Geological Circular 78-1

Mineral Lands in the City of Dallas

BY
ANN E. ST. CLAIR

Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas
W.L. Fisher, Director

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INTRODUCTION

Surface mining, with its accompanying dust, noise, truck traffic, and land disruption, generally conflicts with most urban land uses. Urban development, however, is dependent upon the availability of nearby mineral resources for the construction of roads and buildings. As a result of this conflict, many urban areas are now faced with rapidly rising construction costs, partly because of a failure to recognize and use aggregate resources before building over such resources or making them unavailable by zoning.

Applying the concept of sequential land use to the problem of mining in urban areas can help prevent loss of resources by encouraging exploitation of minerals before development of the land. Mining can therefore be considered an interim land use, after which the land can be reclaimed for recreational, residential, or commercial uses.

The first step in implementing this reclamation policy is to locate areas with resource potential, as well as areas from which minerals have already been extracted. After the resources have been identified, decisions that affect use of these areas can be made with consideration of the mineral potential of the land. Comparing the advantages of sequential land use of mineral areas with the advantages of the other alternatives, such as urbanization or zoning to prevent mining, first requires information on the availability and the location of potential resources with respect to the urban area. Such a comparison also requires data on the types and effects of mining, requirements and costs of reclamation, and projected demand for resources. Considering all these factors promotes informed land use decisions and prevents both unnecessary loss of resources and increases in construction costs.

In 1976, the City of Dallas contracted with the Bureau of Economic Geology, The University of Texas at Austin, to study mineral lands within the City of Dallas. The purpose of the project was to delineate mineral lands, to describe alternatives for reclaiming mined land, and to evaluate the economic impact of zoning mineral lands. This study was designed to provide basic data for policies to ensure availability of mineral resources, and to promote the use of these resources with minimal long-term environmental disruption.

MINERAL LANDS MAP

A map of mineral lands in the City of Dallas accompanies this report. It shows the distribution of mined land and potential mineral resources within the Dallas city limits (as of early 1977). The map is printed at a scale of 1:62,500 (1 inch equals approximately 1 mile) on a topographic base of Dallas County constructed from U.S. Geological Survey 7.5-minute quadrangles that are photorevised to 1973. Topographic contour interval is 20 feet. The base map also includes State and Federal highways, major streets, railroads, airports, streams, and lakes.

The map displays in black the location of surface-mined land in Dallas, and classifies such land according to its present condition. Wherever possible at the map scale, the outline of the mined areas is shown; symbols are used for smaller mines. Each active mine is designated by a pattern and letter indicating the material in production. Inactive mines are shown by patterns or symbols designating whether the mined area has been used as a landfill site, has been filled, developed, or left unreclaimed. Mapping and classifying mines were based on field work, supplemented by information from the City of Dallas, U.S. Bureau of Mines, and U.S. Mining Enforcement and Safety Administration.

Outcrop areas of potential mineral resources—sand and gravel, limestone, and clay—are shown by red patterns. Resource delineation is based primarily on geologic mapping by Clark (1976). Additional data were obtained by field checking, and from mapping by Barnes (1972), Hendricks (1976), and unpublished Soil Conservation Service maps.

A black hatchure pattern printed over the mineral lands information outlines the principal nonurbanized areas in the City of Dallas. These areas were mapped from semicontrolled mosaics of 1972 aerial photographs at an approximate scale of 1:62,500. Mapping of nonurbanized land is generalized, and lines are based on density of man-made features. Thus, open areas such as parks and golf courses may be included as nonurbanized land, whereas open areas within heavily developed parts of the city may not be shown. Undoubtedly, urban development has extended into many of the nonurbanized areas since the date of the photography, but the mapping is adequate as a general indication of the location of undeveloped land.

POTENTIAL RESOURCE AREAS

The map of mineral lands in the City of Dallas shows the areal distribution of potential mineral resources. However, many of the areas over these deposits have been urbanized, making such resources unavailable. General nonurbanized areas are shown on the map. Using this information with the resource data points out areas where mineral extraction may be feasible. Because this determination is made strictly on the basis of general geology and the absence of urban development, important factors such as land ownership, proposed land uses, adjacent land uses, environmental sensitivity, and zoning restrictions are not considered here. These factors, however, can be as critical in establishing the suitability of an area for mining as are geologic considerations. Thus, the mineral lands map can serve as a guide for locating major areas with resource potential, but it does not provide all the data needed to locate specific deposits and to determine their suitability for mining.

MINERAL RESOURCES

Principal mineral resources in the City of Dallas are sand and gravel, limestone, and clay. These materials are low unit-value resources, typically costing only a few dollars per ton. They are used in large volume by the construction industry and are generally transported by truck. Because these resources are bulky and have low unit values, transportation costs can quickly multiply consumer costs (fig. 1). For this reason, the proximity of mineral production to the market is critical in keeping costs low. Markets for sand and gravel, limestone, and clay are predominantly areas where urbanization is occurring, and where construction of roads, buildings, and homes is underway. Knowledge of resource distribution in these areas is necessary to allow utilization of nearby materials, thereby minimizing costs of construction materials.

Several aspects of the mineral industry should be noted here. Mineral resources are limited because they are formed by distinct geologic processes. Resources, therefore, do not occur everywhere, and they must be mined where they are found. In addition, evaluating a mineral deposit depends on current economic conditions—a deposit will be worked only if mining can operate at a profit. If extraction or transportation costs for a particular deposit are so high that prices are not competitive, mining will not continue. Changes in economic conditions can force the closing of mines even though the deposit has not been exhausted. On the other hand, if the supply of materials that can be mined at a given cost has been depleted, the operation must either mine lower grade materials or move to more distant deposits, despite higher costs.

Because of this sensitivity to economic conditions, characteristics defining a profitable deposit may change. Depth and thickness of the deposit, percentage of useable material, and distance from markets all affect production costs. Consequently, a sand and gravel deposit that was uneconomical to mine 20 years ago because it was too deep, too thin, or contained too much clay may now be a valuable resource because of increased demand and higher market prices. A deposit once so far from the market that transportation costs made prices uncompetitive may now be considered mineable.

Distribution of resources is limited geologically because of the specific conditions required to form a mineral deposit. However, the availability of resources is limited even further by economic factors determining whether minerals can be extracted profitably.

Sand and Gravel

Sand and gravel are used primarily as concrete aggregate in building and road construction. They are mixed with cement to make concrete, which typically contains 80 to 85 percent aggregate by weight. Obviously, large amounts of these resources are required by the construction industry. Sand and gravel are also used in tar and asphalt paving, and as road base and fill material. In 1975, approximately 28 percent of the sand and gravel produced in Dallas County was used in highway and street construction; 32 percent was used as concrete aggregate in residential and nonresidential construction; and 39 percent was used for other purposes, such as fill material and the manufacturing of concrete products.

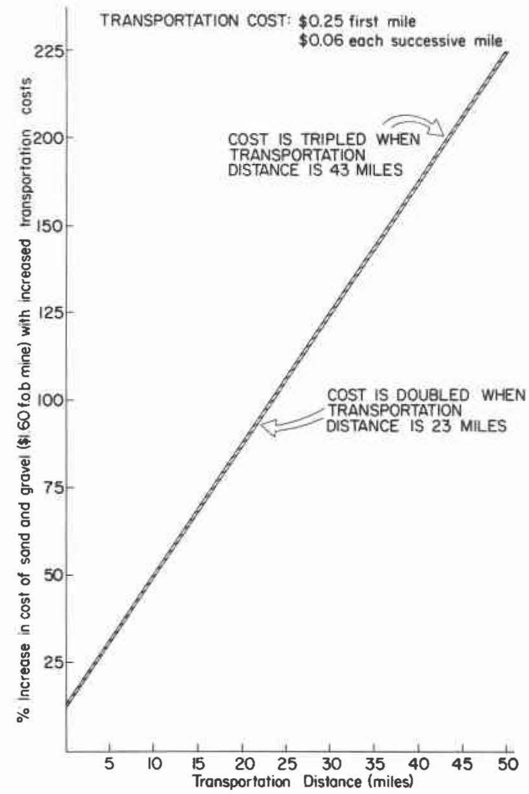

Figure 1. Effect of transportation costs on total cost of low unit-value minerals.

Sand and gravel occur in two principal types of deposits in Dallas: (1) in floodplains of the Trinity River and other streams, and (2) in terraces along the Trinity River.

