

CITY OF LONG BEACH GENERAL PLAN

SEISMIC SAFETY ELEMENT

Department of Planning and Building

October, 1988

**REVISIONS TO
CITY OF LONG BEACH
SEISMIC SAFETY ELEMENT**

Prepared for:

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Long Beach, California

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CITY OF LONG BEACH
SEISMIC SAFETY ELEMENT

1.0 INTRODUCTION

Long Beach, and indeed, all of southern California is a seismically active region similar to many other areas in North and South America which border the Pacific Ocean. Because of the magnitude and complexity of this single hazard, a Seismic Safety Element is mandated by the State of California as a part of the City's General Plan. Government Code Section 65302 mandates the creation and adoption of this Element. Furthermore, the California Council on Intergovernmental Relations has promulgated advisory guidelines to be used in developing this and other mandatory plan elements.

To establish a proper perspective, it is imperative to note that historic losses in the United States due to earthquakes has been relatively small as compared to other natural hazards such as hurricanes, tornadoes, floods, and even expansive soils. While the losses have been fewer, the sudden loss potential for earthquakes substantially exceeds that of any other natural hazard. Table 1 illustrates these conclusions in the form of annual loss estimates from natural hazards in the United States. Within the State of California the potential earthquake hazard is more significant as indicated by the projected losses due to geologic hazards to the year 2000 (see Table 2). The State Division of Mines and Geology estimates a total loss of over \$55 billion dollars in earthquake-related damages during the 30-year time period between 1970 and 2000. Seismic studies, such as this Element of the General Plan will hopefully mitigate the existing situation and thus lessen these estimated losses.

TABLE 1
ESTIMATED ANNUAL LOSS FROM
VARIOUS HAZARDS IN UNITED STATES

Natural	Average Annual	Sudden Loss
1. Earthquakes	0.2×10^9 (1)	$\$50.0 \times 10^9$
2. Tsunami		
3. Floods	2.5×10^9	3.5×10^9
4. Hurricanes		
5. Tornadoes	0.5×10^9	2.0×10^9
6. Local Winds		
7. Hail		
8. Lightning	0.5×10^9	1.5×10^9
9. Frost		
10. Snow and Ice Storms		
11. Avalanche	0.1×10^9	0.3×10^9
12. Coastal Erosion		
13. Soil Shrink-Swell Consolidation	6.0×10^9	8.0×10^9
14. Drought	0.3×10^9	1.0×10^9
15. Landslides	0.1×10^9	0.3×10^9
	<u>$\\$10.2 \times 10^9$</u>	

(1) 10^9 = one billion

Source: Wiggins, 1974.

TABLE 2
PROJECTED LOSSES DUE TO
GEOLOGIC PROBLEMS IN CALIFORNIA
1970-2000

Geologic Problem	Project Total Losses 1970-2000, Without Improvement of Existing Policies and Practices
Earthquake Shaking	\$ 21,035,000,000
Loss of Mineral Resources	17,000,000,000
Landsliding	9,850,000,000
Flooding	6,532,000,000
Erosion Activity	565,000,000
Expansive Soils	150,000,000
Fault Displacement	76,000,000
Volcanic Hazards	49,380,000
Tsunami Hazards	40,800,000
Subsidence	<u>26,400,000</u>
Totals	<u>\$ 55,324,580,000</u>

Source: CDMG, 1973

From a seismic safety planning viewpoint, Long Beach is both unique and fortunate. While not significantly unlike the entire Southern California Region in terms of seismic risk, Long Beach does present numerous seismic factors to be identified, evaluated, and appropriately prepared for in an objective manner. For study purposes, it is fortunate that Long Beach is an area of well studied geology. Having been through a major earthquake in 1933, there is a wealth of data in many fields related to geology and seismicity.

Purpose of Study

The purpose of this Seismic Safety Element is to provide a comprehensive analysis of seismic factors so as to reduce loss of life, injuries, damage to property, and social and economic impacts resulting from future earthquakes. To achieve maximum feasible safety from seismic risk, the Seismic Safety Element focuses upon current developmental policies as well as the allocation of future land uses. This Element is a seismic safety planning tool. It is neither a design tool nor a tool to be used for land planning purposes other than those related to earthquakes.

The discussions and recommendations presented in this document should not be interpreted as an intention to prevent the development of any particular area, but rather to provide the background for rational and documented land planning decisions.

In other words, it is hoped that this report will serve as a guide for future development and will encourage development that is responsive to seismic safety considerations.

Report Outline

Goals - To provide a general direction of accomplishment, goals regarding seismic safety were formulated and presented in this chapter.

Methodology - The approach utilized in gathering, analyzing, and applying technical and geotechnical information is discussed in this section. The overall application of seismic consideration to land use allocation and current developmental policy is set forth.

Seismic Safety Planning - The science of seismicity is discussed as it relates to the general planning process. Acceptable and avoidable risks are also discussed.

Long Beach Geological Setting - This section describes Long Beach in terms of its geologic profile. Soil types, ground water levels, significant slopes, and the Newport-Inglewood Fault Zone are discussed.

Seismic Hazard - An evaluation is made of all seismic hazards, including fault rupture, ground shaking, liquefaction and earthquake-induced settlements, slope instability, earthquake-induced flooding, and tsunamis and seiches. Based on detailed study of these data, the City is zoned in terms of seismic response. Each Seismic Response Area in the City is an expression of earthquake sensitivity.

Recommended Guidelines - This section presents guidelines to assist in reducing the level of seismic risk for siting, design, and construction of buildings and essential facilities in the City of Long Beach. The guidelines address the major seismic concerns of potential surface

fault rupture, seismic ground shaking, areas of potential seismicity induced liquefaction, and seismically-induced flooding and large sea waves (tsunamis).

Seismic Response Area-Structure Compatibility - This section categorizes structural types and assesses their compatibility in each of the established Seismic Response Areas. Compatibility is determined on the basis of expected structural damage. Areas and structures of least risk can then be correlated in a matrix format. The structural types can be converted to various land uses so as to utilize the information as a seismic safety planning tool.

Siting and Design Recommendations - It is the intent of this section to provide the building official with information to evaluate the levels of earthquake investigation and design consideration required for various types of structures according to their proposed location within the City. Site-specific seismic analysis may be appropriate for particular types of structures in certain areas of the City.

Data Retrieval - In order to take full advantage of the information in planning and evaluating land uses, and to prevent redundant data gathering, a data retrieval system is recommended for the continuous up-dating of pertinent information.

Disaster Planning and Operations - The City's Fire Department Bureau of Support Services is currently revising our policy for disaster operations. Safety precautions to follow during and after an earthquake, operational procedures, and disaster assistance will be contained within this document.

Recommendations - Major findings are summarized in this section and implementation aspects of the study are identified. Policy guidelines for improved seismic safety are recommended.

Sources of Information

Woodward-Clyde Consultants, a specialized firm of consulting engineers and geologists, was retained to provide the necessary background data and interpretation. The technical and geotechnical information provided by the consultants served as input in the formulation of the Seismic Safety Element itself. The consultants methodology and the staff conversion of technical data to an applicable General Plan Element are discussed in detail in a later section of this document.

As no site investigations or laboratory tests were conducted for this study, the raw data used for this report are chiefly from the following sources:

- a) Soil and geologic reports and boring logs in the files of the City of Long Beach, the Long Beach Harbor Department, Divisions of Highways, and Woodward-Clyde Consultants;
- b) Public papers;
- c) Interviews with representatives of the Building and Safety and Engineering Departments of the City, as well as representatives of the Department of Oil Properties and the Office of Emergency Preparedness, among others;

- d) Woodward-Clyde Consultants experience in the southern California area;
- e) The 1975 Seismic Safety Element Draft Prepared by the Long Beach City Planning Department; and
- f) The 1974 Seismic Safety Study prepared for the City of Long Beach by Woodward-McNeill & Associates.

A more complete and detailed listing of the various sources of information are provided in the References section of this document, see Section 13.0.

Data Viability

Land planning must be a dynamic process or it becomes out-dated and obsolete. The same is true for the background data used to make land-planning decisions. It is therefore, intended that the technical information and resulting recommendations presented in this document be updated as additional data become available. It has been attempted within the body of the report to point out limitations in data and areas where additional study is necessary (Section 4.0 discusses the general state-of-the-art regarding seismicity and more fully identifies areas of limitation).

2.0 GOALS FOR SEISMIC SAFETY

Public policy should ideally reflect the values held by the community at large. The term "value" is very abstract and difficult to define exactly. Generally, values are the basics that govern human behavior. Because of the level of abstraction involved, it is difficult to measure or discuss seismic safety in terms of its consistency or conflict with community values. To discuss community values in terms of seismic safety, these generalizations must be converted into a tangible and understandable level. Values must be stated in terms of specific community goals.

Goals give form to the community values which reside in an urban area in statements of aspiration. Thus, a goal may be defined as a desired state or condition toward which effort is directed. It is an end to be sought although it may not be attainable. Goals should generally be stated in the "positive" and should not be solution oriented. Goals should state the desired end results and not be concerned with the specific actions necessary to achieve them. This practice will avoid biases toward particular actions.

Many of the Departments of the City have established goals for the operation of their particular function. Likewise, other elements of the General Plan have set forth goals toward which the City should strive. In many instances, the seismic safety goals are interrelated with other community aspirations. The interrelationship may be complementary or conflicting. The attainment of a particular seismic safety goal may produce a beneficial by-product, resulting in the achievement of other related community goals. Contrarily, movement toward the attainment of a seismic safety goal may be in conflict with other desired aspirations. When such is the case, compromises and trade-offs are essential. This

does not imply that some of the goals are invalid. Nor should it lessen the ambitiousness in striving to attain all of the established community goals. It simply means that each goal cannot be fully achieved and that in some instances less than "ideal" circumstances will prevail. Just as community values were put to work in establishing the various goals, so must these abstract values come into play in determining the degree and direction of compromise. It is essential that seismic safety considerations and goals be viewed as single purpose objectives and that absolute earthquake safety (absolute achievement of the stated goals) is often not possible due to other constraints or community desires.

To be effective and operational, goals must be dynamic and flexible. The importance and timely significance of various goals must be continually reviewed if they are to remain of value to the community. Goals must be altered, updated, deleted, or added in response to changing circumstances within the City. Thus, the following list of seismic safety related goals is not necessarily exhaustive or immutable.

Management Goals

1. Develop implementable mechanisms for a more stringent review of the earthquake potential associated with various projects.
2. Coordinate and cooperate with other political jurisdictions in implementing seismic safety programs.
3. Establish seismic safety guidelines to evaluate all potential hazards and mitigate existing problems.

Development Goals

1. Utilize seismic safety considerations as a means of encouraging and enhancing desired land use patterns.
2. Provide an urban environment which is as safe as possible from seismic risk.
3. Use physical planning as a means of achieving greater degrees of protection from seismic safety hazards.
4. Encourage development that would be most in harmony with nature and thus less vulnerable to earthquake damage.
5. Strive to encourage urbanization patterns which preserve and/or create greater earthquake safety for residents and visitors.

Protection Goals

1. Reduce public exposure to seismic risks.
2. Reduce the potential adverse economic, environmental, and social conditions which could result from a major earthquake.
3. Assure continued economic stability and growth by minimizing potential seismic hazards.

