Urbanization and Its Effect on Mineral Resource Availability

WILLIAM A. VOGELY and ALFRED L. SERVICE,
Respectively, Assistant Director—Mineral Resource Evaluation, and Physical Scientist, U. S. Bureau of Mines

•IN ONLY 30 years, more than 200 million people will be living in major metropolitan areas of the United States. These people must be housed; they must have places of work; they must have roads; they must have food; and they must have all of the products and services that characterize our affluent society.

When a person sees "mineral resource availability" in a title, what comes to his mind? The average city dweller, with no exposure to or experience in resources, will probably think of iron and steel, aluminum, copper, and brass. He is not likely to think of the natural gas that he burns in his home, the gasoline that he puts in his car, or the Interstate Highway and Beltway that he uses for commuting. But on a volume basis, these are the mineral products that must be moved and brought to the point of consumption to supply his needs.

In 1967, for example, American consumers used somewhere in the neighborhood of 150 million short tons of metals, but they used 1.8 billion tons of the major construction materials (sand and gravel, crushed stone, clays, asbestos, gypsum), and another 1.6 billion tons of mineral fuels to supply their energy requirements.

Many of these products were transported long distances over well-developed transportation networks. The iron ore that forms the basis of our steel industry flows to the United States from worldwide sources. Petroleum flows to the United States through pipelines from Canada and Mexico and by tankers from the rest of the world. Natural gas flows to markets in urban centers through an interwoven pipeline transportation network from the gas fields of Louisiana, Texas, and other portions of the country. Coal flows to the major urban areas on the railroads, and the energy from coal is distributed through wires from central electricity generating facilities. For these products, the cost of transportation to the market, although a substantial percentage of their total cost, does not rule out major resource sources.

The transportation situation is much more acute for the 1.8 billion tons of construction materials. It is economically impossible to transport these materials for distances greater than a few miles. They must be available at the very site of the population concentration. These are the materials whose resource availability is called into question by the very fact that creates their demand—that is, population growth.

The Bureau of Mines has recently conducted studies to evaluate the nature and extent of land-use conflicts and environmental damage resulting from mineral industry activities. These studies deal with various environments and with many different mineral commodities and industry activities.

The best way to outline these conflicts is to show what was found. The illustrations are in five groups.

SUBSIDENCE

Figure 1 shows damaged homes in Coaldale, Penn., caused by collapse of a steeply dipping anthracite coal bed. The badly damaged home in the picture was ultimately

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Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

engulfed by the continuing subsidence. These homes have all been razed, and an Appalachian subsidence project is now in progress here to prevent further movement of the surface.

Figure 2 shows street, public facilities, and adjoining buildings in Scranton, Penn., that were damaged by collapse of flat anthracite measures. The mounds of earth shown in the slide are barricades erected to prevent traffic from traversing the street.

Figure 3 shows severe damage caused by lead-zinc mining in Picher, Okla. The ore body in this area is mined by the room-and-pillar method, with the room ranging in height from 50 to 100 ft, separated by pillars approximately 50 ft apart. The ore body lies from 200 to 300 ft below the surface.

Figure 4 shows subsidence prevention in the anthracite region, effected by flushing crushed coal refuse material with water down boreholes from the surface and through pipelines 8 in. in diameter to the empty mine chambers. Note the pitch on the coal bed of approximately 25 degrees. At the bottom of the chamber to be flushed, a battery is first erected to hold the materials, then a drain box is installed to draw off the water from the flushing operation. The material is thereby permitted to settle and tightly pack the void, reinforcing the coal pillars and providing roof support in the empty chambers.

This technique, of course, can only be used before subsidence progresses too far and is employed in Appalachian subsidence prevention projects (such as the one shown) when surface evidence indicates that the underground pillars are weakening and beginning to cause surface subsidence. It is usually possible to check conditions by an underground examination.

WATER POLLUTION

Figure 5 shows acid mine drainage overflowing from abandoned anthracite mines near Scranton. This drainage eventually finds its way into the Susquehanna River. The discolored water contains sulfuric acid, sulfates, and iron and aluminum salts. The sulfuric acid leaches the rocks and clays it encounters to form more of these objectionable materials, thus increasing the acid potential, hardness, and solids content of the waters.

Figure 6 is another view of mine drainage overflowing from abandoned mines in the Northern Anthracite field above Wilkes-Barre, Penn.

