GEOLOGIC HAZARDS

This chapter deals with the three most important and common geologic hazards in the Colorado Springs area: landslides, subsidence, and expansive soils (Maps 3 and 4).

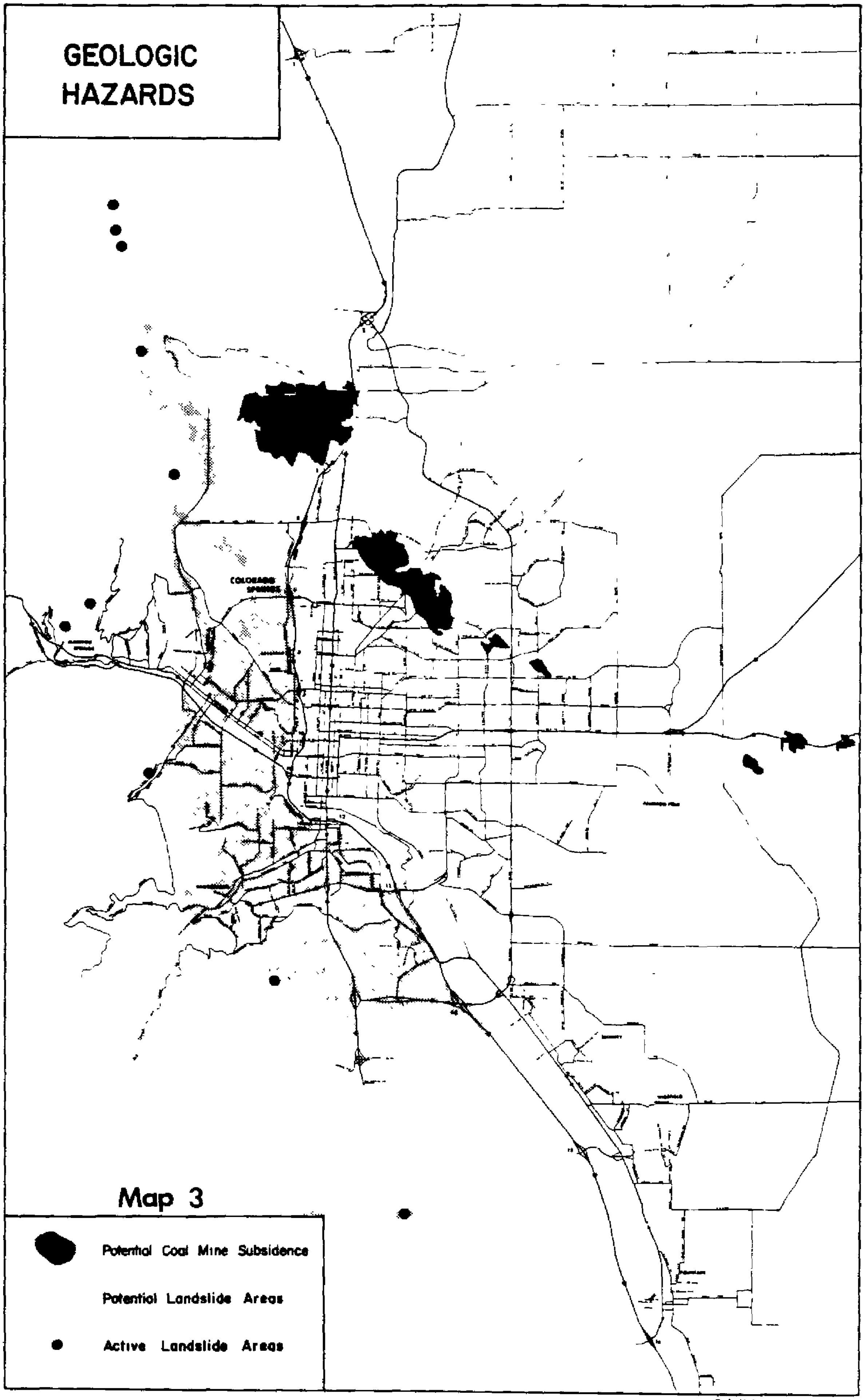
Landslide

Landslide is a commonly used term describing a particular type of mass wasting (the process by which large masses of earth or rock are moved downslope by gravity). Within the Colorado Springs area the specific types of mass wasting include rockfalls, rock slides, soil creep, earth slump, and debris flow.

Mass wasting occurs in response to gravity exerting a downward pull on rock and soil. Resistance to the pull is most often overcome when water is introduced into the soil and rock, reducing friction and causing a loss of cohesiveness. The water also contributes to the collapse by adding to the weight of the material. Heavy rainfall, snowmelt, or the introduction of water by artificial means can all lead to increased landslide activity.

In addition, earthquakes and human activities may also cause landslides. Earthquakes can trigger instantaneous slope failure by increasing shear stress and reducing shear resistance. Human activity can directly lead to slope failure when hillside excavation, such as roadcuts, oversteepen and unbalance a slope.

