During this period, the city was the center of multiple urban disturbances. One of the most distinctive events was the riot that took place in 1866. During this riot, large numbers of African-americans were killed, and many warehouses and properties were burned, especially in African-american neighborhoods. Two years later, a yellow fever epidemic affected Memphis in such proportions that the City Council urged citizens to depopulate. In 1879 the city was bankrupt and surrendered its charter.

However, between 1880 and 1900 Memphis regained dominance in cotton trading over other southern cities. Two elements influenced the growth of the City of Memphis during this early period: the construction of the railroad system which open new land for development, and the construction of the Great Bridge across the Mississippi River which influenced the opening of commercial flows from different parts of the nation.

As early as 1920, there was a great concern in terms of land-use beyond the city's limits. While Memphis was growing east, the conditions of downtown had worsened significantly. During the beginning of the twentieth century, the commercial downtown area lacked any comprehensive plan.

The City Planning Commission was established in 1920 as a corrective answer to the many urban problems affecting Memphis. Within its first year of existence, the Commission approved Memphis' first zoning ordinance. Two years later, the first Comprehensive City Plan was completed. This plan together with other plans prepared the following years have been the major tools of the city planning administration for monitoring the growth and development of Memphis.

Memphis did not annex any contiguous suburban areas during the 1930s. Indeed, the city was convinced that enough land was already available to support existing urban growth. During this period the eastern limits of the city extended about 6 miles from the Mississippi River, and the northern and southern boundaries were about 3 miles from downtown Memphis.

By and large, the period from 1905 to 1929 was important for downtown Memphis. It was a period of urban revival. A multitude of new buildings were constructed expanding onto the adjacent streets of traditional downtown, obsolete commercial business structures were transformed under the influence of the Chicago School into large steel framed structures. During this period, Memphis became a developed city.

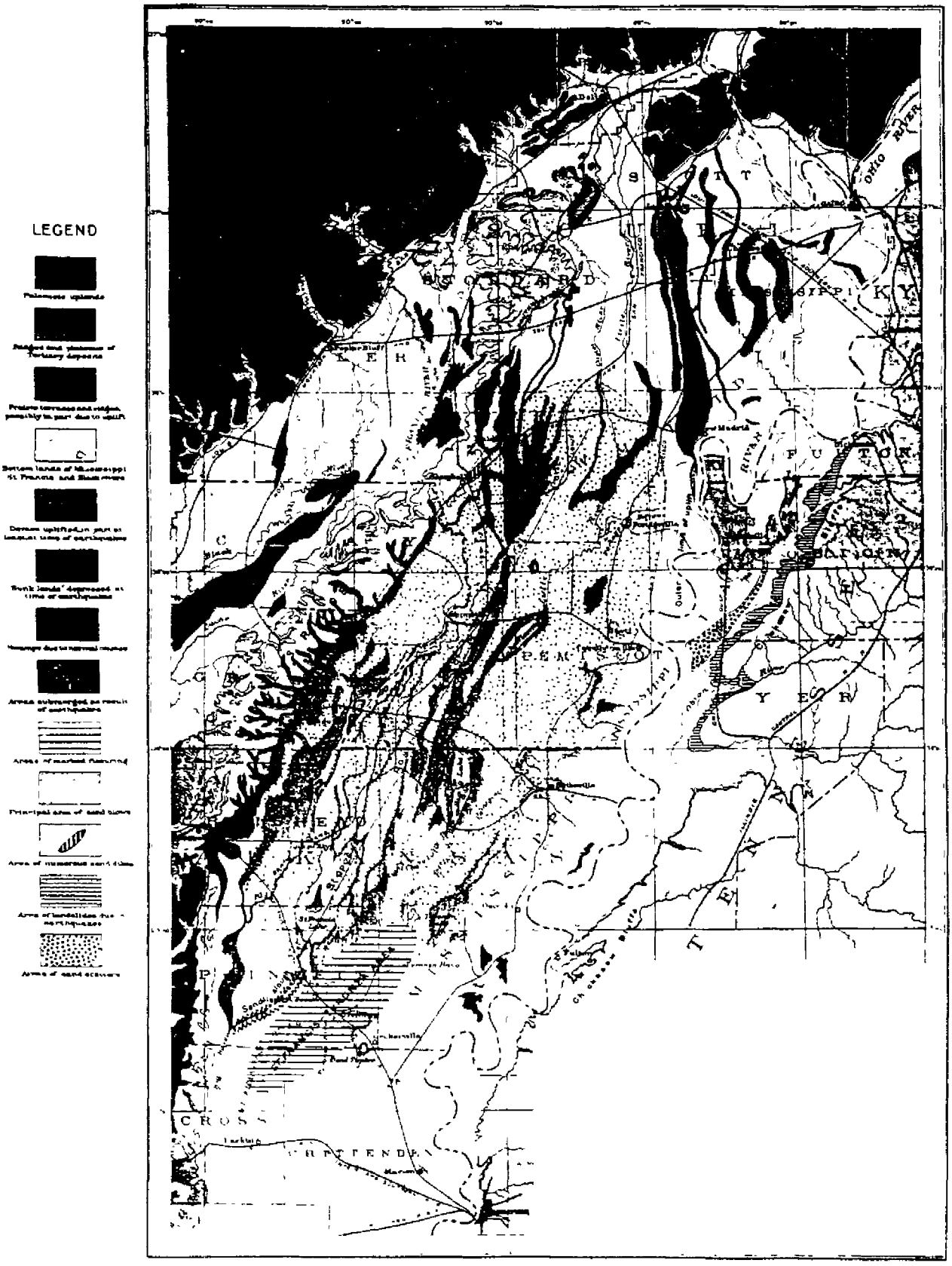
However a few years later, Memphis was hit by the Depression. Real estate values declined drastically in 1930, 1931, and 1932. Memphis fell from fifth to eighth place in population among the principal cities of the South and Southwest and unemployment skyrocketed. These social conditions brought Memphis back to a similar situation to the one experienced before 1905. The city was described by many as *"a slum-ridden city."* (Sigafoos, 1979) Store vacancies ran high and the city was ringed by a large extension of slum housing and blight. The Memphis Housing Authority reported that half of the city's inhabitants were living in substandard housing. During this period the city became an enclave of low and modest income groups.