Alluvial material in the floodplain of the Trinity River constitutes the primary source of sand and gravel in the Dallas area. Sediment derived from weathering and erosion of rocks upstream has been deposited as interbedded sand, gravel, silt, and clay. Deposits are discontinuous, and they vary in thickness, depth, and extent. Evaluation of the commercial value of a deposit requires extensive drilling and sampling at the site to determine the thickness of overburden, thickness of the deposit, percentages of sand, gravel, and clay, composition of the gravel, and depth to water. According to local producers, floodplain deposits being mined are generally 10 to 20 feet thick and occur at depths of 5 to 15 feet. As demand increases, it is likely that thinner, deeper deposits will be mined.

In recent years, the amount of gravel mined from deposits along the Trinity River has been insufficient to meet the demands of urban growth in Dallas. Sand production has continued from the floodplain, but crushed limestone from Wise County, northwest of Dallas, has largely replaced gravel as coarse aggregate in concrete.

Alluvium in smaller streams, such as White Rock Creek and Fivemile Creek, may have some potential as a source of sand and gravel. However, the coarse fraction of alluvial deposits along these streams is commonly composed of fragments of the Austin Chalk, which is generally too soft for use as construction aggregate. These stream deposits have been used as local sources of road base and fill material (Richards, 1965). The ecologic sensitivity and significance of areas along creeks such as White Rock Creek have been reviewed, however (City of Dallas, 1976), and the importance of such areas as open space may preclude further use of these gravel deposits.

Terraces along the Trinity River are from 20 to 120 feet above the level of the modern floodplain. They are remnants of relict floodplain deposits that have been incised as the river cut down to its present level. Sand and gravel deposits in the elevated terraces vary in depth, thickness, composition, and extent. Delineation of specific resources requires onsite drilling. Trinity River terraces may be overlain by deep alluvial soils approximately 6 to 12 feet thick. According to several local producers, terrace deposits generally have a higher percentage of clay than do floodplain deposits. Calichification of the deposits may necessitate crushing the aggregate material before use. Terrace gravels may also be heavily iron stained, making them undesirable as aggregate. Terrace deposits, however, have been used for road base (Richards, 1965).

Sand and gravel are commonly mined by the area stripping method. Power shovels or draglines remove the overburden in long parallel cuts and pile it in rows adjacent to the active cut. Sand and gravel exposed in the floor of the cut are removed, loaded into trucks, and transported to the processing plant to be washed, screened, and sized. Strip mining of sand and gravel results both in piles of overburden from several feet to 25 feet high, and in intervening low areas commonly filled with water (fig. 2).

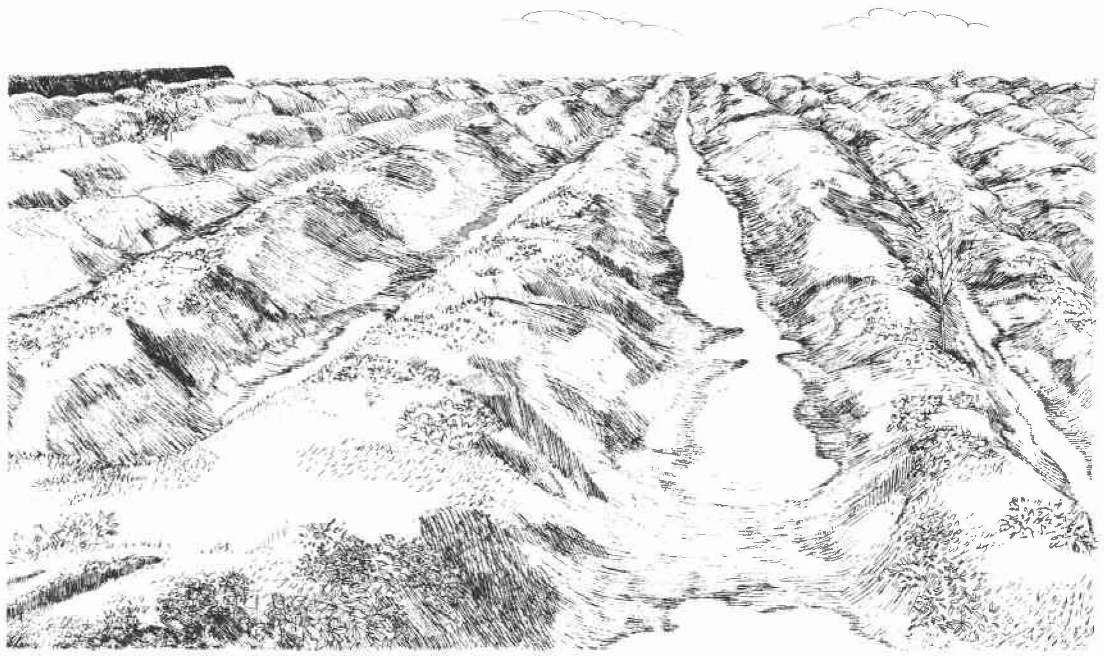

Figure 2. Appearance of land mined for sand and gravel by the area stripping method.

Several areas in Dallas are underlain by potential sand and gravel resources. Approximately 42 square miles of floodplain deposits and 6 square miles of terraces are located in nonurbanized areas of the city.[1] Included are several large areas of interest along the Trinity River (based solely on general geology and lack of urban development): (1) Trinity River floodplain between the levees of the Dallas Floodway, (2) Trinity River floodplain at the confluence with White Rock Creek, and (3) the area south and east of Lemmon Lake in the floodplain of the Trinity River (fig. 3). Site-specific studies in these and other areas of resource potential may indicate the presence of significant sand and gravel deposits. Generally, the Trinity floodplain probably has greater potential as a source of construction aggregate than the terraces or smaller creek deposits. Nevertheless, material suitable for fill or road base may be found in all these areas.

[1] Values included in this report for the areal extent of map units were determined by the point-count method, using a grid constructed with 64 points to the square inch (each point represents .016 square miles at the map scale).

[2] Personal interviews on February 7, 1977, and August 4, 1977, with Delbert L. Olson, Gifford-Hill and Company.

One local producer (Olson,[2] personal communication, 1977) reports that deposits in the vicinity of Lemmon Lake were found to have too much chalk gravel to be used as concrete aggregate, and that removal of the chalk is too costly under present conditions. He added, however, that the material might be used for road base. He also pointed out that most producers in the Dallas area are now working deposits which were at one time rejected because of high production costs. As economic conditions have changed, it has become possible to mine such deposits at a profit. It is therefore important to recognize the potential future value of these resource areas, even though they may not be mined economically at this time.

Limestone

The Austin Chalk crops out extensively in the City of Dallas. The formation consists of interbedded soft limestone, or chalk, and marl. Individual chalk beds range from less than a foot to 6 feet thick. Chalk occurs throughout the formation, but beds are generally thinner and less common in the middle part of the unit. The middle part of the Austin Chalk crops out north and west of White Rock Lake, and south of the Trinity River in the area between Interstate Highways 35 and 45.

Crushed limestone can be substituted for gravel as coarse aggregate in concrete. Although

