailed mineral resource study or perhaps would not even need one. Every county in the state has, however, some potential resources, and each county should at least be aware of what resources it has so that they can be managed now or in the future. 8) With the limited time and money available at the local level, a county or city should be able to expect some minimum amount of work on a contracted project, or the project would not be worth the expenditure in the first place. For example, a resource-distribution map, production statistics, reserves estimates, references, and some attempt at evaluation would not at all be unreasonable to request and obtain. Whether or not these items constitute a minimum, they are all items that would logically be included in most reports. 9) Because of our limited staff and funding, we can do only so much original work ourselves. We will continue with statewide and regional studies and hope to conduct more site investigations, city-scale and small area studies. We will continue to coordinate activities with the local governments and consultants to obtain the most usable products. Here I would stress that some of this work can be coordinated through the academic community. Within our colleges and universities are many undergraduate and graduate students who could work on cooperative projects with both the local and state governments and at the same time fulfill some of their curricular requirements. Finally, it is important to realize that we, as geologists, will never know all the answers. We attempt to give educated opinions based on the available data--no geologist's word can be taken as the gospel or the final word on an area. The bits of information that are collected and organized over the years, coupled with practical experience, can only add to our overall view of the geological picture of Colorado.

FIGURE 6. Identification of metallic mineral deposits (uranium) in western Colorado. This detailed geologic map of a part of the Uravan mineral belt shows the inferred trend of the belt and known uranium deposits. For purposes of designation, the outcrops of the principal ore-bearing members of the Morrison Formation can be traced directly, thus including the known and the undiscovered deposits. To include undiscovered deposits at depth, younger rock units (Kbc and Kd) overlying the Morrison may be included in the MRA. (Base map and geology after Williams, 1964).

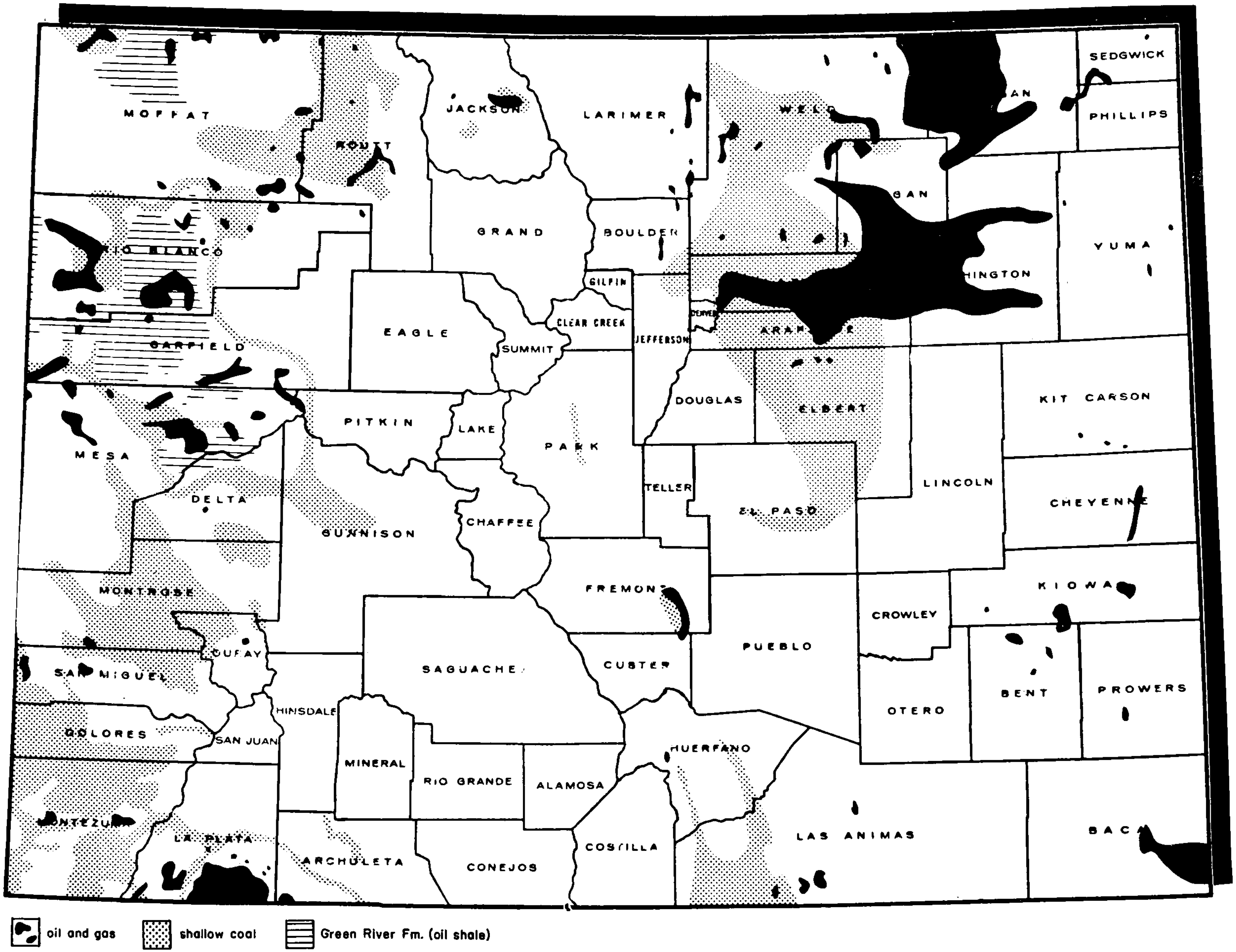

FIGURE 7. Oil and natural gas, shallow coal, and oil-shale resources of Colorado (after Colorado Land Use Commission, 1974; Murray, 1974).

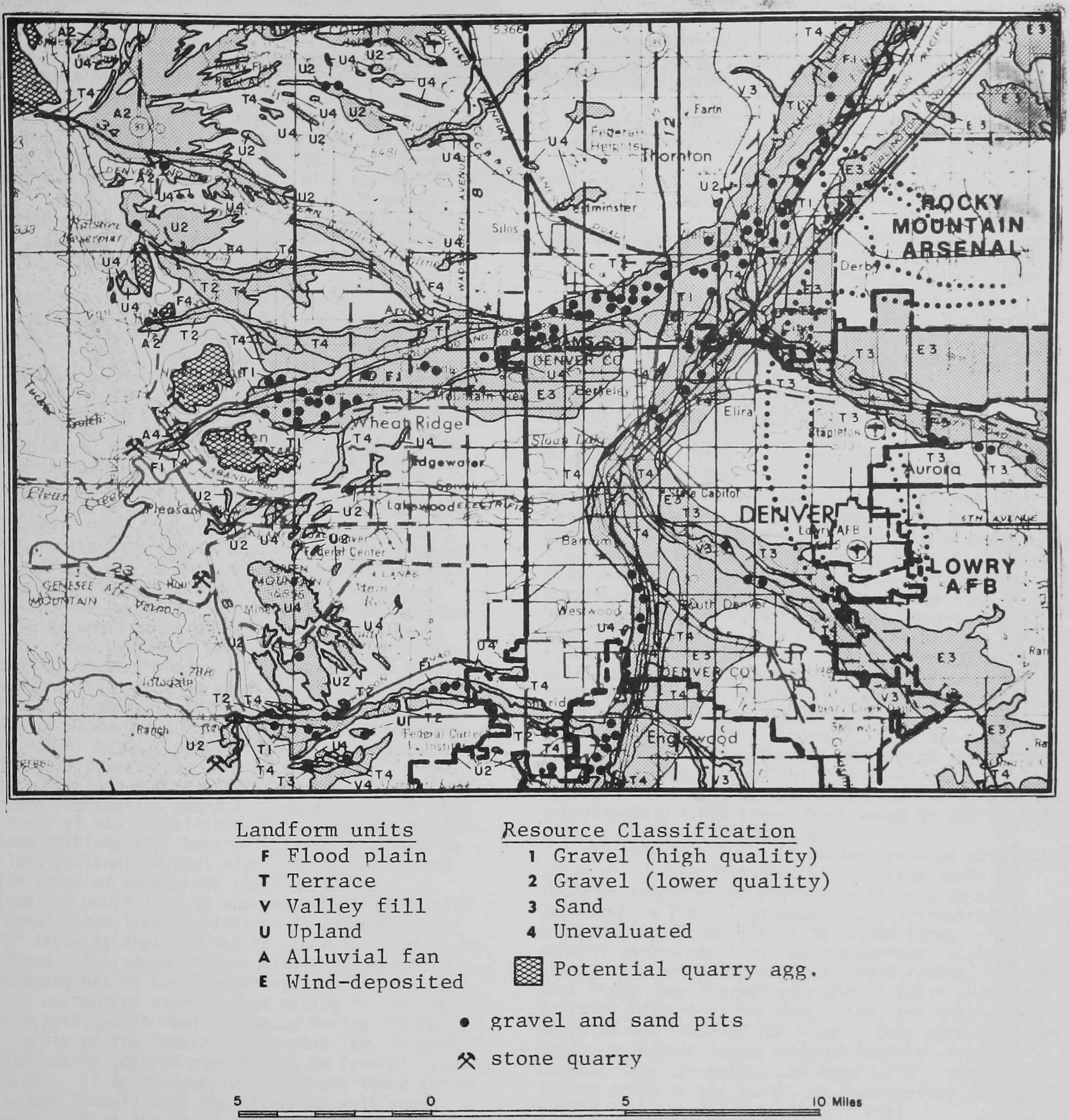

FIGURE 8. Example of aggregate mapping and evaluation in the Denver metropolitan area, a project completed by the CGS for HB 1529. The sand and gravel deposits were mapped as simple landforms, and general evaluations (classification) were determined by various criteria. This 1:250,000-scale map, compiled from the 1:24,000-scale basic-data maps, is useful in regional planning studies for mineral resources (from Schwochow and others, 1974, pl. 2).

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MINED LAND RECLAMATION IN COLORADO

John W. Rold

Director and State Geologist, Colorado Geological Survey

First, I should probably answer the question in many of your minds, "Why is a paper on mined-land reclamation included in a session devoted mainly to House Bill 1041 and land-use decision making?" House Bill 1041 specifically addresses itself to the problems of mineral resources and to the identification, designation and management of Mineral Resource Areas. The majority of people at this meeting are either land-use decision makers or as staff or as consultants, provide information and data to land-use decision makers. Many of those land-use decisions will directly relate to mineral resources and their development. If you are to provide adequate information and make intelligent decisions on mineral resource matters as they relate to land use, you should understand the current status of reclamation efforts in the state. You certainly have the right and the responsibility to know what will happen to that potential mineral resource land after the miners have left.

Another question I think someone will have is, "Why is the State Geologist talking about mined-land reclamation?" As many of you know, I wear several hats in State government. One of those hats is the statutory position as one of five members of the State Mined Land Reclamation Board.[1] As a member of that Board since it was established in 1972, I have developed some opinions and, hopefully, some expertise on mined-land reclamation that might not be associated with the image of an average state geologist.

Today, I would like to address three widely held myths about mined-land reclamation in Colorado. The first of these is that the entire state is going to be strip mined. The second rather widely held myth is that Colorado has no surface-mining laws and that the State has no control over surface mining in Colorado. The third myth, which really came up during the emotional debate on the federal strip-mine law, is that the State has no control over mining on federal lands in Colorado. If we could briefly address those three myths today, I would feel the afternoon well spent.

Let's look at the first one--that the whole state is going to be strip mined. Admittedly, a precise, accurate inventory of past surface mining does not exist. Frankly, we don't know the location or exact amount of acreage that has been disturbed in the past in Colorado. We need a detailed surface mining inventory of both the amount of land that has been disturbed and its present condition. Geologists are used to working with incomplete data; so let's look at the best data that I have been able to find and build some reasonable estimates. An old report by the Department of Interior (Strip and Surface Mine Policy Committee, 1967) contained numerous statistics, some of which related to Colorado. Their data, derived mainly from the Soil Conservation Service, although not too accurate, was rather exact. The report stated that 55,021 acres (Table 1, p. 110) had been disturbed by all types of surface mining in Colorado up to 1965. Most of the experts or people that have some experience with surface mining believe their figures are probably 10 to 20 percent too high. If we accept that figure as 55,000, whether or not it is 10 or 20 percent high or low, it is probably not too important in orders of magnitude. That gives us some idea of what has happened before 1965. What has happened since then? Again, we are not sure because we have no data between 1965 and 1972. In 1972 the Mined Land Reclamation Board was established; so we have some data from its files. From July 1972 to September 1975, the Board issued 141 separate surface mining permits, covering 3,947 acres. Obviously, this was not the amount that was disturbed but the amount the permit allowed. If we assume that 25 percent of these permitted 3,900 acres has been disturbed, we come up with approximately 1,000 acres which added to the 55,000 gives a total of 56,000 acres.

Exactly what types of mining produced this 56,000 acres of surface disturbance? The Department of Interior report cited previously gives a detailed breakdown in Table 1 on page 110. Interestingly, gold placering leads the list with 17,100 acres. People exhibit varied reactions to the abvious, largely unreclaimed placer spoils in Clear Creek Canyon, along the Blue River near Breckenridge and in South Park near Fairplay (Figure 2) and Alma. Some see them as evidence of the "rape of the land." Some perceive the spoils as scenic beauty without knowing or caring whether they are natural or man-caused. Some take fierce pride in the spoils as representing the state's mining heritage and its historic past.

Sand and gravel rank second with 15,500 acres. Assuming the accuracy of the disturbed land figures, and the State Division of Mines' cumulative sand and gravel production value of $501,000,000, a simple calculation indicates an average produced value of approximately $30,000 for each acre of disturbed gravel land. Ponds and lakes of varying sizes and shapes along major alluvial valleys and numerous small pits along roads and highways provide mute testimony to the unreclaimed gravel lands of the state. However, without specific detailed knowledge or careful historic research, few people can detect the presence of the equally numerous reclaimed gravel pits throughout the state. Some of the more noteworthy include: Cherry Creek Shopping Center, Bronco Stadium, Stockyards Coliseum parking lot, Aloha Beach, Birdland Park at 51st and Garrison Streets, Big Thompson Ponds State Fishing Area along I-25 east of Loveland, and Island Acres along I-70 near Palidade.

Stone ranks third with 6,200 acres. The Lyons flagstone, common to old sidewalks in Denver and Boulder, and used in many of our more beautiful buildings in the Front Range area is only one example of stone. Its production resulted in the numerous, readily apparent quarries dotting the Lyons Hogback along the Front Range from Boulder to Fort Collins. Clay's 2,000 acres are most apparent as linear strips along the Dakota Hogback. Material from these scars has contributed to our brick homes, ceramic art works, pottery, and even the ceramic nose cones of the space rockets. The report even lists 25 acres for an open-pit iron mine near Ashcroft. Miscellaneous other unspecified minerals for 11,400 acres complete the total.

What does this reasonably accurate total of 56,000 acres of disturbed land in Colorado equate to? How large is it? For those of you who are familiar with the term "section," there are 640 acres in a section--a piece of ground one mile square. For those familiar with the term "township," there are 36 sections or 23,040 acres in a regular township. The total disturbed lands of the state, therefore, equal altogether approximately two and one half townships. To put it another way, visualize driving down a highway at the 55-mph speed limit for approximately 20 minutes. Then, visualize the lands within 3 miles of either side of the road. That area would approximately encompass the total of all of the lands in Colorado that had been disturbed by surface mining since we became a state. For those who are mathematically inclined, the 56,000 acres of lands disturbed in a hundred years of mining represents only 84 hundredths of one percent of the total 66 million acres of land in the state.

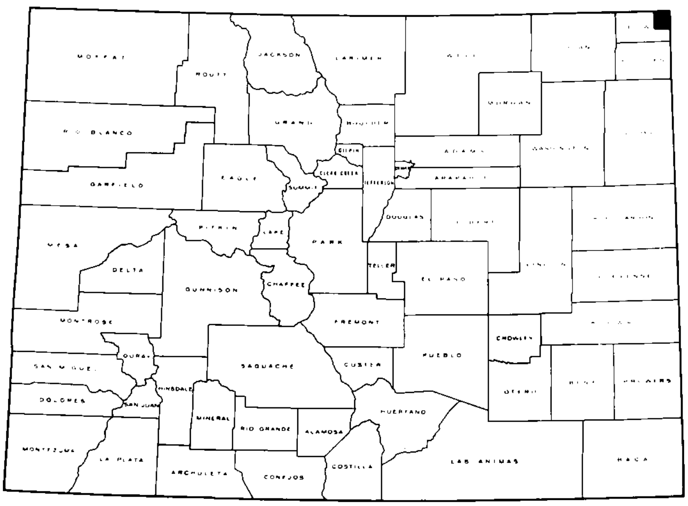

FIGURE 1. This map of Colorado portrays diagrammatically the relationship of surface-mined lands in Colorado to the area of the entire state. The small black square in the upper right hand corner of the map represents the total area (56,000 acres) that has been disturbed by surface mining since Colorado became a state. The entire state covers 66,000,000 acres. Even though surface coal mining and gravel extraction are accelerating rapidly, the entire state is not going to be stripped.

The second myth is that Colorado does not have regulation of surface mining. I heard so much emotional debate over the federal strip mining bill, I began to wonder myself if it were really true. Reclamation laws were first passed in Colorado in 1969. They were strengthened, amended and changed in 1972, when the Reclamation Board was constituted, and again in 1973 when HB 1529 was passed. The Reclamation Board consists of five people: myself as State Geologist, the Director of the Department of Natural Resources as the Chairman, the Chief Inspector of Coal Mines, the head of the State Division of Mines, and one man selected by the State Soil Conservation Service Boards.[2] HB 1529 expanded the jurisdiction of the Old Coal Mine Reclamation Board to include not only coal but also sand and gravel, limestone for construction purposes, and quarry aggregate. To summarize a very lengthy, detailed law, it first requires a permit, which requires a detailed list of items.[3] When one of the people at the conference asked me if there was really much to this permit, I started listing requirements for a permit application. My comment, "Most of those we're getting now are about 3 inches thick." seemed to impress him--that considerable planning and basic information were required for a permit. Second, the law requires a reclamation plan detailing the grading, the planned revegetation and the final land use. Third, the Board then sets a bond that is held against the satisfactory final completion of the reclamation and revegetation. Interestingly, to date, the Board has not yet released a bond on any reclamation plan. In our estimation, the reclamation has not yet been completed on anything. Although much reclamation work has been done,none has been completed or carried out to the stage where we think the operator's bond should be returned. The amount of bond is set at the discretion of the Board--there is no minimum, and there is no maximum. The Board sets the bond at what they believe would be the cost to the State if it were to take over the reclamation at any time during the life of the operation. Estimated inflation of costs is also included. To date, total bonds in the State have averaged about $1,000 per acre. The major problems with the law are not with the law itself, but with the funding appropriated to staff, to carry out the law. The Board is currently writing new, slightly tougher, stronger and, hopefully, more understandable and logical regulations. These will be promulgated in a matter of weeks.

Reclamation of operations for other minerals was addressed in the law of 1969 which is loosely called the "Hard Rock Law."[4] Although not as exact or specific as HB 1529 or the Open Mined Land Reclamation Law, it gave the Division of Mines authority to issue regulations, provided for bond, and provided for reclamation plans. Again, and even more with that law, the problems have been with the funding and the staffing pattern to carry out the law more than with the law itself.

Third is the myth that Colorado has no control over mining on federal lands. The State has exercised jurisdiction over the reclamation of federal lands. The Attorney General issued an opinion that this was legal. Even more importantly, the operators on federal lands have understood that we have jurisdiction, and they are willingly submitting to this jurisdiction. We are issuing reclamation permits and taking bonds on federal lands. Admittedly, a few federal solicitors do approach me quietly and tell me that a constitutional question is very definitely involved. In their minds, the State doesn't have the authority to exercise its police powers over federal lands. This might be true, but from a practical standpoint, somebody had to carry the ball. The Board feels it has the power, and we are exercising it. We have decided to let the solicitors go ahead and get ulcers. We will worry about it some time 10 or 15 years from now when a court case might decide once and for all whether or not we have jurisdiction and the authority. I hope you feel a little better to realize that we are taking control over reclamation on federal lands, and we've had no problems with it to date.