In 1938, a second plan was prepared oriented at promoting housing rehabilitation programs in the city's older neighborhoods in order to help offset decentralization. However, the city did not follow this plan. One principal reason was public reaction against the plan's suggestion to further downgrade zoning, particularly from commercial to residential since owners of commercial property were extremely opposed to downzoning attempts.

It is important to point out that neither the plans developed during the early 1900s nor present plans include any earthquake safety programs. Furthermore, seismic code provisions have only very recently become an enforced requirement for the City of Memphis. Indeed, before 1990, whenever construction took place in Memphis, seismic safety was generally overlooked in spite of the fact that Memphis was and is considered a major earthquake risk area.

Exhibit 11

EARTHQUAKE FEATURES
NEW MADRID DISTRICT



Source: *New Madrid Earthquakes* (Fuller, 1912)

Memphis' economy experienced great growth during World War II. The city became the location for major military and naval installations and a center for manufacturing war materials. Thousands of workers immigrated to Memphis from 1942 through 1945, increasing the population, and thus, the demand for housing. This situation soon ended; after World War II most of the factories closed, releasing thousands of workers into the job market. This labor surplus in addition to a shortage of housing, exacerbated the growth of slum and blight in the city. Memphis Housing of Authority estimated that six square miles of the city were *"wretched slums."* Through the mid 1950s, the number of substandard housing units increased steadily. (Sigafoos, 1979)

In 1955 Memphis turned to the Federal government to finance slum clearance. Under the *workable program* established by the Housing Act of 1949, the City of Memphis initiated its first urban renewal project. Urban renewal lasted until 1956. During this period the city struggled to eliminate slums and revitalize its downtown. A combination of poverty, decay, crime, and traffic problems became the blight of downtown. For instance, during this period Memphis was rated the city with the highest crime per capita in the U.S. In 1955, a traffic study estimated that 131,000 cars were entering downtown Memphis daily while there were only 20,000 parking spaces available. (Sigafoos, 1979) The struggle to revitalize the downtown area continues today. City authorities are still confronted with similar problems that they faced in the mid 1950s which have resulted in low-occupancy rates and a lack of building maintenance in the downtown area.

On a block-by block basis urban renewal programs targeted the conservation of good housing while advocating the demolition of substandard housing. By 1957, under the city's housing improvement program some 7,000 structures were rehabilitated, and by 1969 a total of 1,500 new housing units were constructed. It is important to point out that originally the federal program was based on replacing slum housing with new housing and supportive types of facilities. Later, more diversified types of renewal treatment were permitted, and cities were not compelled to replace slum housing with new housing. As a result, considerable portions of inner-city land still remains vacant today. However, by and large the city has been successful in marketing most of its renewal property.

During the 1950s and 1960s peak population shifts were recorded when the working population massively moved to the suburbs. This exodus was closely followed by land annexation. Continued unplanned annexations have created great concern within the planning community.

In 1955, the city adopted a new plan and new zoning ordinances were enacted into law. This was the first major revision in zoning since 1931. In spite of the fact that one of the basic goals of this plan was to reduce unplanned annexations, by the 1960s rezoning application approvals were increasing. By 1965 Memphis had a population of 550,000 and included an area of 165 square miles. During this period, hundreds of subdivisions flourished outside the city's boundaries; migration to the suburbs was followed by an influx retailing and wholesale stores, and office buildings; and transportation corridors were clearly established. As the bulk of city dwellers moved further north, east, and south of the downtown, Memphis' business district became more geographically isolated from consumers.

REDEVELOPMENT IN MEMPHIS

In Memphis, several institutions have played an important role in the preservation, rehabilitation, and redevelopment of the downtown area. These agencies typically exist under the assumption that inner-cities are of increasing interest to developers. The underlying argument is that inner-cities offer sites near well-established, prestigious locations or institutions; close-in infill sites which are often less expensive than well-located suburban sites and more convenient than distant suburban sites; and a wide variety of obsolescent buildings and underdeveloped parcels of land that are economically adaptable. Normally these agencies receive federal grants, acquire property, widen streets, install public improvements, and create the necessary incentives for private investors.