Although virtually all geologic formations in the Colorado Springs area are subject to slope failure if the right conditions are present, most activity occurs along the foothills in steep terrain underlain by shale and mudstone of the Dakota Group, Benton and Pierre Shales, Laramie Formation, and


GEOLOGIC
HAZARDS
COLORADO
SPRINGS
Map 3
Potential Coal Mine Subsidence
Potential Landslide Areas
Active Landslide Areas
C J Huber

Dawson arkose. Mass wasting in the Colorado Springs area is largely limited to clearly defined areas where problems have a high degree of predictability. Defining these areas can be accomplished by examining present conditions and understanding past landslide events in a particular region (Map 3).

As continued development and population growth occur in Colorado Springs, more persons and property will be subjected to the effects of mass wasting. Developments such as Cedar Heights and High Point Centre in the foothills area are likely to suffer from landslides, rockfalls, and soil creep due to the steepness of the slopes in those areas.

Rockfall. Rockfall is perhaps the most evident mass wasting event in the Colorado Springs area. Most of these landslide occurrences are recognized by landslide deposits; less than 1% of them are observed as they actually occur. Rockfalls have occurred near the Sunbird/Popes Bluff area, along Douglas Creek, and in the west side of the city. Additional rockfall deposits have been found at the following locations:

1) Cheyenne Mountain. These deposits--the most extensive in the area--are from an event 500,000 years ago that may have been triggered by an earthquake. Deposits extend from the base of the mountain across Highway 115 into Fort Carson.

2) Along Highway 115 and within Fort Carson. These deposits are found along the steep slopes on the west side of the highway and on the side of "Agony Hill" southwest of Butts Army Air Field.

3) North of Glen Eyrie near Castle Concrete Quarry.

4) Southwest of Mt. St. Francis.

5) West of the Air Force Academy. Four deposit areas occur along the face of the Front Range.

6) Bear Creek.

7) Ute Pass near French Creek.

Rock Slide. This type of mass wasting occurs when a mass of rock breaks free as a block along a bedding plane and slides downward. The area where this type of failure is most prevalent is along Highway 24 in Ute Pass. The construction of the highway itself has effected the area by oversteepening the toe of the slopes and causing several slides.

Soil Creep. Soil creep is characterized by a slow movement of unconsolidated materials in a downslope direction. The rate of soil creep is dependent on the slope and the amount of water present. Soil creep is most often noticeable when tree growth is altered by the moving soil, causing a characteristic "pistol butt" appearance. Such trees are present along some sections of Cheyenne Mountain and in the Black Forest area.

Slumping. This type of mass wasting has occurred in the Garden of the Gods along 31st Street and in the Mesa section south of Fillmore and North of Uintah. Slumping usually occurs when a slope is oversteepened either through natural processes such as stream erosion or through human activities such as excavation or road construction.

Debris Flow. These events commonly start as rockfalls or rockslides in steep canyon areas, especially when unconsolidated material is loosened during heavy rainfall. Debris flows behave as heavy fluids and have an astonishing capability to transport large boulders, trees, and other heavy objects. Some of the steep canyons south and west of the Broadmoor have experienced debris flows in the past.

Hazard Mitigation

Mitigation of landslide hazards can be divided into five categories:

1) Change of slope shape. An oversteepened slope is the main cause of slope failure, so grading the slope to alter its shape and angle can reduce the failure hazard.

2) Water drainage control. Water saturation is directly related to slope failure since moisture reduces resistance and cohesion and increases stress by adding weight. Drainage tiles and channels can lower the risk of failure.

3) Control and retaining structures. Such mitigation includes the use of retaining walls, anchors, buttresses, and piles.

4) Special treatment. This technique might include planting vegetation to control erosion, covering the slope in cement, or removing the slope.

5) Avoidance of landslide areas. Avoidance of the hazard may be the best mitigation practice if at all possible. This is especially true in areas of rockfall and debris flow hazards.

Hillside Overlay Zone

In 1983 the City of Colorado Springs adopted a hillside zoning ordinance covering the portion of the city most seriously affected by steep slopes. Those areas lying within the overlay zone which are to be developed must meet certain additional criteria over and above the normal standards for grading and construction. The ordinance is intended not only to mitigate landslides, but also to ameliorate other environmental concerns such as expansive soils and erosion. Specifically, these objectives are (City of Colorado Springs, 1983):

1) To conserve the unique features of hillside areas.

2) To provide safe and convenient access to hillside areas.

3) To minimize water runoff and soil erosion problems caused by development.

4) To assure proper development types compatible with the hillside areas.

5) To assure limited taxpayer liability attributable solely to development on hillside areas.

The ordinance itself requires a land suitability analysis, a developement plan, a master facilities plan, a grading plan (with erosion control and reclamation provisions), and maintenance guarantees for all developments in the designated areas.

There are three general approaches to hillside development control: the density approach, the soil overlay approach, and the guiding principles approach. This last is the one actually used by the City of Colorado Springs.

The guiding principles approach is the most flexible of the three and allows great latitude for enforcement. However, this is both a strength and a weakness. If the flexibility is used to design specific criteria to suit individual situations, the guiding principles approach is a sound way to direct hillside development. If, on the other hand, this flexibility leads to watered down criteria and multiple zoning regulation variances, this approach can become little more than another emaciated zoning ordinance. Care must be taken to ensure strong enforcement of the ordinance and proper punitive measures if the ordinance is violated.