4. Inform the public of existing or potential seismic hazards and what to do in times of earthquake events.

5. Provide the maximum feasible level of seismic safety protection services.

Remedial Action Goals

1. Eliminate or reconstruct uses and structures which pose seismic risks.

It is important to note that the above listed goals serve to direct actions and represent desired end-results. There are various specific methods and strategies which may be employed in implementing or achieving the established seismic safety goals. The recommendations section of this report will set forth some of these specific actions.

3.0 METHODOLOGY

Upon commencing the research activities, the consultant and the City defined the scope and objectives of the Seismic Safety Element. Input was obtained from various City Departments as a part of this effort. The consultant then collected the necessary background information. Much of these raw data were available from various departments of the City and the 1975 Seismic Safety Element Draft. The geotechnical data then served as the basis for zoning the entire City into earthquake response zones. Each of these zones are unique in terms of their geologic profile, soil description, and seismic hazard potential. Once the parameters are established, this process becomes quite objective and can easily be substantiated by fact.

In an effort to apply these seismic considerations to the land planning process, structural types were established, with inputs from the Building and Safety Department. The various structural types were then assessed as to their compatibility in each of the Seismic Response Zones. Compatibility was determined on the basis of expected structural damage during a seismic event of defined magnitude. The compatibility rating was a rather subjective process, reflecting the judgements of the consultant and the structural engineers retained to accomplish the task. While other knowledgeable experts in the fields of seismicity and engineering may differ somewhat as to their estimates of potential damage, the overall results can be considered indicative.

Based upon the seismic response area/structural compatibility, siting and design policies were established. Improved building design and construction can increase the structure/land use compatibility. No seismic response area

is categorically considered as unsuitable for development. The proposed policies, which would affect current building activities, address themselves to the levels of earthquake investigation and design consideration required to construct a particular structure in a particular zone. Site-specific seismic analysis would be required prior to construction of some structural types in certain areas of the City. The site-specific seismic analysis would allow building officials and environmental planners to determine the appropriateness of any proposed structure in terms of its location in the City. In other words, a proposed structure must be designed to withstand the potential earthquake hazards expected to occur in the Seismic Response Zone in which the structure will be located.

Limitations

It is important to note that the process of seismic response zoning for the City of Long Beach is a relative matter. The zones were established on the basis of geotechnical data and then compared to one another as to their suitability for various types of building construction. The suitability of any particular structure in any given area was evaluated only by comparison to other areas within the City. No attempt was made to compare Long Beach with other municipalities or jurisdictions. The objective of the Seismic Safety Element is to serve as a guide for land development and land planning within the City, not to make a comparative analysis of Long Beach with any other area of southern California. Therefore, any construction requirements recommended in this document and subsequently implemented into City policy reflect the City's concern for the safety of residents and visitors as well as the protection from property damage rather than indicating absolute severity in terms of earthquake hazards.

Inter-Departmental Coordination

Aside from the cooperative effort in providing the necessary background data, various City departments were involved throughout the study at various stages of completion. Two draft reports were distributed to City departments prior to the completion of the final 1974 technical report from the consultant. These draft reports were critiqued and discussed in a series of interdepartmental meetings. The same procedures were followed during the revision of Section 5.0 through 8.0 by Woodward-Clyde Consultants in 1988. While the consultant provided expertise in the matter of seismic safety planning, this Element reflects inputs and concerns from a variety of sources and disciplines.

Element Formulation

The technical and geotechnical information was compiled and presented in a systematic fashion by the consulting firm. Once the consultant's report was received by the City, however, it was necessary to convert this information into a usable Seismic Safety Element. It is important to note that the consultant's basic input of technical advise was not altered. The technical report was reconstructed and augmented so as to be in compliance with General Plan Guidelines.

A basic consideration in converting the technical report into a Seismic Safety Element was establishing seismic goals for the community and recommending an implementation program that would lend itself to current building permit operations and to the allocation of future land uses.

4.0 SEISMIC SAFETY PLANNING

It is important to note that the inclusion of seismic considerations in a General Planning process is a relatively new concept. The inclusion of Seismic Safety Elements in the General Plan program necessitates a multidisciplinary effort. To be effective, it is essential that geologists, structural engineers, building officials, and city planners develop a commonality of understanding and esoteric jargon. As seismicity, itself, is in a stage of expanding knowledge, the seismic safety planning process is extremely dynamic and mutable at this point in time.

As seismic safety planning is not a fixed process, numerous approaches have been taken by various jurisdictions in completing their seismic safety studies. Plans and programs from other jurisdictions run the gamut from the general to the specific. Recommended actions have covered the span from Federal legislation to specific building materials to be used in construction at particular sites.

The approach taken in accomplishing this element was one of performing a systematic review of all seismic hazards and identifying areas where particular caution should be exercised in further urban development. For land use planning purposes, the study sets forth response area/structure compatibilities. For more operational purposes in reviewing day-to-day building permit applications, the report is intended to serve as a guide in terms of identifying where more specific soil analysis or seismic study is warranted. While the approach is systematic and thorough, the report does not address itself to every aspect of earthquake safety. Related matters which are not specifically studied in this document include:

- o Modifications to the existing municipal code relative to earthquake resistive requirements
- o Development of a fixture and contents anchorage code
- o Development of a planning and policing procedure of inside space use so that sliding and rolling furniture and fixtures will not be hazardous
- o Implementation strategy for enforcement of Chapter 18.68, Earthquake Hazard Regulations (Subdivision 80)
- o Post earthquake instrumentation to monitor future earthquakes
- o Specific earthquake damage estimates

While these matters were not studied in detail as a part of this Seismic Safety Element, their importance to the City is acknowledged, and thus recommendations regarding these matters have been included where appropriate.

Acceptable Risk

In the General Plan guidelines set forth by the California Council on Intergovernmental Relations it is suggested that the Seismic Safety Element specify the level or nature of acceptable, unacceptable, and avoidable risks. These terms are defined below.

Acceptable risk: Level of risk above which specific action by local government is deemed necessary, other than making the risk known.

Unacceptable risk: Level of risk above which specific action by government is deemed necessary to protect life and property.

Avoidable risk: Risk is not necessary to take because the individual or public goals can be achieved at the same or less total "cost" by other means without taking the risk.

"The Governor's Earthquake Council has given public agencies the following charge: The basic objective is to reduce the loss of life, damage to property, and economic and social dislocations resulting from future earthquakes. This means that there are three risks to consider: the risk to human life and limb, the risk to property, and the risk of societal disruption" (Tri-Cities Seismic Safety and Environmental Resources Study, p. 8). For philosophical purposes, it would appear that these three basic types of risks could be prioritized in the order in which they are presented. Such a priority rating however, is of questionable value in that from a practical viewpoint the three categories of risk are very much interrelated. While human life could be of greater concern than property damage, the two are not likely to occur independently.

Furthermore, it would be impossible to ascertain specific levels of risk without a thorough inventory of the structural condition and occupancy rate of every building in the City. With inputs as to the costs of replacement or renovation where necessary, it is possible to construct

probability models that could quantitatively measure risk. Such mathematical models, however, could not include the price of life and would therefore in actuality serve little purpose.

A pragmatic approach to the matter of acceptable risk is to review each new construction project on the basis of its own merit, based upon the information provided in this document and the specific geologic and structural information provided by the developer. For existing problem areas, such as Pre-1933 buildings, acceptable risk should be reflected in the strategy of implementing Chapter 18.68, Earthquake Hazards Regulations (Subdivision 80). This would allow the City to determine risk acceptability on a structure-by-structure basis, which would be, by necessity, tied to economic feasibility. Realistically, acceptable risk must be determined at this micro-level if it is to be meaningful and operational.

5.0 LONG BEACH GEOLOGICAL SETTING

Long Beach is located on a broad, slightly elevated coastal terrace flanked by two flood plains on the east and west. Faults associated with the Newport-Inglewood Fault Zone cut diagonally across these features. In general, Long Beach is of low relief with a lack of significant slopes. The greatest relief is in the Signal Hill, Reservoir Hill, and Bixby Knolls areas, reflecting ancient activity along the Newport-Inglewood Fault Zone. Other areas of moderate relief include sea bluffs along the coast and lesser bluffs along the flood plains.

With the exception of isolated hilly areas, the ground surface elevation is generally less than 60 feet. The ground water level is typically less than 60 feet below the ground surface, and less than 20 feet below the ground surface in many areas.

The City is located on the coastal margin of the Los Angeles Basin, which is underlain by over 15,000 feet of stratified sedimentary rocks of marine origin. Since deposition of these units in the Long Beach area, regional up lift along with local folding and faulting has raised the central portion of the study area to its present elevation.

The low areas now occupied by the Los Angeles and San Gabriel rivers represent channels that were cut deeply into the marine sediments by ancestral rivers during the lower sea level stand of the last Ice Age in late Pleistocene time. Over the last 17,000 years, the rivers have filled these channels to their present levels with relatively unconsolidated sand, silt, and gravel.

The physiographic features within the City of Long Beach reflect these subsurface geologic conditions and can be separated into the following six distinct areas:

1. The row of low hills extending from Bixby Knolls southeasterly to Seal Beach, including Signal and Reservoir Hills, and known as the Newport-Inglewood Fault Zone;
2. The broad, slightly elevated coastal terrace lying south of this row of hills;
3. The Los Angeles River flood plain, which lies along the western side of the City, extending from north Long Beach, through the gap in the hills (Dominguez Gap) to the long Beach Harbor area;
4. The San Gabriel River flood plain and channel, which lies along the southeasterly portion of the City, cutting through the low hills to form the Alamitos Gap, just inland from Alamitos Bay;
5. The raised terrace lying to the north of Bixby Knolls and Signal Hill that grades northerly into the alluvial plain of the Los Angeles Basin; and
6. The coastal area including the sea bluffs, beach, and harbor areas.