The importance of incorporating seismic safety within urban redevelopment programs is centered in the concept that buildings are not located in isolation; buildings, infrastructure, and urban functions are strongly interrelated. When an earthquake occurs, its affects on the urban fabric would be similar to the aggregate effects on individual buildings. By seismically upgrading the urban system, total earthquake damage would decrease while safety in the urban environment would be considerably increased.

The role that public agencies play in urban redevelopment can be highly significant for earthquake safety.

Center City Commission. The Center City Commission was created in 1977 to promote private development in downtown Memphis. The Commission coordinates the comprehensive revitalization of downtown as the economic, cultural and governmental center of the city and county. One of the most successful programs of this Commission has been the restoration of Beale Street. The city agreed to lease the existing buildings to a private development group, who, in turn, rehabilitated and then subleased the improved buildings for various commercial components of the Blue Light District. Since its inception over $1 billion has been invested in the downtown's redevelopment program.

The Center City Commission has established three affiliated agencies; the Center City Revenue Finance Corporation, the Center City Development Corporation; and the Design Review Board.

Of particular interest is the Center City Revenue Finance Corporation (CCRF). The Corporation's prime responsibility is to offer financial incentives for downtown redevelopment. For this purpose the Corporation can freeze a property's assessed valuation at its redevelopment level for a number of years, thus providing a tax break to developers. It also offers revenue bond financing for approved projects, as well as, below market interest rate loans for facade renovation. These incentives are applicable for both rehabilitation and new construction projects. All projects are reviewed by the Center City Design Review Board (established to review quality and consistency of design in redevelopment projects) and/or the Memphis Landmark Commission.

There are several controversies in terms of how and when urban redevelopment in Memphis should take place. Since the early 1900s a dichotomy between the need to facilitate the urban growth outside the boundaries of the city and to rehabilitate the central downtown area has dominated the urban configuration of Memphis. The decline of the central city has been tied to the belief that property taxes have become less significant for central cities. Biased assessments tend to underestimate the value of properties located in the downtown area. In addition the goal of urban renewal programs has been the eradication of blight areas that have become a fiscal and social burden for the city.

However, others argue that urban renewal programs can yield profitable returns for the city. For instance, Sigafoos (1979) found that the taxes contributed from renewal areas exceeded the taxes contributed from these areas before renewal. This situation seems most remarkable for the City of Memphis since much of the renewal land sold has been to tax exempt entities.

Several incentives and fiscal tools can be used to promote seismic safety when rehabilitation or new construction takes place in the inner city. The procedures and policies developed by this Corporation are in place to promote the adoption of earthquake provisions. The Corporation is allowed to promote incentives when projects coincide with public interest (Compliance with CCRF Objectives, section 4). It is in the best interest of the public that earthquake risk is minimized since future earthquakes affecting the inner-city can result in large death tolls, and property damage.

Various incentives could be utilized to promote earthquake safety. For instance the Center City Revenue Finance Corporation could require as a precondition for eligibility that new construction must observe *minimum* earthquake requirements and that retrofitting should be mandatory when rehabilitation takes place in older buildings. The latter is particularly appropriate since only projects that improve over fifty percent of the total cost are eligible to benefit from incentives granted by the Corporation. The central argument to include an earthquake safety component in projects endorsed by the Corporation is that if fifty percent of the building's total value is to be modified, retrofitting the entire building would not create substantial additional costs.

Special below market rate loans can be offered to finance increased costs when using seismic safety provisions. To create interest the city might consider using municipal bond funds and resources from lending institutions that may have an interest in the earthquake safety program.

Tax forgiveness can also be an important incentive for the adoption of earthquake mitigation measures. At present, the City of Pasadena, California is looking into tax rebates for downtown property owners who seismically strengthen their buildings. As identified by the California Preservation Foundation, this approach has an up-front tax loss, but the reduction of tax revenues when a damaged building is out of service for months and perhaps demolished is considerably larger.

Tax increment financing, and obligation and revenue bonds can serve to finance the rehabilitation of both substandard and historical buildings without extreme budget burdens for local authorities. In Memphis, the Pyramid building was built by the city using primarily revenue bonds. According to local officials, this 32 story building was built without seismic requirements due to scarce funds. Financial incentives can play an important role by serving to finance the additional costs resulting from designing and constructing with adequate seismic safety standards and/or seismically retrofitting public buildings and historical landmarks.

It is important to indicate that issuing bonds and creating incentives to finance earthquake safety related elements requires that the potential threat to earthquakes be well established, that key municipal players are aware of such a threat and the consequences of a disaster on their community, and that they are willing to take action. (Pantelic, 1992)

In spite of the fact that these conditions are not fully in place in Memphis a recent event suggests that the awareness of the community to earthquake safety issues is higher than what has been commonly assumed in the past. The construction of the Pyramid in 1991 without the earthquake provisions required by SBC, created great controversy between local officials and the community.

Memphis and Shelby County Division of Planning and Development. One of the most influential offices in Memphis in terms of redevelopment activities is the Division of Planning and Development. The mission of this office is to develop community wide and neighborhood plans, and direct matters related to planning studies, land-use, public facilities, housing, and transportation. This Division encompasses the Office of Planning and Development (i.e., land-use control, plan development), the Office of Economic and Resource Development (i.e., energy management, special programs, private industry programs), and the Office of Construction Code Enforcement (i.e., building permits, licensing, zoning compliance).