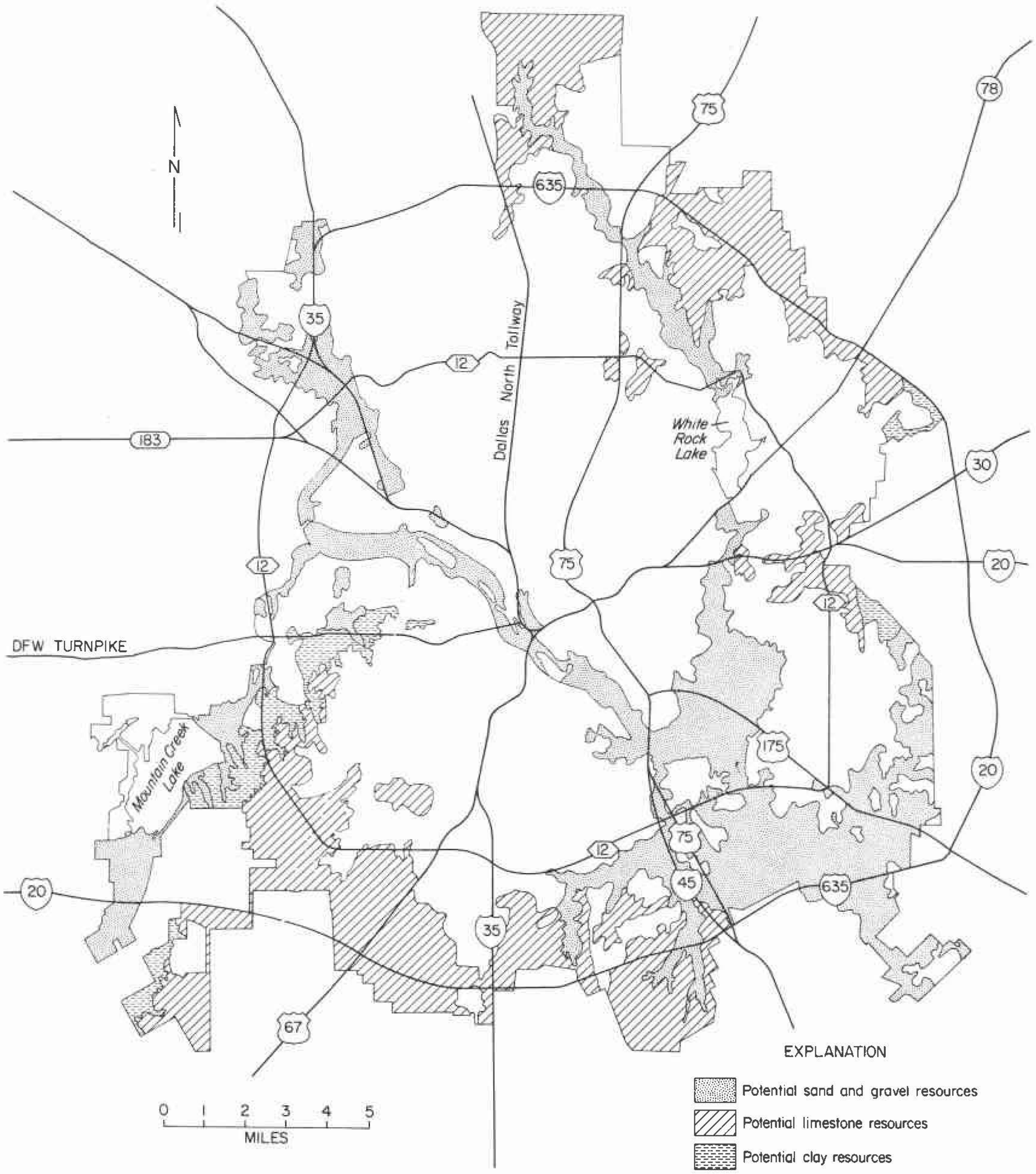

Figure 3. Principal areas in the City of Dallas with potential sand and gravel, limestone, and clay resources.

chalk in the Austin Formation is generally too soft for this use, the chalk has been crushed and used locally as road base and fill material. Such usage is demonstrated by the numerous small pits and hillside cuts along small streams and in upland areas in the northeastern and southern parts of the city.

The principal use in Dallas of limestone from the Austin Chalk is as a raw material for cement production. Crushed limestone is combined with other materials in specific proportions to manufacture Portland cement. Within the City of Dallas, chalk is quarried at the Trinity Division, General Portland Cement plant. A mixture of approximately 90 percent chalk, 7 percent clay, and 3 percent sand is calcined to produce the cement (Richards, 1965).

Limestone is mined in quarries in the Dallas area. The rock is fractured by blasting and removed by power shovels and trucks (fig. 4). Generally very little waste material remains after a quarrying operation is completed. The resulting landscape consists of a rock wall or steepwalled pit. In Dallas, the sizes of these operations range from small hillside cuts 10 to 20 feet deep, to large quarries over 50 feet deep covering several acres. Quarries producing stone for cement production are typically located adjacent to the cement plant in order to minimize trucking costs.

Principal nonurbanized areas with potential limestone resources are (1) the southern part of the city, (2) the northernmost portion of the city, and (3) northeastern Dallas between Richardson and Garland (fig. 3). In all, approximately 53 square miles of the nonurbanized portion of the City of Dallas is underlain by the Austin Chalk. Primary use of these deposits will be as sources of road base and fill material.

Because cement plants require a large capital outlay, a supply of stone sufficient for many years of production must be assured. It is unlikely that cement producers will compete with the pressures of urban development to mine chalk in areas within the City of Dallas. Furthermore, much of the cement now marketed in Dallas is transported from plants in Ellis County. Plants in the area are not operating now at capacity (T.J. Evans, personal communication, 1977). An extreme change in economic conditions would be required to stimulate construction of new plants within the city.

Clay

Clay occurs in the Eagle Ford Formation in the southwestern part of the city and near North Lake. The Taylor Formation, which crops out in east Dallas, is also composed of clay. These clays are suitable for the production of cement, expanded aggregate, and brick.

Clay is mixed with limestone in manufacturing Portland cement. In Dallas, clay from the Eagle Ford Formation is mined for use in cement at the Trinity Division, General Portland Cement plant. This clay is also used by Texas Industries to make expanded aggregate. Clay is heated in kilns, and the escape of gases produces a porous, lightweight material used as aggregate in lightweight concrete and cinder blocks. Brick has been manufactured from clay in the Dallas area in the past, and clay from the Taylor Formation is now used in bricks at Ferris in Ellis County. Eagle Ford clays were used in the early 1900's for brick, but according to Ries (1908), they are very difficult to work and contain "about all the undesirable elements that a clay might have . . . ."

Clay is mined in open pits where it is removed by draglines and shovels, and waste material is piled adjacent to the pit (fig. 5). Generally, the volume of waste material is small compared to that produced in most sand and gravel operations. The typical result of clay mining is a 20- to 40-foot-deep pit that may be filled with water and may cover several acres.

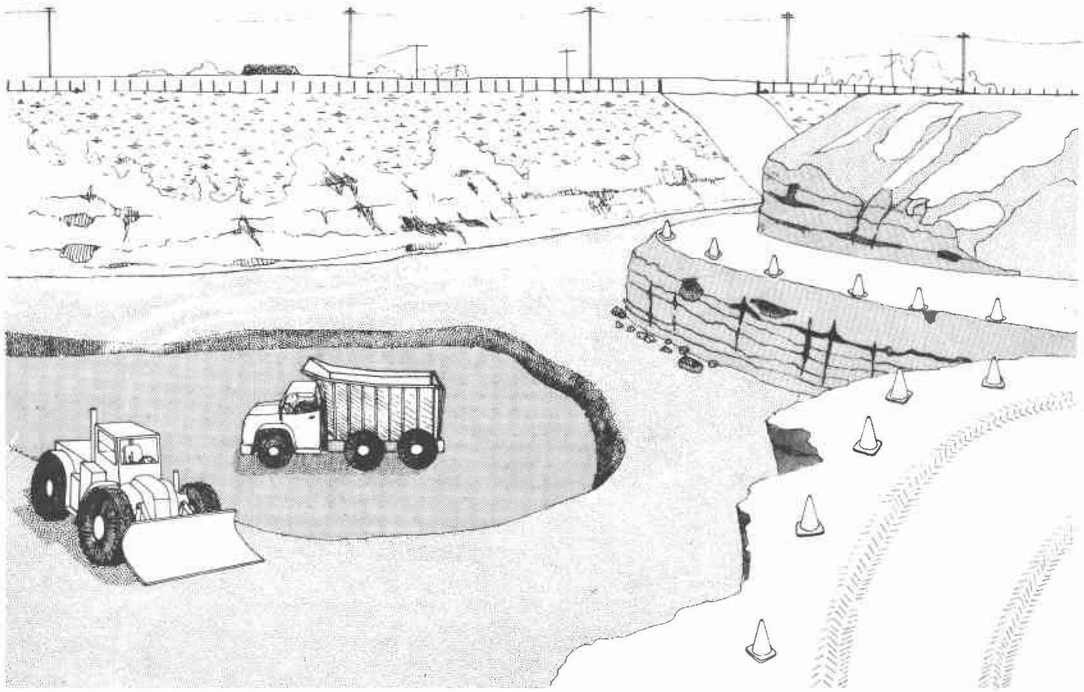

Figure 4. Mining of limestone (Austin Chalk) by quarrying. Note that little waste material is available for quarry reclamation.