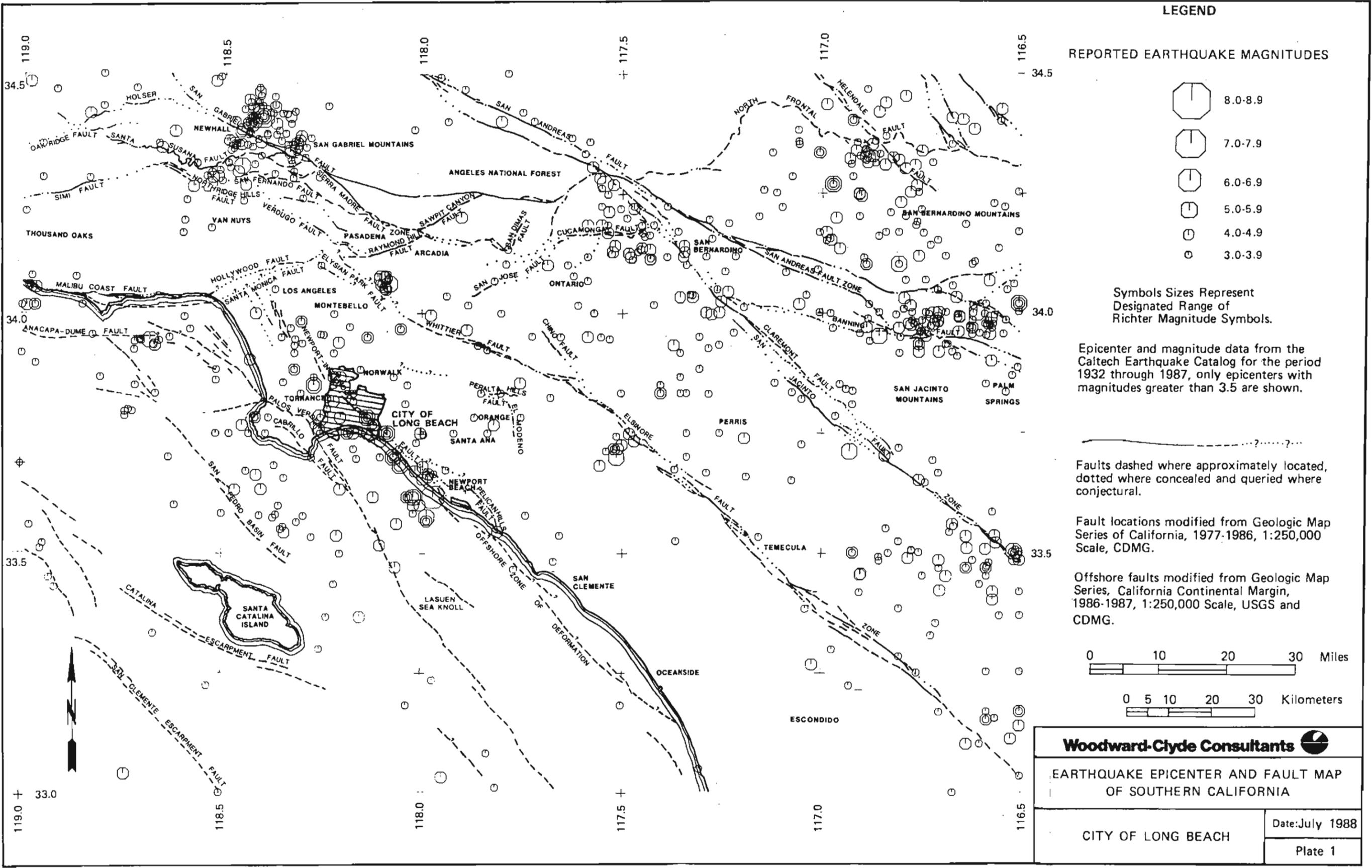
The low lying coastal areas, especially along the seaward portions of the ancestral Los Angeles and San Gabriel Rivers, have been highly modified by dredging and landfill operations associated with construction of recreational and

harbor facilities. These areas are of particular concern as a seismic hazard because of the large landfill areas, the unconsolidated underlying sediments, and the shallow ground water conditions.

The folding and faulting that has uplifted and deformed the sediments within the City of Long Beach has been mainly concentrated along a nearly continuous row of hills referred to as the Newport-Inglewood Fault Zone. The structural features and their relationship to possible seismic hazards in the City of Long Beach are discussed in the following section.

Important fault features fall into two general categories. First, those faults whose traces pass within the boundaries of the City of Long Beach for which ground rupture as well as seismic shaking must be considered as potential hazards. Second, those faults that do not transect the City, but are sources for nearby earthquakes for which ground shaking potential must be considered. A discussion of the surface fault rupture hazard is provided in Section 6.2 and in Appendix A, and a general discussion of earthquakes and faults is contained in Appendix B.

Plate 1 shows the major faults in the greater Los Angeles area, along with the historic seismicity of the area. The most significant active faults within the City lie along the Newport-Inglewood Fault Zone. This fault system is considered active and rupture along one of these faults produced the 1933 Long Beach Earthquake. Rupture on another segment of this zone caused the 1920 Inglewood Earthquake. The Palos Verdes Fault is another significant fault near the City. It transverses along the northern edge of the Palos Verdes Hills and trends offshore through Los Angeles Harbor to lie just offshore of the City of Long Beach. This fault



LEGEND

REPORTED EARTHQUAKE MAGNITUDES

-  8.0-8.9
-  7.0-7.9
-  6.0-6.9
-  5.0-5.9
-  4.0-4.9
-  3.0-3.9

Symbols Sizes Represent Designated Range of Richter Magnitude Symbols.

Epicenter and magnitude data from the Caltech Earthquake Catalog for the period 1932 through 1987, only epicenters with magnitudes greater than 3.5 are shown.

Faults dashed where approximately located, dotted where concealed and queried where conjectural.

Fault locations modified from Geologic Map Series of California, 1977-1986, 1:250,000 Scale, CDMG.

Offshore faults modified from Geologic Map Series, California Continental Margin, 1986-1987, 1:250,000 Scale, USGS and CDMG.

0 10 20 30 Miles

0 5 10 20 30 Kilometers

Woodward-Clyde Consultants 

EARTHQUAKE EPICENTER AND FAULT MAP OF SOUTHERN CALIFORNIA

CITY OF LONG BEACH

Date: July 1988

Plate 1

is also believed to be active and could produce severe seismic shaking within the City. These two faults are described briefly in Section 5.1. The other regional faults in southern California that could cause potentially damaging seismic shaking in the City are discussed in more detail in Appendix C, and their pertinent seismic parameters are summarized in Table 3.

5.1 Local Faults

Newport-Inglewood Fault Zone

The Newport-Inglewood Fault Zone is a right-lateral wrench fault system consisting of a series of en echelon fault segments and folds. This zone is visible on the surface as a series of northwest trending elongated hills extending from Newport Beach to Beverly Hills, including Signal and Dominquez Hills. Topographic highs along the zone are surface expressions of individual faulted anticlinal structures, and these faults and folds act as ground water barriers and, at greater depths, form petroleum traps.

Detailed studies along the fault zone show it to exhibit right lateral displacement of up to 6,000 feet since mid-Pliocene time, with a maximum displacement of up to 10,000 feet since late Miocene time (Woodward-Clyde Consultants, 1979). Vertical displacement has also occurred along the zone and appears to be primarily due to the associated folding. The average long term horizontal slip rates appear to have been a relatively consistent 0.5 mm/yr. An estimated maximum earthquake of 7 has been assigned to the zone on the basis of its estimated rupture length and its slip rate (Woodward-Clyde Consultants, 1979).

Active or potentially active faults of the Newport-Inglewood Fault Zone within the boundaries of Long Beach include the

TABLE 3

CHARACTERISTICS AND ESTIMATED MAXIMUM EARTHQUAKES FOR FAULTS CONSIDERED FOR CITY OF LONG BEACH SSE

Fault Name	Fault Classification	Approximate Distance to City Miles (km)	Approximate Fault Length Miles (km)	Estimated Slip Rate mm/yr.	Maximum Historic Earthquake Magnitude	Estimated Maximum Earthquake
Newport-Inglewood Fault Zone	Right Lateral	0-3 (0-5)	44 (70)	0.5(e)	6.3 (1933)	7(b,c)
Palos Verdes	Right Lateral-Reverse	4.5 (7)	50 (80)	0.8(g)	3.9 (1972)	7(b)
<u>Santa Monica-Malibu Coast Fault Zone</u>						
Santa Monica	Reverse Left Lateral	23 (38)	35 (56)	0.4(d)	5.2(1930)(m)	7(h)
Hollywood	Reverse Left Lateral	24 (39)	11 (18)	0.4(d)	--	7(h)
Malibu Coast	Reverse Left Lateral	26 (42)	34 (54)	0.1(d)	--	7(h)
Anacapa-Dume	Reverse Left Lateral	28 (45)	50 (80)	0.4(d)	5.0(1979)(m)	7(h)
Raymond	Reverse Left Lateral	24 (39)	14 (22)	0.2(c,d)	--	6-3/4(b)
Verdugo	Reverse Right Lateral	25 (40)	19 (30)	0.1(f)	--	6-3/4(b)
<u>Sierra Madre Fault System</u>						
Sierra Madre Segment	Reverse Left Lateral	28 (46)	11 (18)	2(d)	--	7(b,c)
Duarte Segment	Reverse Left Lateral	29 (47)	10 (16)	3(c,d)	--	7(b,c)
Dunsmore Segment	Reverse Left Lateral	31 (50)	9 (15)	3(c,d)	--	7(b,c)
San Andreas (South Central)	Right Lateral	50 (80)	196 (314)	36(i)	7.9 (1857)(i)	8-1/2(a,b)
San Jacinto	Right Lateral	50 (80)	160 (256)	8(d)	7.0 (1899)	7-1/2(a,b)
Elsinore	Right Lateral	27 (43)	137 (219)	4(j)	--	7-1/4(b)
Whittier	Right Lateral-Reverse	19 (30)	28 (45)	1.2(e)	4.2 (1976)	7(b)
Elysian Park-Montebello Zone of Deformation	Reverse	19 (30)	13 (20)	0.4(l)	6.0 (1987)	6-1/2(a)
Catalina Escarpment	Right Lateral	37 (60)	60 (96)	0.8(g)	--	7(g)
San Pedro Basin	Right Lateral	20 (32)	28 (45)	0.5(g)	--	7(g)
San Clemente Escarpment	Right Lateral	48 (77)	150 (240)	0.8(g)	5.9 (1951)	7(g)

NOTES:

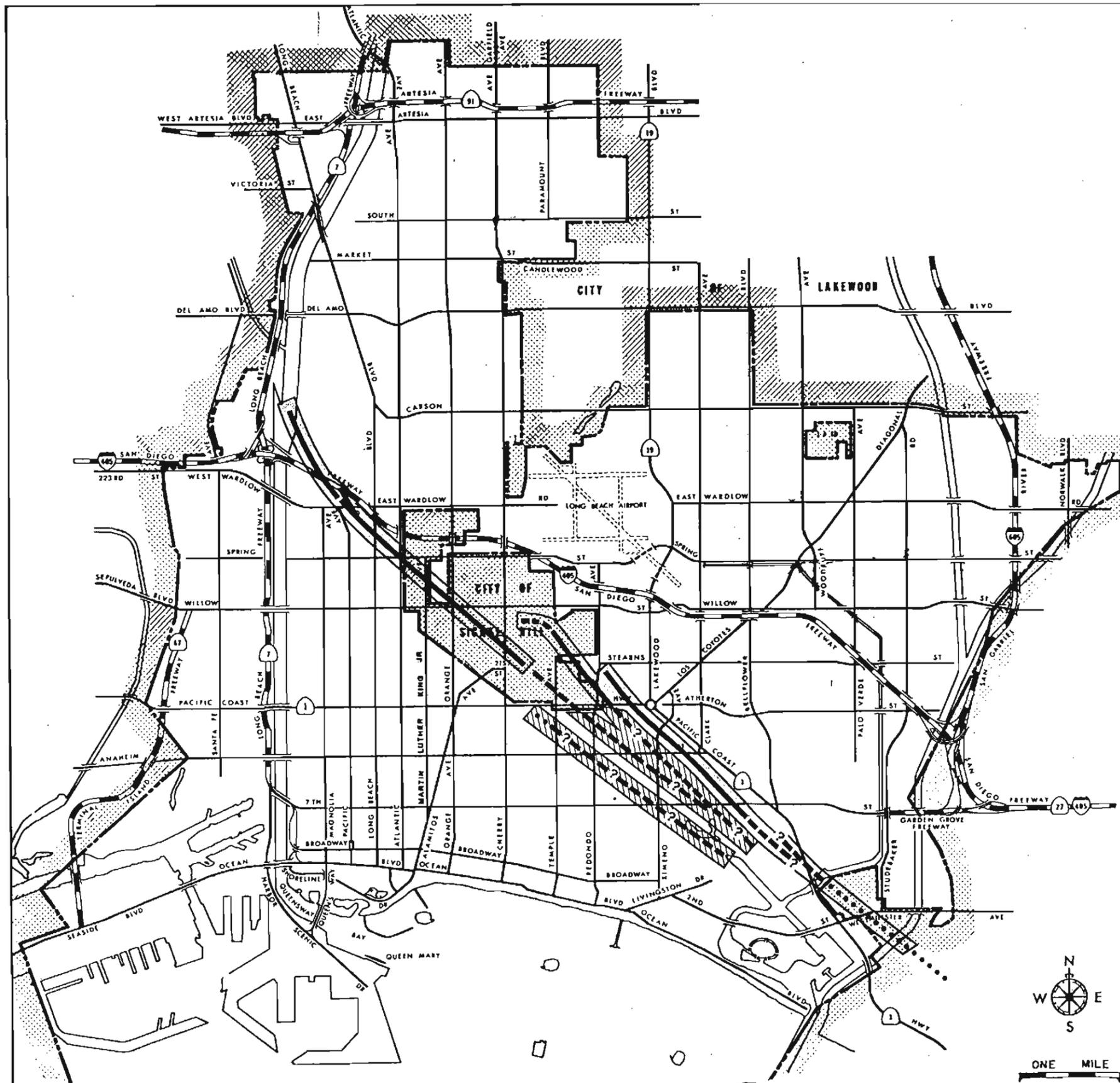
- (a) Based on historical events.
(b) Based on estimated rupture length and Slemmons (1977 and 1982).
(c) Based on Crook et al (1978); and Matti et al (1982).
(d) Based on Clark et al (1984).
(e) Woodward-Clyde Consultants (1979).
(f) Unknown, assumed to be approximately 0.1 mm/year.
(g) Based on comparisons with the Newport-Inglewood Fault Zone.
(h) Based on comparisons with segments of the Sierra Madre Fault System.
(i) Sieh (1984).
(j) Wesnousky (1986).
(k) Ziony and Yerkes (1985).
(l) Based on comparisons with Raymond and Whittier faults.
(m) Hauksson and Saldivar (1986)