In 1981, the Office of Planning and Development prepared *The Memphis 2000 Policy Plan*. This Plan is a guide for the physical, economic and social development of Memphis and Shelby County through the year 2000. The plan was based on an inventory of population, economy, housing, land-use, and public facilities.

Memphis 2000 recommends changes in existing procedures and sets forth policies and action in areas previously not addressed. For instance the Plan recommends a more contiguous land-use pattern (increasing land-use densities within the urban service boundary) during the next twenty years in order to achieve a more efficient and cost effective use of public services and facilities. The Plan also recommends the construction of new universities, hospitals, and industries in appropriate and compatible areas.

A first step in terms of including natural hazards considerations in the plan has already occurred. Memphis 2000 Policy Plan includes natural hazard safety provisions. Policies relating to the natural environment include development in floodplains; practices which aggravate soil erosion, sedimentation, or increase runoff; and practices which expose people to harmful substances. The Plan advises that there should be no significant construction in any of the identified floodplains, in accordance with the current zoning ordinance.

Similar provisions could be developed in regard to earthquake hazards. As mentioned before, high quality earthquake and geological information has been produced by Memphis State University. By assimilating this information into land-use planning, city officials can reduce the potential loss of private and public investments in areas designated as top development priorities. The Memphis and Shelby County Division of Planning and Development is the comprehensive planning unit for the city of Memphis and Shelby County, as such, it can influence the quality of community planning. Within this program there are several incentives that can be promoted by the city and/or county in order to reduce human and economic loses than might take place if a major earthquake occurs in Memphis.

In addition Memphis 2000 recommends that public facilities and services be provided in a coordinated, cost efficient manner to adequately serve the local population. Critical facilities can be severely damaged during an earthquake and cause great urban disruption due to the high dependency of the urban system on critical facilities, such as fire fighting services, after a major earthquake.

Memphis 2000 could easily incorporate earthquake recommendations as an integral component of land-use regulations. As in the case of the Memphis Landmarks Commission, pounding effects, cladding, building setbacks and the design of open spaces could be regulated for earthquake safety.

Moreover, the city is in the process of revising its Master Plan; thus earthquake concerns can be incorporated during the revision process. A year ago a major controversy arose when the city decided to enforce stringent earthquake considerations as part of their current building code. The Division of Planning and Development staff expressed that this controversy plus the Browning earthquake prediction episode[9] has increased public officials and citizens awareness in terms of earthquake safety.

Hopefully, the earthquake programs adopted by many cities in other states and described throughout this report, can benefit and help Memphis establish a sound seismic retrofit and rehabilitation program for buildings located in downtown Memphis.

The Memphis Landmarks Commission. The city's public involvement in preservation efforts began officially in 1976 with the creation of the Memphis Landmarks Commission. This Commission is responsible for the legal protection of historic, architectural, and cultural landmarks in the City of Memphis. In both historic preservation and historic conservation zones, the Memphis Landmarks Commission is mainly concerned with the review of new construction, demolition, relocation of structures, and all types of exterior alterations. Earthquake safety is not listed among the Commission's priorities.

[9] Iben Browning forecasted a New Madrid earthquake for December 3, 1990. Although widely reported the predicted earthquake never occurred.

Preservation movements became very significant during the early 1970s. During this period there was a growing consensus for preserving structures of historical value. Unfortunately, unlike Charleston, Memphis did not have a strong tradition of historical preservation and twenty years of urban renewal programs had taken a toll on important landmark buildings. Indeed, many structures of historical interest were demolished in the wake of urban renewal and other land clearance programs.

Early movements for historical preservation were led by several neighborhood associations, young couples, and longtime residents who found downtown and midtown Memphis attractive and of historical value. Efforts were made to refurbish older homes and improve physical and social conditions of the downtown area and contiguous older districts.

Revitalization programs were aided by two laws. The National Historic Preservation Act of 1966 promoted the inclusion of properties of local and state significance as well as those of national importance. This legislation stimulated private investment in the restoration of landmark buildings. In addition, the Tax Reform Act of 1976 provided special tax incentives for the rehabilitation of historic structures by granting developers rapid depreciation write-off privileges for the cost of rehabilitation.

The Memphis Landmark Commission is the primary regulatory body for the control and rehabilitation of old structures in downtown areas. However, major concerns of the Commission focus on the aesthetic components of the buildings and disregard almost entirely key safety issues, such as earthquake safety. For instance, the Commission has developed guideline procedures for the design and review of historic buildings. These guidelines include elements such as building height, scale, setbacks and *rhythm of spacing*, materials, texture details, roof shape, and orientation of new structures.

The regulations of the Memphis Landmarks Commission could include seismic design criteria, such as pounding, cladding, building setbacks, and the design of open spaces that could serve as emergency shelters or escape routes in case of an emergency. A clear illustration of the present approach of the Memphis Landmarks Commission in terms of earthquake safety is its failure to consider exterior cladding. In spite of the fact that the Commission devotes great efforts at developing design criteria for the exterior appearance of buildings in historical zones, cladding has not been included. When an earthquake occurs, the most vulnerable nonstructural system in a building are the elements used to clad its exterior, e.g., exterior non-structural walls (masonry infill, precast concrete panels), attachments (parapets, cornices, building ornaments, and decorations), and urban fixtures (signs including electrical ones).