Subsidence

The Front Range has a long history of coal mining dating back to 1859 with an estimated 900 mines having been opened and developed since then. Of those, more than 50 mines, all presently inactive, were opened in the Colorado Springs area (Amvedo and Ivey, 1982).

The Local Hazards. Within Colorado, the Colorado Springs area probably has the highest potential for subsidence and related damage because the region includes several fully developed areas located over very shallow mines. Approximately 2400 acres of the city (Lucas, 1983) are undermined by inactive coal workings.

There are two major areas of Colorado Springs known to be above inactive coal mines--Rockrimmon and Cragmor-Country Club (Map 3). The Rockrimmon area is characterized by relatively deep mining 250'-500' below the surface while the Cragmor-Country Club area contains much shallower mines with some only 30' below the surface. There were 22 mine subsidences classified as emergencies in Colorado Springs between 1979 and 1983 (Cantwell, 1983) with most of them occurring in the Cragmor-Country Club area; all together they have cost the

Office of Surface Mining $767,000 (Cantwell, 1983). Several more subsidences have occurred since that time. The potential for future subsidence events and resulting damage continues to be high as development continues over both undermined areas. Cragmor-Country Club, for example, has approximately 3,000 people living over undermined areas, and projected development will only increase the population at risk.

To understand the problem of abandoned mine subsidence, it is necessary to understand the mining processes utilized to extract coal in the Colorado Springs area. The seams of coal present in the Colorado Springs field ranged in thickness from 1' to 14', and the mining technique utilized in all mines was the room and pillar method. The "pillars" are unmined coal left in place to act as a support for the roof during the mining process. The "rooms" are the voids left when coal is mined out between pillars (Myers, 1983). Entry to most mines in the Colorado Springs area was through inclined openings driven down the dip of the coal beds (Amvedo and Ivey, 1982). A few mines were entered through vertical shafts with the Klondike mine shaft being the deepest--extending 500' below the surface (Amvedo and Ivey, 1982).

Variables affecting subsidence potential include thickness of the mine void, extraction ratio (how much coal was removed), overburden thickness, and mining method. The Cragmor-Country Club area, because of its shallow overburden thickness, is especially susceptible to the development of sinkholes; many have appeared in the Country Club area (Cantwell, 1983). The greater overburden thickness in the Rockrimmon area will probably result in the development of subsidence troughs as opposed to sinkholes.

Another variable affecting subsidence is water. In the Colorado Springs area, groundwater can have a beneficial effect by acting as a support and providing buoyancy. The amount of support is determined by the permeability of the roof rock. If this water is removed, the loss of support can lead to mine roof instability and collapse (Myers, 1983).

Hazard Mitigation. Those areas eroded by coal mines need not be abandoned or rejected for development. There are at least five solutions and alternatives available to deal with the subsidence problem:

1) Acceptance of the risk. This is, in effect, the option currently being followed in Colorado Springs. A problem, of course, is that not all the participants involved are aware of the risk being taken.

2) Land use planning. Uses in those areas not yet developed could be limited to open space, land fills, or farming (Shelton and Prouty, 1976). This solution is of limited use in Colorado Springs because approximately 86% of the area above abandoned coal mines is either already developed or currently undergoing development (Myers, 1983).

3) Insurance. There are three subsidence insurance programs in effect in the United States--in Pennsylvania, West Virginia, and Illinois. Colorado is currently examining the possibility of implementing a similar program. A national effort, similar to the National Flood Insurance Program, could also mitigate the hazard.

4) Subsidence resistant construction. Structures can be constructed to be either extremely flexible or completely rigid to withstand the stresses caused by subsidence. Flexible systems allow a structure to conform to the new shape of a collapsed surface without showing the effects of the movement. Similarly, utility lines can be constructed using flexible line and telescoping material to avoid breakage during subsidence events (Myers, 1983). Rigid construction involves making foundations as rigid as possible to insure that buildings remain intact during subsidence. Through the use of jacks, buildings can then be restored to their previous level position.

5) Subsurface treatment. Subsurface treatment consists of filling the mined areas, eliminating the mine voids, and/or creating support. In Colorado Springs, the Office of Surface Mining has responded to emergency situations by filling voids. However, this solution has problems that limit its application, including:
   a) the need for accurate maps so backfilling holes will intersect voids,
   b) the need for large supplies of water and filling material, and
   c) the high cost of filling voids which requires a large number of holes to fill a relatively small area (Amvedo and Ivey, 1982).

Other methods of treating the subsurface involve eliminating the void through blasting or dynamic compaction. In the developed areas of Colorado Springs undermined by mines, this process would be extremely dangerous because the results are not predictable.