The following pictures will, hopefully, restate some of the points made previously, and provide a background for understanding some of the reclamation problems in Colorado. They were selected from the numerous colored slides used during the oral presentation. The informal, narrative style of their discussion follows that used during the slide presentation.

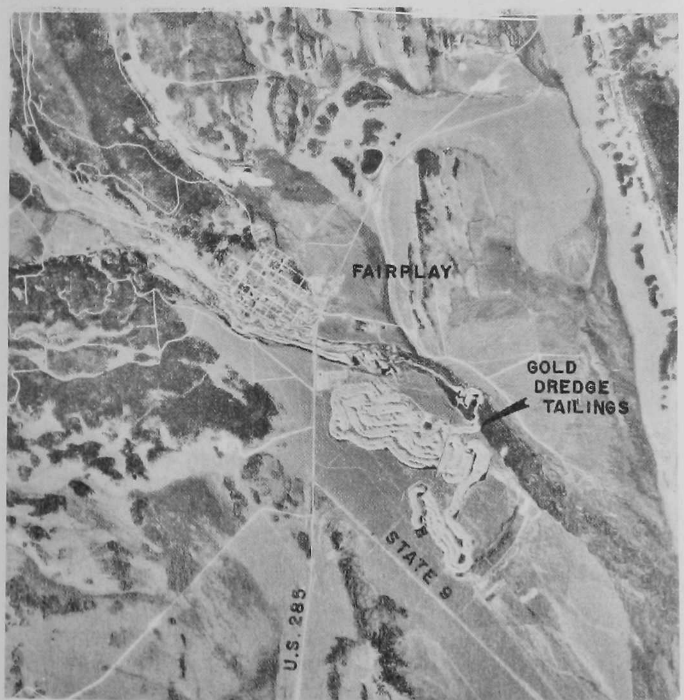

FIGURE 2. This aerial photograph shows approximately 340 acres typical of the total 17,100 acres disturbed by past gold dredging operations throughout the state. The dredge spoils, and the abandoned dredge itself are readily apparent from U.S. Highway 285 and State Highway 9 on the east side of the road 1 to 2 miles south of Fairplay. The wormlike trails trace the path of the dredge where it started in the South Platte River channel (upper right) to its final resting place at the dredge pond (black square at the lower end of the dredge pile). Parker (1974, p. 221, 224) reported that the dredging took place mainly between 1941 and 1952 with a hiatus from 1942-1945 during World War II, and that $3,074,650 in gold was recovered and sold. This would average slightly over $9,000 per acre of recovered value. Today's prices would be 3 to 4 times more than that.

No reclamation efforts were made, and natural revegetation of the coarse boulders is almost nonexistent. Even so, numerous small ponds among the boulder piles have been leased for many years by an exclusive fishing club. Reliable reports indicate that phenomenal growth rates and fish size are attained in these old dredge ponds.

FIGURE 3 indicates the widespread conflicts between gravel resources, their extraction and other land uses in an urban area. HB 1529 was an attempt by the legislature to preserve commercial gravel deposits in the populous counties from encroachment by other land uses until the gravel lands could be extracted and reclaimed. HB 1041 allows and encourages local government to identify various mineral deposits, define them as Mineral Resource Areas, and manage them for maximum extraction of the mineral resource consistent with and compatible with other land uses. Proper reclamation provides an ultimate beneficial end use of the land after the mineral resource has been extracted.

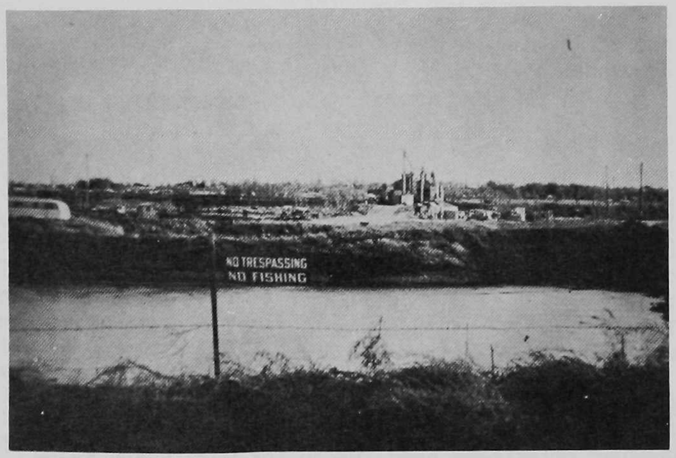

FIGURE 4 represents the too common, but often true, image of an abandoned gravel pit. In the past, many have been an eyesore and a hazard to unsuspecting children and unwary animals. Non-reclamation such as this causes many neighbors and surrounding landowners to object strenuously to proposed nearby gravel operations. Abandoned operations such as this were one of the incentives that caused responsible sand and gravel operators to lobby strongly for HB 1529, and for sound reclamation requirements. They were rightfully concerned that the actions of a few were adversely affecting the image and future livelihood of the total sand and gravel industry.

FIGURE 5. In the past, many abandoned gravel pits have been utilized as trash dumps. In many areas, ground water may become polluted and foundation conditions may cause problems for post-fill construction.

FIGURE 6. Aloha Beach at 3065 West 62d Avenue in north Denver, within a mile of the pit shown in Figure 4, proves that worked-out gravel pits do not have to be liabilities. Although an abandoned gravel pit may never be a "thing-of-beauty" itself, if properly reclaimed, it can attract some "things-of-beauty."

FIGURE 7 shows another beneficial final land use for gravel resource lands. Potential home buyers should have no prejudice against living next to this abandoned gravel pit in north suburban Denver. Fishing, swimming and backyard water skiing represent some of the amenities available to innovative reclamation and development of worked-out gravel lands.

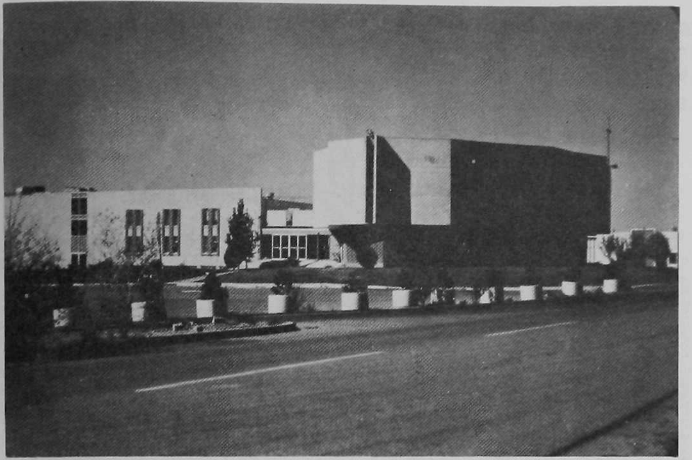

FIGURE 8. This church along the South Platte River in south Denver represents another beneficial, high-value, final land use. Multiple-sequential land-use phases at this site were agricultural, extraction of thick, high-quality gravel deposits, landfill, and finally the church. Numerous similar examples such as the Cherry Creek Shopping Center, many industrial buildings, residential homes, Bronco Stadium, Stockyards Coliseum and even truck farms could also be cited.

FIGURE 9. All steps in an efficient multiple-sequential land-use operation can be seen in this one photograph near Windsor, Colorado. The surface of the gravel terrace in the background is agricultural. Gravel is currently being extracted from the terrace face. Expensive homes in the left foreground and background are already constructed on the pit floor. The landowner here was essentially able to sell his land twice. The top 10 feet were first sold for sand and gravel, and then the remainder of the land was sold for homesites.

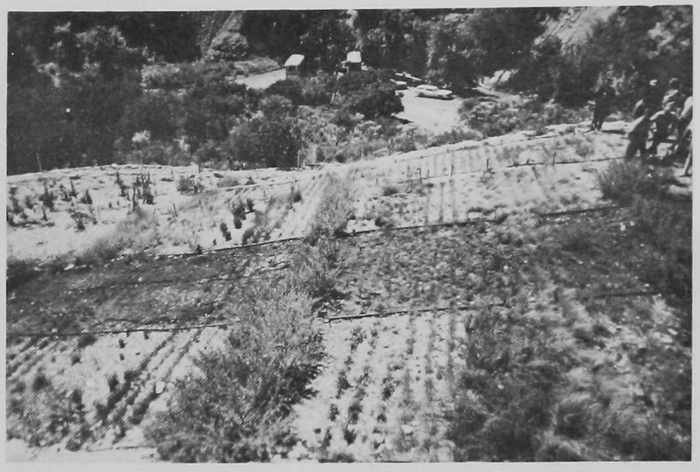

FIGURE 10. Reclamation and revegetation of spent shale from future shale oil extraction represent serious potential problems if and when large-scale production takes place. These test plots constructed by Colony Development Corporation near their pilot mine and retort on Parachute Creek were designed to evaluate and solve revegetation problems. Expert advice from Colorado State University, Soil Conservation Service and industry agronomists was utilized in plant species selection and manipulation of the spent shale. The photograph clearly indicates relative successes and failures for various species of grasses, bushes and trees with varying soil cover, soil mixtures and untreated spent shale.

FIGURE 11 shows test plots constructed by Colorado State University near Anvil Points as part of a Federal- State- and industry- funded research project, "Rehabilitation and Revegetation of Spent Shale and Distrubed Lands." Plots were constructed with north- and south-facing slopes and designed to evaluate various plant species, shale treatments, irrigation techniques and runoff characteristics. The 7-ft

cyclone fence around the plots indicates a problem common to all revegetation efforts. Even partial revegetation success attracts deer, rabbits and livestock which will quickly browse off new growth and stymie the efforts.

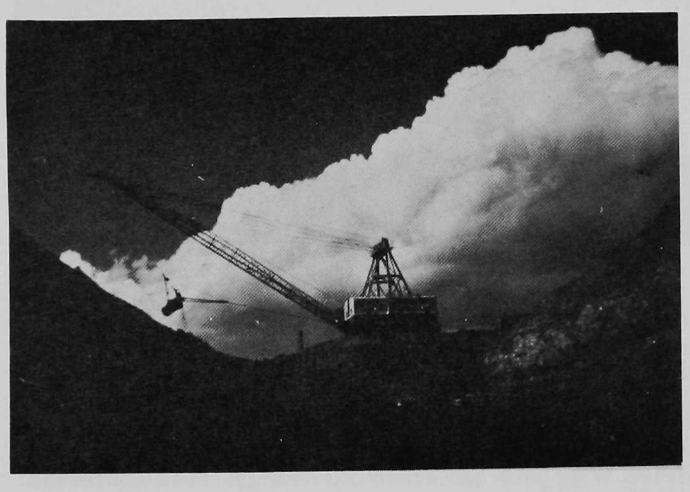

FIGURE 12. Storm clouds gathering behind this dragline at a surface coal mine in Routt County, symbolize the growing reclamation problems as coal production in the state accelerates. Coal production, with an historic high of 12.5 million tons produced in 1918, has risen rapidly from 5 1/4 million tons in 1971 to 8 1/2 million tons in 1975, and can reasonably be expected to double in the next few years. Achievement of that production will depend to a large measure on the economic and emotional aspects of reclamation.

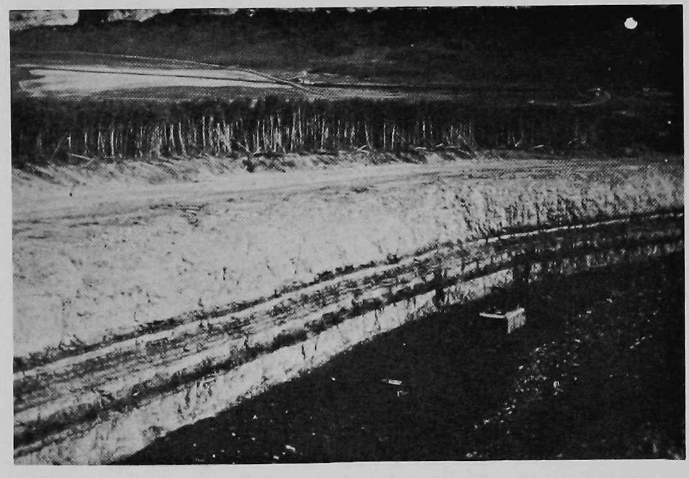

FIGURE 13 shows a view of the "highwall" at a surface mine in northwestern Colorado. The "original ground," in this case a dense stand of aspen, shows in the middle of the picture. The vegetation and topsoil have been removed prior to drilling and blasting the rock strata overlying the coal. The power shovel (barely discernible at lower right) removes coal in the bottom of the strip.

FIGURE 14. Extraction of the coal represents the most unsightly stage in the development process. The row of peaks to the left on the skyline is overburden deposited in the strip from which the coal has been removed in a previous pass. After the coal (foreground of this photo) is removed by power shovels and trucks, the next pass utilizes a dragline to move the overburden from the right to the void where this coal was removed, leaving another row of conical peaks. In the reclamation process, these peaks must be graded to a gently undulating surface to inhibit erosion and provide the base for revegetation. Care must be exercised that toxic materials are buried and not left at the surface. Normally, soil materials are stripped before overburden is removed and are placed on graded overburden from a previous strip. Plant species chosen for reclamation depend on climatic conditions, soil types and the desired final land-use objectives.

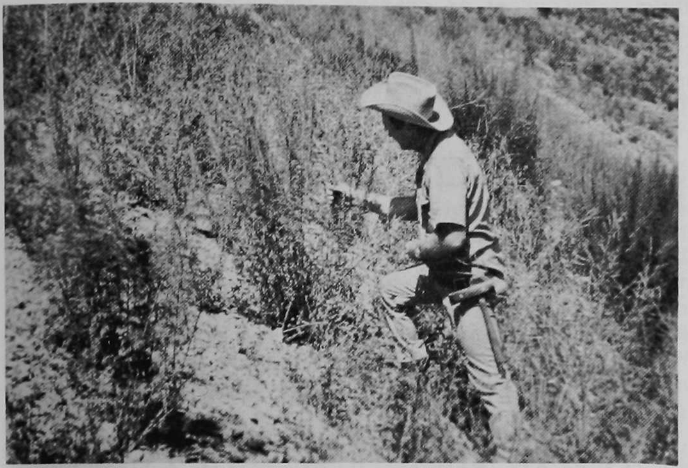

FIGURE 15. Even moderately steep slopes can be successfully revegetated to prevent wind and water erosion and provide forage. In this picture, an exotic species of sage with a high deer-browse value is tested on overburden spoil at a mine in Routt County.

FIGURE 16 shows the working face at the Castle Concrete Co. limestone quarry near Colorado Springs. As in coal, the limestone extraction phase represents the greatest disturbance in the sequence of resource development. An active operation, whether it be a limestone quarry or the home kitchen during preparation of Sunday dinner, usually appears quite messy. Likewise, a limestone quarry--as the kitchen--can be, should be, and now usually is, cleaned up before the operation is finished.

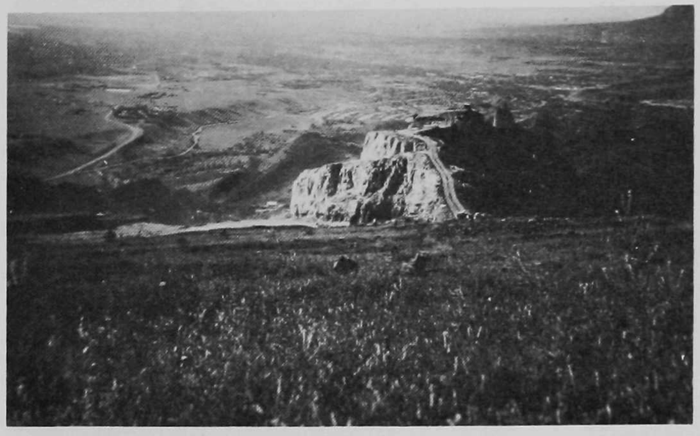

FIGURE 17 was taken above and looking toward Figure 16. The foreground shows the worked out and reclaimed quarry floor of Sawatch sandstone. The active working faces are the light-colored cliffs of overlying Manitou dolomite in the middle ground. The hill, which represents the only remaining limestone reserve in the quarry area, will be completely removed, leaving the smooth dip slope of the Sawatch sandstone, which will be reclaimed and revegetated as done in the foreground. In the background, one can see the rock spires of the Garden of the Gods, and beyond them the city of Colorado Springs. This sets the stage for an obvious conflict. This scenic location, since opening as a quarry in 1956, has provided 65 percent of the high-quality concrete aggregate for construction in the city. It also provides the source of the red decorative stone used to beautify many homes and office buildings in the Front Range area.

Some residents have derisively labeled the quarry "The Scar." A more correct analogy would be that the quarry itself would be an open wound. The healed wound or reclaimed surface, which is barely discernible from the city, should be the scar. Approximately 9,000 residents signed petitions attempting to shut down this quarry in mid-operation because they felt it was aesthetically degrading to the city. Ironically, if they had been successful in shutting down the operation, they would have been looking at the offensive (to them) quarry operation forever. Normal completion of the quarry operation with its staged reclamation will result in an unobtrusive true scar which, in a few years, will blend with the natural scenery.

Significantly, reclamation had begun, final reclamation plans had been designed, and bonds guaranteeing their completion had been placed with the state before reclamation laws were passed.

Another lesson to be derived from this operation concerns wildlife and mining. Most environmentalists and many wildlife experts stoutly maintain the theory that mining operations will drive wildlife from an area. Yet a herd of Rocky Mountain Bighorn Sheep inhabit the area of this quarry. They commonly lie on the sunny south-sloping reclaimed area above the quarry face seemingly paying little heed to the men, heavy equipment and blasting. In fact, heavy browsing by the bighorn sheep and mule deer have seriously hampered the establishment of many types of shrubs and trees.

FIGURE 18. As shown by this photo of an old lime kiln and limestone quarry site above Meredith, Colorado, Nature always attempts to heal its wounds. Probably this view, if taken during active operation around 1900, would have looked similar to or worse than the current active quarry operation shown in Figure 16. Although short growing seasons at this elevation are adverse, ample rain and snowfall and abundant supply of seeds from nearby vegetation have provided excellent natural revegetation over the past 70 to 80 years. Even though excellent success was achieved here by Nature, man can, with proper grading, proper species selection and fertilization, speed the process considerably.

In summary: if one accepts the concept of multiple-sequential land use, how could it be effectively implemented for areas of significant mineral resource potential? How does HB 1041 provide for multiple-sequential land use for the optimum benefit of the community and the landowner?

First, one should identify those areas of significant mineral potential so that they are not inadvertently committed to some other single-purpose prohibitive land use. In so doing, one must realize the difficulty of determining the exact location of yet undiscovered, or discovered but undeveloped resources. In this era of inflation and changing technology, one must realize that an uneconomic deposit, or an interesting mineral occurrence may in a few short years be a county's source of significant employment and a significant portion of the county's tax base. As only one example, many of us can remember when uranium minerals were only of interest to a few academic mineralogists, and to those who were attempting to extract radium. Now it's not only the basis of an intense international weaponry struggle, but the source of considerable present and greater potential peaceful electrical and heat energy. Most of us are now cognizant of the "energy crisis," but few people realize that in the next decade mankind will experience a "mineral resource crisis" that will make our current "energy crisis" look like a Sunday school picnic. The existence and the development of these mineral resources is critical to your county, the nation and the entire society of mankind. The way of life we enjoy today depends on the development and production of energy and mineral resources. Without them, society, as we know it, will pass from the face of the earth.

Secondly, as land-use decision makers, you can assure that the development of these resources proceeds in such a manner that it tolerates and is tolerated by neighboring land uses and land users. Although we as society's land-use decision makers cannot afford the luxury of dedicating mineral resource lands to those uses that deny their utilization, we likewise should not dedicate mineral resource lands so that their development precludes reasonable neighboring land use or prevents a beneficial final use of that land itself.

Third, adequate reclamation assures a reasonable mining plan and realistic achievement of a final land use that will not only coordinate with local land-use planning but will ultimately benefit not only the landowner, the neighbor, and the developer but society as a whole. Hopefully, this discussion of reclamation points the way towards achieving that goal.

QUESTION: I am interested in knowing if an operator on a federal lease proceeded to start to strip mine without appearing before your Board, what your actions would be. Would you stop him?

ROLD: Yes. First, we would try conciliation, and that's always worked so far. The second step is injunction, with the attorney general handling that.