The Community Development Division was created under the authority of the Housing and Community Development Act of 1974. Congress replaced the traditional urban renewal concept of clearance with a new program concept concentrating on a neighborhood rehabilitation approach to urban improvement. This Division was responsible for bringing 1,600 dwellings up to building code standards. (Sigafoos, 1979)

The present land-use pattern of Memphis is dominated by residential development. More than 50 percent of the developed area in the city is residential; approximately 36 percent of the urbanized area in the county is in residential use. The present pattern of growth indicates that this urban pace will continue growing. Memphis has become the service-distribution center for the entire Midsouth. Strong demands will continue for the redevelopment of the older parts of the city.

Projections estimate a doubling of the metropolitan population over the next 25 years and will demand an additional 82 square miles for 148,00 new dwelling units. The amount of land required for future residential development is greater than that required for all other uses combined -- more than three fourths of all the additional land to be urbanized by 1990.

In this sense, the construction of adequate housing and the current inventory of obsolete and dilapidated housing is of extreme importance to earthquake safety. Many states throughout the U.S. are currently using Community Development Block Grant (CDBG) programs for rehabilitation and retrofitting (see Chapter 4 and Appendix 1). For instance, Los Angeles and Salt Lake City have extensively used CDBG funds for retrofit activities. Santa Rosa and Santa Cruz used CDBG funds for reconstruction activities after the earthquakes which devastated large portions of the downtown area in both cities In addition 108 Loan and Loan Guarantee Program and the Section 8 program have become invaluable tools provided by HUD-related agencies for earthquake safety.

EARTHQUAKES AND MEMPHIS

The earthquake history of the Central United States is dominated by a series of great earthquakes which occurred during the winter of 1811-1812. These events are characterized by the large number of aftershocks and the extent of their felt area. According to Penick (1981), Jared Brooks[10] counted a total of 1,874 shocks between December 16 and March 15, eight of which can be classified as violent, ten as very severe, three as moderate but alarming, and the rest between generally and barely perceptible. Major earthquakes and some of the aftershocks were felt in areas as far away as New England, Detroit, Quebec, far up the Missouri River and in New Orleans.

The 1811-1812 earthquakes, as well as 90 percent of present-day seismicity in Central United States, are related to the New Madrid fault zone system. These great earthquakes occurred on three different dates. On December 16, 1811 three large earthquakes occurred on the southern branch of the fault in eastern Arkansas, which extends from a point 25 miles northwest of Memphis to Reelfoot Lake in northwestern Tennessee; their epicenter location is believed to be in a region west of present-day Blytheville, Arkansas. The first of these earthquakes had a Richter magnitude of about 8.2 and the two other earthquakes had magnitudes of about 8.1 and 8.3. These three events ruptured the entire southern segments of the New Madrid fault, a length of about 90 miles. (Nuttli, 1990; Stewart and Knox, 1991)

On January 23, 1812, an earthquake of Richter magnitude of 8.1 ruptured the central segment of the New Madrid fault, a length of about 33 miles; the epicenter location is believed to have been north of Little Prairie, Missouri, now Caruthersville. On February 7, 1812 an earthquake of about magnitude 8.3 occurred near the town of New Madrid, Missouri. It ruptured the entire northern branch of the fault, a length of about 60 miles. The New Madrid fault is a complex system of faults extending about 10 miles from Marked Tree, Arkansas, to Metropolis, Illinois, in a band about 50 miles wide. The fault system crosses five state lines encompassing portions of Tennessee, Missouri, Arkansas, Kentucky, and Illinois. (Nuttli, 1990) The New Madrid fault system has been extensively studied. (i.e., Fuller, 1912; Liu eta al, 1979; Proceedings Conference XXXV, 1986; Nuttli 1990) However, the delineation, locations, orientations, and movements of the entire fault is still unknown. Unlike the San Andreas fault which is easily identifiable in the surface rocks, the New Madrid fault is not visible. Furthermore, the events of the fault are known to be episodic; some parts may remain quiet for decades or centuries which makes its identification still more difficult. The documented sections of the fault have been identified through geophysical measurements of gravity and geomagnetism, by seismic reflection prospecting and by mapping the thermal anomalies underlying the area.

The 1811-1812 earthquake series have been usually identified with New Madrid, a town of more than 600 people. The village was devastated, although the epicenter of the first series of shocks was about sixty-five miles to the southwest in northeastern Arkansas. It was reported that the houses of brick, stone and log were

[10] A Louisville engineer and surveyor

torn to pieces, and those of frame thrown upon their sides; and the tallest tress were hardly seen above the water. (Penick, 1981)[11]

Nuttli (1990) summarizes the effects of these earthquakes and indicates that they produced extensive ground deformation throughout the area. He states that sand craters and sand-blows were created in the Mississippi River flood plain from south of Saint Louis to the mouth of the Arkansas River, in the Ohio River Valley from Cairo, Illinois to southwestern Indiana, and in the San Francis River Valley, Arkansas. Liquefaction and landslides affected an area of about 6,000 square miles in southeast Missouri, western Tennessee, and northeastern Arkansas.