Mined Land Reclamation Division Recommendations. The Colorado Mined Land Reclamation Division supervised a study by Dames and Moore Engineers (Dames and Moore, 1985) which extensively analyzed the subsidence problem in Colorado Springs. They drilled 118 rotary holes and five full-length core holes to help determine the exact extent of the subsidence hazard in the city. The study found only six actual or possible cases of mine subsidence in the Rockrimmon area which is above the deep mines in the region; it found one incident of subsidence in Palmer Park, and it found over 2,400 sinkholes and cracks in the Cragmor and Country Club Estates area. Obviously, the highest hazard areas are over the shallow mines of Cragmor-Country Club Estates. One other high hazard area was found on the northeast border of the Digital Equipment Company's plant in Rockrimmon.

Dames and Moore recommends that vacant land over high hazard mine areas not be developed. Currently, the city does not regulate the development of such land. Therefore, either new regulations or intensive public education will be needed to preclude extensive development of these properties. If development is to occur, the areas should not be built on unless:

1) Detailed studies of the property show that more favorable conditions exist at that exact location than are outlined in the Dames and Moore study,

2) Significant measures are taken to ameliorate the hazard such as backfilling, adding slurry, and plugging mines, or

3) The structures are designed to withstand extensive subsidence.

Because the locations and severity of future subsidence cannot be exactly determined, the study recommends against a widespread program of trying to lessen the subsidence hazard to all existing structures in the hazard areas. What is recommended is a comprehensive insurance program designed to help those landowners affected by actual subsidence events.

Two other general recommendations are not to remove groundwater from mines since groundwater helps to support the overburden weight above mines, and to maintain complete and precise subsidence event records. These records could help determine subsidence rates and predict future characteristics.

Other Related Hazards. In addition to subsidence there are three other hazards associated with inactive mines--drainage hazards, mine/waste bank fires, and mine openings.

Mine drainage hazards can produce both physical and chemical risks. Physical hazards occur when the water volume exiting an inactive mine is large enough to cause significant erosion. Chemical hazards occur when the mine water is acidic or contaminated with metals or other pollutants. Currently, there are no known problems produced by water draining from coal mines in the Colorado Springs area. However, the effect on ground water quality has not been investigated and may prove to be a problem in the future.

Mine fire hazards are of two types: those in the mine itself or those in waste banks outside the mine. These fires can be started by any of several different agents including camp fires, natural events (lightning, forest fires, grass fires), and spontaneous combustion. Once started, they can be extremely difficult to control or put out. A fire has been burning south of Florence, Colorado since July, 1982, and some officials are worried that it may burn almost to Canon City before extinguishing itself. The U.S. Office of Surface Mines has already spent $300,000 attempting to control the blaze (Denver Post, 1983). Although no mine fires have occurred in the Colorado Springs area, the potential for ignition is always present.

Mine opening hazards are usually associated with inadequate warnings, fencing, or plugging. Openings easily accessible to large numbers of people (such as those in the Colorado Springs field) should be filled or plugged completely to prevent access. Openings farther away from development can be protected more simply with warning signs, fences, or locked gates. In the Colorado Springs area there are two mine opening hazards: one near the Wilson Ranch and one at the northern edge of the Cragmor-Country Club area (Amvedo and Ivey, 1982). A problem associated with mine openings occurred on April 13, 1979, when the airshaft of the Klondike mine (I-25 and Woodman Valley Road) reopened to a depth of 500 feet following surface subsidence. The shaft had been previously capped, but the surface plug deteriorated, leading to the reopening.

Expansive Soils

In the United States, expansive soil movement causes over two billion dollars in damage annually. This exceeds the combined average annual damage due to floods, earthquakes, hurricanes, and tornadoes. Colorado is classified as one of three states in the U.S. which has severe expansive soil problems.

The effects of swelling soils on structures were first recognized in the 1930s as brick increasingly replaced wood as a building material, resulting in more rigid structures. In 1938 the potential problem of building on swelling soils was officially recognized by the U.S. Bureau of Reclamation, and in 1959 a national conference was held at the Colorado School of Mines to discuss the problems of building on expansive soils--the first such meeting.