QUESTION: Under what law?

ROLD: Under the reclamation law. Constitutionally-again, I'm not a constitutional lawyer but I've listened to several of them talk about it-on the basis that it is a rightful police power of the State.

QUESTION: On federal lands?

ROLD: On federal lands.

QUESTION: Well, I wish you luck.

QUESTION: Can you apply that same question to land owned or administered by the State Land Board?

ROLD: Our reclamation laws very definitely apply to State Land Board lands and we have no problem there. Now, if you're talking about, "Can the counties make planning decisions on State lands?", I think that you're in an area which is not part of the State Geologist's job. If you want my personal advice, I would say go ahead and consider State lands in your planning process. I think you will find that using conciliation and then coercion, that will probably be enough. If you try to work with those three gentlemen, the Land Board Commissioners, you'll have pretty good success.

QUESTION: Well, to use your example with regard to the federal lands.

ROLD: Well, from the reclamation standpoint, there's no problem. I think that if the counties go ahead and do it, to a certain extent they can work out their problems with the State. I don't see the State Land Board as any dictatorship at all.

QUESTION: Will the profits from oil shale stretch to permit any reasonable reclamation or will they help pay for reclamation? If not, who will pay for reclamation?

ROLD: First of all, it's not clear that there's going to be any profit from oil shale extraction at this time. Secondly, a reclamation bond and reclamation costs will be part of the cost of the operation, the same as digging the shale out. They're going to have to figure the reclamation in the cost of the operation just like the mining costs. The same person that pays for the mining costs will pay for the reclamation costs, and that will ultimately be the consumer.

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1./ After the talk was presented, HB 1065 (34-32-101-124 CRS 1973 as amended) established a new Board effective July 1, 1976, that did not include the State Geologist. For makeup of the Board, see footnote 2./

2./ HB 1065 established a new Board consisting of seven members: The Executive Director of the Department of Natural Resources who shall serve as secretary to the Board, a member of the State Soil Conservation Board appointed by such Board, and five persons appointed by the Governor with the consent of the Senate. Such appointed members shall be three individuals with substantial experience in agriculture or conservation, and two individuals with substantial interest in the mining industry.

3./ For current legal requirements of reclamation, refer to HB 1065 (34-32-101-124 CRS 1973 as amended), and the lengthy Regulations of the Mined Land Reclamation Board.

4./ Hard rock minerals were put under jurisdiction of the Reclamation Board with 1976 passage of HB 1065.

OVERVIEW OF HOUSE BILL 1041 PITKIN COUNTY, COLORADO

Hal Clark

Pitkin County Land-Use Administrator

I would like to welcome you to Pitkin County, if no one has taken the trouble to do that. We're certainly pleased to have the Colorado Geological Survey have its conference here. I've attended several other conferences put on by C.G.S. over the last several years, and this is definitely the biggest conference; it's also the best conference. In Pitkin County we don't normally relate those two terms very well, but in this particular instance I think that they are compatible.

First of all what I think I'll try to do for you is to set the stage of Pitkin County as HB 1041 burst upon us. Karen Smith will then elaborate more on our responses to 1041.

I would like to give you a little physical overview and let you know what impacts have occurred in Pitkin County; the threshold crossings that have occurred as far as our public facilities are concerned, and also our general reaction to those threshold crossings, planning efforts, and so on. Then, as I said, Karen will introduce you to some more of the specifics about 1041.

Pitkin County consists of 975 sq mi, 80 percent of which is U.S. Forest Service or U.S. Bureau of Land Management properties. The importance of that is not, "My God, you've got 80 percent Federal land, what are you worried about?"; the importance is that 20 percent of that is private land, and that's about 200 sq mi. It consists of virtually all the valley floors and all the prime developable property. Our situation is that we think that the Federal lands, which are the 80 percent of the county, are impacting the 20 percent, and I would like to tell you what I mean by that. First of all, we think we should be able to qualify for Federal funds for an impacted area. I grew up in the Washington, D.C. area, and I remember that every year they would circulate a petition to the school children asking whether your parents worked for the Federal government or not. If you signed "yes" and your school had a certain ratio of Federal employees, we received a money bonus every year from the Federal government qualifying as a Federally impacted area. Well, we think that Pitkin County is a Federally impacted area, and we think so because of a variety of reasons. The major reasons are the following: the Forest Service grants permits for ski areas in Pitkin County; they have numerous public camp grounds in Pitkin County; we have mining activity that is basically controlled by the Federal government and leased by the Federal government; we receive highway funds which, of course, are 90 percent financed by the Federal government; and, we have one large water reservoir project Federally funded and several other proposed dam projects (Bureau of Reclamation projects mainly for water storage and water diversion). Our view of it is that we've had to spend considerable time lately trying to keep track of where our water is going. We looked out our window about two weeks ago and noticed that for a mile stretch of river through the Town of Aspen, the river was completely dried up. I will just let that sink in for a minute, and let you think about what it's like to live next to the Roaring Fork River and wake up to find it completely dry. We are involved in water diversion fights, water rights, etc. Anyone who is familiar with water rights law knows that it's a terribly complicated problem.

These impacts which I've summarized have created substantial problems for Pitkin County, and these problems, I think, are summarized by the following set of statistics. We have a state highway serving the City of Aspen that's generating the use of 22,000 cars per day in the summer months on a design capacity of about 5,000 to 6,000 cars. It's difficult to analyze the design capacity of a highway these days because highways generally fluctuate depending on their maintained condition. So, we consider that we have a significant traffic congestion problem coming into the town. We had word from the State that if they fully began an implementation program to correct or improve the highway, it might take as long as 20 years to complete because you can only build about a mile of highway at 8,000 ft in any given year.

In addition, we have a hospital that has been threatened with closure by the State Health Dept. for numerous deficiencies, mostly overcrowding. Our local jail was built in 1907 and looks like a birdcage. We have the second highest cost of living in the U.S.--not continental, just the U.S. The highest cost of living (to no one's surprise) is in Fairbanks, Alaska. We also, I might add, have the highest cost of housing in the U.S., including Fairbanks, Alaska (from a recent Chamber of Commerce study). We also have, and I should mention this because I think it's extremely important if you are involved in public service, an extremely high rate of hard drug usage and a tremendously high rate of venereal disease. City hall and the county courthouse were built in the late 1800's, and you can imagine what kind of a physical plant that entails. We've had significant population increases.

Let me summarize some population figures from 1967 to 1972. The population has increased at an average of 15 percent a year, which creates a doubling in less than five years. In 1960 the population of this area was 2,381; this year it is estimated at about 14,000. We have a winter peak population of about 28,000 people. Our skier visits have been averaging an increase of 22 percent a year for the last five years. Government spending is averaging an increase of 17 percent a year. Our law enforcement costs are averaging 20 percent increases per year. Real estate values are increasing at an average of 22 percent per year. A basic fact is that we have been the fastest growing county in Colorado during that period from 1967 to 1972.

I wanted to let you know those facts because we think we have serious problems in Pitkin County and in Aspen, and we constantly are catching a lot of flak from people who are wondering why we are taking such a hard slow-growth attitude. I think you really have to look at those growth rates to better understand why Pitkin County is taking such, I guess for lack of a better word, a radical approach to land-use decisions. We feel we have had a crisis for the last five to eight years, and in the last two or three years we have been reacting to that crisis.

Now, let me summarize what we've done to react to those growth figures. Approximately two years ago the residents here elected two county commissioners who both ran on very strong slow-growth or anti-growth policies. One of the first things they did was to review the existing zoning which was initiated in Pitkin County in 1955 and really had no relation to the kind of world we were seeing in 1975. They immediately decided that we had to drastically reduce the allowed densities on that zoning plan. We cut the allowable densities from something like 400,000 to about 40,000 people. We significantly down-zoned high-density areas in the Snowmass and Buttermilk areas, and in the County areas around the Town of Aspen. As a result, we got ourselves involved in $40 million worth of litigation initiated by private land owners. Nick McGrath, our County attorney, is speaking to you later this afternoon concerning the status of these law suits. I'm named in most of the suits so I'm fairly well aware of the progress of the suits. To this date, we have not lost any of the suits that have been filed against Pitkin County. Second of all, all the suits except one that I can think of (and there were about eight or nine) are not proceeding with any haste. They all, in effect, were filed within about a week after the down-zoning, and that was over a year ago. None of the people who are litigating against us have proceeded to pursue those suits, except one, and that's the Aspen Post Co. Most of these suits were brought in part to "establish their rights" to sue.

Another interesting figure for Pitkin County is our legal budget which has this year gone over $160,000. To put that in perspective, Pitkin County has an annual budget of $5 million, which includes several large FAA grants for airport expansion. A great part of that $160,000 figure are substantial sums we are paying to our water attorneys who are defending our water rights and keeping water in the Roaring Fork valley, the Crystal River valley, and the Frying Pan valley. People on the eastern slope feel that they are running out of water, and they have to extend their diversion projects (Twin Lakes). We have taken an absolutist policy of totally opposing any further diversions from the Roaring Fork Valley, and it's costing us a great deal of money.

What has the Pitkin County planning office done to counteract these impacts? We have updated our 1955 Master Plan. We have adopted a trail system plan for the county and for the city, and in the last two years we've spent almost a half million dollars in the construction of trail systems around the City of Aspen and leading away from the city into the county areas. The concept is to try to create a pedestrian transit system for the city so that one doesn't have to have an automobile when in town.

If you wonder what that construction is right next to the road outside of this building, it's a trail that's being constructed this summer that will connect on up Ute Ave.; cross to the children's park; cross the river; and then go over into Highway 82 and connect up with the suburbs on the other side of Highway 82.

We've initiated a Roaring Fork greenway plan and urban runoff management plan. We've adopted floodplain regulations, stream-margin review criteria, and 160-acre zoning for large parts fo the Pitkin County area. I might add that 160-acre zoning, I think to everyone's surprise, was initiated by a group of ranchers in Pitkin County to help protect their ranching lands in Snowmass and Capitol Creek valleys. Since then we have been expanding that concept to other areas, and there are proposals now for the Woody Creek area and the Frying Pan area to receive 160-acre zoning.

We have established viewplain corridors in the city. We are rewriting our land-use codes for the county to combine our zoning, subdivision, and building permit review regulations into one, hopefully, understandable document. Karen Smith, who will be speaking to you next, is mainly in charge of that program, and with the integration of HB 1041 into those codes. We've also received from C.G.S. and other sources a substantial amount of environmental data for this area and Bruce Bryant's (USGS) quadrangle maps, which most people have probably seen. The CSU environmental resource analysis maps, present environmental data for all of Pitkin County; and, we have received additional geologic amps for the Aspen-Glenwood area. We've created and implemented a sanitary landfill plan by starting a recycling program at the site. We are storing areas of different recycling potential so that a future date when it becomes economical, we might have a way of extracting them for reuse. We've introduced energy conservation regulations, written an insulation code for the county and adopted a master plan for the airport. We've also crossed various public facility thresholds. Basically, the reaction of government to growth kind of goes on a threshold basis where there is a certain amount of operating cost that is increasing every year. There is also a threshold cost where, in effect, you come to a point where you have to build a new hospital; you have to build a new police office; you need to build a new jail; you need to build new school systems, and so on. We have reached a point in the last two years such that in 1975 we initiated construction of a new airport terminal, which I think many of you saw yesterday who were on that field trip, and we broke ground for a new hospital last Monday. We have completely remodeled the county courthouse, and by the way, if you want to see an interesting building, I thoroughly recommend that you go and see it. We spent almost $300,000 remodeling it in the last year and a half, and basically it is in the Victorian style and very attractive. We are remodeling City Hall; we've increased social services by adding human resource directors and housing administrators and by increasing law enforcement programs. We've started a program of open-space acquisition. The City has spent over $7 million in the last three years on open-space acquisition. The principal purchases were the golf course property immediately west of town and the Rio Grande property which is below the courthouse. We've expanded the sewage treatment facility, rebuilt the City-County dump which I've already spoken about; we've installed an intra- and inter-city bus system, which, if you haven't had the opportunity to ride one of our many buses, I thoroughly recommend that you do. It's quite an experience. If you can find the double-decker, ride in the second floor of the double-decker, and if the girl will let you, kind of sway a little bit, and you'll find it's kind of an exciting experience. We were going to use some from here to Snowmass, but we're not sure that we can make the corners with them so that we're going to keep them inside the city limits.

In essence, that's kind of what's been happening in Pitkin County. We've had some major impacts and major public facility problems. We have a lot of old locals who are just simply leaving because they just don't like the amount of change that has occurred in the town. I think that the "quality of life" is a very vague and probably overused phrase, but we are very aware of that phrase in Pitkin County and we are quite involved in a struggle to try to preserve what quality of life we have. I might add that when I was writing this speech this week, I was thinking of ending the progress section of HB 1041 right there and turning it over to Karen because it occurred to me that one of the problems that we are having with HB 1041 is what do you say to your regional planner when he says, "What have you done under HB 1041?" What I've just run through is basically what Pitkin County has been doing for the last 5 to 10 years. We've had tremendous impacts; we've been reacting as fast as we can to the impacts; we have been extremely active in the land-use field and I think everybody can agree on that. We've enacted about every regulation we could possibly think of, but literally when it comes to answering the question, "What have you done under HB 1041," we inevitably kind of pause because HB 1041 is such a vast and complex bill. It's a bill that's caused us a lot of internal confusion in Pitkin County. I might add just quickly before Karen goes on with our latest thinking on HB 1041 what we have been doing as part of our initial HB 1041 work program. One was simply to extend the flood-plain designation along the streams in Pitkin County. That's an item that we've been involved in for over a year, and frankly as of today we haven't finalized that with the Water Conservation Board about getting matching money; so that's been somewhat unsuccessful. The crux of our HB 1041 program really was in this mapping system, and I didn't know we were going to have so many people here at this conference; otherwise I would have taken my slides and turned them on the wall. Just to briefly summarize our mapping concept, Pitkin County felt that its major land-use problem was to assimilate and coordinate what it had done to date. We didn't think that we needed to run out and do five million additional studies and identification matters. We've had a lot of that done. We've written a lot of laws and a lot of regulations. We thought our biggest problem was assimilating, coordinating, and making understandable the laws that we already had in effect. And we've attacked that through two means: One, hiring Karen as a consultant to redo the land-use code. Then secondly, we had hoped to get together a composite mapping system for the county. We've been involved for two years in that effort, and I can look at you now and tell you that it is nowhere complete today. The system is to computer map all the private property ownerships in Pitkin County. Anybody that has ever dealt with computers and with mountain surveying will understand some of the problems involved. We were going to map on a 1 in.= 200 ft scale all the private properties in the county, overlay them with environmental data and the current zoning and use them as a composite map. There are benefits, and there are also problems with this, as I am sure the Colorado Geological Survey would like to point out. The basic benefit that we saw in this approach was to give the public a way to relate to the physical constraints that exist on their property. They could see the survey of their property, see exactly how it related to the constraints, and get a general idea of what they could do and what they couldn't do. We'd have excellent mapping of the zoned areas. We would have excellent planning maps. We'd have an ability to combine all of our land-use data on one set of maps rather than fumble around through the filing systems looking for the maps of such and such studies that were done years ago. We would have it all on one set of maps. Well, that was a grand and glorious process. The problems that we have had with it were: 1) that the computer keeps throwing out all the surveys and won't accept them for maps; 2) the specialists who have done our environmental data work have been very reluctant and understandably so, to change the scale of their mapping work. The study was done on a 1:24,000 scale and they have been very reluctant to transpose it to a 1 in.= 200 ft scale, which I'm sure you can understand. The accuracy level really degenerates. I understand that, and I accept that as a deficiency. We thought we would deal with that just with a variance mechanism in the code, so that in effect, the person's responsibility would be to show us that a constraint does not really affect his property. If he could show that, then, in effect, we would proceed with the development. But, we did think that it was necessary to get an overlay so that we could have a centralized system showing people what were the problem areas of their property. That's generally what that mapping system is about. The problems with the computerization of the surveys have been substantial, but we have been very successful. I think that in essence the progress we have made under HB 1041 is very nebulous because I think Pitkin County has made substantial progress in land-use legislation without HB 1041.

PITKIN COUNTY
PROGRESS AND EXPECTATIONS

KAREN SMITH

HB-1041 Administrator, Pitkin County

As Hal said, I was to take over and talk a bit about progress and a lot about expectations under our HB 1041 program, specifically. Or maybe a better title is, "What do you do when your mapping system fails". I was just looking over the program and noted that John Birmingham is speaking this afternoon, and then I noted the title of his talk. For some reason, while we are both talking about HB 1041, his title is, "Land Use Commission: Progress and Plans", and our title is, "Pitkin County: Progress and Expectations". I guess that means we're both moving forward, but one of us sounds a bit more sure of where we're going.

As some of you may have surmized from the field trip yesterday, in Pitkin County one doesn't know what to expect from one day to the next unless it's the unexpected. I suppose that is to be expected when you're breaking new ground. We broke new ground when we proposed the train system to the Urban Mass Transit Administration, a proposal that two years ago would have been laughed right out of the mailbox. We did that with the down-zoning effort, and HB 1041 is no exception.

In my brief tenure here I always expected that Pitkin County was going to accomplish the objectives of HB 1041, but I cannot yet anticipate exactly how we are going to do that. Nevertheless, I think we have crossed many bridges and made a lot of progress in our own interpretation of the best way to handle matters of state and local interest, and we would like to share some of that with you with the hope that your expectations will be somewhat more assured.

Pitkin County had long ago, as Hal mentioned, even before the passage of HB 1041, decided that many of the matters of state interest were important land-use considerations. The Commissioners had decided to identify hazard and resource areas, even before the first $25,000 of funding under HB 1041 was in the mailbox. We did this in the form of the CSU report that Hal has mentioned, and the accompanying maps. For that initial investment, we got identification of many of the matters of state interest and a good start in our HB 1041 program. In addition, Pitkin County some time ago, as Hal also mentioned, decided that its land-use regulations were fairly outdated. The prospect of adding a new set of regulatory procedures and criteria having to do with matters of state interest under HB 1041 to an already overlapping set of zoning and subdivision regulations was mind-boggling. So the Commissioners decided that a consolidation of regulatory mechanisms was in order. The first draft of that was prepared by the Rocky Mountain Center on the Environment and later modified by me. In the interim, HB 1041 had been passed, so we decided to throw that into the pot as well. The two events together, the mapping and Code work, formed the foundation of our program for HB 1041. By the end of this year or early next, we hope to have a code adopted that utilizes the available identification of hazard and resource areas, and new identifications of certain key facility areas. We hope that this Code will put us in the business of administering these areas and activities of state interest by early next year.

Here are some of the features of the system that I think would be helpful to you all. For identification we are using the available material, as I said. First of all, the CSU maps, which were prepared on a scale of 1:36,680, cover wildfire hazard areas, wildlife habitat, for the time being just for big game areas, and geologic hazard areas. The only exception to use of the CSU report will be for snow avalanche areas in the Aspen quadrangle. Art Mears has recently completed a more detailed mapping, and we will substitute that map for the CSU maps in the areas where they overlap. Mineral resources: we have the USGS maps prepared by Bruce Bryant for the Aspen quadrangle. If you were on the field trip yesterday, you know how good those are. And, we have the CGS maps for the remainder of the County. We know that we are somewhat deficient here, and this will probably be one of the aspects of further identification, or refined identification, that we will undertake over the next year. Also, there is a problem here in that we are mixing the scale--the USGS maps are at 1:24000 while the CGS maps are at 1:48000. Hal mentioned the flood plain identification; we've got two Army Corps of Engineers studies. We are undertaking a third, detailed engineering study from Aspen to Basalt. We have an historical sites inventory and, as I said, the Planning Office is now mapping areas around key facilities, for example, around the airport and certain transmission lines, and around proposed mass transit routes.

We know that some of the information isn't as accurate as it could be, but it's available, and it's all we've got, and I don't think, frankly, that we are ready to spend a penny more of money in addition to the probable $100,000 we've already spent on this program to restudy anything until we see how what we've got works.