Since 1812, only two earthquakes of magnitudes greater than Richter magnitude 6.0 have occurred in the Central United States. The 1843 earthquake occurred in central Arkansas at the extreme southern end of the New Madrid fault, about 25 miles northwest of Memphis. This event had a magnitude of about 6.3 (MMI VI) encompassing a felt area of about 60,000 miles. The effects of this earthquake caused damage to Memphis and southwest Tennessee and affected the extreme northwest corner of Mississippi (Nuttli, 1990).

The second large historic earthquake occurred on 1895. The epicenter of this earthquake was located near Charleston, Missouri, at the northern end of the New Madrid fault. It had a magnitude of Ms 6.7 and caused structural damage in the surrounding area of Missouri and in a narrow band of northern Kentucky and southern Illinois bordering the Ohio River, extending eastward to near Evansville, Indiana. The felt area has been estimated at approximately 125,000 square miles. The collapse of chimneys, and heavy damage to walls and foundations were reported as far away as St. Louis, Missouri.

Twenty other moderately large earthquakes ranging from a magnitude of 5.0 to 6.7 occurred in the Central United States between 1838 and 1990. (Nuttli, 1990)

Research in the field indicates that about eight to ten moderately large earthquakes with magnitudes in the 5.0 to 6.5 range are to occur in the Central Unites States each century. Large earthquakes with magnitudes of about 7 have not occurred in the history of the Central United States except as aftershocks from the great 1811-1812 New Madrid series. The average repeat time suggested for earthquakes of this magnitude is once every 200 to 300 years. The occurrence of great earthquakes with magnitudes of 8.0 to 8.8 approaching those that occurred in 1811-1812 have been estimated at every 600 to 1,000 years. The last occurrence of an earthquake of 6.3 magnitude was in 1895. This size earthquake is largely overdue in the New Madrid fault region since the period of return for such an event has been estimated at between 55 and 85 years. (Nuttli, 1990)

Johnson and Nava (1985) estimated the period of recurrence for destructive earthquakes along the New Madrid fault to be about 40-63 percent probability of occurring in the New Madrid fault within 15 years and about a 90 percent probability of occurring in that fault within 50 years (Nuttli, 1990) Other scientists (Nishenko and Bollinger, 1990) have estimated a longer period for the probability of earthquakes in the area. However both studies suggest that the area will be subjected to earthquakes ranging from moderate to major within the next 50 years.

That no significant earthquake has affected Memphis in over one hundred years has given the city a false sense of security. Studies performed by the Applied Technology Council (1978), Algermissen (1982), and Johnston (1986) states that Memphis, Tennessee is the most vulnerable metropolitan area in the eastern United States.

---

[11] From the New York Evening Post, 1812)

Penick (1981) introduces an additional element of concern. He underlines the fact that Memphis, in addition to being both close to the origin of the disturbance and built on unconsolidated sediment, it is located atop a bluff that has a layer of wet sand right below water level. Furthermore, the USGS had estimated that in many areas of the County (Shelby) the acceleration from seismic waves would be increased by factors of 40-80 percent due to the soil response. In addition to this aggregated problem amplitude-distance curves show that seismic focusing occurs near Memphis and St. Louis. This focused energy apparently increases seismic amplitudes by 1000% over background amplitudes at these sites, which would be roughly equivalent to an increase of at least three Modified Mercalli units. (Johnston and Shedlock, 1992)

The majority of housing in the New Madrid Seismic Zone is of wood frame construction while the majority of schools, commercial, industrial and public buildings are of masonry bearing wall and shear wall construction. Also, most of the residential structures are spread out and located away from the city in areas of lesser intensity as opposed to non-residential structures which are primarily located in more dense arrangements in areas of higher intensity. What this means is the injury and casualty rate due to structural failure will be much higher if an earthquake occurs during daytime hours when the majority of the people are occupying the more vulnerable buildings as opposed to the evening hours when most people are in their homes.

The estimated number of deaths related to structural failure resulting from a magnitude 7.6 earthquake during the night is 203 while the same earthquake during the day would result in an estimated 1,796 deaths related to structural failure. This number is almost doubled in both day and night categories in the event of an magnitude 8.6 event.

A study done in 1985 by FEMA's Central U.S. Preparedness Project estimates the damage to six different cities in the New Madrid Seismic Zone in the event of either a magnitude 7.6 or a magnitude 8.6 earthquake. Memphis is of particular concern because of its large population and because it is a major regional and national center for all transportation modes, for commerce and for health services.

Memphis is the regional medical center for the mid-south region of the United States which covers West Tennessee, East Arkansas, North Mississippi, Southwest Kentucky and Southeast Missouri. Approximately 22 main hospitals are located in Memphis or Shelby County most of which are located in the Medical Center of downtown Memphis. Of the 25 major structures associated with the thirteen major hospitals surveyed, only half are estimated to be available following a magnitude 7.6 earthquake and a third available following a magnitude 8.6. The 5,711 beds associated with these hospitals constitute 86% of all hospital beds in Shelby County. In the event of a Ms 7.6 quake only 52% are estimated to be available; a Ms 8.6 event would leave only 37% of the beds available. Blood storage facilities had a survival rate similar to that of hospitals. Of the 19 facilities surveyed, 54% would survive an Ms 7.6 event and 37% would survive an Ms 8.6 event with all surviving facilities retaining emergency power. Ambulances in the area are generally parked outdoors giving them a probable chance of survival. Many of the buildings that service these vehicles however are at risk. Ambulance service structures contain supplies, communications equipment and personnel which contribute significantly to the providing of ambulance service. Of the 22 structures surveyed, 50% are estimated to survive an Ms 7.6 earthquake and 37% an Ms 8.6 earthquake.