Figure 7 shows an abandoned, unreclaimed strip-mined area with highly contaminated water collections in bituminous mining.

Figure 8 shows acid mine water overflowing into a clean stream in Kentucky.

AIR POLLUTION—BURNING AND NONBURNING COAL REFUSE BANKS

Figure 9 shows burning coal refuse banks in Scranton, a result of anthracite mining.

Figure 10 is another burning bank in Scranton that has subsequently been extinguished and graded through a demonstration project conducted by the U. S. Bureau of Mines on the side closest to the viewer, and partially extinguished on the opposite side by demonstration projects conducted by others.

Figure 11 shows unburned anthracite refuse bank and old stripping spoil banks on the environs of Scranton. While banks such as these do not emit smoke and fumes, they are a potential hazard by being vulnerable to ignition, and are a source of windborne dust over the community.

Figure 12 shows fissures emitting smoke and gases with accompanying sulfur deposits in an earth blanket placed in an attempt to smother a fire in a burning refuse bank. While this blanket was approximately 3 ft deep, such cracks and fissures are known to develop in cases where the blanketing material, usually earth, was deposited to a depth of 6 ft.

Figure 9.

Figure 10.

Figure 11.

Figure 12.

Figure 13.

Figure 14.

Figure 15.

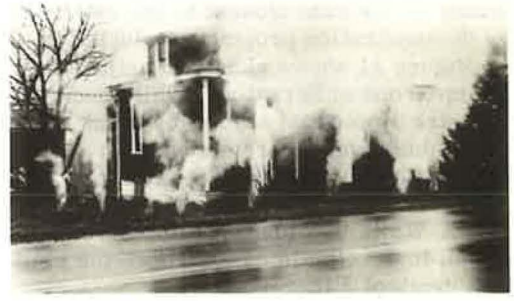

Figure 16.

MINE FIRES

In Figure 13 clouds of water vapor with some smoke intermixed arise from extinguishing operations on a burning refuse bank over the Cedar Avenue Appalachian mine fire control project. The high pressure water jet used in this operation may be seen at the right of the photograph. Scranton, threatened by this mine fire, is in the background. When this project is completed it will protect the city and its surburbs from the mine fire, which could have spread under the entire area.

Figure 14 is another view of the Cedar Avenue mine fire control project undertaken under the Appalachian Regional Development Act of 1965. In this view, the isolating trench, which is the technique employed in this operation, may be seen extending from the coal bed outcrops at the bottom right corner of the photograph over to the center upper section near the Lackawanna River, where a barrier pillar exists. When completed, this trench will have been excavated at its deepest point to approximately 180 ft. This point will be at the sharp turn shown at the right of the photograph. The trench extends down through two beds of anthracite, with a portion of a third bed having been excavated near the lower right corner of the picture. All of these beds were mined and partly stripped. A part of the suburban area of Scranton that will be protected is shown adjacent to the trench operation. As the work cuts through each mined coal bed, incombustible sand is placed in the cut to form an effective seal at the horizon of each bed. The remainder of the trench is being backfilled with rock and other material excavated from the original trench. The entire operation is expected to be completed in about one year at a cost estimated to be $4.5 million.

Figure 15 shows another Appalachian mine fire control project near Wilkes-Barre in the anthracite field. Smoke and fumes are issuing from cracks in the earth near the outcrops of the three affected beds. These beds dip down into the earth and extend under the city in the background. This operation comprises drilling 8-in. diam boreholes from the surface into the mine voids, then flushing the voids with sand and water to form a containing barrier that will prevent the spread of the fire up and down the valley and over toward the city.

Figure 16 shows smoke and vapor containing noxious gases issuing from 8-in. diam boreholes drilled around a dwelling into the mine voids below to permit flushing a barrier that will contain the fire and prevent destruction of the dwelling. This location is near Pittsburgh in the bituminous coal region. Fly ash, gathered from electric generating station stacks, is now being successfully used for this purpose.

RECLAMATION

In Figure 17, a reclaimed bituminous area strip-mined in Kentucky is shown. The spoil banks are contoured to a rolling topography and planted with trees and grasses. The lake is stocked with fish. The entire reclamation program in this area is devoted to hunting and fishing activities.

Figure 18 shows a golf course built on a reclaimed area strip-mined near Steubenville, Ohio.