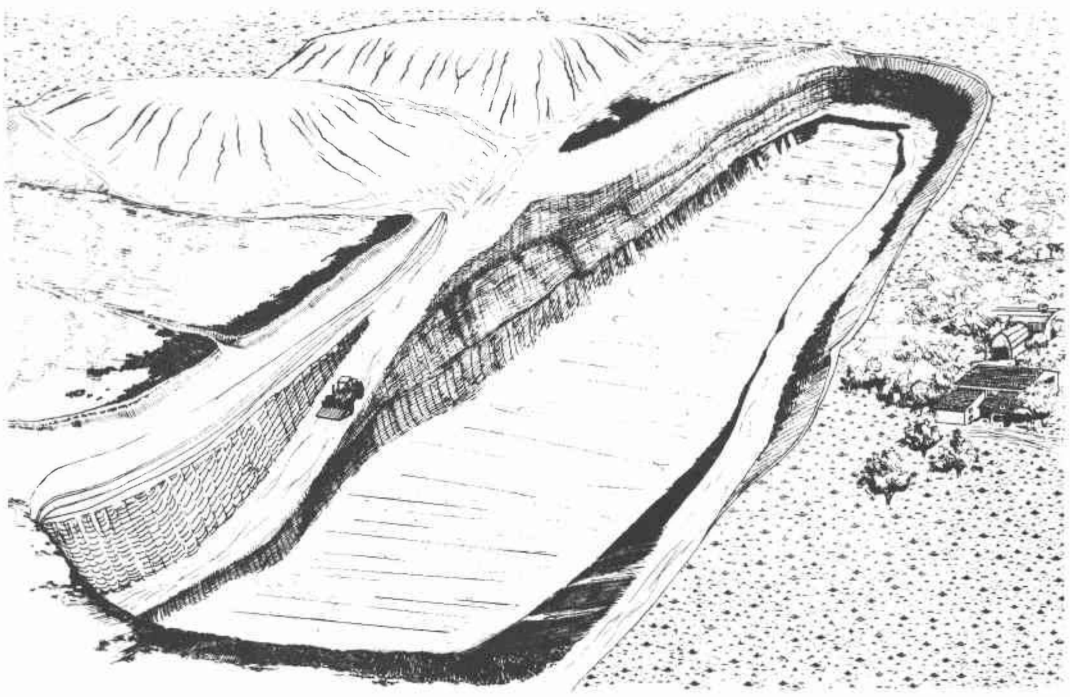

Figure 5. Mining of clay by the open-pit method. Note that waste is piled adjacent to the pit.

Areal extent of nonurbanized potential clay resources in the City of Dallas is approximately 9 square miles. These areas occur principally in southwestern and eastern Dallas (fig. 3).

Though there are potential clay resources in the City of Dallas, it seems very unlikely that supply and demand will stimulate their production. The volume of clay required to meet the construction needs of rapid urbanization is much smaller than that of sand, gravel, and limestone. In addition, clay used in cement is commonly mined near the cement plants. Unless new cement operations open in the city, it is unlikely that these nearby clay deposits will be worked. Increased demand for lightweight aggregate products and brick could stimulate mining of these areas, but large reserves of clay are available outside the city, where establishing production operations would not conflict with urban development.

In summary, recent trends in demand for and production of construction materials indicate that there is probably a greater incentive to mine sand and gravel within the city than there is to mine limestone and clay. This is not due to variations in the quality of the deposits, but rather to the circumstances surrounding production and marketing.

Sand and gravel are consumed in great amounts, and resources near the City of Dallas are rapidly being depleted. Because of the low unit value of sand and gravel, market costs are extremely sensitive to transportation costs. Consequently, the advantages of utilizing deposits within the city are significant.

Value added to limestone and clay by production at the mine site of cement, expanded aggregate, and brick minimizes the impact of transportation costs on the total cost of these materials. Because these manufactured commodities have a high unit value relative to sand and gravel, transportation costs amount to a smaller percentage of the total cost. Because distance from market areas is less critical, and because long-term supplies of limestone and clay must be available in order to realize a return on the large capital investment of plant installation, other incentives must be developed if mining of limestone and clay within the city is to be encouraged.

GROWTH TRENDS IN THE DALLAS AREA

A review of some of the trends in urban growth in the Dallas area is useful in understanding the relationship between urbanization and the construction mineral industry. Figures 6 and 7 illustrate population growth and expansion

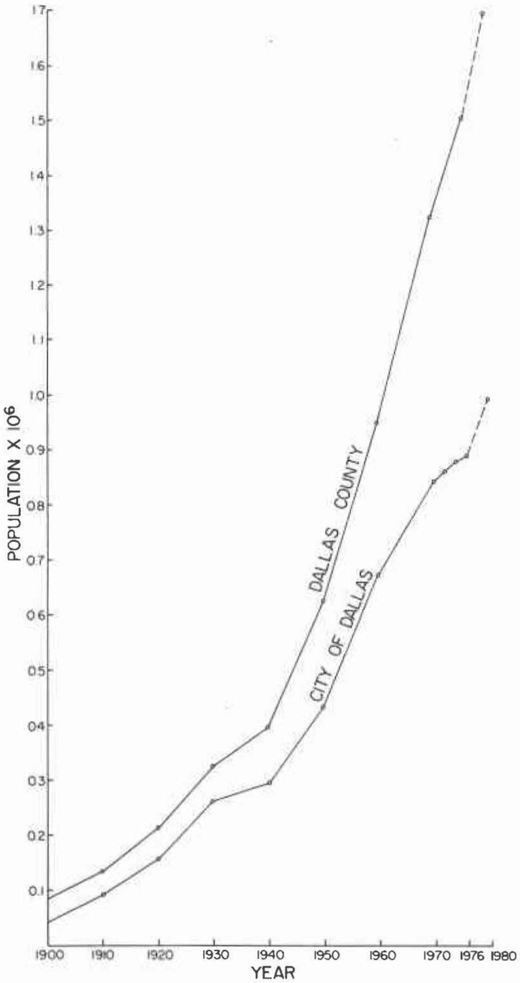

Figure 6. Population growth and projections in the City of Dallas and Dallas County (data from the Texas Almanac, 1974-1975, and City of Dallas, 1973a).

Figure 7. Growth of the urbanized area in the Dallas vicinity (areas mapped from county highway maps and aerial photographs).

of the urbanized area in the City of Dallas and Dallas County. Because of the role of Dallas as a center of trade and manufacturing, the population of the city has tripled since 1940, and that of the county has almost quadrupled (fig. 6). This population growth has been accompanied by rapid expansion of urban development both within the city and in outlying communities (fig. 7). Construction activity is also reflected in the general increase in the value of building permits in the City of Dallas (fig. 8).

Growth is projected to continue in the area, with the 1980 population of the county expected to be 28 percent greater than in 1970, and the population of the city expected to be 18 percent greater (fig. 6). Urban development is projected to be greatest toward the north. Figure 9 shows the areas expected to experience the greatest increase in new housing between 1975 and 1985. Note that while growth in the area is principally toward the north, production of sand and gravel is moving southeastward. Active mines in Dallas County are concentrated in the southeastern corner of the county. Mining is expected to continue downstream along the Trinity into Ellis County, with resulting higher transportation costs for sand and gravel.

Trends in mineral production in Dallas County are shown in figures 10, 11, and 12. These trends are related to urban growth in the Dallas area. As shown in figure 7, urban development increased markedly between 1953 and 1964. It was also during this period that dramatic increases in production of sand and gravel (fig. 10) and cement (fig. 11) occurred. Growth in consumption of these construction materials is related not only to urban development, but also to the expansion of the interstate highway system as a result of increased Federal funding (T.S. Patty, personal communication, 1977). Trends in production of sand and gravel generally followed the change in value of building permits in the city (fig. 8), particularly after 1960. Cement production, generally a good indicator of limestone and clay production in Dallas County, reflects the growth of Dallas through the mid 1960's. Production declines for cement in the late 1960's are due to both the opening of the Gifford-Hill cement plant at Midlothian in Ellis County, and the closing of the Lone Star cement plant in Dallas. In addition, a cut in Federal highway funds in 1968 may have caused a decline in demand for construction materials (Patty, 1970).