Fire stations typically store all of their vehicles and equipment inside of the structure hence, the loss of structure contributes greatly to the non-availability of needed equipment. Of the 57 structures surveyed in Memphis, 53% would be available following an Ms 7.6 earthquake and 39% would be available after an earthquake of Ms 8.6. Of the 2 surveyed police service structures in Memphis, 1 would be available after an Ms 7.6 and neither would survive an Ms 8.6 earthquake.

Within the city limits, damage to the major highway network would be extensive from the Ms 7.6 scenario event. Half the highway sections would have a survival probability of less than 50 percent. One of the two Mississippi River crossings would probably not be usable, and most of I-240 around the city would be impassable. An Ms 8.6 event would leave very few major highway sections available for use, severely restricting

mobility throughout the city. An Ms 7.6 event would probably interrupt at least half of the eleven major access routes to the city of Memphis and an Ms 8.6 event would likely close all but two or three of the major access routes.

River ports, due to unfavorable soil conditions, would probably not be available for use following the occurrence of either scenario earthquake. Airport runways, in general, have a high survival probability due to the very little pressure they exert onto the ground in their unloaded state. It is to be noted, however, that serious liquefaction and differential settlement of the subgrade can cause misalignment of the surface pavement. Most navigational lighting systems are comparatively simple and resilient and would survive an Ms 8.6 event but would still be susceptible to electrical distribution failure if no back-up power is provided. In larger airports, delicate and complex landing aid instruments and devices requiring careful calibration and adjustment, as well as some lighting, would be at risk and are not estimated to be available in the occurrence of either of the scenario earthquakes.

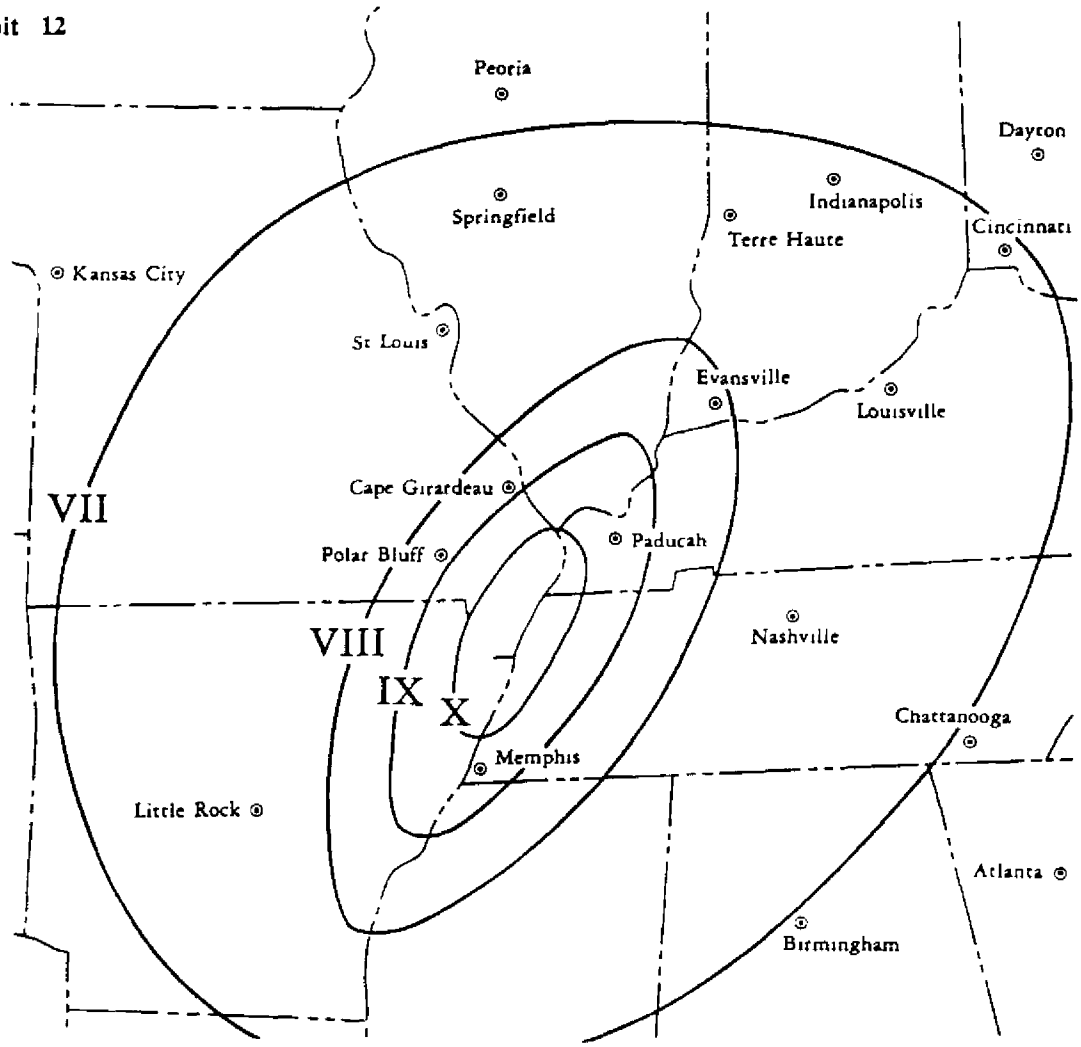
The availability of electric utilities to Memphis after either scenario earthquake is estimated at 0% with both the steam generating plant and eleven substations surveyed being generally unavailable. Substation equipment is usually not designed to withstand seismic forces. Generally it is held in place by gravity and not securely fastened or bolted down. Transformers and other heavy equipment can often withstand several times their own weight in the vertical direction but very little force in horizontal or rotational directions. These circumstances result in high probability of equipment damage from a number of different factors. Outage time for electrical systems would depend on the extent of damage, work crews available, construction equipment, road access to substations, access to a mobile spare or spare transformer, transportation of spare or whether spare needs to be purchased.