The second aspect of our program is that we have nearly completed the Land Use Code, which replaces the separate zoning and subdivision regulations with a consolidated procedure for all development application review, and which also adds the criteria for evaluating and regulating areas, such as geologic hazard areas, under HB 1041. We don't have all the guidelines that would be useful from the State. For example, the geologic and mineral resource guidelines from CGS are probably among the best--if not the best--guidelines that we've yet received from the State. While they are truly informative on how to identify a hazard area and help laymen like most of us planners and HB 1041 administrators to know why it's important to regulate an area and just what we are regulating, they fell short when it comes to giving us substance as to how to mitigate a hazard condition, for example, or what to require an applicant to submit in order to demonstrate mitigation of hazardous conditions.

Nevertheless, we have incorporated guidelines for administration of areas of local and State interest within the Land Use Code. These guidelines supplement the requirements of the underlying zone district and effectively make any development proposal within an adopted area a use permitted only by special review. Thus, the HB 1041 permit system is integrated with our existing special review procedures, which, in turn, are integrated with all other zoning and subdivision procedures. Thus, if an application involves a PUD subdivision in a geologic hazard area, the hazard problems along with other considerations are reviewed at the first phase of a three-step review procedure.

The third aspect of our program, and this is where the great expectations come in, is that we are planning to hold a hearing, probably in November, on all 21 matters of State interest. It's a new aspect of our HB 1041 program and frankly, it really lit a fire under some of us when one of the County Commissioners proposed it. Basically what we are saying is, let's get it all out on the table. We may, in fact, at the conclusion of the designation hearing decide not to regulate a matter of State interest. We may, in fact, choose at the conclusion of this hearing--which we hope to conduct jointly as a designation and rezoning hearing--to go the route of zoning or HB 1034 rather than designation and regulation under HB 1041. The main point is that we're going to accomplish all the objectives of HB 1041. Then again, it really doesn't matter which way we go in terms of the Land Use Code. The regulations and the procedures will really be the same, and the only difference that HB 1041 adds is a slight headache to those of us who are drafting the Code to go back through and make sure we have met all the hearing and notice requirements of HB 1041.

The fourth aspect of our program over the next year will be feedback on how the program is working with the available information, undertaking further identifications in areas where we now know we are slightly deficient, undertaking further identifications in areas which become apparent as being deficient. I might add that in the Code, we provide for the applicant proving that our boundary line is wrong whether it is a designated boundary line under HB 1041 or whether it's an adopted district under HB 1034 or zoning enabling.

Let me conclude with one last thought: We've all been pondering the ramifications of HB 1041 for a long time now. We've been mystified by the legal questions left by that act. We've been trying to interpret the legislative intent. Lastly, we've been trying to second-guess the LUC and various State agencies in their future guidelines and model regulations. Some of us have forgotten that HB 1041 is basically a local bill and still leaves a lot of discretion up to local governments on how to regulate within the intent of that act. At some point, you simply have to stop pondering and do something. We're saying that we are at that point, and we are not exactly sure how it's going to come out, but we're not afraid to go ahead and try it. We would hope that our experience is positive and will encourage many of you to do the same thing.

CAN MESA COUNTY SUCCEED IN LAND USE REGULATION

JAMES P. KYLE

Mesa County, Land Use Administrator

I wonder just how deeply I should go into my philosophy of land use since I am pretty much of a novice at the political game. Before we continue this morning's session, let me assure you that I am going to try to do my part in putting you back on schedule.

Let me give you just a little bit of background on how I got into this land-use administrator's job in Mesa County and perhaps that will explain some things that I could not otherwise explain.

I have lived in this beautiful country, in Colorado West for a little over 34 years. I came here during World War II and established residence, and returned immediately after the service, establishing a small business in Grand Junction, and went from there into a number of fields. The lumber business, contracting--I've had the opportunity of building in or around nearly every community in Colorado West. The Upper Colorado River Basin Storage Project is operated by a microwave control system. It was my privilege to build most of the foundations and set most of the microwave buildings on the system, so I have learned about the land of Colorado from the builder's point of view. For the past 7 years I have been in public relations. Now, I'm getting a liberal education from a technical point of view that I never dreamed of getting. What I am trying to convey is that I feel very much part of this country.

As a land-use administrator looking at the subject today, can Mesa County regulate the use of land, I submit that they have been doing it ever since Mesa County became a county back in the 1880's. In 1879, a couple of scouts for George Crawford, who was the governor of the Kansas Territory and moved out here to develop Colorado, came from the town of Gunnison, down the Gunnison River, to the confluence of the Gunnison and the Grande (at that time it was the Grande River and not the Colorado). They discovered that here was a very natural building site. In those days the ideal building site was close to water and in the middle of some flat lands in a place open enough that the Indians couldn't come in and scare you at night. This was a good place to start a community. There was no law or regulation that told the early settler how or where to build a new community. In 1884 the first H.B. 1041 problem arose--a big flood happened. This flood wiped out the new town, which had been built. From that point on, the development of Grand Junction took place on a little higher ground. The next step in land use was a decision that without irrigation water, Grand Junction would have very little chance to survive. I'm speaking of Grand Junction because this is the major point of Mesa County development today. There were many, many ideas on the kind of an environment that should be created. The railroad created a shipping center for the surrounding communities and areas which were developing at the same time, such as Collbran, DeBeque and Palisade. Others found that with a little water they could grow some beautiful orchard crops--apples first; then peaches a little later. Agriculture won the battle. Valley farmers organized a water company and put in the first phase of the Highline Canal, which later on became a federal project. This made the valley one of the more beautiful and profitable agricultural areas. It was also a great place to build a home. But nature entered into land-use decisions again. Apple trees began to blight, and orchards began to decline. They were pulled out one by one and replaced with sugar beets, tomatoes, alfalfa and garden crops. Palisade became the major area for the fruit industry and still exists as such. Nature plays a vital role in determining land use. Perhaps that's why the good Lord put man here--to overcome and conquer the land according to our concepts and needs. No easy job, is it? Regarding the avalanche areas we saw yesterday, are we going to try to control those avalanches so we can develop on them? I can't imagine an avalanche being a natural resource, especially a developed resource.

One of the greatest hazards of all is the loss of prime agriculture land. That isn't even mentioned in H.B. 1041. Is it possible to protect a peach tree the same as we would protect an eagle?

The legislature addressed itself to the <u>activities</u> of state interest. It is intended that we <u>look into</u> the future and set aside areas that are going to be required in future development and for orderly growth of our county. The areas--the danger areas, as we sometimes term them--the natural hazards that you are mainly interested in as geologists and engineers, are the areas we need to identify in our country because of the immediate and very severe pressures which are forming due to development of natural resources, and I don't mean pressure, I mean crunch. Our building permits have jumped 36 percent over a like period of 1974. An increasing number of people need housing. Without stringent control we will be building houses on the runways of the airport or in avalanche paths.

We are already ripping up agricultural land by the section. With proper interpretation and reasonable application, 1041 gives new meaning to land use.

Our first effort in Mesa County is to designate an area of influence for the airport. The way we are going about this is to get as much public and individual input as possible. As an example, the airport is of primary importance to our economy and transportation needs. It serves as a regional airport. We will probably need to expand that airport. Now which way does it expand? 1041 criteria state that we separate uncontrollable (airport) noise and danger from existing communities. A properly defined area of influence will accomplish this.

The cooperation that we have received from at least two state agencies has been outstanding. The cooperation from Colorado Geological Survey and the Colorado Water Conservation Board, and their willingness to help us get educated in areas of their responsibility has been outstanding, which brings me to my last point--education.

Education of the public and public officials is the key to all our land-use success. Land use is viewed by each of us through different eyes. It's according, as I have often said, to whose ox is getting gored. It's according to how it affects you, your property, your feeling, your life style, and your income. The need for education is paramount. The need for understanding of what is trying to be done in land use, the explanation of activities and areas of state interest, is our major responsibility. This is why I'm involved in land use. It's a public relations job, specializing in the land I love.

I had a whole list of sayings that I thought might be pertinent. One of them was, "That it is better to ask some questions than to know all the answers". My question is, do you have any questions?

Question: You indicated that you were going to move ahead on designation of the airport, and I have really two questions: Are you going to control notification of hearing process under 1041, and remaining areas of activities of state interest, are planning the 1041 designation now, or are you planning the zoning H.B. 1034 route, or have you decided yet?

I think we have a format. We have held our first formal hearing on the airport under 1041. There is an existing state law that says that any matter that goes into the master plan of a county or region must first be approved or disapproved by the planning commission. We held a hearing for the public with the county and municipality planning commission and the Land Use Steering Committee. We had input from the people, and we had technical input from the Land Use Commission. Maurice Miller was there, Charlie Foster was there, and people from FAA attended. We tried to hear what these people had to say about what would happen if we made a designation according to what had been determined as reasonable area of influence for the airport and to separate the airport from unrelated development.

An airport regulation has been drafted, based on public input and hopefully one that meets local technical and land use needs. The information that we are getting and the input that we will get, will go through another public hearing conducted by the county commissioners. They will either approve or deny the recommendations for designation. If approved, the area of influence will be under the permit system and be very restrictive. We feel it is important to keep the land around the airport for the development of the airport and use of the airport. Other hazard areas will be handled in the same manner, in relation to the development pressures.

THE GEOLOGIC HAZARD IDENTIFICATION PROCESS IN ROUTT COUNTY

ALLAN E. MILLER

Consulting Geologist

The previous speakers have set a tone of breaking new ground or going through a learning process, and certainly those of us in Routt County involved in geologic hazard identification and delineation have been going through exactly the same process.

The County required, as the end product of the hazard identification process, United States Geological Survey 7½-minute topographic quadrangle mylar base maps with the geologic hazards identified, labeled and deliniated. The County further required a map explanation be attached to give a brief description of each of the hazard types. The final map was to be capable of being reproduced in a simple ammonia blueprint machine. The scale of the 7½-minute quadrangles (1 in. = 2000 ft) was chosen to allow an interested party to easily locate any piece of property in question.

We were very fortunate in having all the basic data available for Routt County. The USGS 7½-minute topographic map coverage was completed for nearly all the approximately 650,000 acres of private lands that made up the study area. Most of the County has been mapped geologically, and the Colorado Geological Survey had recently released a compiled geologic map of Routt County on the scale of 1:125,000 (1 in. = 2 miles). We were able to obtain, on loan, a complete stereographic set of aerial photos of Routt County from the local Agricultural Stabilization Corps.

The first step in hazard identification was to become familiar with the geologic formations in the County. This was done by direct observation in the field; by reviewing published geologic maps and noting formations that tended to fail on slopes leaving landslide debris; and by reading geologic reports for subdivisions on file in the Routt County Land Use Planners office. Construction sites were visited, and the relationship of rock type and structure to geologic hazard problems were noted. Some time was spent with the Soil Conservation Service people who were aware of hazards in the county, especially those hazards related to irrigation. State and County road maintenance crews provided excellent information on slope failures in road and highway cuts and fills. From these sources it became apparent which geologic formations were adversely affected by development pressure and what role the structure of the rocks (dips, folds and faults) plays in increasing or decreasing the hazard potential.

Routt County may be divided into three provinces on the basis of geology and topography (Figure 1). The eastern one third of the county encompasses the west slope of the Park Range. Elevations range from over 12,000 ft in the mountainous east margin to 6500 ft in the rolling foothills to the west. Glaciated valleys and uplands are common and glacial drift deposits mantle much of the bedrock. The bedrock in the mountainous area consists of crystalline Precambrian granites, schists and gneisses. These rocks are generally competent and present few hazards. A thin soil cover is present on the more gentle slopes. Paleozoic sedimentary rocks, poorly consolidated Tertiary sediments and Quaternary glacial till overlap the Precambrian bedrock in the foothill zone. Of particular importance is the Tertiary sediment called Browns Park Formation. This unit is a notorious "bad actor" wherever encountered in Routt County because of its poor stability on slopes. Where the Browns Park rests on Cretaceous Mancos Shale, the severity of the instability problem is even more pronounced. The Browns Park consists of a 100- to 300-ft-thick basal conglomeratic sandstone member overlain by a poorly consolidated tuffaceous, silty sandstone member ranging from 0 to 1500 ft thick. Well preserved lateral moraines are present at the base of the mountains, especially in the vicinity of Steamboat Springs. This section of the county is wetter than the other two parts, and its average is 23.51 in. of precipitation, the bulk of which is snowfall.

The overall topography of the central portion of Routt County is one of rolling hills and broad valleys with occasional peaks in the Elkhead Mountains rising to 10,000 ft. There are areas of strong dissection with elevations ranging from 6000 to 9000 ft giving 2000 to 3000 ft of relief. The confluence of the south-flowing Elk River and the north- and west-flowing Yampa River occurs in this sector of Routt County. Precipitation is somewhat less here than in the eastern one third. The rocks in this sector of the county consist of Cretaceous and older sedimentary formations. These interbedded sandstones and shales have a regional westerly dip with local folding. Many coal beds occur in these units. This central portion also contains widespread and thick occurrences of the Browns Park Formation and other Tertiary sediments along with unconsolidated surficial deposits. A belt of north-south-trending Tertiary intrusive-extrusive (sills, dikes, plugs and flows) rocks fills out the geologic picture in this central portion of Routt

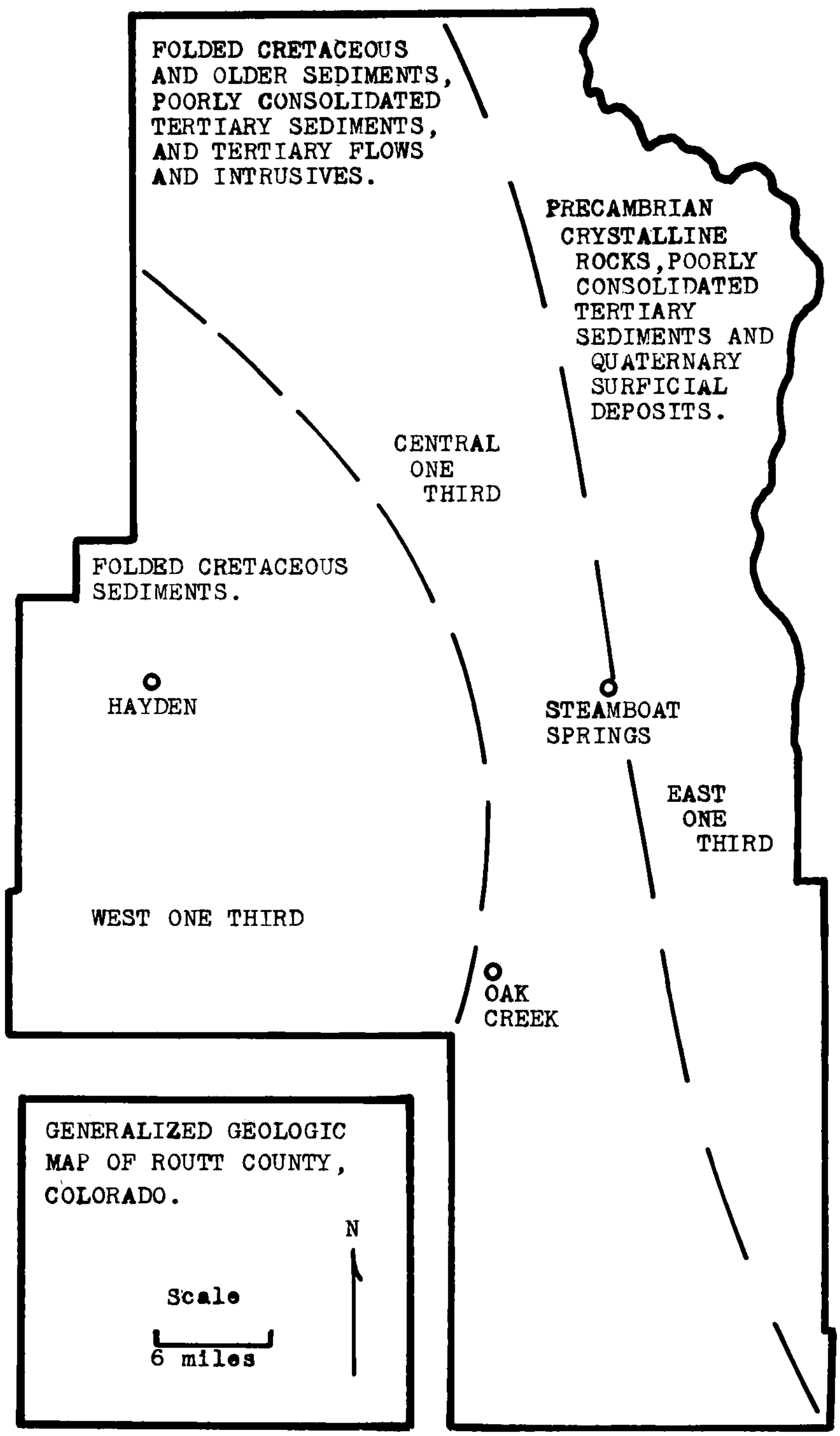
FOLDED CRETACEOUS
AND OLDER SEDIMENTS,
POORLY CONSOLIDATED
TERTIARY SEDIMENTS,
AND TERTIARY FLOWS
AND INTRUSIVES.
PRECAMBRIAN
CRYSTALLINE
ROCKS,POORLY
CONSOLIDATED
TERTIARY
SEDIMENTS AND
QUATERNARY
SURFICIAL
DEPOSITS.
CENTRAL
ONE
THIRD
FOLDED CRETACEOUS
SEDIMENTS.
HAYDEN
STEAMBOAT
SPRINGS
EAST
ONE
THIRD
WEST ONE THIRD
OAK
CREEK
GENERALIZED GEOLOGIC
MAP OF ROUTT COUNTY,
COLORADO.
N
Scale
6 miles

FIGURE 1.

County. Most of the peaks in the Elkhead Mountains are composed of these Tertiary igneous rocks.

The western one third of Routt County contains sedimentary rocks of Upper Cretaceous age (Lewis and Lance Formations) and younger sediments including a few scattered remnants of Browns Park Formation. There are a few basalt flows on higher uplands and occasional unconsolidated surficial deposits in stream valleys. The Cretaceous rocks are interbedded sandstone and shale (predominantly shale), have north and west dips, are locally folded and contain a few coal beds. The topography then is one of fairly gentle relief with moderate dissection of upland areas between occasional broad valleys. This is one of the drier portions of the county, and a good part of the precipitation comes as summer thundershowers.

The second phase of the Hazard Identification Process in Routt County was to identify and outline the geologic hazards on air photos by stereoscopic viewing. Hazard boundaries were then transposed to 7½-minute work sheets and labeled. Upon completion of this stage a set of 35 7½-minute maps were turned over to the Routt County Land Use Planner as preliminary and subject to additions and corrections.