Figure 19 shows a recreational area constructed on a reclaimed strip mine in Ohio, designed primarily for camping, boating, and fishing.

Figure 20 shows an active sand and gravel dredging operation conducted simultaneously with reclamation. The area in the foreground and the island in the left center are part of the reclamation procedure. The location is adjacent to Indianapolis, Ind. Operations of this nature are preplanned for work procedures and reclamation design.

These pictures illustrate the headline aspect of urban-mineral conflicts. Our studies have shown another aspect of the conflict that is also of great importance. The press of urbanization is forcing many mineral producers to move away from their market areas. The problem arises for construction materials, and they are the lifeblood of urbanization.

The National Sand and Gravel Association pointed out in 1965 that reserve deposits of sand and gravel are being depleted at a rate of 6 percent per year. Geographically

the rate of depletion varies considerably. The following depletion rates were reported by the NSGA in 1965:

Area	Rate (%)
Mid-Atlantic	11
New England	10
West North-Central	9
Pacific	6
Mountain	6
South-Atlantic	5
East North-Central	4
South Central	3

The geographic areas showing the greatest depletion rate (and experiencing the greatest difficulty in acquiring future reserves) are those with large and rapidly expanding cities. Note that these depletion rates refer only to the use of the material; that is, they do not take into account the loss of reserves because of conflicting land use. A Denver study in 1961 indicated that the tons of resources lost through conflicts were four times the consumption rate.

Sand and gravel are high-bulk, low-value commodities that cannot be shipped great distances to the consuming market. The average value of sand and gravel used in construction is $1.00 a ton. A common rule of thumb for transportation is 25 cents per ton for the first mile and 5 cents per ton for each additional mile. Each mile adds 5

Figure 17.

Figure 18.

Figure 19.

Figure 20.

cents per ton to the consumer price. An average increase of only one mile would raise the costs to the consumer $90 million a year.

The social, economic, and environmental forces accompanying urbanization have effectively curtailed production of minerals, and losses of potentially valuable mineral deposits have occurred in almost all metropolitan areas in the United States. The degree of curtailment of operation varies, but nevertheless production has been affected, and mine operators have been forced to shut down operations or move to areas where they can continue mining on an uninterrupted basis.

Do not get the impression that urbanization creates problems of resource availability only for construction materials. Take, for example, the commodity that is ubiquitous in every home, salt.

Salt has been mined from beneath Detroit since the deposits were discovered in 1895. The present level of operations is 1,200 ft below the surface, and the character of the overlying rocks precludes any possibility of subsidence or other surface expression of the underground workings. You might think this is an ideal situation, yet International Salt Co. is experiencing costly and sometimes difficult or complicated problems resulting from urbanization. When salt mining first started, the area was productive agricultural land; the city limits of Detroit were more than 10 miles away. Industrial complexes and urban development now completely surround the surface mine buildings, and mining has progressed far beyond expected limits, creating many operational problems. Among these problems are complaints of noise from exhaust ventilating fans on the surface, vibration and noise from blasting, and traffic congestion during peak periods of demand for salt. Most important, though, from the standpoint of mineral resource availability, is acquisition of mineral rights from the surface owners to permit mining the salt.

An equivalent of approximately 25 acres of land is mined out every year; and to assure continuing operations, the mining rights to large areas of land must be purchased from surface owners. What were formerly large tracts of land with single owners are now subdivided into many small parcels for residential development, and negotiating for purchase of mining rights is almost impossible. As a result, the company has restricted its efforts to the few remaining large landowners, and consequently the salt deposits outside the boundaries of these areas are lost. Once the mineral rights to these large areas are acquired, the company must obtain the rights to 40-ft-wide accessways for transportation. Most of these accessways have to pass under small residential properties and a single owner or group of owners can refuse to sell their rights, and the purchase of the large tract where reserves of salt can be mined has to be cancelled. This type of scattered ownership has resulted in a patchwork type of mine development with circuitous access from the production area to the processing site. It has been reported that the added distance has increased haulage costs by as much as 25 percent. There may come a time when land acquisition and increased haulage costs will force closure of the mine and loss of large tonnages of potential salt resources.