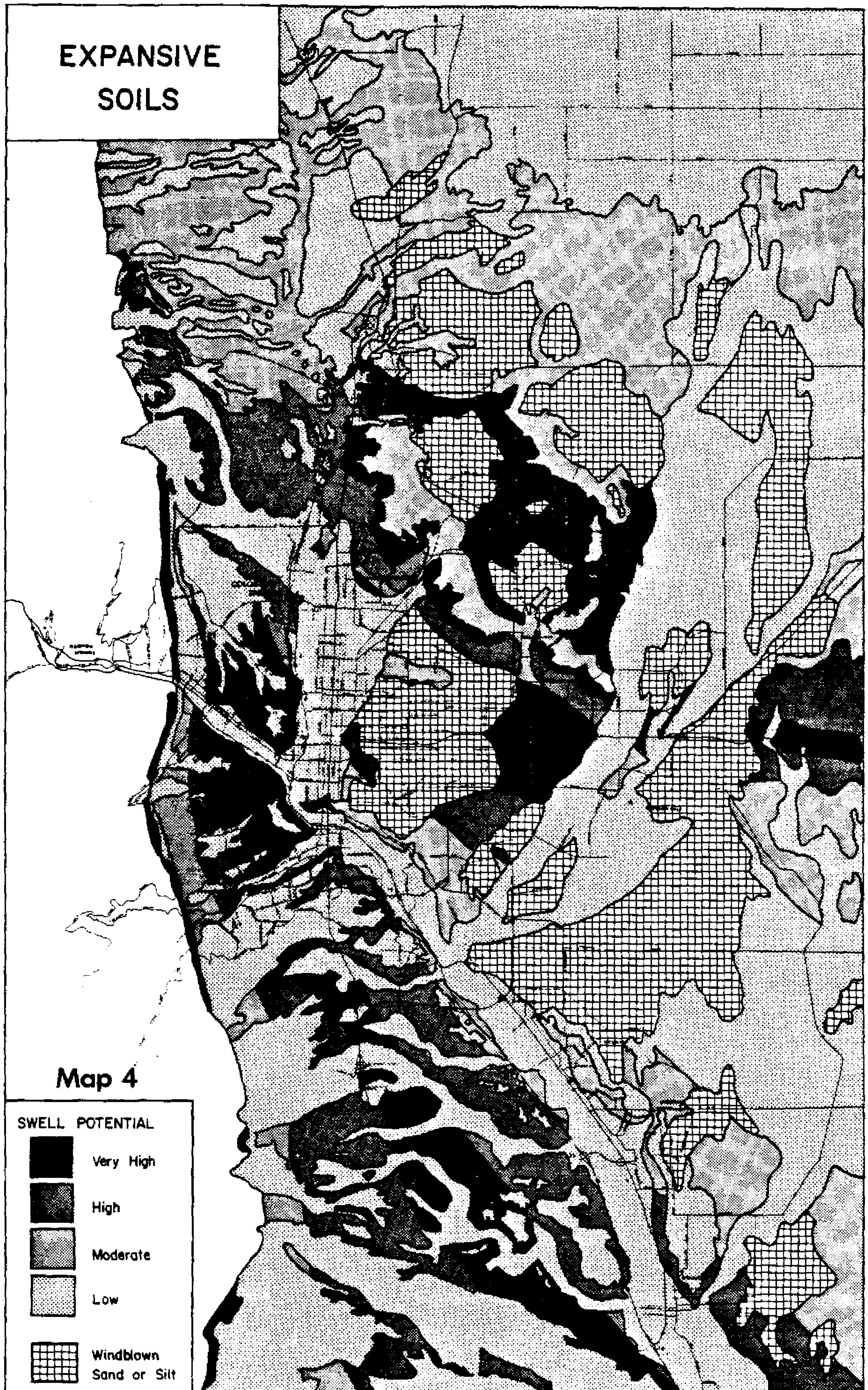
Expansive soils are ones that shrink and swell depending upon the water content of the soil. Such materials contain smectite minerals--clays which can absorb large amounts of water because of their lattice structures. There are two primary parent materials from which swelling soils may be derived: basic igneous rocks such as basalts and gabbros in which feldspars and pyroxenes decompose to form smectites, and sedimentary rocks which contain smectites.

The latter is the source of expansive soils in the Colorado Springs area which are derived primarily from Pierre shale and to a lesser extent from the Laramie formation.

Expansive Soils in Colorado Springs. A significant portion of the Colorado Springs area is underlain by potentially expansive soils (Map 4). Their presence is especially apparent in the western part of the city which contains large portions of the Chaseville-Midway soil complex. This soil lies at elevations ranging from 6100 to 7000 feet in slopes with angles of 5 to 50%. The Chaseville soil forms about 70% of the complex and is found on the steeper slopes and on ridge tops. The Midway soil makes up about 20% of the complex and contains most of the expansive material. Permeability ranges from rapid in the Chaseville to moderate/low in the Midway. This low permeability in the Midway soil exacerbates the expansion problem.

The City of Colorado Springs deals with the problem through building code restrictions. Construction within the city is governed by the Unified Building Code which is modified by the Pikes Peak Regional Building Code. Foundation restrictions are based on soil type, and soil samples can be required before approval of plans by the Regional Building Department, especially if expansive soils are suspected in the area.

Hazard Mitigation. The first step toward mitigating the problem of expansive soils is to identify the problem accurately. This can be done through soil testing and analysis by a certified engineer. If the soil is found to be expansive, there are several ways to ameliorate the problem. In fact, design techniques for managing smectite are sufficiently advanced that expanisve soils do not need to be considered a severe problem unless the mitigation techniques are ignored or not properly used. Millions of dollars are spent in Colorado every year to correct and repair damage resulting from


EXPANSIVE
SOILS
Map 4
SWELL POTENTIAL
Very High
High
Moderate
Low
Windblown
Sand or Silt
C.J Huber

expansive soils which were not handled properly. Some of the methods which permit construction in smectite areas include:

1) Proper foundation design. Foundations must be used which are designed to concentrate the weight of buildings below the zone of moisture change. In addition, floating slabs can be used to allow floors to move independently of foundations.

2) Proper drainage design. Lots must be designed to have at least a six inch vertical fall within ten feet of buildings. Downspouts and splash blocks should be placed so that roof runoff will be carried at least four feet from buildings. In areas of heavy lawn watering, peripheral drains may be necessary to remove water from around foundations.