Cherry Hill Fault, the Northeast Flank Fault, and the Reservoir Hill Fault. A possible fault may exist in the area of the marine stadium. A topographic scarp suggestive of faulting exists along the western end of the marine stadium, roughly paralleling the old Pacific Electric right-of-way, see Plate 2.

Subsurface movement on the Newport-Inglewood Zone produced the 1933 Long Beach (magnitude 6.3) Earthquake that caused severe damage in the City of Long Beach; and the 1920 Inglewood Earthquake (estimated magnitude 4.9), that resulted in notable damage in the City of Inglewood (Taber, 1920). Ground breakage has not been observed along the faults of the Newport-Inglewood Zone in historic times within the City of Long Beach. However, the existence of the well defined fault scarps is suggestive of ground breakage in recent geologic time (last 10,000 years; Barrows, 1973).

Since enactment of the Alquist-Priolo Studies Zones Act in 1972, about 70 geologic reports have been prepared covering properties within the zones in the City of Long Beach (Clarke, 1987). The purpose of these reports was to investigate for possible faults on the property and if found, determine whether or not the fault represented a potential surface rupture hazard to the proposed buildings. Several branches of the Newport-Inglewood Fault Zone have been examined by subsurface trenching and have showed evidence of recent (Holocene) displacement (Clarke, 1987). Other fault traces that have been investigated were reported by various authors to not cut sediments of Holocene age or older. The City of Long Beach has an active program of reviewing the Special Studies Zones geologic reports. The

FAULT MAP WITH SPECIAL STUDY ZONES



LEGEND

- Newport - Inglewood Zone of Deformation Faults
- Dashed where Inferred
- Dotted where Concealed
- Querried where uncertain
- Alquist - Priolo Special Study Zones
- Caution Zones for Essential and Hazardous Facilities

Sources: 1) Base Map - Bureau of Engineering - City of Long Beach
 2) State of California - Special Studies Zone Maps, 1986

Alquist-Priolo Special Studies Zones are shown on Plate 2 and are discussed in Section 6.2 (Surface Fault rupture) and a complete text of the Act is given in Appendix A.

Palos Verdes Fault Zone

The Palos Verdes Fault lies immediately offshore of the City of Long Beach and is one of several major northwest trending faults in southern California that are tectonically associated with the northwest trending San Andreas Fault System. As shown in Plate 1, most of the mapped length of the Palos Verdes Fault is offshore of southern California extending northwestward from Lasuen Knoll into San Pedro Bay, through Los Angeles Harbor, across the northern front of the Palos Verdes Hills, and into Santa Monica Bay. In Santa Monica Bay, the fault appears to bend to the west down Redondo Canyon.

The onshore segment of the Palos Verdes Fault has apparently uplifted Palos Verdes Hills over 1,350 feet (410 m) since the middle Pleistocene. Extensive deformation and folding of late Pleistocene and Holocene age sediments onshore, along the northern edge of the Palos Verdes Hills, would also indicate that compression across the Palos Verdes Fault has been active in the Holocene (Freeman et al, 1987).

Several marine geophysical surveys have been run in Los Angeles Harbor and offshore of Long Beach. These surveys have found evidence of warping in Holocene sediments near San Pedro and evidence of faulting of the sea floor southward along the Palos Verdes Fault trace.

The Palos Verdes Fault is in the same tectonic environment and is nearly parallel in orientation to other active faults, such as the Newport-Inglewood, Elsinore, and San

Andreas fault zones. An estimated maximum earthquake of 7 has been assigned to this fault based on comparisons with the Newport-Inglewood Fault Zone. Other fault and earthquake parameters estimated for the Palos Verdes Fault are presented in Table 3.

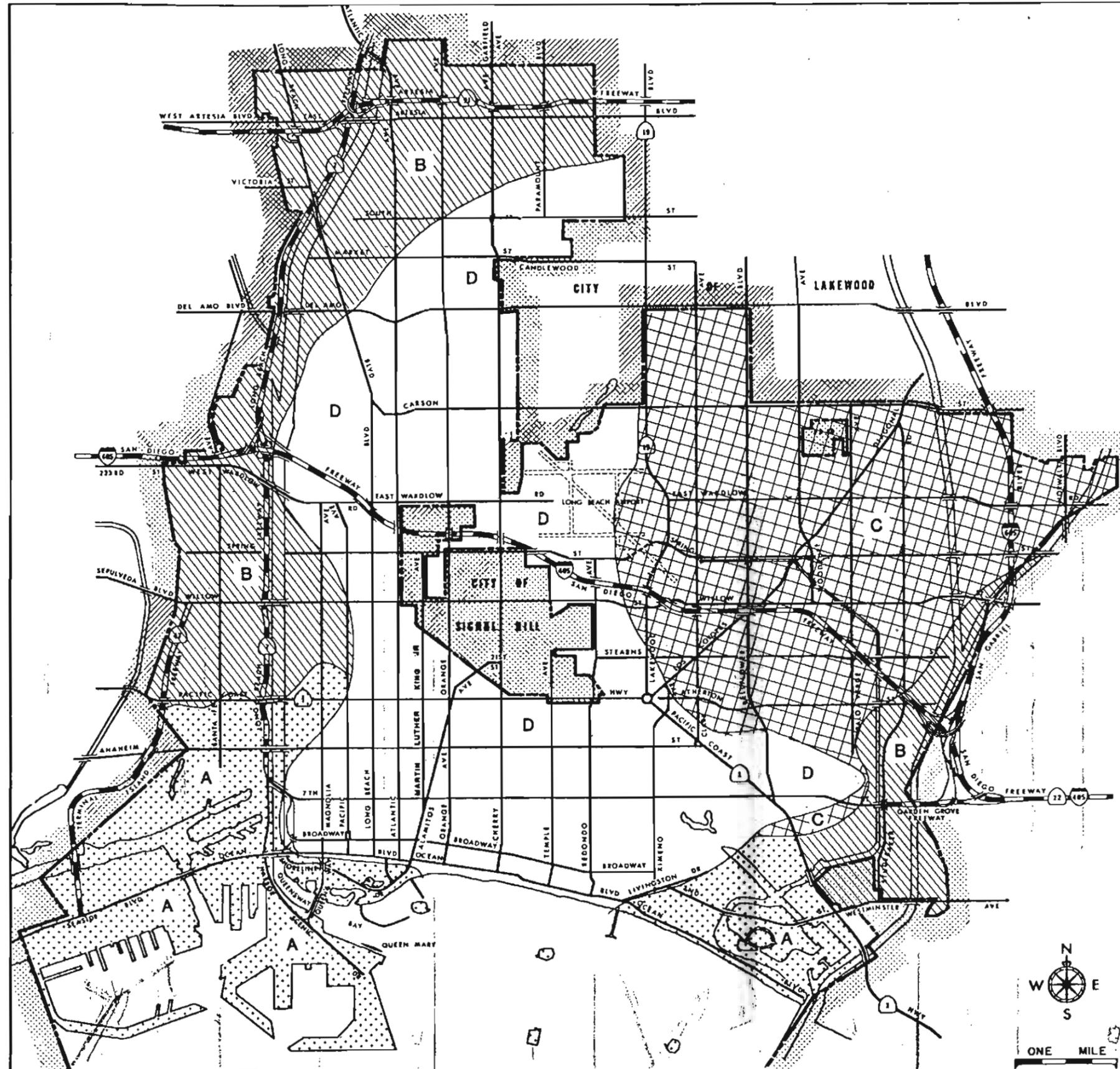
5.2 Characteristics of Lithologic Units and Soils

For the purpose of seismic zoning, the City of Long Beach has been subdivided into four predominant soil profiles. These profiles are shown on Plate 3 with letter designations A through D. The profiles are briefly discussed as follows:

Profile A is predominantly man-made fill in the Harbor and Naples areas. These fill areas consist of dredged and hydraulic fills, assorted man-made fills, and may contain soils of questionable origin, especially in the ancient marsh areas. They are generally composed of fine sand and silt. This profile also includes the four man-made drilling islands. The hydraulic fill areas for the harbor area and the offshore drilling islands are characterized in Appendix F.

Profile B covers the majority of the low areas now occupied by the Los Angeles and San Gabriel rivers, other than the harbor areas covered by Profile A. These lowlying areas represent channels that were cut deeply into the uplifted marine sediments by ancestral rivers during the lower sea level stand of the last Ice Age in late Pleistocene time. Over the last 17,000 years, the rivers have filled these channels to their present level with relatively unconsolidated sediments.

The ancestral Los Angeles River Channel, which cuts through Dominguez Gap, contains a maximum of 180 feet of these



SOIL PROFILES

LEGEND

- 

A Predominantly man-made fill areas consisting of hydraulic-fills, assorted man-made fills, and soils of questionable origin, generally composed of fine sand and silt, includes drilling islands.
- 

B Sandy and clayey alluvial materials composed of interlayered lenses of cohesionless and cohesive material overlying the shallow Gaspar or Recent aquifers, includes some local filled areas.
- 

C Sandy and clayey alluvial material overlying Pleistocene granular marine sediments at shallow depths.
- 

D Predominantly granular non-marine terrace deposits overlying Pleistocene granular marine sediments at shallow depths includes adjacent beach area.