Another example is coal. In 1966 more than 81 million short tons of bituminous coal were produced in counties that were included in the Bureau of the Census listing of Standard Metropolitan Statistical Areas. This is about 15 percent of the total U. S. production. These are the areas where demographers predict the greatest influx of people from rural to urban environments and the greatest outward growth of metropolitan areas. Will these people and the urbanization accompanying them have an effect on the future availability of these coal resources? This question cannot be answered at this time, but judging from past events, it is very likely that there will be losses in reserves. The same can be true of oil and natural gas, but to a lesser extent. For example, one of the largest producing fields is in southern California, where population is increasing very rapidly and metropolitan areas are expanding almost daily.

The foregoing discussion makes clear that there are conflicts between urbanization and resource availability. They arise from the fact that the use of resources involves a modification of the land that overlies the resource, and the process of producing the resource sometimes requires industrial operations that are inconsistent with maintaining the quality of the environment demanded by the urban area.

In such conflicts, of course, human values will prevail. Society must make a choice, however, as to the most efficient or, to use the economist's term, cheapest way that the demands can be met while preserving the values of people. There are two major alternative routes toward achieving this balance—planning and technology.

Planning for optimum use for a low-value bulk commodity, such as sand, gravel, and crushed stone, is extremely complex. It becomes involved with the total system of the urban environment and is not susceptible to piecemeal solutions.

For any given urban area, the following factors, at a minimum, must be considered in such planning: (a) the demands for construction materials by very small geographic areas, (b) the resource sites and costs for construction materials adjacent to or in the urban area, (c) the alternative uses for the land surface overlying these resources, (d) transportation networks, both current and future, (e) municipal revenues from alternative land uses, and (f) the time span of resource use at specific sites.

Obviously a dynamic interrelated system with multiple variables is being described. To optimize planning for any such system, whatever the criterion for optimization, will require a complex total systems analysis of the problem. The Bureau of Mines is assisting in one approach to this problem, undertaken by Rensselaer Polytechnic Institute. They are developing a computer simulation of the planning problem. The computer simulation involves an estimate of the demand for construction materials on square-mile grids, plotting on the same grid structure the available construction material resources, and computation of the shifting weighted demand center for construction materials. Such a computer model will permit the measurement of alternative planning decisions of a zoning nature and will allow the planner to assess the impact of his decisions over time.

One hopeful aspect of this conflict problem lies in the increasing demand for outdoor recreation areas near urban centers. The extraction of construction materials by surface mining methods creates a pit. This pit can be developed for outdoor recreation in several ways. Most obvious is the standard use as a swimming hole. However, to consider these pits only as swimming holes is to understate their potential for outdoor recreation of a kind that is not now available to the urban resident. For example, could not the steep sides of a stone quarry be made into an ideal rock-climbing site for the practice of mountaineering? Are not the sloping sides of a sand pit ideally suited for the establishment of target ranges in heavily populated areas? Perhaps some pits could be converted to support the winter sports of skiing and bobsledding, with perhaps ice skating on the flat bottom.

These are far-out ideas, but they illustrate the fact that the resource use of land is limited in time. With the need for open space in urban areas clearly recognized, the planner should consider the fact that, after resource use, there is a unique open space remaining. By planning that takes account of the total values involved, the impact of urbanization on resource availability may be minimized to the benefit of the human values of the urban population, as well as to their economic benefit.

The other attack on the problem is technology. The technological attack has to do both with the mining of the resource and with its processing and manufacture. The development of rapid excavation techniques would permit the exploitation of low-value bulk resources via underground methods rather than surface mining. With proper mining methods and procedures to prevent subsidence, this would make possible both the use of the surface and the winning of the resource. In addition, it would create underground space that could be very valuable for certain manufacturing operations, transportation systems, and other activities. On the very far-out side, one can even imagine our cities going down rather than up, utilizing the materials excavated for the construction of the structures and permitting major urban areas that on the surface have the appearance of parks and broad landscapes.

Technology may also present the alternative for the manufacturing operations that will not be tolerated in urban areas. Air, dust, and noise controls can greatly minimize the environmental impact of these operations.

In summary, population growth and urbanization are creating problems in resource availability. Failure to recognize these problems and to take the alternative steps available will result in an increasing economic burden on the American population.

However, planning, using new approaches through computer simulation and research and development of new technologies, holds the hope of reducing the economic burden and permitting resource use without the conflicts that are now inherent. The Interior Department's Bureau of Mines is beginning to work in both of these areas. However, much more effort is needed, and to mount this effort, the public must be apprised of the seriousness of the problem and the cost of doing nothing.