3) Proper landscape design. Backfill around new foundations must be compacted properly. Plantings and sprinkler systems should be at least four feet from foundations. As noted above, the most critical aspect of landscaping is to provide proper drainage.

4) Proper interior design. All paneling, drywall, and interior partitions added to basements and garages must maintain the freedom of vertical movement created by floating slabs.

Since the knowledge and technology does exist to lesson or eliminate the damage caused by expansive soils, their existence need not be a serious constraint on urban development. Proper design methods must be used, however, if serious and expensive damage is to be avoided.

METEOROLOGICAL HAZARDS

Severe weather is an ever-present hazard during all seasons in the Colorado Springs area. For the most part, moderate weather patterns prevail, but the Pikes Peak region can experience harsh extremes. Straddling the margin between the Great Plains and the Front Range of the Rocky Mountains, Colorado Springs is subject to the hazards of both zones, including thunderstorms, tornadoes, high winds, blizzards and other heavy snow storms.

Local Climate Hazards

Colorado Springs receives an average of 15.5 inches of precipitation annually, 80% of which comes between April 1 and September 30, mostly from heavy rains during thunderstorms. These heavy rains are usually localized and of short duration, enhancing the possibility of flash flooding (see Chapter 2); the incidence of thunderstorm days in the area is a high 60 days per year.

An additional major hazard from these summer thunderstorms is hail, which poses a very serious threat to property and crops. A single moderate hailstorm can cause millions of dollars of damage to property in the city.

Potentially, the most violent and destructive element of any severe thunderstorm is a tornado, and the Colorado Springs area can expect, on the average, three tornadoes per year. There have been 450 reported tornadoes in Colorado over the last 30 years with 2 resulting in deaths. Most of these occur during June, the peak month for tornado activity in Colorado, in the Great Plains (eastern) part of the state.

A fourth potential hazard associated with thunderstorms is lightning. Lightning kills more people in the United States than floods, hurricanes, or tornadoes, and because of the high number of thunderstorms in the Colorado

Springs area, residents and visitors run an above average risk of injury or death from lightning. The high rate of tourism and outdoor activity in the Pikes Peak region also increases the risk. In addition, lightning is one of the major causes of forest fires in the Rocky Mountain region.

Localized high winds may also accompany thunderstorms. These winds are affected by the topography of the Pike's Peak area which makes them difficult to predict and avoid. The most devastating winds, however, are usually associated with Chinook conditions during the late winter and spring. Chinook winds often reach 100 miles per hour with gusts even higher. The foothills area along the mountain front is the most affected zone in the city.

Winter storms are another major meteorological hazard. Snow can be expected from September through June, with the greatest quantities falling during the spring. At that time, frontal systems can develop and intensify east of the mountains with moisture from the Gulf of Mexico adding to the potential snowfall during upslope (easterly) wind conditions. El Paso County often experiences heavy snowfall. The largest snowfall in 24 hours was 18.0 inches, and the most snow in a month was 42.7 inches--both in 1957. Strong winds may accompany heavy snow creating severe drifting and complicating traffic and clean up operations long after the snow itself has stopped falling.

The Alert System

The National Weather Service (NWS) is the primary source of watches and warnings for hazardous weather in the Pike's Peak area. Its office is located at the Colorado Springs Municipal Airport (Peterson Field) where it receives and evaluates information from weather observation facilities at the airport itself, from the radar station at Limon, from private observers, and from other public sources (e.g., law enforcement officers). The National Oceanic and Atmospheric Administration also helps to disseminate weather information by providing weather radio broadcasts and telephone recordings to the general public.

When issuing an alert, the NWS reports to the Civil Defense system in the city. The Civil Defense system issues watches and warnings to local officials and to the media which in turn relay the information to the public. The Civil Defense system also decides if other warning measures, such as sounding warning sirens, are necesary.

Hazard Mitigation

The NWS follows a systematic protocol concerning possible meteorological hazards and takes the following actions when a specific hazard is imminent:

1) Tornado and severe thunderstorm.

   a) Issue a warning if:
      - a tornado or a funnel cloud is sighted.
      - a thunderstorm is observed by a law enforcement officer, a trained spotter, or the public (requires verification by radar).
      - a Limon (Colorado) radar operator detects a tornado or severe storm.

   b) Coordinate warnings with officials in the surrounding area.

   c) Use the proper warning format to accelerate the distribution of the warning.

   d) Call for additional help to guarantee proper coverage and confirmation of the storm.

   e) Log all events and actions taking place during the storm.

2) High Wind Warning.

   a) Issue a warning if:
      - a sustained wind speed of 50 miles per hour persists for a half hour or more.
      - a sustained or gusting wind reaches or exceeds 60 miles per hour.

   b) Issue warnings to proper authorities and the public.

c) Issue aviation wind warnings when gusts are expected to exceed 35 knots.

d) Issue updated reports of peak gusts, wind speeds, damage, and time when warning is expected to expire.