Source: Base Map - Bureau of Engineering - City of Long Beach

recent materials in the harbor area with shallower thicknesses averaging around 100 feet, further inland towards Compton (Zielbauer and others, 1962). The Channel filling sediments are composed of a basal sand and gravel aquifer (Gaspur Aquifer) overlain by less permeable flood plain and tidal marsh deposits of fine-grained soils. These near surface soils (upper 50 feet) are characterized as consisting of alternating layers of cohesionless and cohesive soils. The cohesionless soils consist generally of silty sand and sandy silt and are typically loose to medium dense. The cohesive soil layers are generally clayey silts and silty clays of soft to stiff consistency.

The ancestral San Gabriel River Channel, which cuts through Alamitos Gap, is shallower, containing from 40 to 80 feet of recent sediments. These units also thin in a landward direction from their maximum thickness at Alamitos Bay. The sediments in this gap area also consist of a basal sand and gravel aquifer (Recent Aquifer) overlain by fine-grained deltaic and tidal marsh deposits, (Lundeen and Roth, 1976). These upper units can also be characterized as consisting of alternating layers of cohesionless and cohesive soils. The cohesionless soils consist generally of silty sand and sandy silt, which are typically loose to medium dense. The cohesive soil layers are generally clayey silts and silty clays of soft to stiff consistency.

Profile C covers the northeastern portion of the City where the underlying Miocene and Pleistocene units are covered by a thin layer of sandy and clayey alluvial materials, see Plate 3. The units in this area are highly variable ranging from cohesionless sand and silty sand to cohesive clayey silt. The deeper units are similar to those of the central elevated terrace deposits described in Profile D.

Profile D covers the centrally located terrace that is underlain by over 15,000 feet of stratified sedimentary rocks of marine origin. This deep marine section is composed of interbedded units of sandstone, siltstone, and shale ranging in age from Miocene to late Pleistocene. The near surface soils on the terrace consist predominantly of cohesionless soils such as sand, silty sand, and sandy silt that are generally medium to very dense. Cohesive soils such as clayey silt and silty clay, although less dominant are also present as layers in these surficial deposits. The consistency of these units is described as ranging from stiff to hard.

Underlying these surficial deposits are several water bearing aquifers of upper Pleistocene age, which carry the names from top down: Artesia, Gage, Lynwood, Silverado, and Sunnyside.

5.3 Ground Water Conditions

The depth to ground water is an important factor in consideration of certain seismic hazard evaluations, especially when evaluating the potential for seismically induced liquefaction. This phenomenon is discussed in Section 6.4. Briefly, it is a condition where saturated, cohesionless soils lose their grain to grain contact and tend to act like a fluid for short periods of time during an earthquake. Thus, areas with shallow ground water conditions need to be identified for a seismic analysis.

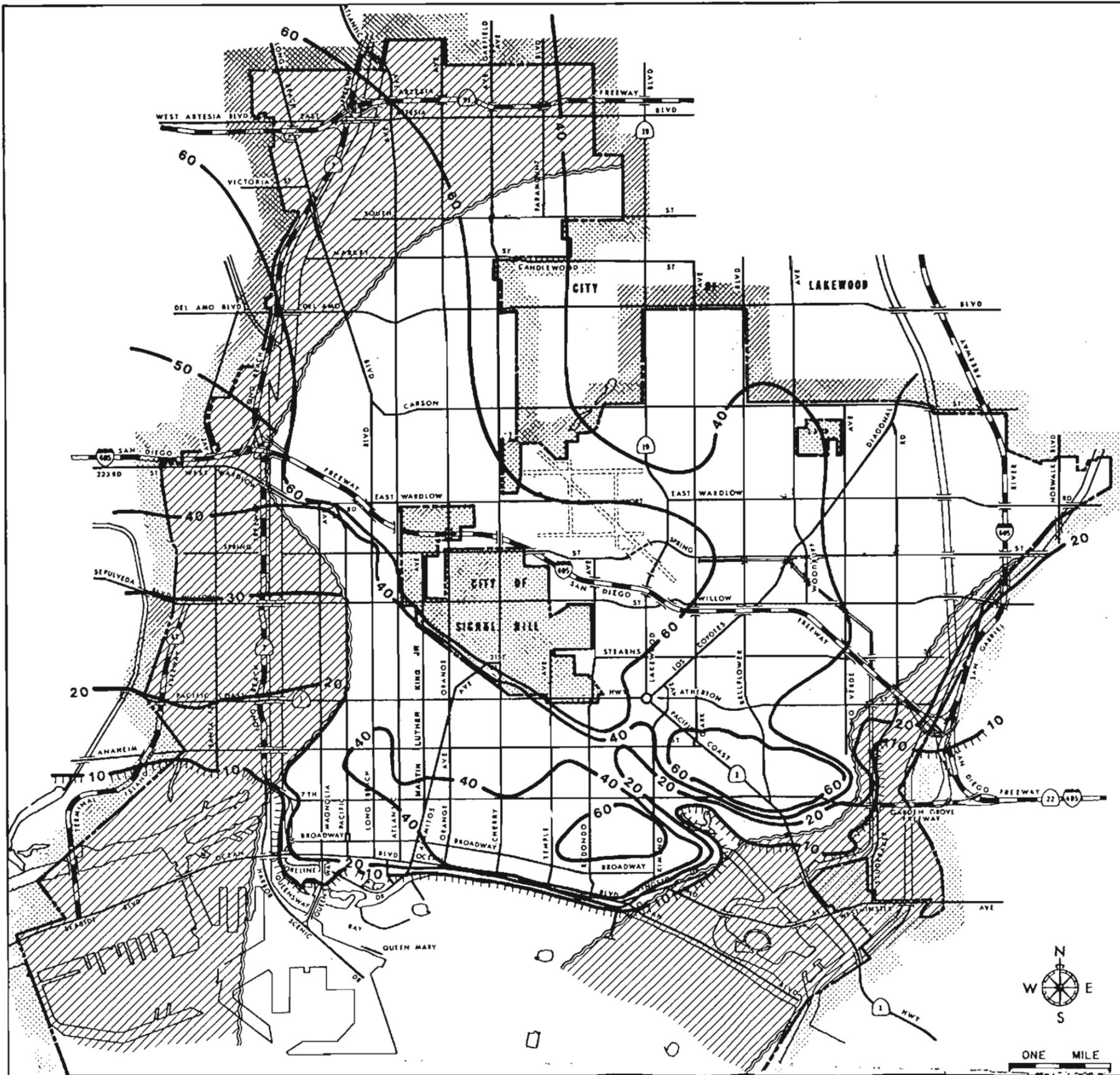
The depth to the shallowest saturated water level was estimated primarily from water well data monitored by Los Angeles County and boring logs from soil reports available through the City of Long Beach, Departments of Engineering and Building and Safety. A generalized depth to ground

water map was prepared by taking geologic influence into account where appropriate and where documented control was sparse or absent. This map shows the approximate depth to ground water in the City, and is presented as Plate 4. Because the shallow ground water data came from many sources, which covered a time span of several years, the data should be considered as only approximate, but generally representative of the conditions as of the fall of 1986.

Four hydrologic regions are recognized within the Long Beach area. Two of the areas are the low-lying ancestral Los Angeles River Channel and its present flood plain including Long Beach Harbor, and the low-lying ancestral San Gabriel River Channel and its present flood plain including the Marine Stadium and Alamitos Bay. Each of these areas contains a basal sand and gravel aquifer that is overlain by less permeable, finer-grained soils. Between the flood plain areas, the elevated Long Beach terrace is subdivided into a Coastal region and an Inland region by the Newport-Inglewood Fault Zone. Faulting along the zone has created ground water barriers in the underlying aquifers.

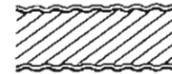
In the harbor area, ground water is generally less than 5 feet below the ground surface, being highly influenced by sea level. Inland along the Dominguez Gap the ground water level slowly drops, being generally greater than 20 feet deep north of Pacific Coast Highway and greater than 40 feet deep north of Wardlow Road. Similar shallow ground water conditions exist in the Alamitos Gap area. Ground water is generally less than 10 feet below the surface throughout the entire area south of the San Diego Freeway.

The ground water table is generally much lower in the centrally located terrace regions ranging from 30 feet to greater than 60 feet below the surface. However, in some



DEPTH TO GROUND WATER

LEGEND

- 
 Contours Indicate Approximate Depth in Feet to Ground Water below Ground Surface.
- 
 Contours indicate area where ground water is less than 10 feet below ground surface.
- 
 Lines define approximate limits of Shallow Holocene Aquifers.

Source: Base Map - Bureau of Engineering - City of Long Beach

areas, especially north and east of the Long Beach Airport, a number of soil borings and monitoring wells have encountered shallow perched water. Perched ground water occurs where isolated sand beds or porous units have trapped and held water above the static water level. The perched water conditions may or may not affect the seismic stability of an area depending on the thickness and lateral extent of the water bearing beds.

Throughout the City, the shallow ground water is termed unconfined and occurs in the near surface soils more or less independent of their permeability. Underlying this shallow water, however, are several deep water bearing zones or aquifers that have historically been used for domestic water sources. Published reports of ground water levels generally refer to these deeper zones in which the thickness of coarse-grained material, its permeability, the piezometric head, and water quality are favorable to significant water production (Department of Water Resources, 1961; Los Angeles County Flood Control, Zeilbauer et al, 1961 and 1962; Lundeen and Roth, 1976).

Some of the producing aquifers, especially those in the ancestral river channels, extend to and are interconnected with sands on the ocean floor. Withdrawal of fresh water from these zones in the past has resulted in intrusion of salt water (Zielbauer et al, 1962). The Los Angeles County Department of Public Works has established water injection barrier projects to control sea water intrusion in these areas. These operations began in 1971 and have resulted in a general rise in water levels of up to about 20 feet in the shallow aquifer inland of the barriers. Seaward from the barrier operations, water levels have risen to approximate sea level.

5.4 Historic Seismicity

Reliable instrumental seismic records have only been available since 1932. Earthquakes that occurred during the previous 150 years of habitation of the Los Angeles area are documented only by subjective personal accounts and some experimental instrumental data. Barrows (1974) summarizes several catalogs of earthquake reports prior to 1933. He lists 170 events reported in the Los Angeles area. Of these events, he considers 93 to have possibly been associated with the Newport-Inglewood Fault Zone. However, felt reports are generally inadequate to delineate specific seismic sources, ie, causative faults. The first network of seismograph stations in southern California was installed in 1926, and the systematic calculations of earthquake epicenter locations and the compilation of catalogs began at Caltech in 1932.

Plate 1 shows the locations of significant earthquakes in the Los Angeles Basin from 1932 through 1987, as reported by the Caltech Southern California Seismic network. Plate 1 indicates that the Newport-Inglewood Fault Zone has been the center of much seismic activity in this region. Since 1973, the University of Southern California (USC) has operated a high-gain, short-period seismic network in the Los Angeles Basin (Teng et al, 1973; Hauksson, 1987). The major and notable earthquakes that have occurred along the Newport-Inglewood Fault Zone and that have been felt in the City of Long Beach are discussed in the following paragraphs.

Long Beach Earthquake of 1933

One of the most destructive earthquakes in the history of southern California occurred on 10 March 1933, although the main shock was of moderate Magnitude 6.3 on the Richter Scale. The epicenter was about 18.5 miles (30 km) southeast of the Long Beach City Hall, but the subsurface fault

rupture propagated to the northwest towards Long Beach, concentrating the strongest shaking and damage in the Cities of Compton and Long Beach.