The symbols used on the Routt County hazard map Explanation are shown in Figure 2. The final legend is somewhat different than the one with which we started the project. We actually started with about 15 symbols and gradually combined or eliminated several as the project evolved. Before discussing the Explanation, it would be well to mention geologic hazards not included. Routt County has no known radioactive hazard areas. Routt County does, however, possess a great deal of shrink-swell or expansive soils and rocks. This constraint is so prevalent and variance so great that it should be handled by building code requirements, and a soils investigation should be made for each and every construction site. Beginning in the upper left-hand column of Figure 2 we have the following hazards and legend descriptions:

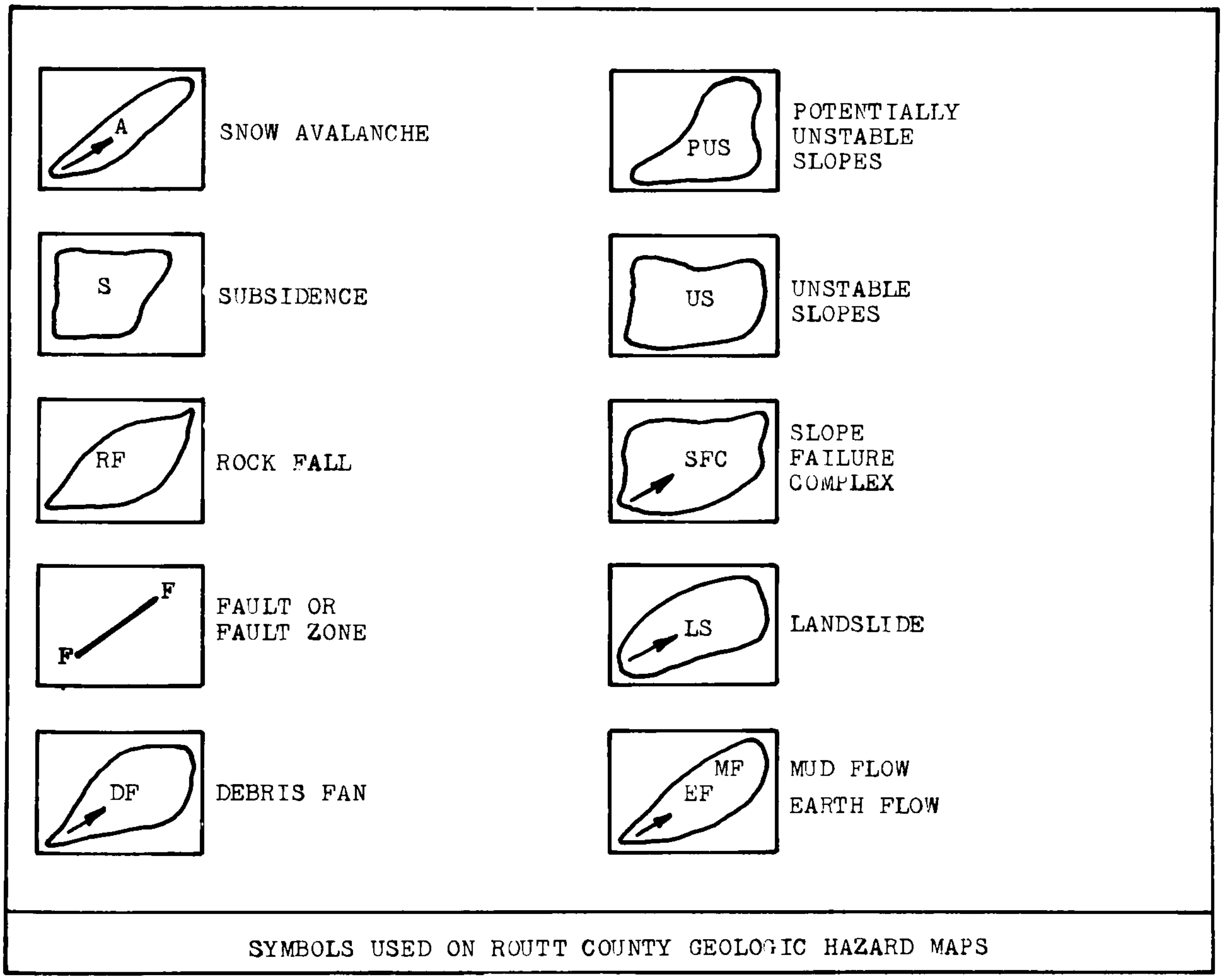

FIGURE 2.

A----SNOW AVALANCHE — Boundary of avalanche danger area and flow direction.

S----SUBSIDENCE — Areas of potential ground subsidence. Surface boundaries of underground mining operations; includes filled gravel pits, landfill and strip mine spoil.

RF---ROCK FALL — Boundary of danger zone from falling rock, includes source and roll-out zones.

F----FAULT OR FAULT ZONE — Surface trace of known (documented) plane of rock displacement. Potential for movement exists along these planes during seismic activity. Routt County is in Seismic Zone II.

DF---DEBRIS FAN — Boundary of cone-shaped stream-deposited material. Area subject to recurring flooding and deposition.

PUS--POTENTIALLY UNSTABLE SLOPES — Boundary of slopes, with geologic conditions present that may lead to instability when disturbed. Slope failure may be either surficial or deeper seated.

US---UNSTABLE SLOPES — Boundary of slope areas where slow downward movement is in evidence in the form of slump, soil creep, minor earth flow or heavy erosion. More rapid movement possible. May be man induced or natural. Includes both surficial and deeper seated slope failure.

SFC--SLOPE FAILURE COMPLEX — Boundary of large areas of failure of surficial and/or bedrock deposits. May consist of different slope failure types, i.e. rockslides, landslides, debris slides, mudflows and debris avalanches.

LS---LANDSLIDE — Boundary of a large-scale slope failure involving surficial and/or bedrock material. Generally consists of one slope failure type, i.e. a rockslide or a landslide.

MF---MUD FLOW — Boundary of a flowing or solidified mass of predominately fine-grained earth material possessing a high degree of fluidity during movement.

EF---EARTH FLOW — Boundary of an area of plastic flowage of a mass of earth material.

The relationship of geology to geologic hazards in each of the three provinces of Routt County is generalized in Figure 3. The thin soil cover on Precambrian rocks in the eastern one third of the county is quite fragile and tends to slough off above cuts. The large scars on U.S. Highway 40 attest to this problem. Similar conditions exist in the development area adjacent and south of the base of Mt. Werner. Problems here probably will not be catastrophic, but continual soil slough onto roadways will have to be removed and these slopes will present esthetically displeasing scars. Glacial drift in the form of moraines presents different problems. Slope stability in this material varies as to permeability; the better drained material tends to be more stable. Most lateral and terminal moraines are considered to be potentially unstable, while areas of ground moraine and outwash appear to have fewer problems. The Browns Park Formation presents the areas of greatest potential for slope failure. Any slope in this unit over 16 or 18 percent is suspect. Higher portions (with higher precipitation) of this third of Routt County contain the snow avalanche areas; however, this is U.S. Forest Service land, and almost no developable ground is in proximity to the hazards. The oversteepened glaciated valleys present limited hazards from rockfall and rockslides. Occasional mudflows and debris fans are present, and subsidence is related to artificial fill in old gravel pits and on areas built up by fill on flood plains. Material from the Browns Park Formation is often used for this purpose; it generally does not make the best fill.

The central portion of Routt County contains the largest areas of slope instability hazards. Dip slopes (pitching) of interbedded sandstones, shales and coal beds provide abundant slip surfaces. Resting on these rocks and aggravating this situation is the incompetent Browns Park Formation often capped by basalt flows. The resistance to weathering of the basalt flow rock allows oversteepening of slopes around its edges, admits water to the underlying material, and thereby creates a geologic setting for large areas of mass wasting we have termed "slope-failure complexes". Earth flows are common in this sector of Routt County and are generally found in deeply weathered and dissected shale rocks. In many cases irrigation is the triggering mechanism. This sector is also the main part of the Yampa Coal Field in Routt County, and subsidence potential from underground mining is greater here than elsewhere in the county. Areas of surface mine spoil are included in the subsidence category. Rockfall hazard zones are prevalent here and are created from cliffs formed on sandstone rimrock and basalt flow caprock.

The western one third of Routt County presents geologic hazards similar to the central portion except that not nearly so much Browns Park or basalt flow rock is present. Dipping, interbedded Cretaceous shales and sandstones of the Mancos, Iles and Williams Fork Formations offer their usual slope instability

GENERALIZED GEOLOGIC HAZARD RELATIONSHIP TO GEOLOGY, ROUTT COUNTY, COLO.			
GEOLOGIC HAZARD	WEST ONE THIRD OF ROUTT COUNTY	CENTRAL ONE THIRD OF ROUTT COUNTY	EAST ONE THIRD OF ROUTT COUNTY
SNOW AVALANCHE	--------------	-------------	RESTRICTED TO STEEP SLOPES IN MTNS.
SUBSIDENCE	RESTRICTED TO MINING ACTIVITIES.		ARTIFICIAL FILL IN GRAVEL PITS, ETC.
ROCKFALL	WIDESPREAD IN SANDSTONE RIMROCK AND BASALT FLOW CAPROCK.		OCCASIONAL PROBLEM IN GLACIATED AREAS.
FAULT OR FAULT ZONE	FAULTS PRESENT IN ALL SECTORS; NO EVIDENCE OF RECENT MOVEMENT.		
DEBRIS FANS	SCATTERED THROUGHOUT THESE TWO SECTORS.		NOT COMMON.
POTENTIALLY UNSTABLE SLOPES AND UNSTABLE SLOPES	WIDESPREAD ACTUAL AND POTENTIAL SOIL CREEP, SLUMP AND SLUFF OF SURFICIAL EARTH MATERIAL ON SHALE BEDROCK; DEEPER SEATED SLIPS IN HIGHLY WEATHERED SHALE.		SURFICIAL SOIL SLIPS ON DISTURBED PRECAMBRIAN TERRANE WITH DEEPER SEATED FAILURES ON SLOPES IN UNCONSOLIDATED SEDIMENTS.
SLOPE FAILURE COMPLEX	ABUNDANT AND OF LARGE AREAL EXTENT; DIP SLOPES IN UPPER CRETACEOUS SHALES AND SANDSTONES VERY SUSCEPTIBLE.	WIDESPREAD, RELATED TO UNCONSOLIDATED TERTIARY SEDIMENTS RESTING ON SHALE AND PROTECTED BY RESISTANT BASALT FLOW CAPROCK.	OCCASIONAL SLOPE FAILURE COMPLEX IN POORLY CONSOLIDATED TERTIARY SEDIMENTS.
LANDSLIDES	COMMON ON SHALE AND SANDSTONE DIP SLOPES AND UNDERCUT REVERSE SLOPES.	WIDESPREAD ON SHALE AND SANDSTONE DIP SLOPES AND ON OVER-STEEPENED SLOPES IN POORLY CONSOLIDATED SEDIMENTS.	OCCASIONAL ROCK-SLIDE IN GLACIATED VALLEYS.
MUDFLOWS EARTHFLOWS	ABUNDANT MUDFLOWS. OCCASIONAL EARTH-FLOW.	ABUNDANT EARTHFLOWS OCCASIONAL MUDFLOW.	OCCASIONAL MUDFLOW.

FIGURE 3.

hazards. This portion also contains rocks of the Upper Cretaceous Lewis and Lance Formations. These consist mostly of incompetent shales, and many slope failures are recognized in these units. Mud flows are common as a great deal of fine, eroded material is available in drainages. Summer thunderstorms provide the moisture to activate these hazards. Rockfall is common, although not as ubiquitous as in the central portion of Routt County.

Faults are present throughout Routt County, although no cases of recent movement are known. Routt County is in Seismic Zone II, the eastern part of Colorado being in Zone I. Routt County is actually one of the more active seismic areas in Colorado. Earthquakes of 5 intensity on the Richter scale have been recorded here. Reactivation of older faults by future earthquakes is one potential danger; the other is the triggering of failure on slopes normally in equilibrium.

The third step was field checking and interviewing property owners. Questionable hazard areas were resolved, while the more obvious ones were verified. Selected areas within each 7½-minute map were inspected. Various land owners were visited and queried as to the last activity of local hazards.

The final phase was correcting the work sheets and transferring all data to the mylar base maps with legend attached.

In conclusion then, we have gone through a learning process in "The Routt County Geologic Hazard Identification", and I hope we have learned our lessons well because Routt County has more than its share of geologic constraints.

Question: I would like to ask whether you've reached the point where you can estimate that if Routt County went the full H.B. 1041 route in the designation and adoption of control, what fraction of the area of Routt County would be subject to control regulations, designation and permitting under H.B. 1041 in terms of the various geologic hazards. Do you have a guess on that?

Answer: Approximately 20 percent of the private lands in Routt County.

Question: What are you yourself doing now to aid the county in designation and regulation.

Answer: Not much right now, but I plan to give slide talks to various service groups and interested clubs for the educational aspect.

GEOLOGIC HAZARDS AND LAND USE DECISIONS IN ROUTT COUNTY, COLORADO

DR. J. A. UTTERBACK

Routt County Commissioner

I know there are many people out there that know a lot more about House Bill 1041 than I do, but I don't see any of them here. So I'll speak freely. . .

In the beginning God created the Heavens and the Earth, laid out the void and the deep, and put the featherless biped known as man upon earth to preserve creation's pattern. But much to the Lord's despair, man is tearing the universe apart and wasting its resources.

First came our great-great-great-grandmothers and grandfathers with thin lips and parched throats who, squinting against the blazing sun, fought westward to open a new continent and tame a wild frontier. Two generations have survived and fared well on that land. They have built a heritage and a legend equal to the grandeur of that savage land. But then came the angels of mercy in their Cadillacs, camouflaged in the canopy of growth, progress and gentility. In honor of these supposed virtues, their cannons belched and boomed and the resources of these lands have been devastated. So that today we, the posterity of those pioneers, are living on borrowed time surrounded by the wreckage of destroyed lands. The problem confronting us: how to cope with this devastation in the limited time available to us.

House Bill 1041 may be part of the answer. It provides the counties with more detailed planning information than ever before to help salvage some of the wreckage. It does contain one deficiency about which I have spoken to John Birmingham and others. H.B. 1041 is a land use bill. It should be a land and water use bill. Posession of adequate water is absolutely imperative for our survival because without a drink, we are in a helluva fix. Water should not belong to special districts, speculative investors, water companies or mortgage bankers as it presently does in too many instances.

House Bill 1041 does, however, provide three important tools to assist in salvaging the wreckage--identification, designation and administration. Routt County, which is in the process of writing the authority of H.B. 1041 into our zoning and subdivision regulations, intends to make good use of all three. H.B. 1041 gives the County local land use control for areas and activities of State interest, and we will employ the opportunity wisely.

Prior to writing this authority into our zoning regulations, a developer would bring sketch plans into the Planning Commission for a brief review. Shortly thereafter the developer would schedule an equally cursory appraisal of a preliminary plan. Then the developer was free to go home and draw little squares indicating density and compose little speeches about how many dogs there were going to be, how many trees were to be planted, how much greenbelt was allowed, where the roads of ingress and egress were located, and how many cars would be parked up the back alley. All this, by and large, made up the final plat which was then again presented to the heirarchy of local government. First the Planning Commission and then the County Commissioners--with a 30 cent dollar bill dangled in front of them like the proverbial carrot--would sit bobbing their heads to and fro to emphasize their hearty recommendations of approval. Seldom did these officials inquire into the management capability, the accountability or the credibility of the developer. "Why sure, he's going to increase the tax base", they agreed. "He's going to bring a lot of people into our area. He's going to increase the wealth and we're going to wade around in money up to our knees".

On several occasions I have taken the liberty of inquiring as to the source of the money and the nature of the cash flow. But questions like this, I have been informed, are impolite and of potential embarassment to developers. So with few questions asked, the developer tucks a signed plat under his arm and trots out to sell lots. Of course, most of these lots are on credit and, in many cases, the developer is selling two lots to finance one.

Routt County is putting H.B. 1041 into action. The process begins with a pre-application conference between the Planning Department and the developer whereby it will be determined if a permit is needed or not needed in conjunction with the sketch plan approved by both the Planning Commission and the County Commissioners. In cases where a development does not need to go through the subdivision regulation (i.e., mining operations), a zone change may be granted or the mining may be conducted under a special use permit. At this point the developer can decide as to whether he wants to proceed or not with his development. For example, in geological hazard areas three alternatives are available to him: (1) avoidance; (2) a compatible land use (usually agriculture); and, (3) mitigation.

If the developer wishes to proceed with his development in a potential landslide area, a technical review committee, such as a geologist, hydrologist or building inspector, will confer with him in seeking a solution to mitigate the problems if possible.

If a satisfactory solution is arrived at, then the developer, in an open hearing, can present his preliminary plan to the Planning Commission and the County Commissioners for approval or disapproval. If approved, the developer then proceeds forward to developing his final plat which encompasses density, roads or streets, protective covenants and a subdivision improvement agreement.

Geological hazard areas are areas of economic hazard. Routt County has seen too many buildings--both residences and condominiums--built in geological hazard areas which have resulted in enormous additional costs to prospective purchasers. There have been cases of the earth giving away, walls separating from floors, foundations moving due to insecure keying of footings in unstable foundations. Buildings have actually been put up against mountainsides which were moving, requiring 6-16 ft retaining walls to be buried deeply in underground surfaces in an effort to prevent earth migrations.

We have faced other problems: problems in placing trailer courts, and even residences, in floodplain areas or in wildlife corridors. Problems with high density development around airports rather than in more compatible limited industrial and commercial areas. Problems with building roadways across unstable geological hazard and floodplain areas. We have, however, been fortunate in having a capable resident geologist, Al Miller, to assist us in minimizing poor decisions.

Unfortunately there are glaring examples of the disaster created by land-office sales circuses in Routt County. One of the oddest cases is in the Hahn's Peak Basin where several thousand acres of nature's most splendid and fertile high country has been cut up into small lots and golf courses with little or no water or sewage capability available in the near future and now for all practical purposes, the area is in the state of bankruptcy.

Routt County, like so many other areas, fell victim to the idea that we are going to become stoop-shouldered by pushing money to the bank. We are getting stoop-shouldered, but it is not from pushing money furnished by the developers. It's from shouldering the burdens of high taxes, foreclosures, trustee sales, high living costs--the wreckage that surrounds us. So I close with this warning: "When the wicked beareth the rule, the people shall mourn".

GEOLOGIC HAZARDS AND LAND USE STUDY EAGLE COUNTY, COLORADO

WILLIAM A. GALLANT AND CHARLES S. ROBINSON

Charles S. Robinson & Associates, Inc.

INTRODUCTION

The purpose of the engineering geologic study of Eagle County was to fulfill the requirements of the "identification of the geologic hazards and mineral resources as outlined in Colorado House Bill 1041". Further, in order to implement the identification procedure and assist the layman, developer and land-use planner, additional information in the form of tables and suggested guidelines for the use of the maps were also included in the study to assist the user in better understanding the sometimes technical implications and uses of the geologic information.

It was determined that the majority of the development pressure and private land is found in the Eagle River and Gore Creek area (Figure 1). U.S. Geological Survey 7.5-minute quadrangles were butt-joined for use as a base map at a scale of 1:24,000 for compilation of data. The five sheets were reproduced on 24- by 36-in. mylar reproducible sheet (Figure 2). Photogeology and compilation of available information was done from U.S. Geological Survey and U.S. Forest Service aerial photography. Final compilation sheets were field checked during the summer with final revision of maps and charts continuing through the fall.

ACKNOWLEDGEMENTS

Special thanks to the members of the U.S. Geological Survey, especially Val Freeman and Ogden Tweto, for their discussion and assistance; the Colorado Highway Department and Bob Barrett for assistance and supplying information for review. Also, thanks go to individuals and staff at the University of Colorado and Colorado School of Mines library for their assistance in making available information for use. Numerous thanks go to consultants active in the area, the staff of the Colorado Geological Survey and the ranchers and land owners of Eagle County for making this study possible.

GENERAL GEOLOGY

The maps were compiled at a scale of 1:24,000 or 1 in. = 2,000 ft for use as a general planning tool.

The Bedrock, Surficial Deposits and Snow Avalanche Hazards maps are basic data compiled from available information and photogeology. The Geologic Hazards, Environmental and Engineering Geologic maps, and the Geologic Resources map were interpreted from the basic-data maps and research information. Each map will be discussed briefly as to use to aid the layman in interpreting various information that was compiled.

Bedrock Geologic Map

The Bedrock Geologic map as a basic-data map is compiled from available information and can be used with other data to interpret the geologic characteristics of the area (Figure 3).

The map defines the formational units which in turn gives information as to rock and soil type. A variety of structural information is included on this map. Faults, folds, and strikes and dips of the bedrock units are also included. In Eagle County a wide variety of rock types can be found. Precambrian metamorphic rocks and Precambrian and Tertiary volcanic rocks are common in the upland areas and in the foothills of the Sawatch and Gore ranges. Paleozoic through Tertiary sedimentary rocks outcrop in the Gore creek and Eagle River valley. A wide variety of sedimentary rocks ranging from siltstones to sandstones, limestones and dolomites and extensive deposits of gypsum and shale outcrop in the County. Glacial and surficial deposits cover the bedrock units in many areas.

Surficial Deposits Map

This map was derived from the photogeological study and verified as much as possible by field checking. Very few surficial deposits maps were available, and overall this map contains the newest information (Figure 4). Bedrock contacts between surficial colluvial units was traced from the Bedrock Geologic map. These colluvial contacts therefore may be transitional from one rock type to another depending upon slope, depth of weathering, etc.

This map gives information as to areal extent of surficial deposits and location of colluvial, alluvial and glacial deposits. Surficial alluvial deposits include alluvium, terrace deposits, and alluvial fan deposits. Surficial glacial deposits include morainal deposits in the Gore Creek valley and elsewhere in the county. Colluvial deposits are the most widespread of surficial deposits and consist of weathered bedrock materials, talus, and landslide deposits. Construction and geologic investigations and related slope and foundation stability problems are primarily concerned with these deposits.