Projections of future demand for aggregate materials in the Dallas area can be made on the basis of the forecast annual growth in demand

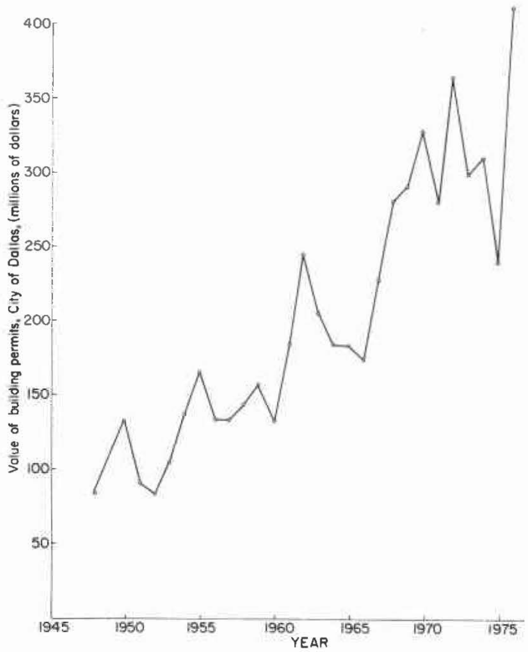

Figure 8. Value of building permits, City of Dallas (from Texas Business Review).

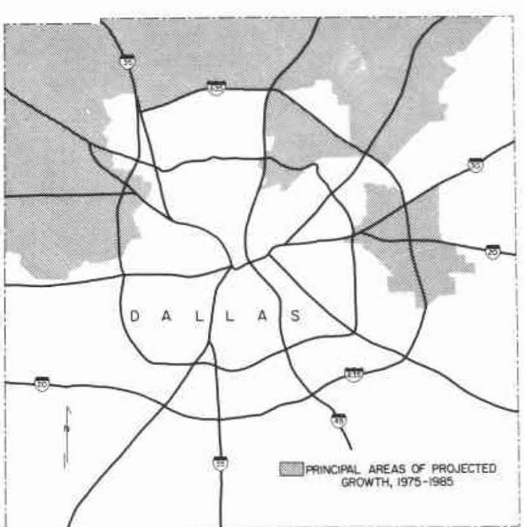

Figure 9. Principal areas of projected growth, Dallas County (from City of Dallas, 1973a).

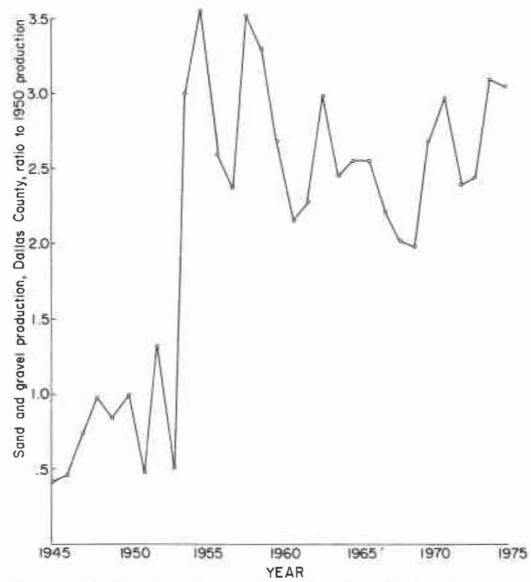

Figure 10. Sand and gravel production, Dallas County, ratio to 1950 production (based on U.S. Bureau of Mines production data).

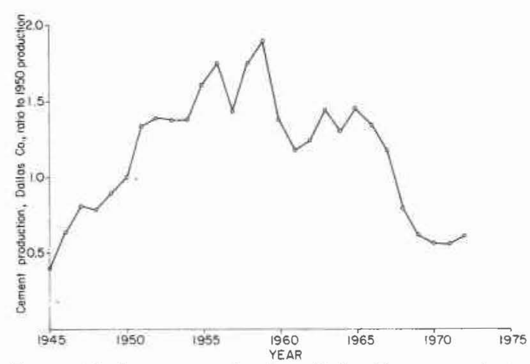

Figure 11. Cement production, Dallas County, ratio to 1950 production (based on U.S. Bureau of Mines production data).

Figure 12. Value of mineral production, Dallas County (based on U.S. Bureau of Mines production data).

for sand and gravel in the United States. According to the U.S. Bureau of Mines (1975), sand and gravel consumption in the United States will increase 3.3 percent annually in the period from 1974 to 1985. Based on the 1975 production in Dallas County of about 4.6 million tons, consumption in 1985 will be about 6.4 million tons, with a total consumption of about 60 million tons between 1975 and 1985. This tonnage is greater than the total production in Dallas County from 1945 to 1965, the period when production of sand and gravel reached its peak in Dallas County, and when the best quality deposits were depleted. It is apparent that demand for aggregate in the future will probably have to be met by mining deposits of lower quality than those mined in the past. For this reason, deposits in the city may be valuable even if they are not of suitable grade to warrant production under present conditions.

MINED LAND

Mined land is classified on the mineral lands map according to the status of the mining operation and the present condition of the land. Active mines are labeled to indicate the material being mined. There are only six active mines in the City of Dallas: three sand and gravel operations, one clay pit, and two limestone quarries (associated with a single cement plant). In addition to these active mines, there may be small operations working sporadically in various locations, usually "cleaning up" after larger producers have abandoned a site.

Classification of inactive mines is based upon the present condition and use of the mined land. The purpose of these inactive designations is to allow a general assessment of both the uses of the land after mining, and the need for reclamation of mine sites in the city. Four categories of inactive mines are shown.

Landfill Sites

One of the principal uses in urban areas of abandoned sand and gravel mines is sanitary landfills. Several municipal and private landfill operations are being conducted on mined land in Dallas. These operations include sanitary landfills, brush disposal sites, and pits filled with construction and roofing materials. The mineral lands map shows active and completed landfill sites.

Care should be taken in selecting future sites for sanitary landfills. Even though one can think of an abandoned mine as a conveniently located hole in the ground that needs to be filled, significant problems can result from using sand and gravel pits for solid waste disposal. High water table, high permeability, and frequent flooding are a problem with many mine sites because they are situated in floodplain deposits. These conditions not only hinder the landfilling operation, but also can result in pollution of ground- and surface-water supplies. Extensive onsite study is essential in establishing the suitability of any area for waste disposal; this evaluation is particularly critical for abandoned sand and gravel pits.

After filling operations are completed, landfill sites can be used either for recreational purposes, or for light construction sites, depending on compaction and stability of the fill.

Filled, Developed Mine Sites

Many of the mined areas in Dallas either have been built over, or are being used for recreational purposes. Some mines have been filled and used for residential, commercial, or industrial development. Others are now being used as lakes in parks and golf courses. Abandoned limestone quarries are generally not filled, but the quarry walls have occasionally been used to enhance the appearance of buildings constructed on these sites (fig. 13). Inactive mines in this category are good examples of the concept of sequential land use—resources have been exploited, and the land has then been put to other productive use.

Figure 13. Utilization of an abandoned limestone quarry in east Dallas for residential and commercial development.

Filled, Undeveloped Mine Sites

Several inactive mines on the mineral lands map have been filled and leveled (or filling is in progress), but no development has yet taken place on the site. These sites are usually good locations for industrial or commercial development. Filling the pits significantly increases the land value, and many of these areas are now valuable real estate.

Unreclaimed Sites

Neither leveling nor filling has been performed for many of the inactive mines in the City of Dallas. These sites are usually at least partly water filled, with hummocky topography. Larger sand and gravel mines have long rows of spoil piles with intervening low areas (fig. 14). The degree of natural revegetation depends on how long the mine has been abandoned; many of the pits now contain large cottonwoods and thick brushy vegetation. Quarries and small hillside cuts are typically dry and sparsely vegetated.

Mined land in this category generally requires some reclamation to restore it to a productive condition. Many of these mines are now used as illegal dumps, and they are both ugly and dangerous.

Figure 14. Abandoned, unreclaimed sand and gravel mine in southeast Dallas County. Note that natural revegetation has occurred.

RECLAMATION

Several physical factors, including type of mining, intended use of the land, and condition of the site, control the reclaiming of mined land. The type of mining affects reclamation potential because the mining technique is closely related to the amount and composition of material available for filling the pits or quarries. Area-stripping operations are generally relatively easy to reclaim because overburden is piled within the mine area, and it can be moved with normal earth-moving equipment. In open-pit operations, however, overburden is piled adjacent to the mine, and movement of this material into the pits can be very expensive. Quarries and hillside cuts also pose significant problems in reclamation because there is generally little or no waste material with which to fill the mines. The material that is available is usually broken rock, which is unsatisfactory for reclamation.