The fault mechanism was right-lateral, strike-slip faulting (N 40°W) with an average subsurface fault slip estimated 12 to 18 inches (31 to 46 cm; Woodward-Clyde Consultants, 1979). The depth of the earthquake has been estimated at approximately 6 miles (10 km) below the ground surface. Much of what is known of the seismic hazard potential of the zone is based on observations of this earthquake. Aftershocks during the remainder of 1933, including the 5.4 Magnitude shock of 2 October, centered near Signal Hill, provided much of the early data relating to the seismicity of the zone. Intensities of up to IX (Modified Mercalli scale) were felt locally, but were more generally in the range of VII and were attributed to the propagation of high amplitude seismic waves in unconsolidated near-surface alluvial sediments.

A preliminary report on the Long Beach Earthquake by Wood (1933), a subsequent report by Binder (1952), and research by Barrows (1973; 1974) provide good insight into the nature of the earthquake. Observations cited by Wood and substantiated by later writers, indicate that conspicuous damage was greatest in areas underlain by man-made fill or loose alluvium, especially where saturated at shallow depth with ground water. Assigned intensities were generally lower in more stable ground, such as around Signal Hill and the San Pedro Hills.

General damage of significant degree, Modified Mercalli Intensity VII and higher, was experienced in an area bounded by an elliptical curve drawn through Manhattan Beach, Inglewood, Hyde Park, Vernon, Downey, Norwalk, Fullerton, Santa Ana, and Long Beach. The longer northwest-southeast

axis of this area roughly parallel the Newport-Inglewood Zone of faulting and folding. Within this area damage was the most severe in areas of either: (1) Man-made fill and unconsolidated alluvium with a shallow water table, or (2) Concentrations of improperly or poorly designed and constructed buildings.

With regard to the former case, the intensity and duration of shaking, ground cracking and concentration of building damage was higher in Compton than it was in Long Beach, although Long Beach was closer to the epicenter. Compton lies in what was then a water saturated basin of young river-lain alluvial sediments while a major portion of Long Beach lies on a raised terrace with a deeper water table. Only a few years prior to the earthquake, Compton had numerous artesian water wells. In downtown Long Beach, structural damage (\$40 million) and human casualties (120 deaths) can be traced to construction defects and to ignorance of the destructive potential of a local earthquake. Most well constructed buildings, even in heavily shaken areas, escaped serious structural damage (Barrows, 1974).

Surface rupture related to known faults did not occur during the 1933 event, but a number of secondary cracks, up to a half mile in length, were found in alluvial lowlands where a high water table existed. In some cases, water was ejected from these cracks as they formed showing evidence that liquefaction occurred in the underlying soils. Several cases of road, bridge, and pier failure were attributed to soil (natural and fill) failure. Only a few small landslides occurred along the coast.

Levels in automatically monitored water wells surged strongly (up to 28 feet) north of Signal Hill and progressively less strongly away from Signal Hill throughout the eastern Los Angeles Basin. Leveling surveys before and after the earthquake showed a regional rise in ground surface elevation with an axial trend paralleling the Newport-Inglewood Zone and slightly to the north. Maximum uplift of more than 1/2 feet occurred in an area north of Seal Beach. Subsidence of a lesser magnitude occurred in outlying areas of Norwalk, Compton, and Wilmington. Local elevation changes of up to 2 feet were attributed to lurching of shallow, plastically behaving sediments during the earthquake. Tsunamis, seismic sea-waves were not generated by the earthquake.

Aftershocks continued throughout most of the following year (1936), and some were strong enough to cause damage to the already weakened structures. Epicenters progressed northward along the Newport-Inglewood Zone from the focus of the main earthquake. One larger event (Richter Magnitude 5.4), centered near Signal Hill on 2 October 1933, may have been a separate strain-release event with its own series of aftershocks. Although seismic activity was well documented near Signal Hill, no damage was reported for the numerous oil wells crossing known faults in the Long Beach Oil Field.

The earthquake occurred late in the afternoon, and luckily, school children were not present in the many school buildings that experienced extensive damage. If the buildings had been occupied, the fatalities might have been ten-fold (Barrows, 1974). As a result, the California Legislature passed the Field Act, regulating the design and construction practices for public schools.

Inglewood Earthquake of 1920

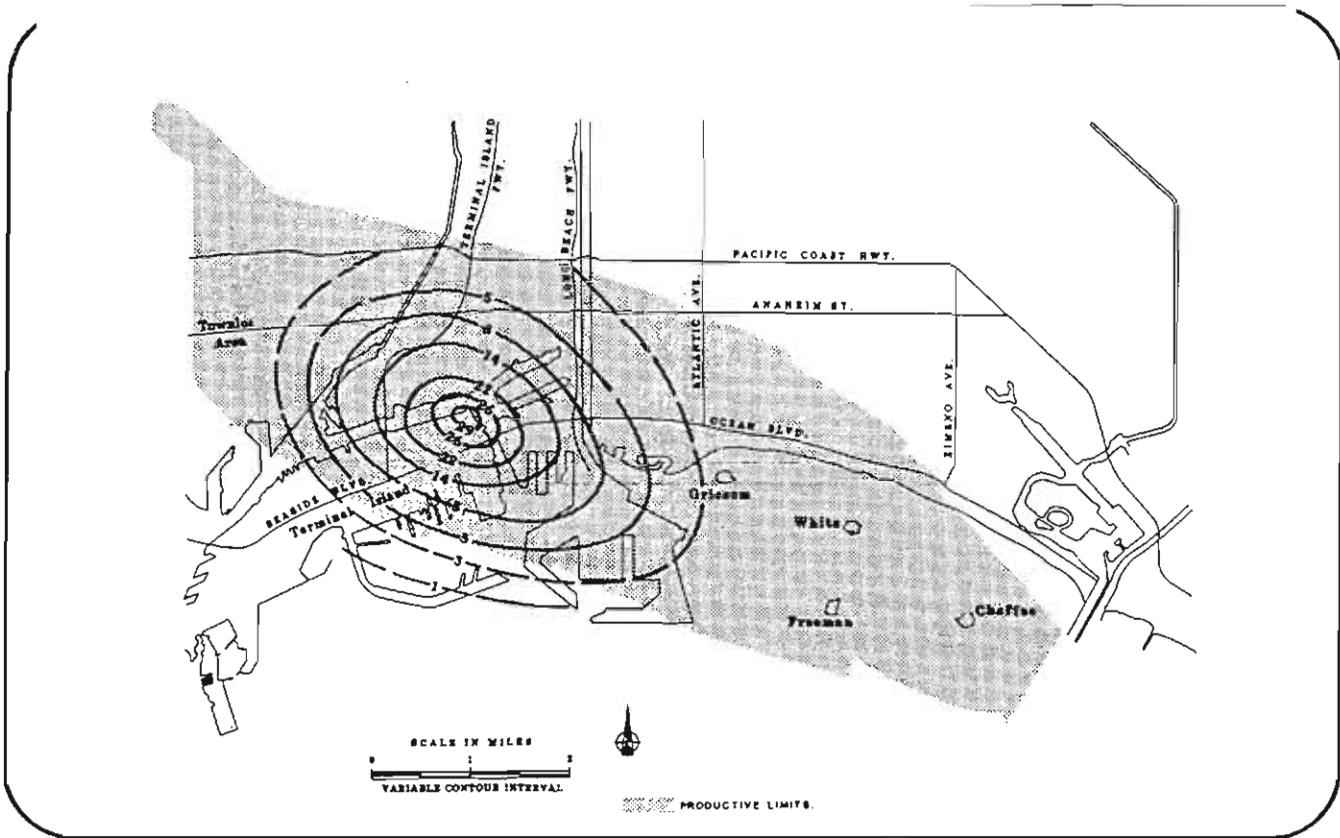
The second most destructive event that has been attributed to the Newport-Inglewood Fault Zone during this century occurred on 21 June 1920, near the city of Inglewood where considerable structural damage occurred, but there was no loss of life. The Richter magnitude of this event has been estimated at 4.9. Stephen Taber (1920) described local intensities as being nearly equal to those felt in the Long Beach area in 1933. However, the worst damage was restricted to the Inglewood-Hyde Park area. The epicenter of the earthquake was approximately 18 miles from downtown Long Beach, and no damage was reported in the City of Long Beach.

Earthquakes of 1941 and 1944

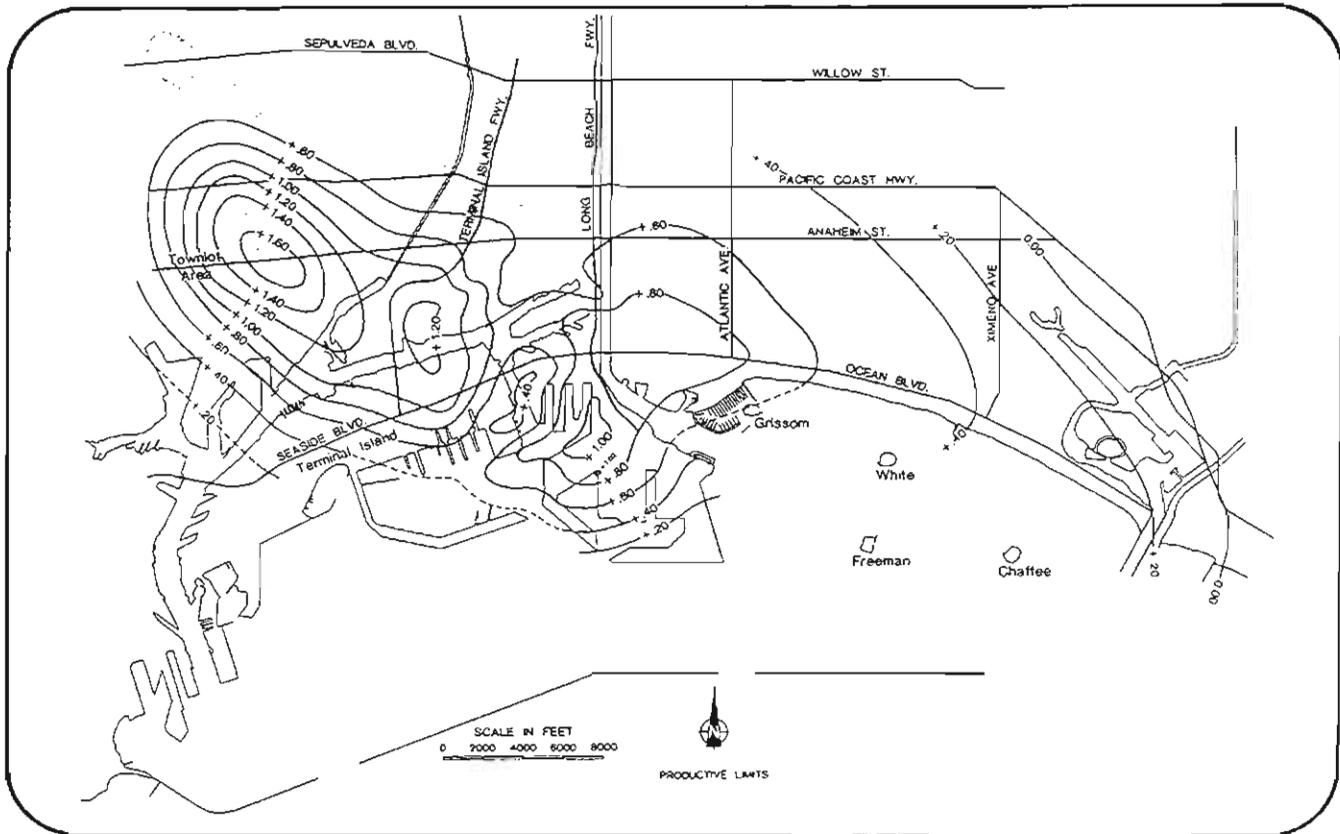
On 21 October 1941, a magnitude 4.9 shock occurred on an epicenter about 2 miles west of Signal Hill. This was the strongest earthquake felt in the Long Beach area since 1933. The next day, a minor event occurred 2 miles to the north, in the vicinity of the Dominguez Oil Fields, where 15 wells were damaged at depths between 5,000 and 7,000 feet. According to Kenneth M. Bravinder (1942), damage occurred across previously known faults. This was the first time that movement along mapped faults within the Newport-Inglewood Zone was documented (Barrows, 1974). Similar damage to oil wells occurred on 18 June 1944, in the Rosecrans Oil Field after a series of earthquakes in the Dominguez Hills, and the strongest one was a Richter magnitude 4.5.