Geologic Hazards Map

The Geologic Hazards map is a map interpreted mainly from the Surficial Deposits map and delineates areas of geologic hazard either defined or inferred from H.B. 1041 and the Colorado Geological Survey Special Publication No. 6 (Figure 5). A wide variety of geologic hazards can be found within the mapped area. Some of the geologic hazards found in the Vail area include landslides (LS), rockfall (RF), subsidence (S ev, S hy), debris fans (DFA), and the Physiographic flood plain (PFP). These geologic hazards may affect construction and engineering practices in Eagle County, but in order to evaluate the hazard, one must rely on site-specific information and not broad general data and relating the site-specific information to other planning information.

A separate map showing the snow avalanche hazard was developed because it is a somewhat different hazard and it avoids crowding on the Geologic Hazard map (Figure 6). Snow avalanche hazard areas are divided into (1) indentified paths, (2) areas highly susceptible to snow avalanche occurrences, and (3) areas slightly susceptible to avalanches under extreme conditions.

Environmental and Engineering Geologic Map for Land Use

The Environmental and Engineering Geologic map for Land Use is the result of the compilation of all of the available data (Figure 7). The map is meant to be used as one of the tools to determine the suitability of an area for development from a geologic point of view. Each class, 1 through 7, represents an increasing degree of study needed for development depending upon the geologic constraints. The classifications also indicate some of the geologic studies that are appropriate in order to evaluate the property as to its suitability for development. The classification showing minimum Engineering Geologic Investigations required for preliminary planning purposes is as follows:

1

Basic Geologic and Engineering Investigations of area as required by Senate Bill 35, adequate for development planning and generally for construction site selection.

2

General Geologic and Engineering Investigations of area required for development planning for each construction site.

3

Detailed Geologic and Engineering Investigations of entire area is required for development planning and for selection of construction sites.

4

Detailed Geologic and Engineering Investigations required for entire area for development planning and some construction sites may require specialized Geologic and Engineering Investigations for design purposes.

5

Detailed Geologic and Engineering Investigations of entire area required for development planning and specialized investigations required for specific construction sites.

6

Extensive detailed Geologic and Engineering Investigations necessary for development planning. Most of the area within this classification may not be suitable for permanent structures.

7

Extensive detailed Geologic and Engineering field investigations required for development planning. Utility corridors, temporary structures and some permanent structures may utilize parts of these areas after extensive investigations and design for the specialized problems involved.

Tables of Engineering and Geologic Constraints for Land Use

Supplementing the basic geologic mapping that was done to fulfill the requirements for the identification of geologic hazards as defined in H.B. 1041, tables were made that define in general the engineering geologic characteristics of each of the surficial and bedrock geologic units. Factors that are defined are description and physical characteristics of the unit, topographic expression, weathering effects, workability, surface drainage and erodibility, groundwater characteristics, suitability for waste disposal, foundation and slope stability, related geologic hazards, and known, reported and possible mineral resources. The data supplied in the tables are general and are not meant to be used as site-specific information.

CONCLUSIONS

Colorado House Bill 1041 has provided a considerable challenge to the geologic consultant in Colorado to provide meaningful and useful information to county officials in regards to geologic hazards. Developers, bankers, civic leaders--all can help in providing for the safe development of property in their respective counties. It is becoming the engineering geological consultant's continuing and increasing responsiblity to fullfill the need of providing basic information to administrative officials so they can make rational land-use decisions in regard to geologic hazards in the State of Colorado.

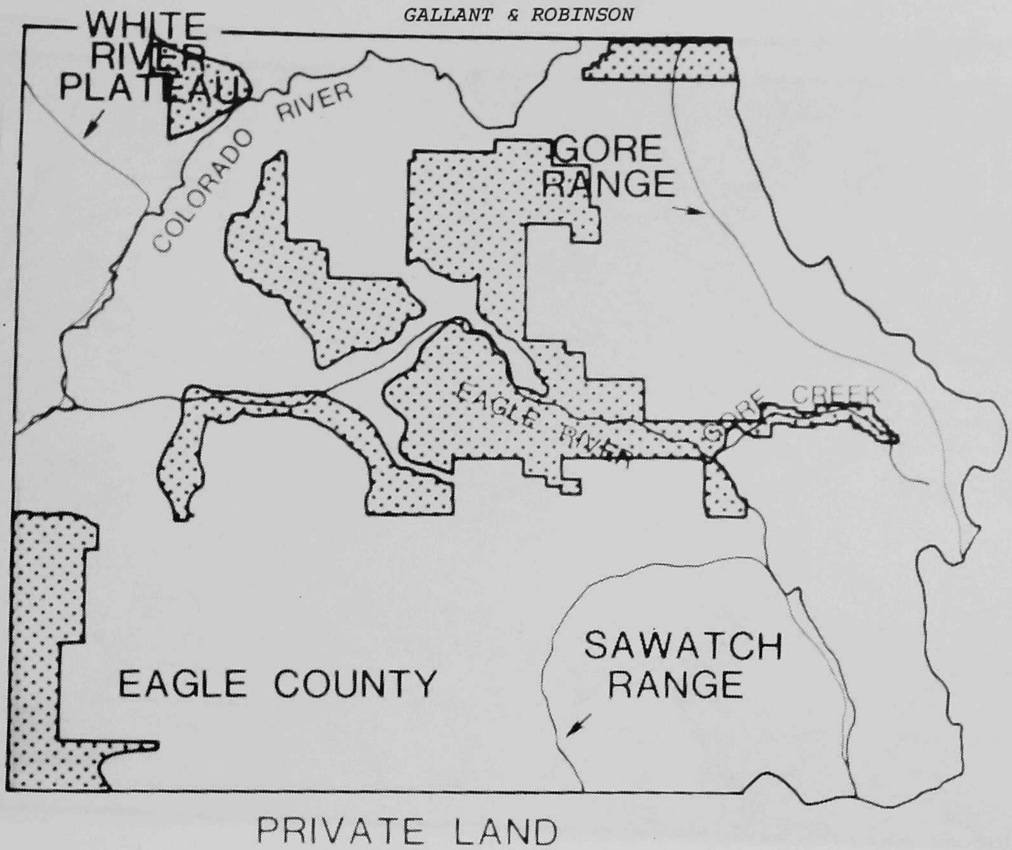

FIGURE 1. Private land, Eagle County, Colorado.

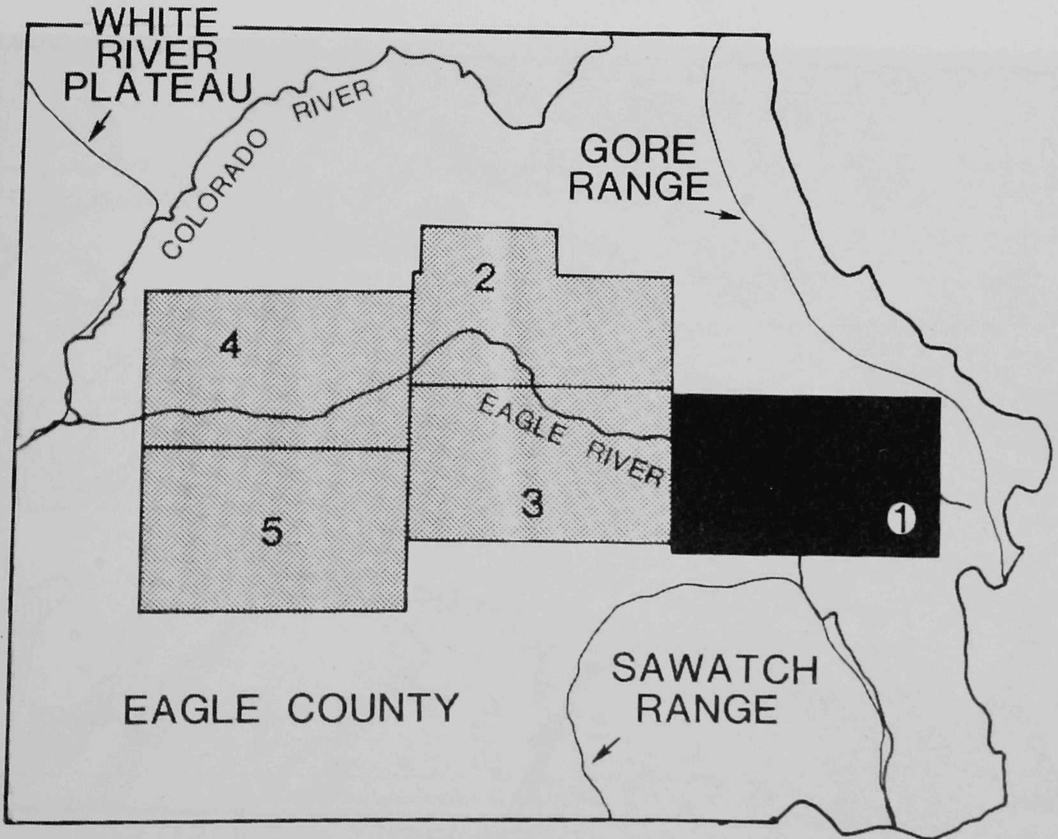

FIGURE 2. Sheet location, Eagle County, Colorado: location of sheet (1) illustrated for this paper.

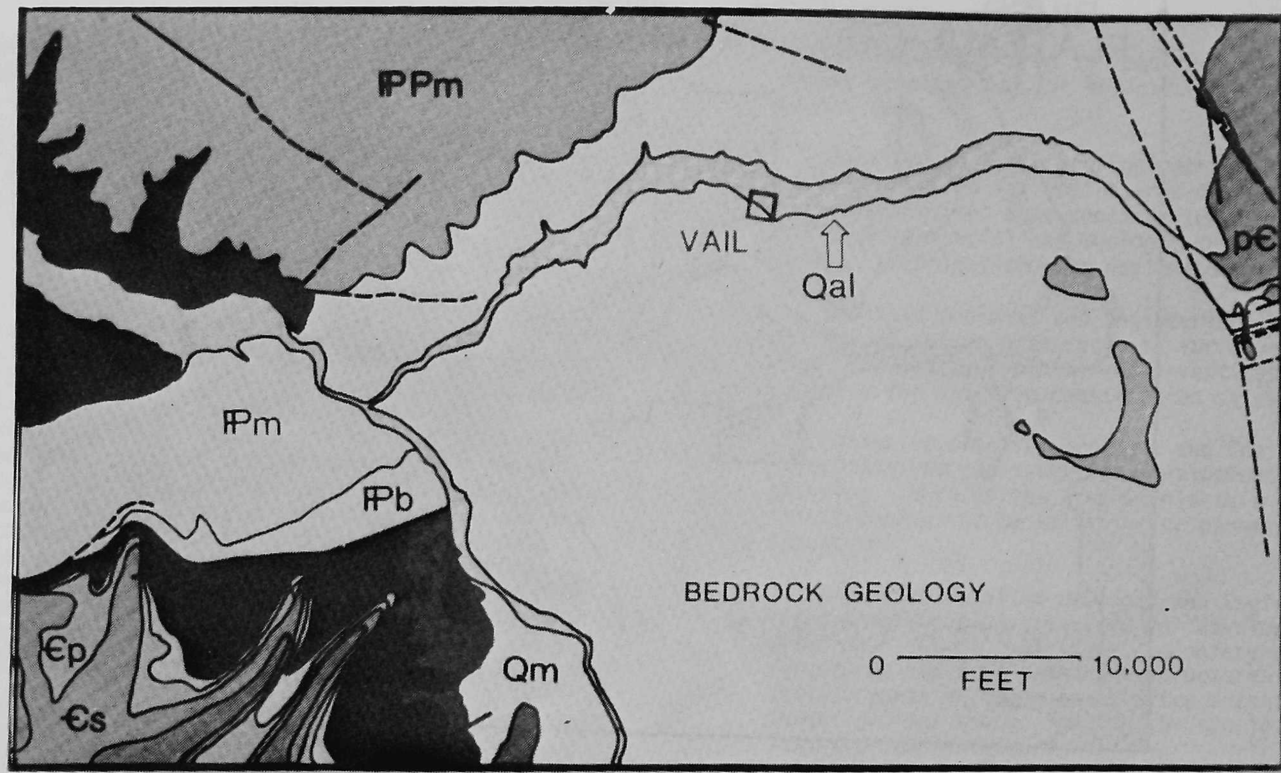

FIGURE 3. Sheet 1, Bedrock Geology map.

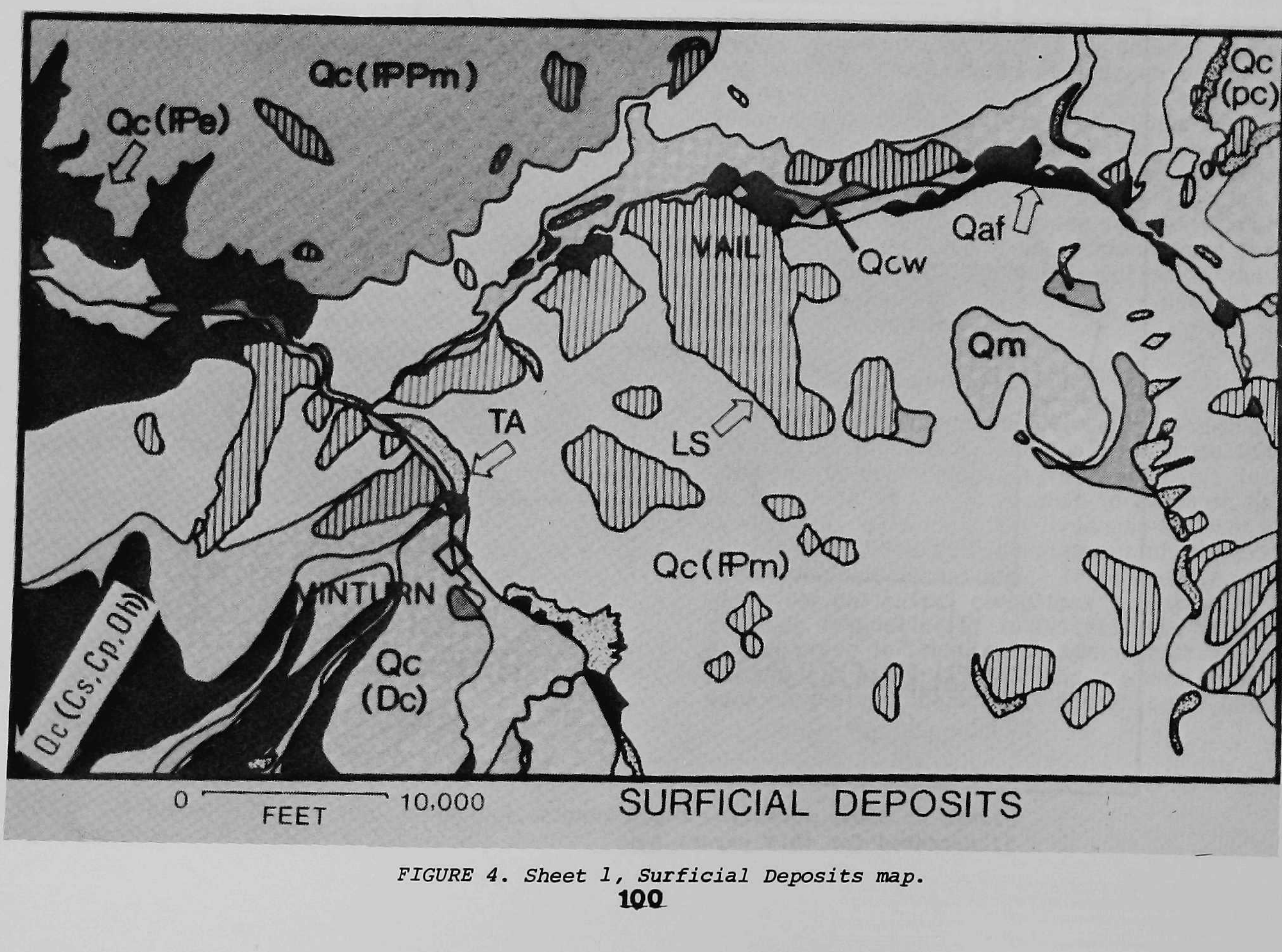

FIGURE 4. Sheet 1, Surficial Deposits map.

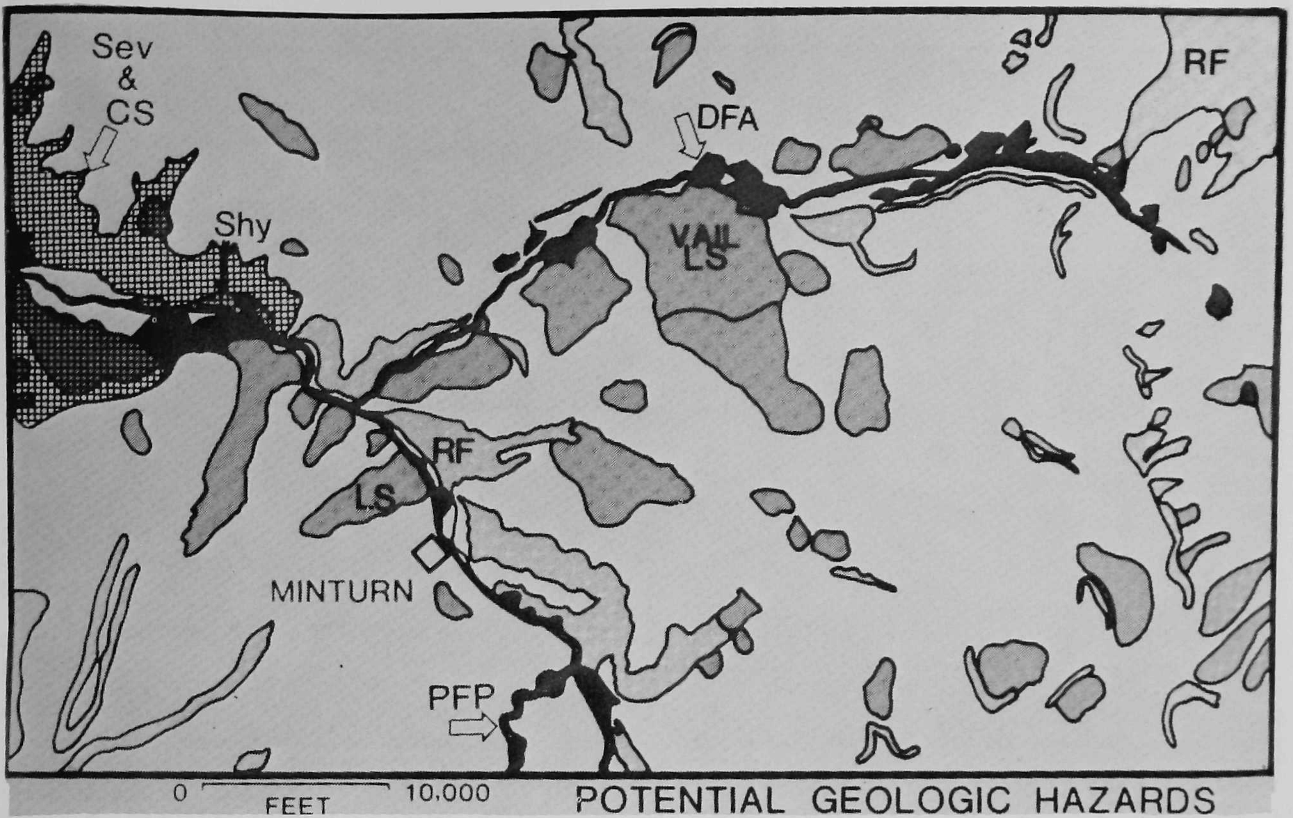

FIGURE 5. Sheet 1, Potential Geologic Hazards map.