The Memphis water system will generally not be operable following either the 7.6 or 8.6 earthquake. Water systems as a whole can become unavailable due to failures at the source, at a water treatment facility, at a storage area or in the distribution system. A major contributor to a shut down in Memphis is the probable loss of electric power. Assuming auxiliary power was available there is a high probability of damage to the underground wells that supply Memphis with all of its raw water. Water utility structures estimated to be available after an Ms 7.6 earthquake are one of nine treatment plants, four of eight elevated storage tanks and eight of nine non-elevated storage tanks. This study acknowledges that in the event of a 7.8 scenario, partial restoration to the system may be established relatively quickly.

Natural gas transmission systems (intra- and interstate pipeline systems)transport natural gas from the Gulf of Mexico to major cities in the Northern and Northeastern United States. Many of these lines run through the New Madrid Seismic Zone and would likely experience failure to some sections in the event of a major earthquake. Isolation and shut-off of damaged sections on individual lines is expected to be easy and quick with lines parallel to the damaged ones maintaining service to the various distribution systems they supply. However the service would be drastically curtailed with the most severely affected areas not being the immediate quake area but the large load centers in the North and Northeast that depend on these pipelines for gas service.

EARTHQUAKE RISKS FOR COMMUNITIES LOCATED ALONG THE NEW MADRID SYSTEM

Exhibit 12



Location of communities in the Central United States relative to isoseismals corresponding to a recurrence of the New Madrid earthquakes. Structural damage would be expected for MM intensities of VIII or greater; architectural damage would be expected for MM intensities of VII.

Source: *Enhancing Seismic Safety in Central U.S.* (in USGS, 1982)

Natural gas lines in Memphis are likely to crack and rupture in the occurrence of an Ms 7.6 earthquake or larger as a result of earth movement as well as falling buildings and debris. Eight percent or so of the pipe lines in Memphis are made of cast iron and due to their brittle nature would be especially at risk of failure. In the event of ruptures, the entire natural gas system would be shut down in order to prevent fire and explosions. Complete restoration of service would require an estimated six weeks time with sections of the community regaining service as the work progressed.

Of the two wastewater treatment plants that service the City of Memphis and surrounding area, neither is expected to be available following either scenario earthquake. This would be due to structural damage to both the treatment plants and the collection system as well as the loss of electricity.

EARTHQUAKE SAFETY

For the central United States, seismic provisions in building codes were almost non-existent until recently. For instance, prior to 1949 for the City of Memphis and 1965 for Shelby County, the building codes in place did not contain sections on seismic design. This situation is also true for almost all the other states affected by the New Madrid fault system. Kentucky was the first of the Central United States to adopt seismic building provisions in 1988. Indiana adopted provisions for the counties closest to the New Madrid Seismic Zone in 1989. Missouri passed legislation to require seismic building codes for the 48 counties which would be most severely affected in the event of a New Madrid earthquake. Arkansas followed with a statewide seismic building code statute in 1991. Due to the fact that these provisions have been only recently implemented there has been no significant impact on the overall level of seismic resistant construction to date. (Center for Earthquake Studies, 1991)

Memphis is currently using the Standard Building Code (SBC) 1988 Edition. Section 1206 Earthquake Loads has received major changes. Previous SBC editions states *"Where seismic design is required by local authorities, all buildings and structures shall be designed to withstand seismic forces in accordance with the requirements of ANSI 58.1 - Building Code Requirements for Minimum Design Loads in Building and Other Structures."* This gave the local authority the option to adopt seismic design requirements. The 1988 Edition was amended to remove *"Where seismic design is required by local authorities,"* stating that *"every building and structure and portions thereof shall be designed and constructed to resists the earthquakes effects determined in accordance with the requirements of this section."*[12]

The earlier edition of SBC referenced ANSI 58.1, whereas the 1988 edition includes seismic provisions in the text itself. Prior to the adoption of this code, there were many years of intensive debate. Many believed that the proposed 1988 SBC would be too restrictive and cause extreme increases in construction cost. Thus, the 1988 SBC version was adopted with local amendments. Amendments have classified Memphis and Shelby County in Zone 2 and utilize several Modified *I* factors, reducing the overall earthquake performance requirements.

---

[12]Information of Memphis Building Codes was widely provided by Terry Hughes, Deputy Administrator/Building Official of Memphis and Shelby County