The intended use of reclaimed land determines the requirements of the completed site. This, in turn, controls such factors as the type and extent of filling, leveling, and replanting necessary. For example, land for construction of residential, commercial, or industrial buildings must be graded and filled to raise it above both the water table and flood levels. Land for recreation, on the other hand, generally requires less filling and grading because irregular topography and lakes are assets in such areas. Table 1 shows the ranges of surface gradients required for various land uses.

Table 1. Ranges of suggested gradients for various land uses (from Schellie and Rogier, 1963).

1%	football field softball field tennis court
2 to 4%	outdoor warehousing industrial site commercial site nursery site school site
2 to 5%	single-family residential tracts (high density) church site
2 to 7%	zoo golf driving range
2 to 8%	single-family residential tracts (medium density)
2 to 10%	riding club country club archery range
2 to 15%	single-family residential tracts (low density) golf course
2 to 25%	hiking trails
2 to 30%	high-rise residential tracts auto test course game preserve
2 to 50%	regional park woodland open space

The condition of the mine site when reclamation begins also has a significant effect on the requirements of mine rehabilitation. The depth of the mine and whether the pit is wet or dry determine both the amount of fill needed and the type of equipment used. The height and composition of the spoil piles control the ease of movement of the material. If a pit has been abandoned for a long time, extensive natural revegetation may hinder grading operations. If dumping has occurred in the mine since it was abandoned, cleanup of the debris must precede reclamation.

All of the above factors impose conditions and limitations on reclamation of mined land. Perhaps the ideal approach to these problems is preplanning reclamation so that reclaiming and excavating can be conducted simultaneously. Sand and gravel operations are particularly well suited for this approach since the spoil is generally easily worked and can be placed in the desired configuration as mining proceeds. This eliminates the need to move the material again. The savings inherent in this approach to reclamation are significant because equipment usage is not duplicated, and the problems of reclaiming an old site are avoided (Bauer, 1965).

A second advantage of preplanned reclamation is that costs of site rehabilitation can be budgeted into the mining program and then recovered when the minerals are sold. Many leases for mineral rights in the Dallas area now require at least some mine reclamation—usually leveling of spoil piles (Mims,[3] Olson, personal communication, 1977). Costs of reclamation operations therefore can be added to the base cost of the sand and gravel because the expense is included in the market price. If a producer owns the land, preplanning reclamation allows recovery of this expense, not only by passing the reclamation costs on to the consumer, but also by developing or selling the land after reclamation.

In practice, few mining operations are actually begun by considering the ultimate use of the land. Consequently, too often mining becomes, by default, the ultimate use. This is illustrated on the mineral lands map by the number of unreclaimed inactive pits. Mineral producers cannot afford expensive site rehabilitation unless the financial benefits are assured, or unless stipulations in the lease require reclamation. As a result, mined land may be left in a nonproductive state, and later reclamation becomes significantly more difficult and costly.

RECLAMATION ALTERNATIVES

As discussed above, the intended land use determines the site characteristics reclamation should achieve. These characteristics, in turn, affect both the development of the reclamation plan and the economics of the entire operation. Three general reclamation programs for mined land in the City of Dallas can be considered: (1) returning the land to its original condition, (2) reclaiming the land for real estate (residential, industrial, or commercial) development, and (3) reclaiming the site for recreational uses. Each of these categories contains many variables, making it difficult to generalize about site requirements and reclamation costs.

Another alternative is to reclaim mined land for agricultural use. Because most of the land under consideration in this study is within or on the fringes of a heavily urbanized area, however, pressures in favor of urban development or recreation are significant (although use of land in floodplains is restricted). Factors considered under the first plan—restoring the land to its original state—are generally the same as those required for reclaiming the land for agricultural use. According to one local producer, however, reclaiming land in the Dallas area for use as pasture or cultivation is not economically sound at this time (Olson, personal communication, 1977).

Returning to Original Condition

The feasibility of restoring mined land to its original condition is particularly affected both by the type of mining and by the characteristics of the land (vegetation, topography, etc.) before mining. This reclamation alternative is virtually impossible for quarried land since mining is conducted in hard rock, and little or no waste material remains. In order to restore open-pit mines to original ground level, fill material generally is necessary. The added cost of purchasing or transporting the volume of fill needed to completely reclaim open-pit mines can be prohibitive.

Land mined by area stripping can be restored, in some cases, to its original condition simply by grading and revegetation. Cost estimates for grading the surface of land mined for sand and gravel to its original level range from $300 per acre (Shanks, 1973) to $400 per acre per foot of total pit depth (Olson, personal communication, 1977). To segregate topsoil during mining and to later replace it in order to promote successful revegetation may cost $500 to $600 per acre (Shanks, 1973). Summer (1975) estimates costs of revegetation and fertilization in Colorado County at $35 per acre. In addition to grading costs, one must add equipment rental and operation, particularly if mining and reclamation are not concurrent. Olson (personal communication, 1977) estimates the cost of a bulldozer and operator at $5,000 per month. If fill must be hauled to the site, reclamation costs can increase significantly. According to figures from one Dallas producer, filling and excavating a 38-acre strip-mine site requiring about 6 feet of fill accounted for over 93 percent of total reclamation costs (the remainder was engineering and equipment costs).

A major consideration in choosing any reclamation alternative must be a comparison of the tradeoffs between that plan and other plans. Returning the land to a natural condition certainly has both aesthetic and ecologic benefits. There may also be economic advantages to such a program. The characteristics of the site before mining determine whether or

[3]Personal interview on February 7, 1977, with Lewis Mims, Texas Industries.

not the mined land will be suitable for such uses as agriculture, real estate development, or parkland. For each site, a decision must be made as to whether or not the advantages of returning the land to its original state outweigh the benefits of other, possibly less expensive, reclamation plans.

Real Estate Development

Reclaiming mined land for real estate development generally assures a higher dollar return than does restoring the land to its original condition or using it for recreational purposes. Although financial advantages may not always be the primary reason for rehabilitating mined land, recovery of the expense of reclamation, and possible financial gain, are undoubtedly major incentives for producers. The potential for gain from restoring mined land is particularly significant in a rapidly growing urban area where residential, industrial, and commercial land is at a premium.

As a rule, reclamation for real estate development costs more than other types of restoration. Not only do all the factors discussed above affect reclamation costs, but the variation in requirements for residential, industrial, and commercial uses also results in wide cost ranges.

An important consideration (and commonly a major expense) in reclaiming sand and gravel mines for real estate development is the location of these areas in floodplains. In most places, extensive filling is necessary because of the high water table and flood hazard. Development in the floodplain is also restricted in the City of Dallas by zoning regulations and by insurance requirements.

The topographic and water features of area-stripped land could be used, in some cases, to enhance the area's potential for residential development. Small lakes or ponds and varied topography have interesting landscaping possibilities (Rickert and Spieker, 1971). Some grading and filling may be required, but flat terrain is not essential. Cost of restoring strip-mined land for a single-family residential development near Irving was estimated by the producer to be about $1,600 per acre (Olson, personal communication, 1977).

Industrial or commercial properties, on the other hand, usually require broad areas with level topography. Some industries may be able to utilize mine lakes for cooling or washing; otherwise, bodies of water are generally undesirable. Access to major highways and railroads is an important consideration in deciding to reclaim land for industrial or commercial uses. Costs are typically higher for this type of reclamation than for most others because of the need for extensive grading and filling, but commercial and industrial real estate also brings a very high price. Figures from one local producer for reclaiming land for industrial-commercial purposes range from about $2,400 to $13,400 per acre. The higher costs were attributed principally to the need to haul fill material from another site (Olson, personal communication, 1977).

Abandoned quarries may be ideal for certain types of development. The broad flat areas in the quarry may be good sites for industrial operations, office parks, shopping centers, schools, or municipal facilities. A large quarry in Dallas is now the site of a regional postal complex. The costs of preparing abandoned quarries for development are minimal—usually limited to removal of mining debris.

Recreation

Reclaiming mined land for recreational use is possibly the least expensive of the three alternatives discussed here. The varied topography and water bodies that characterize sand and gravel mines are desirable features for most recreational areas. If large water bodies exist, areas for swimming and small craft boating, which require only replanting and grading along the shore, can be designed. Mined land with rough topography and isolated small ponds is well suited for parks, golf courses, and wildlife preserves. Using abandoned sand and gravel mines for recreation is also desirable because use of the floodplain for recreation is permitted in Dallas. Using water features common on mined land decreases reclamation costs by reducing the need for filling, grading, and replanting. In addition, costs of fertilizer, mowing operations, and park maintenance may be lower in recreational areas containing water bodies when sedimentation and water quality problems are not encountered (Rickert and Spieker, 1971). Quarries are well suited for recreational purposes, such as zoos, botanical gardens, and natural amphitheaters. Costs of preparing a quarry site for such uses are minimal.