3) Blizzard Warning.

a) Issue a warning if the following conditions are expected to persist for three hours or more:
-wind speeds of 35 miles per hour or more
-heavy falling or blowing snow with visibility less than one quarter mile

b) Notify proper authorities.

c) Update reports giving snow depths and the status of the warning.

4) Heavy Snow Warning.

a) Issue a warning if:
-six or more inches of snow is expected in 12 hours.
-eight or more inches of snow is expected in 24 hours.

b) Notify proper authorities.

c) Issue a statement as soon as possible outlining the endangered area and update periodically with the expected duration of the warning and snow depth reports.

Because meterological hazards can be short-lived, localized, and transient phenomena, it is impossible to always accurately predict where or when they will strike. Most efforts to mitigate the immediate effects of the hazards actually just involve establishing warning procedures about severe conditions. Other mitigation can involve planning for the results of these meteorological hazards, as seen in flood plain management procedures (Chapter 2).

AIR POLLUTION

Under the provisions of the original Federal Clean Air Act of 1970, the Environmental Protection Agency (EPA) established National Ambient Air Quality Standards (NAAQS). Standards were set for total suspended particles (TSP), carbon monoxide (CO), ozone (O_3), and nitrogen dioxide (NO_2), and these standards were then subdivided into primary and secondary levels. Primary standards were those designed to protect the public health and had to be addressed immediately. Secondary standards were those designed to protect welfare and had to be met as soon as possible (APCD, 1982a). Under the provisions of the 1977 Clean Air Act Amendments, states in which there were areas which did not meet the NAAQS had to prepare revised state implementation plans (SIPs) designed to assure compliance with the NAAQS by December 31, 1982. If these standards were not met, the EPA could block all or part of any federal funding to that state (James, 1983). Colorado contained four areas that did not meet the NAAQS, one being Colorado Springs.

State Provisions

In 1979 Colorado requested and received an extension that gave these nonattainment areas until December 31, 1987 to achieve the standards for CO in all four areas and for O_3 in Denver. That same year, Colorado adopted the Colorado Air Quality Control Act, setting forth the policy of the state:

1) To achieve the maximum practical degree of air purity in every area of Colorado.

2) To attain and maintain the NAAQS.

3) To prevent the significant deterioration of air quality where air quality exceeds national standards.

In order to achieve this goal, the Act established:

1) The Air Quality Control Commission (AQCC) with broad regulatory authority.

2) The Air Quality Hearings Board as an appellate authority.

3) The Air Pollution Control Division (APCD) of the Colorado Department of Health as an enforcement agency (State of Colorado, 1979).

The Colorado Springs Problem

In 1982 the Colorado Springs area did not meet the standards for CO and for primary and secondary TSP (APCD, 1982a). A monitoring of the eight-hour concentration of CO at I-25 and Uintah St. showed 16 parts per million (PPM)--nine PPM higher than the national standard and five PPM higher than the 1981 measurement. At 712 S. Tejon St. the CO pollution measured 13 PPM. Furthermore, the number of violation days at the Tejon station went from one in 1981 to three in 1982. At the I-25 site, the number of violation days went from four to fourteen (APCD, 1982b). The Colorado Air Quality Control Program reports that 96.3% of the CO concentration is related to vehicular exhaust, 3.4% is related to residential and commercial combustion, and 0.3% is related to other point sources.

Violations of both primary and secondary standards for TSP were also recorded in Colorado Springs during 1982. For example, 265 micrograms per cubic meter (ug/m^3) were recorded at 3730 Meadowbrook Boulevard over a 24-hour period. The national 24-hour standard for primary particulate matter is 260 ug/m^3--not to exceed more than one violation per year (APCD, 1982b). A violation of secondary particulate matter (202 ug/m^3) was also recorded at 3730 N. Meadowland Boulevard over a 24 hour period. The secondary TSP standard over a 24 hour period is 150 ug/m^3 and is not to be exceeded more than once per year (APCD, 1982b). Eighty-one per cent of Colorado Springs' annual TSP is attributed to "fugitive dust" (due to unpaved roads, land development, sand on paved roads, agriculture, construction, mining, aggregate storage, and cattle feedlots). The other 19% is attributed to point sources (4.7%), mobile sources (6.1%), and combustion (8.1%) (APCD, 1982a). In 1982 particulates ceased to be defined under Federal standards (Coy, 1983).

On June 10, 1982, the AQCC adopted the Colorado Springs plan element as submitted by the Pikes Peak Area Council of Governments (PPACG). The plan is directed toward attainment of the eight-hour CO standard by 1987. Colorado Springs has committed itself, by resolution, to three measures to be implemented at the local level and to a fourth to be implemented by the Colorado General Assembly. The local commitments are:

1) To maintain the existing bus service and to expand it as federal funds become available.

2) To encourage the use of Ridefinders, a carpool locator service, and to seek replacement funding for that service if future federal funding is reduced.

3) To make improvements in traffic flow--especially to contribute to the completion of Union Boulevard as federal funds become available.

Finally, the Colorado General Assembly is urged to retain the Colorado Air Program in order to achieve at least a 25% reduction of CO emissions (APCD, 1982a).