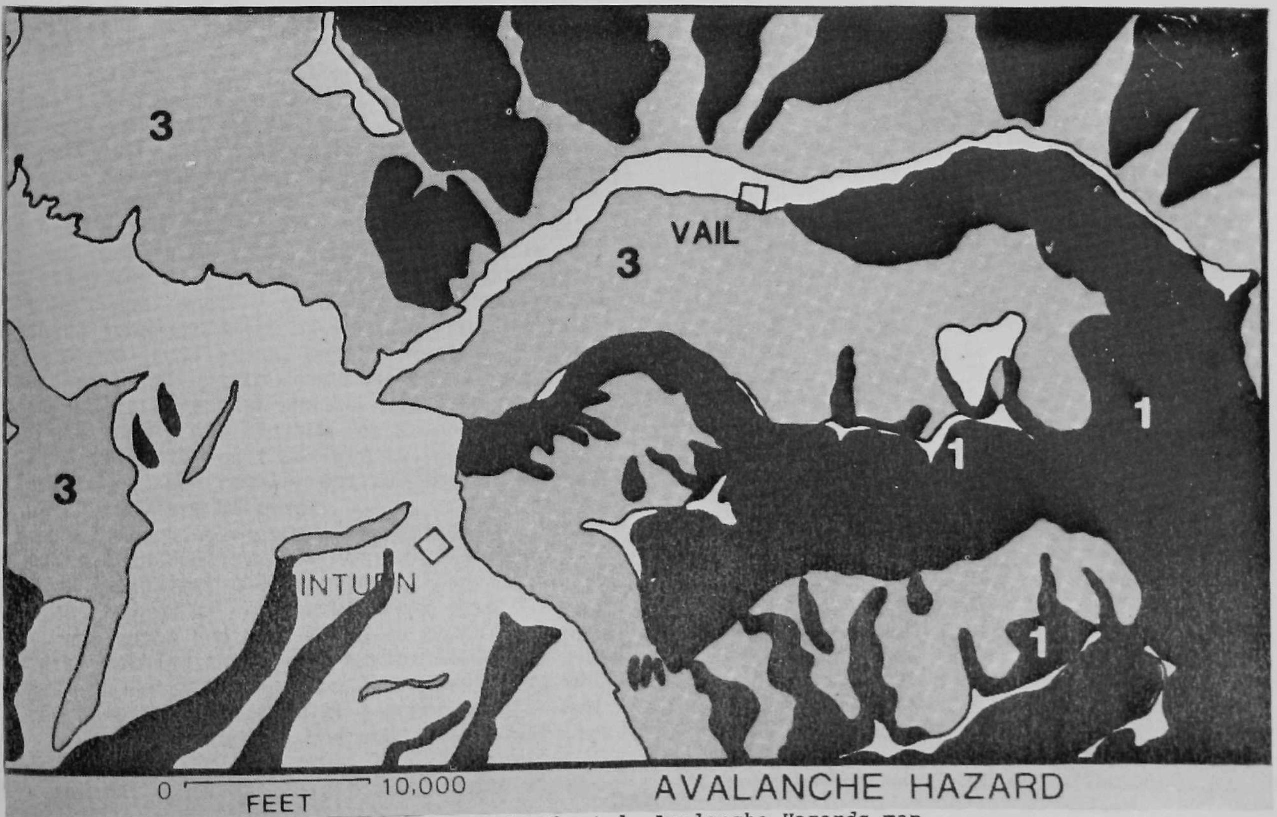

FIGURE 6. Sheet 1, Avalanche Hazards map.

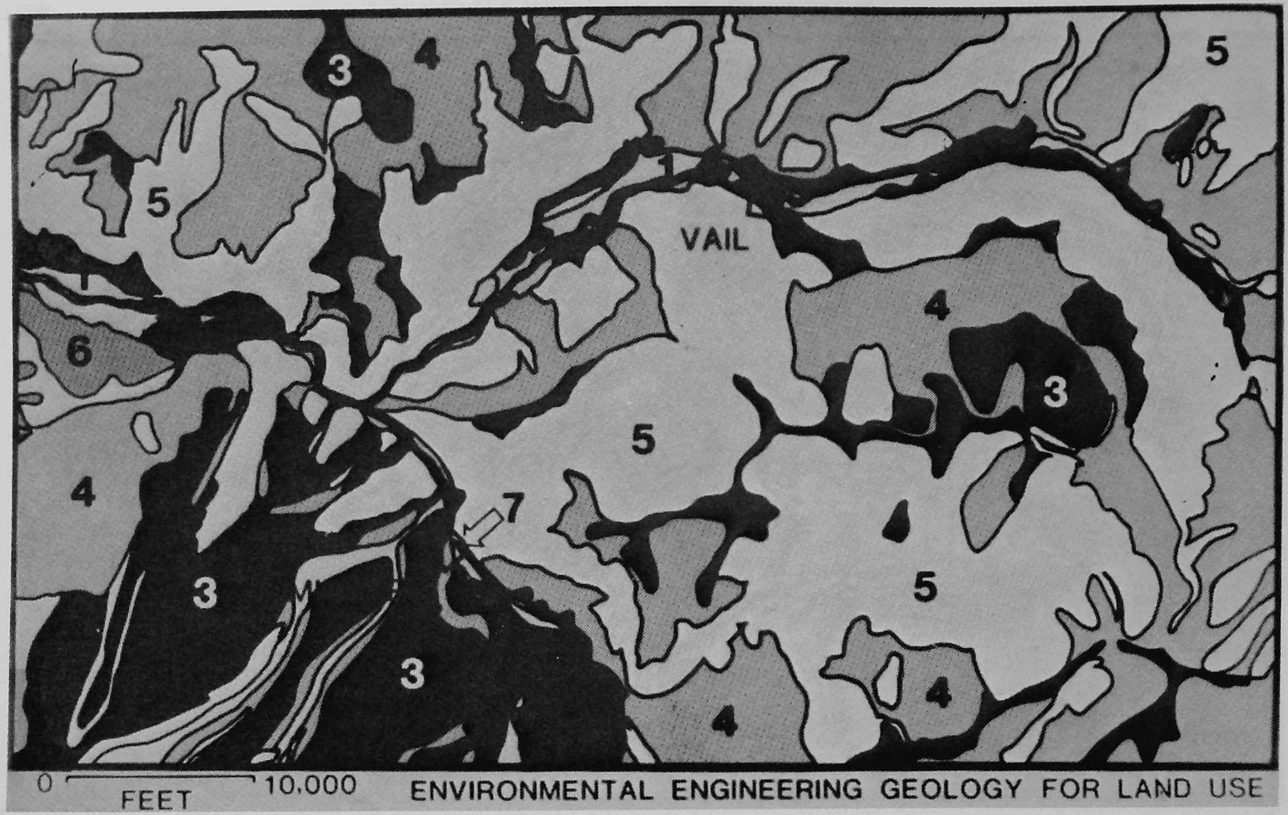

FIGURE 7. Sheet 1, Environmental Engineering Geology For Land Use map.

LEGAL ASPECTS OF COUNTY LAND USE REGULATIONS

J. NICHOLAS McGRATH JR.

Pitkin County Attorney

I understand that Karen Smith and Hal Clark from Pitkin County made a presentation this morning to you on H.B. 1041 and if that didn't shock you enough, I'm here to talk about legal matters and see if I can't shock you a little bit more. Of course, they made their presentation at 8 a.m., so maybe you were not capable of being shocked.

This conference, I gather, is concerned mostly with H.B. 1041. I'd like to try and place that act in context. Some speakers have mentioned H.B. 1034, and I'm going to speak a little bit more about that. By way of background, I would like to suggest that for those of you who are used to talking about the significance, in almost absolutist terms, of private property rights or vested rights and the like, that those terms in this day and age are not really very meaningful. The land is here forever and we are not here for long, and it seems to me that a proper approach to modern land-use law would indicate that we do not own land as we own personal goods. We don't own in the sense of being permitted to consume and destroy. We have a much greater obligation with regard to land, and hence in that sense we are trustees; we merely hold the land and use it as we can, hopefully not to destroy it too much, but rather preserve it for the future, for the unborn. Occasionally when I appear at county conferences and the like, people have heard rumors about what we do in Pitkin County and they think that, good heavens, we're taking everybody's property and so on. I don't think that's the case. I think in some instances we are pushing towards limits of what we are authorized to do by state legislation, but not further. That is sometimes difficult to communicate. If you talk, for example, to a rancher who has had land in his family, the same piece of land for a long period of time, it's very difficult for him to realize the significance of new regulations and the authority under which they are adopted.

I'm not speaking, I hope you realize, of any "ism" other than realism; I'm not talking about economic or political philosophies. There are simply too many of us in some of these little valleys, and maybe too many of us on earth in places, and we are reaching the limits of the land's ability to support us--at the same time our capacity to destroy the land is increasing at a great rate[1]. Now that to me is the framework for modern land-use laws.

I'd like to skip such areas as air and water quality control, public nuisance laws, noise abatement laws, the use of taxation as a land control device, mineral laws, though all of those areas are very important. Instead I would like to focus on the general planning and zoning chapters of the Colorado Revised Statutes with regard to counties, and also on H.B. 1041 and H.B. 1034, and then if I have time, to discuss a couple of cases, such as the recent City of Petaluma[2] decision that some of you may be familiar with. I'd like to make clear a point that John Birmingham mentioned: counties particularly and local governments generally only have such powers as they are specifically delegated by statute. A county is not, for example, like a home rule city, which is an entity that is capable of general government. Rather, a county depends on delegated authority from the state by way of statute, and I think that's an important point that even lawyers often overlook when they're asked to consider the validity of a proposed regulation.

Title 30 in Article 28 of the Colo. Statutes are the general statutes that deal with planning, zoning, subdivision and building codes. Most of the sections go back a long way, as John has indicated, although they have some very modern provisions. For example, the definition of subdivision in S.B. 35 is in my opinion an extremely broad one and an extremely modern one. As you know, subdivision is defined as the division of land into any two parcels; it does not matter what you're going to do with it. If you simply own a piece of land and wanted to convey to someone else a piece of that land, that comes within the definition. Now, it may be exempted, for example if both parcels are over 35 acres, but it comes within the definition. That, to some people, is very startling. It was certainly discomforting to at least one or two of the justices of the Colorado Supreme Court when I argued a subdivision case for Pitkin County there recently. My point is the legislature intended a very broad definition, and that definition has a rational and sound basis.

In looking at the general chapters on planning and zoning, I would like to focus on just a couple of words in each of four sections that indicate the purpose and goals of subdivision and zoning. Section 30-28-107, C.R.S. 1973, in dealing with master plans, talks about the "harmonious development of the county or region", considering "present and future needs"; matters that will "best promote the health, safety, morals, order, convenience, prosperity, or general welfare of the inhabitants, as well as efficiency and economy in the process of development". Now, those are not very meaningful terms alone, are they? Section 30-28-111, which deals with zoning, says you can zone by districts for "location, height, bulk, and size of buildings and other structures, percentage of lot which may be occupied, the size of lots, courts and other open spaces, the density and distribution of population"--and now that starts to get into something that's significant--but the rest of the terms in that general section on zoning are very vague. Also in Section 30-28-113 on zoning, the legislature repeats the same thing about location, height, bulk, size of buildings. So, that's the traditional zoning language. There is also a section (Section 30-28-115) that says that when enacting zoning or subdivision under any of these sections, that the public welfare of the present and future inhabitants of the state is to be promoted. In that section the legislature also adds phrases about reducing the waste of an excessive amount of roads, securing safety from fire, flood waters and other dangers, "providing adequate light and air", and the like. But other than general phrases as to "future inhabitants", "density and distribution of population", there is little use of language relating to new, innovative growth management control tools.

The problem with traditional zoning and subdivision laws is that, first, you are usually talking about the normal gridlike patterns of subdivisions in suburbia, and, second, it is possible under ordinary zoning to have a complete buildout to the maximum density permissible. Now, obviously there are practical considerations--the availability of money, the economy, and that kind of thing. Let me give a specific example. Pitkin County downzoned a greater portion of the County, perhaps a year ago, and it did it by increasing minimum lot sizes and reducing allowed uses to lessen densities. We had a well-qualified expert from Denver come to the County Commissioners a couple of weeks ago to advise a water and sanitation district about their capital expansion program and their ability to finance that. Even under our existing downzoning, this expert felt that a growth rate (permanent residents) of 7 percent was completely possible--and a growth rate of 7 percent doubles the permanent population in 10 years. Now that, obviously, would have a very dramatic effect upon Pitkin County and upon its economy, especially since our economy here depends largely upon the attractiveness of the area to tourists. You folks might like your conference in Durango, if you couldn't walk across Main Street here because there are a zillion cars and a zillion people. So, the problem with traditional and existing zoning is that it doesn't necessarily imply a growth rate. If land is zoned for certain uses, barring other controls of which, of course, there are many, you can come in and get a building permit for whatever use or structure is permitted. So in one year there could be a complete buildout so that we are double the population. In other words, traditional zoning doesn't look at density or growth rates over a period of time. That's why the existing chapters are somewhat inadequate, and that's why H.B. 1034 is important.

I would like briefly to turn to H.B. 1041 and H.B. 1034 and compare them generally. H.B. 1034 is called the "Local Government Land Use Control Act of 1974" and purports to be a very broad delegation of authority to local governments, and indeed it is. It regulates eight areas: for example, it permits local government to regulate development and activities in hazardous areas. Now, immediately you think of natural hazard areas, which is the terminology in H.B. 1041 which defines natural hazard areas as geologic, wildlife, fire, and floodplain. Thus, H.B. 1034 is broader than H.B. 1041 in the sense that H.B. 1034 does not limit by definition of hazardous areas. Now there may be some legal issues with regard to lack of definition, but in terms of what the act permits to be regulated, H.B. 1034 on hazardous activities is broader. Similarly H.B. 1034 says that one can protect lands from activities which would cause immediate or foreseeable danger to significant wildlife habitat; whereas H.B. 1041 says one can regulate only for such wildlife habitat in which the species have been identified by the Division of Wildlife or the Department of Natural Resources. Also, H.B. 1034 permits regulating to preserve areas of historical and archeological importance; H.B. 1041 uses similar terms but, in the definition section, it says historical areas are only those on the national register, designated by statute, or on the state historical list. So, immediately, the local government is a captive of what someone else has defined or has not defined.

There is a provision about regulating roads and federal lands in 1034 that is largely irrelevant. The next four provisions are the ones I would like to focus on. They are: (1) that the local government may regulate "the location of activities and developments which may result in significant changes in population density"; (2) the local government may provide "for phased development of services and facilities"; (3) the local government may regulate "the use of land on the basis of the impact thereof on the community or surrounding areas"; and, (4) that the local government may otherwise plan for and regulate "the use of land so as to provide planned and orderly use of land and protection of the environment". One of the problems that we lawyers have with that kind of terminology is that it's too broad that it is entirely possible that a court might say, "You can't regulate under it". In other words, the legislature has done in H.B. 1034 and H.B. 1041 two diametrically opposed things. In H.B. 1034 they used nice broad language and didn't define anything, and in H.B. 1041, they try to define everything, which leads to some difficulties in both acts. But the principal distinguishing feature of H.B. 1034 is that it uses the kind of phraseology that a planner and a lawyer, defending the planner's decision, need when talking about phased development, phased zoning, growth rates, and legislating growth rates over a period of time. It says "planned and orderly growth", "planned development", and things of that sort. I don't want to downplay H.B. 1041, certainly--it is a very important act. It establishes some new areas for local governments to regulate; areas around key facilities come to mind. It is important because it contains specific criteria for administration for those areas, like airports, and so on. It is grossly defective in terms of penalties and remedies, as Mr. Birmingham has pointed out. S.B. 35, for example--I think that this might indicate the significance of that glaring remedial defect --S.B. 35 was a broad subdivision act, with which you are all familiar, and it was intended to be broad. The legislature said the commissioners have two remedies: one, if someone conveys land in violation of S.B. 35, the party can be fined--it's a misdemeanor--up to $500.00 for each parcel. Now that penalty, a fine up to $500.00, is only good as a practical matter if you are dealing with someone who divides up a piece of land into many parcels and his margin of profit isn't that great, so a $500.00 fine per parcel as the statute says, might be significant. But suppose someone takes a very large parcel, a large ranch of, say, 1,000 acres, and cuts off a 28-acre parcel and he sells it to a Hilton Hotel chain for development. That isn't covered by the $500.00 fine because you know the Hilton Hotel paid him enough to cover his expenses for that minor fine. So that's not going to deter the illegal conduct. Then there is another section, Section 30-28-110 (4) (b), that says that the Board of County Commissioners may "enjoin" a violation. Well, I don't know how it is in your county, but around here subdividers don't call up one of the commissioners or the attorney for the county and say, "We're going to have a real estate closing here; we're going to violate S.B. 35, and you guys are invited". Nor would it do us any good to stand at the Clerk and Recorder's door because first, you can record anything you want, generally, but more importantly, a deed or conveyance (hence a division of land) as between the parties, doesn't depend on recording to be effective. It is effective when the deed is signed and delivered, and that occurs in a lawyer's or a realtor's office, and not in the commissioners' meeting room. So, if you don't find out about it, what can you do? Well, we've argued in a case[3] that is pending in the Colorado Supreme Court that "enjoin" means that one can set aside later a violation or have it declared void when one discovers it. I think we have analytically a good argument, but the more important point is that we shouldn't have to be in the Supreme Court. The legislature, hopefully, will foresee that the remedies sections are often times the key sections in land use regulations because people are used to dealing with land as they damn well please, and unless you have some sort of hammer to say, "Hey, come talk to us", they're not going to bother too often.

So, the remedies in H.B. 1041 are nowhere near what they should be, considering the scope of the act. So that is a fault of the act.

H.B. 1034, I would take it, is a delegation of traditional zoning powers and hence would be enforceable under the ordinary zoning laws. The principal means of enforcement is the denial of a building permit. You can talk about injunctions all you like and the ability to get them or fines, but in the last analysis what someone wants when he is dealing with land is a building permit to do a certain project. And if you have the authority to withhold that for the violation, then you have all the authority that you need to see that good and planned and orderly growth takes place.

H.B. 1041 also is a hassle because of its cumbersome procedure and definition sections. It has taken the Land Use Commission, working very hard, admittedly, a considerable length of time--in excess of a year--to come up with some guidelines. Very few counties have designated anything under it because it is very difficult to understand how they should go about it adequately[4], and H.B. 1034 doesn't have that problem. Also, for those of us who believe that the best land-use planning is at the local level --and I'm not sure whether that would include John Birmingham--the terminology, "areas of state interest" is foreign. Now that terminology doesn't particularly bother me because I think that the act would be exactly the same if it said, instead of "areas of state interest", rather "areas of significant concern". In other words, I don't really see a difference by the use of the word "state". However, throwing in the word "state" has bothered some counties. Their fear is as follows. The legislature says we designate all these things; all of the 60 some counties do designate most of the areas and activities. All follow the LUC's guidelines and so have the same nice numbering system, the same regulations, and so on. Then five years from now, the legislature says, "Well, everything is designated as areas of state interest and we certainly ought to regulate them because we regulate the state". Now that is perfectly within the legislature's authority with regard to counties--not home rule cities--because counties only have such authority as the state may delegate to them. So the possibility of increased state control of local landuse decisions under H.B. 1041 has bothered some county attorneys and some county commissioners I have talked to, but my opinion is that there is no nefarious scheme for the state to usurp local authority previously granted. Sometimes you never can tell what's going on down in Denver. At least we from the western slope might look at it that way.

In any event, H.B. 1034 uses nice, magic words in terms of phased development. In terms of controlling growth rates and density, what does one do? Well, one possibility is lessening density by increasing minimum lot sizes and prohibiting high-density uses, multifamily apartment houses and the like. That is within the ambit of traditional zoning authority. That's what we have done in Pitkin County, and that's what others have done. As some of you may be aware, there have been significant decisions holding that invalid. These decisions, in the East principally--you might have heard of the recent New Jersey decision, Mt. Laurel[5]--hold that in an urban/suburban context, large minimum lot sizes and the preclusion of multifamily dwellings as a permitted use, is exclusionary. That is, such zoning the courts found was adopted for the purpose of keeping out urban, low-economic groups from a suburban area or keeping out racially deprived groups. Thus, when one talks about decreasing densities and precluding growth by adopting large minimum lot sizes, one faces that challenge. Now, fortunately for us here, there is a decision out of a federal court in Connecticut[6] that says that the analysis of exclusionary zoning does not apply in the second home context, the recreational area context, and that is obviously what we consider ourselves to be. In other words, the theory of the exclusionary zoning cases is that in an urban area that is going to expand, there are separate jurisdictions around that urban area, each of which must regulate within its area to provide for its own fair share of the growth of the urban area, its own fair share of the racial groups, the low-economic groups, and the like. That is not the situation, for example, in Pitkin County, because there are obviously a lot of ski resorts in Colorado and elsewhere that people can choose to move to. It is not a question of our absorbing a fair share of predetermined expansion from an urban area. I like to practice that argument because there are going to be a lot of cases involving it, and we hope to convince some courts that that argument is compelling.