Primary expenses of reclaiming strip-mined land for recreation are for grading and replanting. Depending upon the amount of grading needed for the desired topography, the cost of reshaping the land can range from a minimal amount to about $600 per acre. To achieve the desired type of revegetation, topsoil may have to be replaced; this can be expensive if soils were not segregated before mining. Revegetation costs have been estimated at approximately $35 per acre (Summer, 1975), although this figure may be higher for certain uses, such as golf courses, which require special vegetation and maintenance.

Although recreational use is one of the least expensive reclamation alternatives, it also generally brings the lowest rate of return on the investment in site rehabilitation. However, since the value of unreclaimed mined land is so low, it may be feasible for a public agency, such as the City of Dallas, to purchase these lands and to reclaim them for public recreational facilities. Operating private recreational facilities on a fee or membership basis would also help recover reclamation costs.

Summary

Examining the many variables involved in carrying out a reclamation plan reveals the problems inherent in establishing cost estimates for such a plan. The extent of reclamation and the types of expenditures included in the cost estimates also vary widely. Estimates obtained from two Dallas producers for reclaiming sand and gravel pits ranged from $300 to $600 per acre (Mims, personal communication, 1977), to $500 to $600 per acre (Slayton,[4] personal communication, 1977). In these cases "reclamation" meant simply smoothing the spoil piles, without returning the land to its original elevation. Probasco (1971) cites the American Aggregates Corporation as stating that "reasonably good reclamation" can be achieved for a cost under $500 per acre. Other reclamation cost figures, including expenditures for engineering fill, excavation, and equipment rental, range from $1,300 to over $13,000 per acre (Olson, personal communication, 1977). Without a full enumeration of site conditions, procedures, and itemized expenditures for a specific reclamation program, it is very difficult to make comparisons of costs for restoration operations with different conditions and goals. Furthermore, if reclamation is concurrent with mining, it is difficult to separate reclamation costs from normal production expenditures.

Additional discussion of reclamation alternatives and specific site restoration practices can be found in Schellie and Rogier (1963), Bauer (1965), and Johnson (1966).

EFFECTS OF RECLAMATION AND TRANSPORTATION COSTS

Consideration of several hypothetical situations illustrates the effects of transportation and reclamation costs on prices of aggregate materials.

Site Z (fig. 15) is located in the Northwood section of Dallas, where the total number of dwelling units is projected to increase by about 55 percent by 1985 (City of Dallas, 1973a). Sites A and B are undeveloped areas that may be underlain by sand and gravel resources within the City of Dallas. Sites C and D are southeast of the city, where area producers predict most

[4] Personal interview on February 8, 1977, with Bob Slayton, Trinity Division, General Portland Cement.

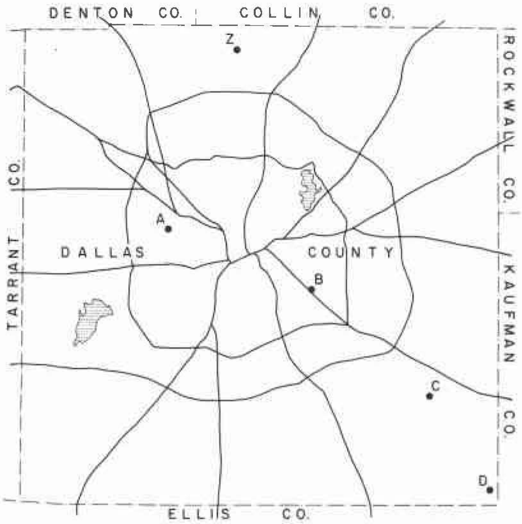

Figure 15. Location map for hypothetical sites A, B, C, D, and Z.

Table 2. Costs of sand and gravel at site Z after transportation from each mine site.

Site	Distance to site Z (miles)	Transportation cost to site Z* (dollars per ton)	Total cost at site Z if unit value is $1.60/ton (dollars per ton)
A	14.5	1.03	2.63
B	18	1.27	2.87
C	33	2.17	3.77
D	37	2.41	4.01

*At 25 cents for the first mile and 6 cents for each successive mile.

Table 3. Effect of reclamation costs on costs of sand and gravel.

	Reclamation Cost Estimates					
	$400 per acre per foot of total pit depth	**$300 per acre**	**$600 per acre**	**$1000 per acre**	**$5000 per acre**	**$13,384 per acre**
Cost added per ton of sand and gravel (dollars per ton)	0.24	0.02	0.04	0.07	0.37	0.99
Total cost at site Z for material from site A (dollars per ton)	2.87	2.65	2.67	2.70	3.00	3.62
Total cost at site Z for material from site B (dollars per ton)	3.11	2.89	2.91	2.94	3.24	3.86

of the future sand and gravel production in the county will occur.

In order to compare the costs of using aggregate resources in the city to the costs of transporting these minerals from more distant mines, one can consider the case of a contractor purchasing sand and gravel for construction of homes at site Z. It is assumed that the material from each resource site is of comparable quality, in order to meet job specifications. If mining is undertaken at site A or B within the city, cost of eventual reclamation must be added to the market price of the mined material. For the purposes of this comparison, no reclamation costs were added to aggregate prices from sites C and D.

Based on 1975 U.S. Bureau of Mines data, the average unit value of sand and gravel sold at the mine in Dallas County was about $1.60 per ton.[5] Figures for the cost of transporting one ton of sand and gravel by truck are cited by the U.S. Bureau of Mines (1975) at 25 cents for the first mile, and 6 cents for each additional mile.

Two methods were used to calculate the cost added by reclamation to a ton of sand and gravel from sites A and B.

1. According to Olson (personal communication, 1977), restoring mined land to its original level will cost about $400 per acre per foot of total pit depth. In his estimation, this cost will double stripping costs, which now account for approximately 15 percent of total production costs. If production cost is assumed to be $1.60, reclamation will add 24 cents per ton to the cost of sand and gravel.
2. According to Mims (personal communication, 1977), sand and gravel production in the Dallas area is typically 10,000 to 12,000 cubic yards per acre. Based on the lower figure and a density of 100 pounds per cubic foot, production would average 13,500 tons per acre. By applying different values for reclamation cost to this production figure, the cost added per ton of sand and gravel for each reclamation estimate was calculated. Several values for reclamation costs were considered. These ranged from figures for areas requiring minimal amounts of reshaping, to the highest estimate available for an area that required extensive filling and grading.

Table 2 shows the cost of sand and gravel from each of the four sites after transportation to site Z. In table 3, the effects of reclamation cost on the total cost of the material were determined. For purposes of this comparison, production costs were assumed to be the same at each site. It can be seen that, except for one value calculated for aggregate from site B using the highest reclamation cost estimate, transportation costs from sites C and D add more to the cost of the sand and gravel than the expense both of transportation from sites A and B, and of reclamation of these sites.

Even if reclamation costs $5,000 per acre at site B, the total cost of sand and gravel from this site ($3.24 per ton) will still be lower than the price of aggregate from site C ($3.77 per ton) or D ($4.01 per ton), despite the fact that no reclamation is conducted at sites C and D.

An additional factor to consider is that,

[5]This value is calculated on the basis of both total production, and total production value of sand and gravel in Dallas County. Unit values of sand and gravel vary according to the degree of processing and specifications for the end use of the material.

because of the savings on transportation costs by mining nearby sites, it may be economical to mine deposits that require higher production costs. Even if the nearby deposits require removing thicker overburden or entail more processing than do outlying deposits, these additional costs may still be less than the costs of transporting material from more distant sites.

According to a representative of one of the companies in the Dallas area producing sand and gravel, the company's reserves of material within the city that are mineable under present economic conditions have been exhausted. However, he pointed out the possibility that when transportation costs from outlying deposits exceed the cost of beneficiating lower quality deposits in the city, production in Dallas may resume. He added that if production in the city does resume, it will be practical to reclaim the land because of its proximity to areas of urban development, with their resulting high land values, as well as because of the need to eliminate the hazardous and unsightly pit conditions. The sand and gravel company's representative also emphasized the importance of preserving deposits of construction minerals from loss due to urbanization (Olson, personal communication, 1977).