5.5 Subsidence

Large scale subsidence, mostly related to petroleum production from the Wilmington Oil Field, has taken place in the Long Beach Harbor area. Nearly 30 feet of subsidence has occurred at the center of the basin near the Navy drydock on Terminal Island as shown on Plate 5. Elevation



Total subsidence, in feet, Wilmington oil field, 1926 through 1967.



Total rebound, in feet, Wilmington oil field, from the time of the lowest measured benchmark elevation through November 1985.

DIVISION OF OIL AND GAS, 1985

changes of 6 feet or more are primarily confined to the harbor area (Allen, 1973; California Division of Oil and Gas, 1985).

Small amounts of regional subsidence had been detected in the Long Beach-Wilmington area at various times prior to 1940, but little attention was given because the amount was very small. Mayuga and Allen (1969) reported that the deepest part of the subsidence bowl sank about 29 feet between 1926 and 1968. However, a noticeable amount of subsidence did not occur until after the major oil field development began in 1939 (Mayuga and Allen, 1969).

Oil production continued to increase and reached a maximum rate in 1951-52, when 50,788,000 barrels of oil were produced from approximately 2,400 wells. Not coincidentally, the maximum measured subsidence rate of 2.4 feet per year also occurred during this period (Strehle, 1987).

Pilot water flooding was initiated in 1953, and full scale injection began in 1958 (Allen, 1973; Allen and Mayuga, 1969). Extensive repressurization of the reservoir through water injection has stabilized the area, which along with substantial remedial landfill operations, has allowed continued use of port, petroleum production, and commercial facilities. As shown on Plate 5, as much as 1 to 1-1/2 feet of elevation rise has been experienced through rebound in some areas. However, it is estimated that this rebound and possibly more may be subject to rapid subsidence if reservoir pressures are allowed to drop through cessation of injection.

6.0 SEISMIC HAZARDS

6.1 Introduction

Evaluating seismic hazards is an important consideration for a community because extensive damage and large number of human casualties have been caused by severe earthquakes. It should be stressed, however, that no environment is risk-free, and, indeed, southern California (including the City of Long Beach) is in a seismically active region similar to many other areas in California and in North and South America, which border the Pacific Ocean. The historic losses in southern California due to earthquakes have been small in comparison to what people have accepted from other natural hazards such as hurricanes, tornados, landslides, floods, and even expansive soils. It is generally agreed, however, that the potential for sudden loss that may be caused by earthquakes exceeds that of any other natural hazard.

To maximize the use of this Seismic Safety Element, Long Beach has been divided into smaller areas in such a manner that the potential for each seismic hazard may be considered similar over each "sub area". The "sub areas" are called Seismic Response Areas (SRA) because they reflect differences from one area to another in the estimated potential for each seismic hazard. The seismic hazards that may affect an area are as follows:

- o Surface Fault Rupture
- o Earthquake Ground Motions
- o Liquefaction
- o Earthquake Induced Settlements
- o Slope Instability
- o Tsunamis and Seiches

These hazards are evaluated for the study area in this section, and the maps that outline the approximate extent of each hazard are included, as appropriate. Following these individual discussions, the potential for each seismic hazard to occur within each of the Seismic Response Areas within the City will be summarized.

6.2 Surface Fault Rupture

A significant damaging effect of earthquakes is ground displacement along faults that might underlie buildings and the infrastructure of a city. Considering the variety of styles of faults that exist in California, such surface fault displacements may be vertical, horizontal, or both. The fault offset at the ground surface may be less than one inch, to as much as 20 feet or more, as occurred in the 1906 San Francisco Earthquake along the San Andreas Fault in northern California.

Earthquake history has shown that the most likely place for surface fault rupture to occur is on an existing fault. Therefore, major active faults, such as those associated with the Newport-Inglewood Fault Zone represent the most likely location for future fault rupture in the City of Long Beach.

Surface fault rupture within Long Beach is not a necessary consequence of an earthquake on the Newport-Inglewood Fault Zone. However, should such surface movement occur, it would be expected to cause severe damage to overlying structures and would probably interrupt the majority of utility facilities and services that cross the fault. Although fault movement has been recorded along some traces of the fault in the Holocene and late Pleistocene age sediments, there is no evidence for historic rupture within Long Beach

for the earthquakes, associated with this fault system, that occurred in 1920, 1933, 1941, and 1944. The potential damage from fault rupture is considered to be less than the potential damage from strong seismic shaking from nearby earthquakes. The faults of the Newport-Inglewood Fault Zone that are believed to cut the surface or near-surface soils are shown on Plate 2.

The zones that have been defined around the major portions of these faults are referred to as Special Study Zones. These zones have been defined by the State Geologist in accordance with the Alquist-Priolo Special Studies Zones Act, which went into effect on March 7, 1973. This act has been amended four times since 1973, and a complete text of the Act is provided in Appendix A. The purpose of the Act is to prohibit the location of most structures for human occupancy across the traces of active faults and thus to mitigate the hazard of surface fault rupture. These Special Study Zones are delineated on USGS Topographic base maps at a scale of 1:24,000 (1 inches equals 2,000 feet). The zone boundaries are straight-line segments and have been transferred from the USGS Long Beach and Los Alamitos Quadrangle Maps to the City of Long Beach base map shown in Plate 2.

The Special Study Zones are delineated to define those areas within, which, special fault studies are required prior to building structures for human occupancy. The State Geologist has provided recommendations for the content of the require studies and geologic/seismic reports; these recommendations are also outlined in Appendix A.

The City of Long Beach has an active program of reviewing the geologic reports that are submitted to the City prior to

issuing building permits. Over 70 such reports have been prepared in compliance with the Special Study Zones within the City of Long Beach (Clarke, 1987).

Because there are uncertainties in the exact location and lateral extent of some potentially active faults within the City, Caution Zones are recommended for surface rupture hazards along some of these faults that have been mapped or projected to lie outside of the Alquist-Priolo Special Study Zones. It is recommended that guidelines be established similar to the Special Study Zones regarding construction of Essential and Hazardous Buildings within these Caution Zones. These recommended Caution Zones are also shown on Plate 2. Suggested guidelines are presented in Section 7.1.

6.3 Earthquake Ground Motions

6.3.1 Introduction

Earthquake ground motions in the City of Long Beach for which zoning can be accomplished depend on three major factors: (1) the seismicity of faults that could be the source of earthquakes in southern California; (2) the proximity of these faults to the City of Long Beach and in the case of nearby faults to sub-areas within the City; and (3) the subsurface ground condition in the City. The following subsections describe the seismicity and seismic sources (6.3.2), the estimated ground motions (6.3.3), and provide consideration to the foregoing major factors. It is noted that the estimated ground motions presented in Section 6.3.3 are considered in terms of peak acceleration and response spectra as a function of probability of being exceeded.

6.3.2 Seismicity and Seismic Sources

The region surrounding the Long Beach area is characterized by a relatively high seismic activity. Large earthquakes in southern California have occurred on faults that are known to be active. The seismic setting of the region is dominated by major, northwest trending active right-lateral strike slip faults. Faults in the region that are significant to the City of Long Beach and their key characteristics are summarized in Table 3. Earthquakes of magnitude 3.5 and greater for the period 1932 through 1987 are summarized in Plate 1.

6.3.3 Estimated Earthquake Ground Motions

The earthquake ground motions in various areas of the City were estimated using a probabilistic seismic hazard evaluation procedure. This procedure involves obtaining, through a formal mathematical process, the level of a ground motion parameter that has a selected probability of being exceeded during a specified time interval. Typically, the annual probability of this level of the ground motion parameter being exceeded is calculated. The inverse of this annual probability is called return period in years. Once the annual probability is obtained, the probability of the level of the ground motion parameter being exceeded over a specified time period can be readily calculated by the following expression:

$$P = 1 - \exp (-pt) \quad (1)$$

P is the probability of the level of the ground motion parameter being exceeded in t years, and p is the annual probability of being exceeded.

The elements of the probabilistic analysis are:

1. Defining the location and geometry of earthquake sources relative to the site.
2. Estimating the recurrence of earthquakes of various magnitudes, up to the maximum magnitude, on each source.
3. Selecting an attenuation relationship relating the variation of the earthquake ground motion parameter with distance and magnitude.

A probabilistic seismic hazard evaluation at a site due to a particular source involves combining the following three probability functions (e.g., Cornell, 1968; Shah et al, 1975; McGuire, 1976; Der-Kiureghian and Ang, 1977; Kulkarni et al, 1979):

1. The recurrence rate is used to calculate the probability that an earthquake of a particular magnitude will occur on the source during a specified time interval. This probability function is usually expressed in terms of the mean number of earthquakes, per year, with a given magnitude on this source.
2. The probability that the rupture surface is at a specified distance from a given area of the City is assessed by considering both fault geometry and the rupture length (or area) magnitude relationship.
3. The probability that the ground motions from an earthquake of a certain magnitude occurring at a

certain distance will exceed a specified level at a given area of the City is based on the selected attenuation relationship.

By combining these three probability functions for each source, the annual probability of exceeding a specified level of ground motion at a given area of the City is computed. If there are N sources, then the above process is repeated for each source, and the contributions are added to obtain the total seismic hazard at the site. A relationship between ground motion level and probability of being exceeded is obtained by repeating the computations for several levels of ground motion. The ground motion level corresponding to a specified probability of exceedance (or return period) is then obtained from the relationship.

The results of the ground motion analyses are tabulated with peak acceleration as a function of return period in Appendix D. For seismic design or evaluation purposes, two levels of shaking are generally considered:

- (1) A level of shaking that has a 50 percent probability of being exceeded during the life of a structure (for a 50-year life this translates to an average return period of 72 years); and
- (2) A level of shaking that has a 10 percent probability of being exceeded during the life of a structure (for a 50-year life this translates to an average return period of 475 years).

For important structures the former probable level of shaking is generally used in elastic design so that the structure can continue to function without significant

repair after the earthquake. The latter less probable level of shaking is generally considered in the inelastic design of the structure so that the structure may sustain structural damage but would not likely collapse during this level of shaking.