Critics, however, claim that a misrepresentative air quality model and the population growth of Colorado Springs will prevent the city from attaining the national carbon monoxide level by 1987 (Coy, 1983). Jim Easton, local air quality control chief, has suggested that the city council consider the air quality impacts of new developments when reviewing future development plans, since growth rates are exceeding the air quality model's expectations (Coy, 1983).

Metro Denver implemented a plan that would attain both the ozone and the one-hour and eight-hour CO standards by 1987. Adopted by the AQCC on June 11, 1982, the Denver plan contains measures advocating:

- Doubling the number of Park-n-Ride lots
- Establishing light rail transit (or expanding the bus fleet)
- Metering freeway ramps
- Establishing exclusive bus ramps (associated wtih ramp metering projects)
- Developing traffic signal projects

- Erecting display signs at drive-throughs
- Improving parking management
- Expanding the Colorado AIR Program
- Creating Share-A-Ride Days
- Enforcing warranties
- Conducting rideshare research
- Conducting gasohol research

It is encouraging to see such an extensive plan implemented in Denver, but at the same time, it is discouraging to see Colorado Springs rely on its limited measures when computer modeling suggests that pollution levels are not declining as rapidly as expected under current controls (APCD, 1982a).

Granted, to date, Denver's air quality is worse than that of Colorado Springs. However, in June, 1983, Wanda Landerdale of the State Air Pollution Division sent the PPACG a memo warning that 1982 figures showed that Colorado Springs was not demonstrating continuous progress toward achieving the national standard by 1987 (Coy, 1983). The Colorado Air Quality Data Report of 1982 shows that air pollution, particularly carbon monoxide, is actually <u>on the rise</u> in Colorado Springs. Almost surely the air quality of Colorado Springs will continue to decline until strict measures, such as those introduced in Denver, are implemented in the Pikes Peak Region.

Possible Mitigation Measures

Since the largest share of air pollution in the Pikes Peak Region is contributed by autos (PPACG, 1977), it important for Colorado Springs to explore ways to curb vehicular use or at least reduce total vehicular miles traveled. With future development planned for the fringe areas, it seems impossible for Colorado Springs to attain the 8-hour CO standard unless strict measures are enacted in the areas of:

- Mass transit
- Traffic flow improvement
- Episodic "Share a Ride Days"
- Environmental impact statements for new developments
- Climatic design and planning

Such measures, as with other pollution control strategies, will require the direction of both elected officials and the citizenry in balancing the costs of control with the benefits of a carefully managed environment (PPACG, 1977).

Mass Transit. The Colorado Springs plan calls for the maintenance of existing bus service and its expansion as federal funds are available. When (and if) these funds are available, the expansion program should consist of express shuttle services during commuter hours connecting outlying fringe areas to major business districts. This program should incorporate an increased number of Park-N-Ride locations and exclusive bus ramps in order to provide quick commuter service. Such a program is already being implemented in Denver.

Traffic Patterns. The worst carbon monoxide concentrations are found where a large number of slow moving cars come together, such as in large parking lots or traffic jams (CAQDR, 1982). Part of the Colorado Springs plan calls for improving traffic flow, but only as federal funds are available. Meanwhile, the problem increases. Since this problem warrants immediate action, one method of decreasing traffic flow might be to apply some form of increased gas tax to local vehicles. Then, as federal funds become available, further traffic flow improvements could be initiated.

Episodic "Share-A-Ride Days". This program involves asking, on a rotating basis, car owners to leave their vehicles at home on winter days when high levels of carbon monoxide are predicted. To be effective, the APCD's technical staff would have to develop the expertise to accurately predict these high pollution days, while APCD's Rideshare unit would have to synthesize a network of employer and community based resources through which people could find alternative modes of travel. Public education and information programs would need to be developed since public support for a voluntary program of this magnitude would be critical for its success (APCD, 1982a).

Environmental Impact Statements for New Developments. The environmental impact on the local air quality of Colorado Springs caused by the continuing development of outlying fringe areas is unsure. Colorado Springs topography makes air pollution particularly hazardous to the lower downtown area. Since new development is occurring at higher elevations (James, 1983), it seems important that Colorado Springs become aware of the ramifications of each new development. Therefore, environmental impact statements should be mandatory for all new developments, and developments that would have a strong negative impact on air quality should not be permitted. Hopefully, such a program would create innovative development schemes that would utilize alternative energy sources.

Climate Design and Planning. Thorough design and planning for climatic conditions is sometimes precluded by the rush to begin construction or by the assumption of owners and architects that climate consideration is not worth the extra time and expense. The use of a climatological study in planning would help to identify beneficial changes in the microclimate of sites and undesirable climatic conditions that might result from land use and development. Thus, such a study can achieve economic, practical, and environmental benefits (McAnelly, 1974).

As 1987 approaches, the people of Colorado Springs must be willing to make sacrifices in their lifestyle and become more involved in air quality control programs in order to meet the national standards for air quality. They must change both how they commute and how their community is developed. Only by developing increased public concern for health and the environment can these sacrifices be achieved.