USE OF MINERAL LANDS

After identifying potential resources within an urban area, planners must formulate a policy regarding mineral lands and their use. There are essentially two general alternatives to consider: (1) a policy encouraging utilization of resources and reclamation of mined land before developing it, or (2) a policy favoring developing mineral lands and obtaining resources from more distant deposits.

The first alternative could include such measures as zoning regulations to protect mineral resource lands from urbanization, tax incentives to encourage mining in the city, ordinances requiring mined land reclamation, and city patronage of producers operating within the city limits. There are several advantages to this policy. By assuring the availability of these potential resources, the total mineral reserves of the area are extended. Utilization of resources near the market area cuts transportation costs of the minerals, and therefore cuts construction costs. Land owners can receive the benefit of the full value of their land since the mineral resources are produced, and the land, after reclamation, is returned to a productive condition—in some cases, with significant financial gains. Finally, an overall economic advantage results from stimulation of trade within the city.

Possible constraints to the first alternative include the unpleasant effects of mining. Although this is a relatively short-term problem, the dust, noise, traffic, and general nuisance that accompany mining have made it an unpopular activity in urban areas. Producers should be encouraged to take measures to screen the operations and to minimize these unpleasant effects. Nevertheless, encouraging mining in the city, particularly in the Trinity River floodplain, may involve a tradeoff between ecologic and economic interests. The Trinity floodplain has been declared an environmentally sensitive area (City of Dallas, 1973b). Certainly, if ecologic concerns are considered critical, such concerns must be weighed against the effects of mining. Decisions to allow mining will have to be made in conjunction with planning and zoning measures designed to protect sensitive areas. Unless stringent reclamation requirements are enacted and enforced, it is possible that mined land will be left in a disrupted state. Finally, requirements for reclamation of mined land will result in increases in the cost of aggregates when the expense of reclamation is passed on to the consumer. Cost increases, however, even from very expensive reclamation programs, are less than the increased cost of transportation from more distant deposits.

The second approach is a policy favoring land development within the city, thereby necessitating utilization of mineral resources from outlying areas. This alternative may actually take the form of a lack of definite policies for preserving mineral resources, with the result that urbanization overtakes mineral lands, thereby requiring that resources be obtained elsewhere. The principal advantage of the second alternative is that the unpleasantness and environmental disruption of mining are avoided. In addition, income, in the form of profit for landowners and tax revenues for the city, is higher for developed land than for land being mined or held for future mining. However, if mineral resources are extracted prior to development of the land, income is received not only from production of the minerals, but also from subsequent development of the land after reclamation.

If urbanization is permitted to extend over mineral lands, valuable resources are permanently lost. The result will be higher costs for transporting materials from outlying areas, and higher construction costs. Economic losses go beyond the increased construction costs, however. Simple calculations, based on the average yield of sand and gravel deposits in the Dallas area (10,000 cubic yards per acre), reveal that in the 48 square miles of potential sand and gravel resources in the City of Dallas there may be over 415 million tons of aggregate. If only half of these resources were mined at the present unit value of $1.60 per ton, the total value would be $332 million. Thus, the economic losses from urbanization of these potential resources could be significant.

The estimate of the actual amount of sand and gravel available in the city (a maximum of 415 million tons) is based on average thickness of deposits in areas that have been mined, and it assumes that such deposits underlie the entire area of potential. It does indicate, nevertheless, that there is a need for evaluation of the resource potential of unmined areas. Of the 48 square miles of potential sand and gravel resources, the area in the Trinity floodplain (approximately 18 square miles) probably has the greatest potential as a source of construction aggregate, possibly containing 242 million tons. Site-specific data are essential, however, for determining the exact nature and extent of the sand and gravel. Undoubtedly, large segments of the floodplain do not contain economic sand and gravel deposits because of the depth, quality, or quantity of material. However, until unmined areas with mineral potential have been evaluated, it is advisable to consider their resource potential (based on general geologic evidence) as similar to that of productive sites.

After areas of resource potential have been identified, sand and gravel deposits in these areas can be evaluated. A common technique is drilling to ascertain the thickness of overburden, the percentages of sand, gravel, and clay, and the geometry and extent of the deposit. Other sources of data include available engineering borings, water well records, driller's logs, and Soil Conservation Service borings.

SUMMARY AND RECOMMENDATIONS

The following recommendations arise from a general conclusion that the City of Dallas needs to preserve and to utilize its construction mineral resources. Several measures are proposed below as ways of incorporating this conclusion into city policy.

1. Consider the establishment of mineral resource districts to preserve critical resources from urban development. This type of legislation has been enacted by the States of Colorado and Vermont, by Fairfax County, Virginia, and Salem, Oregon, as well as by other State and local entities. Such an ordinance could designate the nonurbanized portions of the Trinity River floodplain as mineral resource districts and require an evaluation of the sand and gravel resource potential of any area within the district before issuing permits which might

preclude resource utilization. Numerous local ordinances relating to mineral lands have been enacted in recent years. Preston and others (1974) have examined the use of zoning to reserve and to regulate mineral lands, and they propose a model ordinance for this purpose.

2. If the City of Dallas desires to produce aggregates for use in city projects, planners must evaluate available subsurface information, and conduct borings to determine depth, thickness, and quality of sand and gravel in the Trinity River floodplain. Detailed data are essential for geologically establishing priorities on the areas within the floodplain. Factors such as (a) city ownership, (b) proximity to areas where aggregates will be needed, and (c) proximity to areas mined in the past can be used in selecting sites for evaluation. Trinity River floodplain deposits do have a greater potential as sources of construction aggregate than do areas on the terraces or along smaller creeks, and should therefore be evaluated first.
3. When land within the potential resource areas is acquired by the city for other purposes, such as landfills or brush-demolition sites, planners should evaluate the possibility of using sand and gravel from these sites for city projects.
4. Formulate a land use policy that includes consideration of the significance of construction minerals, particularly sand and gravel, in land use plans. Although many other factors must be examined—legal, environmental, economical, and social—in any land use decision, the significance of available supplies of construction minerals near the growing Dallas urban area should be realized, and this knowledge should be applied to land use policies.
5. Develop a policy to permit rather than to discourage mining in areas in the city where zoning and other conditions are judged suitable. Implicit in such a policy is the idea that with proper regulation and enforcement, the nuisance and environmental disruption of mining operations can be minimized, and the land can be restored to a productive state after mining.
6. Applications for permits to mine in the City of Dallas should include the following:
   a. A plan for the mining operation including mining method, length of time mining will continue, and measures for visual screening and minimizing hazards.
   b. A provision for subsequent use of the mined land, either in the form of (1) an agreement to turn the land over to the city for uses such as landfill, brush/demolition sites, parkland, or open space, or (2) a detailed reclamation plan for site rehabilitation, to be conducted by the producer. The submitted reclamation program should include any plans for leveling, grading, and filling the land intended for development. If no development is planned, the reclamation program should include measures for filling, grading, and compacting the mined land in order to minimize erosion and unstable slopes, as well as a plan for revegetating affected areas.
   c. A provision for a performance bond to ensure compliance with permit requirements.
7. Develop reclamation standards for restoration of mined land in the city. Specifics of these standards can probably best be determined by consulting with area sand and gravel producers, and by reviewing existing ordinances from other areas.

CONCLUSIONS

It is obvious that there is a long-term economic advantage in using resources available in the City of Dallas. However, there are numerous social, environmental, and political factors that affect decisions concerning land use, and in certain cases, such considerations may override the importance of the mineral potential of the land. Nevertheless, implementing a general policy which encourages the use of mineral resources in the city will extend the resource base and will prevent unnecessary increases in construction costs in Dallas. If requirements for reclaiming mined land are incorporated into such a policy, not only will the land be restored to a productive state, but also the costs of site restoration will be minimized by using simultaneous mining and reclamation programs.

Urban development, in the form of residential, commercial, and road construction, is the primary consumer of the mineral resources occurring in the Dallas area. Unfortunately, this consumption has been two-fold. Minerals have been used in construction as the Dallas area has grown rapidly in recent years, but they have also been consumed as urban development extended over areas underlain by potential resources. Without policies assuring maximum use of these mineral resources, urban development could be responsible for the drastic depletion of the very materials upon which its future depends.

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