One might also lessen density and control growth in a phased fashion by controlling issuance of building permits, by controlling expansion of water, sewer, utilities, and the like. Now, most of you, at least those in planning, obviously have heard of the Ramapo decision in New York.[7] That was clearly based on the fact that in a capital development program the city controlled the utilities, the water and sewer systems and could decide the extension or expansion of such capital utility programs in a phased and orderly way. So they could regulate growth by regulating utilities. That is not true in Colorado with regard to counties; it is not available. Counties don't control water districts, and don't control sewer districts, and the like. Such districts are for the most part autonomous entities over which a board of county commissioners has little control. There are cases involving cities in Colorado that have attempted to use that mechanism. The principal case is Robinson v. City of Boulder,[8] in which Boulder had denied extensions of water lines to outlying areas in order to control growth, and the issue in that case, which is presently pending in the Colorado Supreme Court, is whether Boulder was, in effect, like a public utility and had to sell water to anyone who desired it, or whether it was free to regulate growth by regulating the extension of water, which is presumably a different subject matter. And as I say it is pending; I needn't tell you how I think it ought to be decided.

One might also consider controlling growth and regulating it in a phased fashion by master planning for a given population density at a given time in the future. That method is called population capping. The city of Boca Raton in Florida is involved in litigation involving its plan. It said, 70,000 people is plenty for us for at least 20, and we're going to regulate on that assumption.

Perhaps an easier method to phase growth is by regulating the issuance of building permits, not solely on the ground that the proposed use is or is not a permitted one, but rather by number of permits in a given time. That is the method used by the City of Petaluma that was recently upheld by a federal appellate court in California.[9] Petaluma, you may or may not know, is basically a suburban area in the San Francisco Bay area. It adopted a plan that said notwithstanding zoning or subdivision laws (I'm simplifying it to make the point), we will issue in the next five years, building permits for only 500 dwelling units. So if Petaluma receives applications for building permits far in excess of that number, it would put them all in the hopper, and evaluate them according to criteria set forth in Petaluma's plan. The City of Petaluma, I should point out, increased in population over 25 percent in two years, from 1970 to 1972, which is a very significant growth rate, as you might imagine. The federal district court said the Petaluma plan violated what some people call the right to travel under the U.S. Constitution. Now, if you look at the Constitution, it's hard to find words that say, you've got a right to travel, and land use measures that restrict that are invalid. I do not think that the right to travel is an analytically sound ground for attacking local land use measures; the federal court of appeals in California didn't decide that issue; it skirted the issue on the technical ground of "standing". That is, the plaintiffs in the suit, interestingly enough, were largely a construction industry association; they were already in Petaluma, and were trying to raise the argument of the right to travel on part of disenfranchised people elsewhere who presumably would find Petaluma to be the most glorious spot in the world. In any event, the court said the builders could not raise that argument. The court upheld the Petaluma plan otherwise, holding valid the regulation of building permits over a period of time by quoting a case decided in the U.S. Supreme Court that I think is so nice, I'll simply read briefly from: "A quiet place where yards are wide, people few, and motor vehicles restricted are legitimate guidelines. . .The police power is not confined to elimination of filth, stench, and unhealthy places. It is ample to lay out zones where family values, youth values and the blessings of quiet seclusion and clean air. . ." -- can't you see a county attorney loving this? -- ". . . make the area a sanctuary for people".[10] I have that practically memorized, as you might imagine. In any event, H.B. 1034 has the kind of terminology to permit the adoption of plans such as that used by the City of Petaluma.[11]

There are many other tools for growth management control, such as land banking, transferable development rights,[12] tax incentives to preserve agricultural uses, which in a sense preserve open space and visual qualities. Some of these the local governments do not yet have adequate authority for. For example, it is arguable but perhaps difficult to sustain, that transferable development rights could be adopted under H.B. 1034. I would hate to have to argue that because transferable development rights are so innovative--in effect, they are the creation of a new proper right--and to establish that TDR's could be established by local government without something more definite, with no more standards than an act that says "otherwise planning for and regulating the use of land so as to provided planned and orderly growth", would, I think, be very difficult. There was a bill introduced by our local representative in the legislature last year to provide a system of transferable development rights in Colorado. By that I take it everyone understands, you create rights for development purposes that exist, in effect, apart from the land, and you give a landowner the ability to sell the development rights to another landowner. So one can accumulate many development rights; and if you've sold the development rights for a piece of land, then the land would remain basically agricultural in use, or open space, or something of that sort. The bill wasn't passed, and hopefully it will be introduced again, if not by the Governor, which I doubt, in a legislative session in the near future. I think TDR's are one of the new kinds of innovative land use controls that will come into existence around the country. TDR's are presently being used in several areas to regulate historic development, the preservation of historic sites, and there is no reason, analytically, why the concept can't be broadened and used more expansively.

It seems to me, as I said before, that at least at this stage in Colorado and perhaps elsewhere, the best government for land-use matters is local government. It is the closest to the land; it is the closest to the landowners. You should come to a county commissioners meeting occasionally; there is certainly dialogue back and forth, and sometimes I wonder whether at the State level the necessity for that dialogue is adequately understood. I think many of the tools we need exist. I think we need some more legislation. But, I'm one who believes that the government that governs best is the one that governs on the local level.

FOOTNOTES

1. Cf. "How can the spirit of the earth like the White man? * * * Everywhere the White man has touched it, it is sore". A Wintu Indian, McLuhan, Touch the Earth: A Self-Portrait of Indian Existence, p. 15 (1972).

2. Construction Industry Ass'n v. City of Petaluma, Ct. App. 9th Cir., decided August 13, 1975.

3. Board of Co. Comm'r's, Pitkin Co. v. Pfeifer, et al., Colo. Sup. Ct. No. C-652, reported below, _____ Colo. _____, 532 P.2d 51 (1974).

4. Subsequent to this talk, on December 1, 1975, Pitkin County designated under H.B. 1041 certain geologic hazard areas; wildfire hazard areas; floodplain hazard areas; certain historic and archeological resource areas, wildlife habitat areas; areas around mass transit proposed right of way, terminals, and stations; and all activities of state interest. On the evidence at the hearing, Pitkin County declined at that time to designate mineral resource areas, arterial highway interchange areas, areas around airports, areas around major facilities of public utilities, and soils with high corrosivity and high expansive characteristics (as geologic hazards).

5. Southern Burlington Co. NAACP v. Township of Mt. Laurel, 336 A2d 713 (N.J. 1975).

6. Steel Hill Development, Inc. v. Town of Sanbornton, 469 F2d 956 (1st Cir. 1972).

7. Golden v. Planning Bd. of the City of Ramapo, 30 N.Y.2d 359, 285 N.E.2d 291, 334 N.Y.S.2d 158, appeal dismissed 409 U.S. 1003 (1972); see Note, Phased Zoning: Regulation of the Tempo and Sequence of Land Development, 26 Stan. L. Rev. 585 (1974).

8. Robinson v. City of Boulder, Colo. Sup. Ct. No. 26720.

9. See footnote 2.

10. Village of Belle Terre v. Boraas, 416 U.S. 1 (1974).

11. There is an almost unfathomable exception section in H.B. 1034 that could diminish the act's value if the courts viewed the act narrowly and the exception expansively. See Section 106-8-107, C.R.S. 1963 (1974 Sess. Laws, ch.81, p. 354).

12. See generally Carmichael, "Transferable Development Rights as a Basis for Land Use Control", 2 Fla. St. U.L. Rev. 35 (1974).

COLORADO LAND USE COMMISSION PROGRESS AND PLANS

JOHN R. BIRMINGHAM

Colorado Land Use Commission

The Land Use Commission (LUC) has been in existence since 1970 as a temporary commission in the office of the Governor. When the legislature set it up, it gave it the task of classifying lands in the State into four categories by the end of the year. It took most of the year to find a staff director and get organized, and the LUC did not get its task even started. When the legislature then met in 1971, it changed the task to develop a land-use plan for the State by the end of 1973. At the end of 1973, the Commission came in with a report describing procedures that ought to be followed for land-use management in the State. Throughout most of the 1974 session, many people wondered what the LUC would do next. At the very end of the battle on H.B. 1041--just a matter of days before the end of the session--the legislature gave an assignment to the LUC, among a number of things to assist local government to issue certain guidelines and so forth. That gave the Commission really a new life and a new charge.

I was made a member of the Commission by Governor Vanderhoof in May of 1974. In February of this year, after Governor Lamm became governor and made some changes in the composition of the LUC, I was elected chairman. The very first thing I decided as chairman, and really why I took the job, was that the Commission ought to get moving in the preparing of model regulations to be used by local governments.

As I'm sure many of you know, I was in the office of the governor from mid-1973 on and got around the State and became very satisfied that local governments wanted to do the right thing in land-use. More often than not they were inhibited: they didn't have the legal tools; they didn't have the financial base to do what was needed; they didn't have the technical expertise. In the 1974 session not only was H.B. 1041 passed, but H.B. 1034 also, and I'll take credit or blame on H.B. 1034 as I had a good part in writing it. Some of these things happened very quickly, and you may not like the language of 1034 because we slapped it together literally in a matter of a half hour or so right at the press table. Everything underneath the enacting clause of the initial H.B. 1034 was stricken and a new bill substituted. The gist of it is, if you will recall, that whether local governments have had these powers in the past or not, we here ratify that they do have these powers now and we want you to use them, and in case there is any doubt, we've put in a catch-all clause in the end so that they can do anything in land use provided that it was constitutional. There was a clause that the Senate put in that cast some doubt on that, but basically I think most people will interpret H.B. 1034 as a liberating type of statute. Local governments have only such powers as the legislature gives them, and a real problem has been that the basic powers that were given local governments in Colorado were given to them 100 years ago, long before massive, modern developments started. Local governments, I believe, were very improperly charged with not doing good land-use work. They simply didn't have the legal capacity to do it. Since the 1974 session, however, the legal capacity seems to exist.

There are a few other things that need to be done: one, to pass legislation for managing subdivisions that were platted years and years ago, still hanging around but not developed; I think we can and should have legislation to allow those to be "unplatted", if you will. There is also a need for land-use legislation at the State level. The State should be involved in the major, massive developments--coal gasification plants, nuclear power plants, oil shale and so forth--those impacts slap across county lines, often interstate lines. Actually, the State does have a say in these developments already. In the Beaver Creek case, the State stepped in and in effect said we are going to take a position in this. Eventhough the LUC had told the federal government last winter to go ahead and designate Beaver Creek as a ski area, the new governor said no, and so far the federal government has not gone ahead. At some point it probably will, but only after certain changes are made. So we are seeing in effect the evolution of a permit system at the State level; people won't say that you have to have a permit from Governor Lamm, but that's the way the system is working. To remain a nation based "on laws, not man", a site selection statute should replace gubernatorial whim.

There were three things in H.B. 1041 that were of real value. Although it runs 25 pages, and a lot of it ought to be chucked, it has a lot of very cumbersome procedures in it, and as you know, ambiguous features. One good feature was that money was made available to local governments. Another gave a push to State agencies to assist local governments (and John Rold has shown great leadership in picking up the ball that the legislature gave him there). Third, the LUC was given authority to step in on local governments if--and there are some cases--the local governments ought to be acting but are not. Those are the three main features of the bill. Then, there is a laundry list of matters of State interest. You can count the items in it in a number of ways. For practical purposes, we've settled on 21, but that could change. There are also a number of matters that are not in the bill that ought to be such as ski areas and coal gasification plants.

H.B. 1041 has a fair amount of flexibility, and if you look at it in conjunction with H.B. 1034 and existing zoning powers, local governments now have a lot of power. However, problems arise in using these powers, which means you've got to hire a lawyer. To get on top of these problems requires quite a bit of innovative legal work, and it's not cheap. The Commission has been working on this and hopes to make available to local governments model regulations that will in turn save money for the local governments. If 63 different counties have to hire separate lawyers to develop their own flood-plain regulations or geologic hazard regulations, they are going to come up with 63 different solutions, and it will be a mess for everyone involved. What we've been doing and I think we can get substantially completed by the end of the year, is preparing model regulations. These will be models that will suggest how to handle different problems. Hopefully they will be adopted (as many counties adopted the model subdivision regulations), so that a section in one county will be the same as in other counties and that there will be a certain degree of uniformity. If a court test is necessary, the decision will have meaning throughout the State.

H.B. 1041 quite clearly also specified that the Geological Survey, the Forest Service, and the Water Conservation Board should, by September 30th, 1974, issue model regulations for geologic hazards, for forest fire hazards, and for flood plains. I am uninformed whether any county has adopted or used those models. I'm not surprised if they haven't been adopted, not because of faults in those model regulations but because of the other cumbersome procedures in the bill. One reason why the Commission can be helpful and hopes to be helpful is that it is ridiculous for one permit procedure to be used for geologic hazard areas, another for flood plains, a third procedure for forest fires. What if you have one beautiful spot coming around the bend of a river; it's a new community site, there are minerals there, there's wildlife, there's an avalanche coming down;--do you have to get five permits or one permit? These are the things where we can make strong suggestions that should be helpful to the local governments.

The bill also requires the Commission to issue "guidelines for designation". At first we interpreted this as requiring us to prepare a separate method of designation for each of these different matters. It then became apparent that what we ought to do (and this is what we have done) is prepare one procedural model of "how to identify", whether it's a new community, a flood plain, a geologic hazard, and so forth. Is this done by the planning commission, by the governing body of the local area, or by whom? How much notice do you have to give? Who do you send notice to? What are your hearing procedures? We've taken the same approach on designations and the same on permits. Our guidelines on these matters were published and actually became final just last week.

We had hoped that they were final in July. We finished them and then submitted them to the Attorney General for review as to legality and constitutionality under the State Administrative Procedure Act. We thought that they were alright but unfortunately in two provisions were constitutional but not within the authorization of the statute. The most important one a number of you have heard about. Realizing that every community has its different problems, we recognized that for political, legal, and factual reasons, some local governments would want to proceed under H.B. 1034, some under zoning, some under H.B. 1041, and so forth. Therefore, in the development of our guidelines, we created as much flexibility as possible. We said, if identification is completed with H.B. 1041 funds, the actual regulation need not be completed under that bill. Once an area is designated, any development in it requires a great deal of red tape. Even for an outhouse, public notice would be required. In that kind of a situation most local governments would prefer to regulate under one of the more accustomed regulatory procedures. The Attorney General noted that every time the statute mentions identification, it also uses the two additional words "and designation". Thus, there is an implication in the statute that if a local government has taken H.B. 1041 money and used it for identification, it then must go forward and have a formal designation hearing by the governing body of the city council or the board of county commissioners under 1041. Most people are not happy with this. The Attorney General's opinion notes as well, because the statute says it clearly, that once the hearing has been held, it is not necessary to designate, as long as there has been the opportunity to designate. The county commissioners or city council can back off. They can adopt the proposed designation, they can amend it or reject it, or they may regulate under H.B. 1034 or any other authority, or they may reject the regulation entirely. So, the opinion is not quite as bad as you might think. Governments do not have to designate and regulate under H.B. 1041 if they have identified under 1041, but they do have to have the hearing according to the opinion. Most local people I've talked to would like not to be bound quite so much.

I think there may be a way out. As you know, there is a tight budget situation, and there may well be an amendment introduced at the opening of the next session in January of 1976 to amend the "long bill" which is where the money came from. I am going to suggest to the Joint Budget Committee that the H.B. 1041 appropriation be awarded so that instead of the money being only for "identification and designation", it can be used for identification under 1041 and then for regulation under any other authority.

The moment we finished our guidelines, we went to work to prepare a model administrative regulation that could actually be adopted by the local governments. That work is well along. We have had one hearing on it and expect to have a final hearing on it November 14th. We will have a work session sometime before that, and some of you will undoubtedly be involved.

The next things we are working on are several of the specific matters such as flood plains. The models prepared a year ago contain a number of procedural provisions which are no longer necessary in specific regulations if local governments follow the all-encompassing administrative regulation that we've prepared. What has been passed out to you is a rough draft, an outline, of what I think will be forthcoming in the way of a model geological area regulation. You'll see the fine print and old numbers which are taken directly from the 1974 Geological Survey regulation. None of that language has been changed, only the procedural items have been omitted. During the next few days, we'll get together with John Rold and others of you who want to be involved to refine the draft and prepare it for public hearing. Any of you who want to work on it further are certainly welcome. The flood plain regulation is no further advanced than this, but it has the same general format. Wildfire and wildlife regulations, because they deal with "areas", should follow in the same general pattern. We are also working on areas around airports. The HUD 701 money was used by the Dept. of Local Affairs to hire a consultant on airports to prepare a model regulation. That was done last spring, and it's a very good model but again, it doesn't tie in with our particular procedure. If local governments want to use our administrative procedure, then we have to tinker with the model. That's well along.

One of the many things our staff is going to have to get into is the working under H.B. 1041 with minerals, and working closely with the Dept. of Natural Resources so that the model H.B. 1041 regulations that we prepare dovetail very nicely and closely and have all the nuances and so forth that are worked up by the Mine Reclamation Board and others.

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7 - POTENTIALLY SWELLING SOIL & ROCK IN THE FRONT RANGE URBAN CORRIDOR, COLORADO, S.S. Hart, 1974, 23 p., 13 figs., 4 pls., 1 table, 4 apps. Colored maps (scale 1:100,000), 3.00.

8 - ROARING FORK AND CRYSTAL VALLEYS--AN ENVIRONMENTAL & ENGINEERING GEOLOGY STUDY, EAGLE, GARFIELD, GUNNISON, & PITKIN COUNTIES, COLORADO, F.M. Fox & Assoc., 1974, 64 p., 3 figs., 3 pls., 6.00.

9 - GROUND SUBSIDENCE & LAND-USE CONSIDERATIONS OVER COAL MINES IN THE BOULDER-WELD COAL FIELD, COLORADO, Amuedo & Ivey, Geologic Consultants, 1975, text and plates (all scale 1:24,000), 10.00

10 - GEOLOGIC HAZARDS, GEOMORPHIC FEATURES, AND LAND-USE IMPLICATIONS IN THE AREA OF THE 1976 BIG THOMPSON FLOOD, LARIMER COUNTY, COLORADO, J.M. Soule, W.P. Rogers, and D.C. Shelton, 1976, 4 pls. (scale 1:12,000), 4.00.

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6 - GUIDELINES AND CRITERIA FOR IDENTIFICATION AND LAND-USE CONTROLS OF GEOLOGIC HAZARD AND MINERAL RESOURCE AREAS, W.P. Rogers and others, 1974, 146 p., 32 figs., 7 tables, 3.00.

7 - COLORADO AVALANCHE-AREA STUDIES AND GUIDELINES FOR AVALANCHE-HAZARD PLANNING, A.I. Mears, 1978, Final report in press.

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BULLETINS

32 - PRAIRIE, PEAK, & PLATEAU--A GUIDE TO THE GEOLOGY OF COLORADO, John Chronic & Halka Chronic, 1972 [reprinted 1977]. 126 p., 4th printing. (Quantity discounts available), 4.00.

37 - BIBLIOGRAPHY & INDEX OF COLORADO GEOLOGY, 1875 to 1975, American Geological Institute, 1976, 488 p., 3 figs. Softbound 7.50; Mailed 8.50; Hardbound 10.00; Mailed 11.00.

38 - GUIDELINES AND METHODS FOR DETAILED SNOW AVALANCHE HAZARD INVESTIGATIONS IN COLORADO, A.I. Mears, 1976, 125 p., 32 figs., 4.00.

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STATE GEOLOGIC MAP, U.S.G.S., 1935, (scale 1:500,000). Repr[illegible] discounts available.) Mailed folded or over-the-counter [illegible]