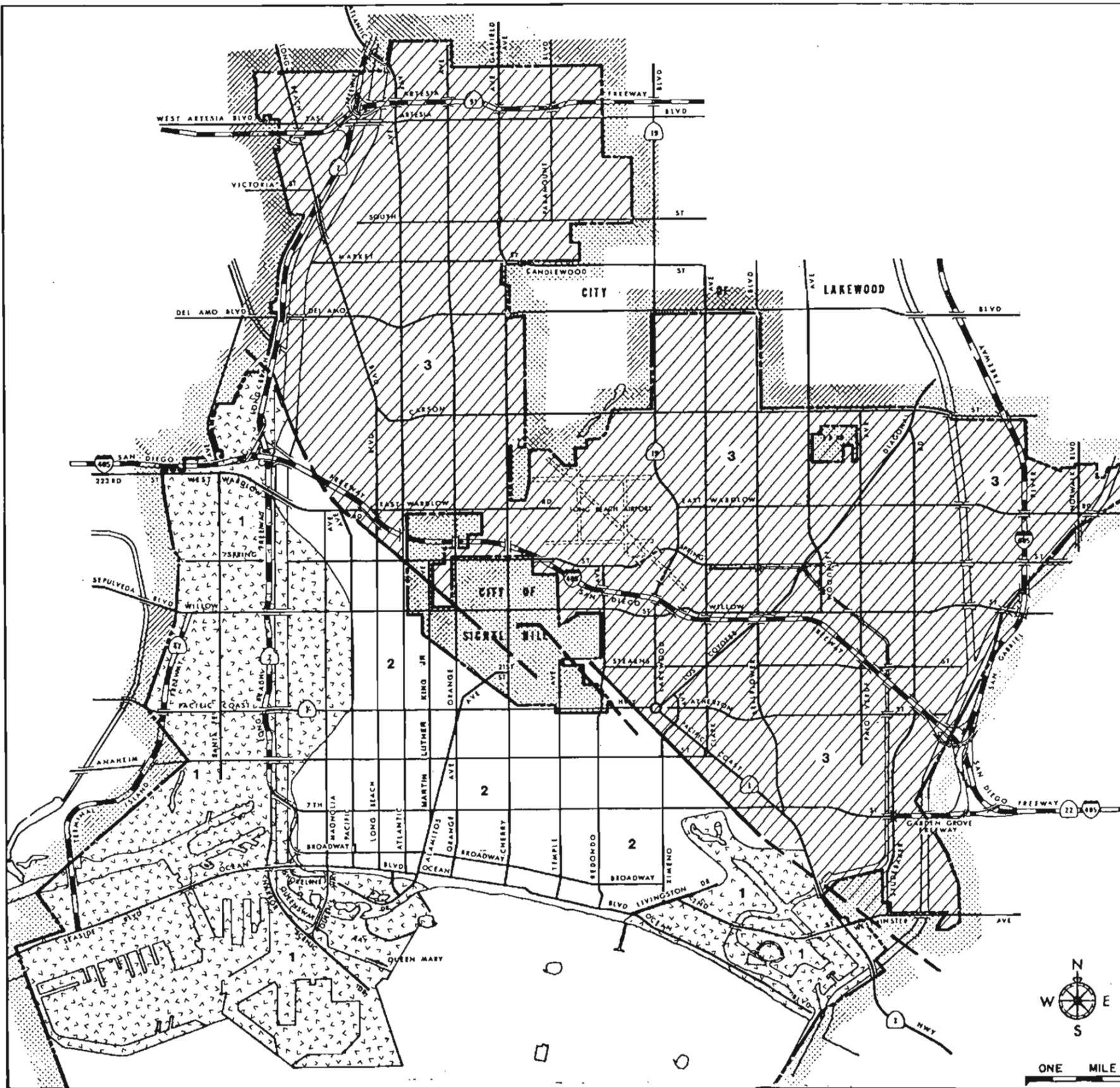
To estimate these two levels of shaking in the Long Beach area, calculations using the procedure outlined in this section were made at three selected locations. The values of peak horizontal accelerations calculated for these three locations and the general areas they represent are tabulated as follows:

<u>Location</u>	Area <u>Designation*</u>	<u>Peak Horizontal Acceleration</u> <u>Having an Average Return Period of</u>	
		<u>72 Years</u>	<u>475 Years</u>
Pier J	1	0.18 g	0.43 g
Anaheim and King	2	0.18	0.44
Carson and Clark	3	0.17	0.36

*For extent of area, see Plate 6.

Thus, the calculated peak acceleration for Area 1 and Area 2 are almost the same and both are higher than for Area 3. However, because the site condition in Area 1 is deep and in Area 2 is deep-stiff, they will still provide for different response spectral shapes and will be characterized by different shaking zones.

The above accelerations represent peak instrumental values that may be recorded during future earthquakes in these areas. For design purposes, it is common practice to adjust these instrumental values to account for: (a) the fact that the peak instrumental value occurs only once and a smaller, more repeatable, value would be more appropriate for most structures and structural systems; (b) wave passage affects



GROUND SHAKING AREAS

LEGEND



Deep Soil Conditions with Deep Alluvium in Gap Areas



Deep-Stiff Soil Conditions South of Newport-Inglewood Faults



Deep-Stiff Soil Conditions North of Newport-Inglewood Faults



Faults of the Newport-Inglewood Zone of Deformation

Source : 1) Base Map - Bureau of Engineers - City of Long Beach



ONE MILE

Woodward-Clyde Consultants

Plate 6

which act to average out the values of ground motions because the peaks do not occur simultaneously at all points along the base of the structure (note that this effect depends on the width of the structure and on the wave length of the motion under consideration); and (c) soil-structure interaction effects for embedded structures tend to reduce the ground motions especially in the short period range (less than about 0.5 seconds). Accordingly, taking these factors into consideration, instrumental values can be reduced by about 15 to 35 percent depending on the duration of the expected ground motions. For peak accelerations in the above three areas, the instrumental values were reduced by approximately 20 percent for the purpose of selecting average design level accelerations. Thus, the design level accelerations in these areas would be:

<u>Area</u>	<u>Design Level Acceleration Having An Average Return Period of</u>	
	<u>72 Years</u>	<u>475 Years</u>
1	0.14	0.35
2	0.14	0.35
3	0.14	0.30

Response spectral ordinates were computed in a similar way to obtain peak response spectral ordinates for these three areas. For the same reasons described above, the peak spectral ordinates were also decreased to obtain design level values. These design level values for 5 percent damping are summarized for the three areas in Appendix E.

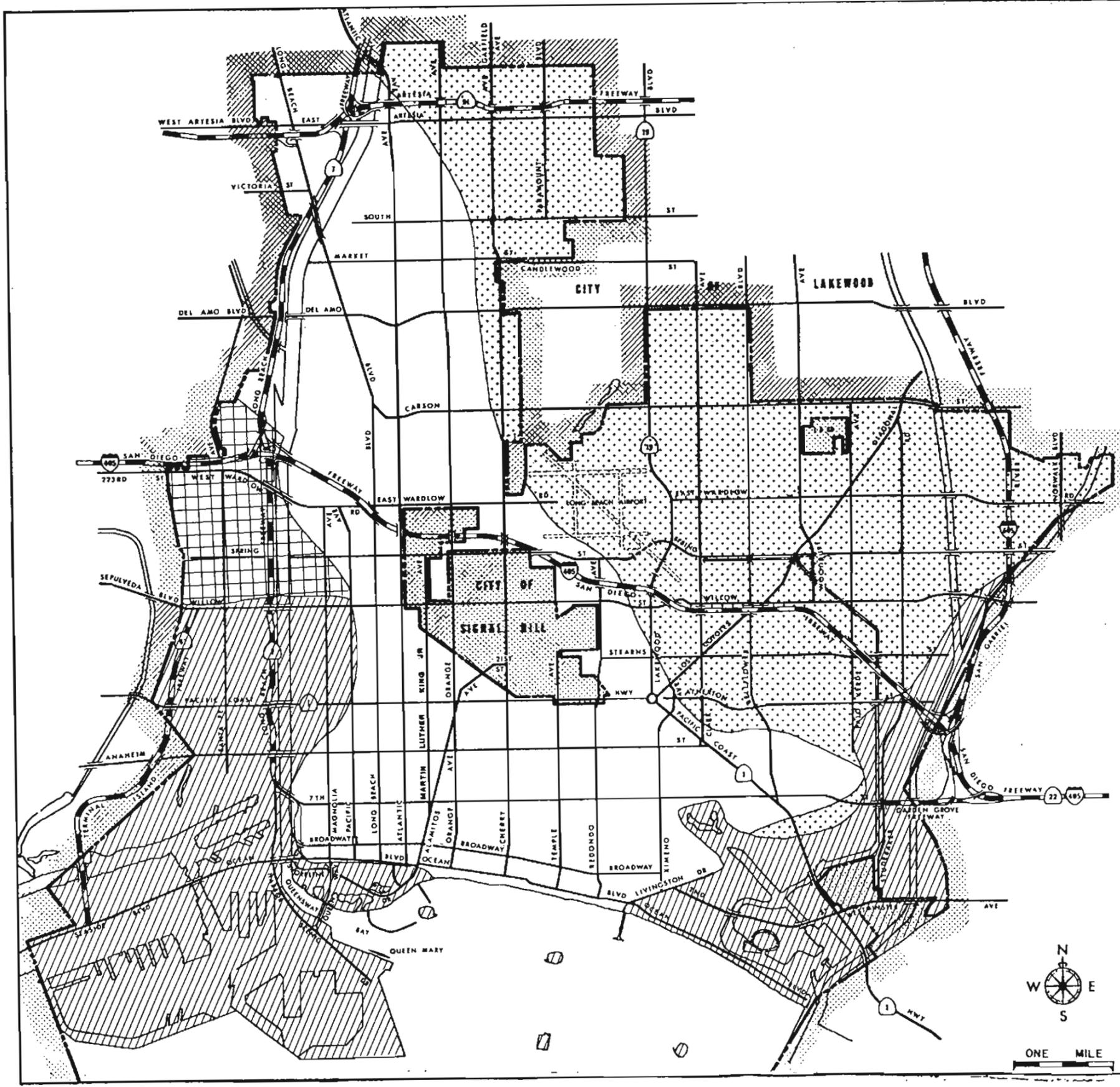
6.4 Liquefaction

The potential for liquefaction in Long Beach depends on the levels of shaking described in Section 6.3, the ground water conditions described in Section 5.3, and the subsurface soil

conditions described in Section 5.2. The procedure used to evaluate liquefaction was that developed by Seed and Idriss (1982). This procedure uses the normalized SPT blow counts (N_1) corrected for soil classification to characterize the subsurface soils to estimate soil resistance and the peak acceleration and magnitude to calculate seismically induced stresses. The charts recently published by Seed et al (1985) relating blow count to shear resistance for various accounts of fines content were used.

For the present case, the format of evaluation was to calculate a critical set of N_1 values for which liquefaction would be expected to occur (N_{1C}) and to compare the N_{1C} values to the N_1 values obtained from available boring logs. If the available N_1 values were higher than the N_{1C} values for a given peak ground acceleration, the potential for liquefaction would be low. However, if the N_{1C} for a given level of shaking is greater than N_1 , the potential for liquefaction would be high.

To define liquefaction hazard for the purpose of zonation of Special Study Areas in Long Beach, accelerations were based on earthquake ground motions having a 10 percent chance of being exceeded in 50 years. The values of N_1 were compiled from 33 selected soil investigation reports from the Long Beach area, and the value of N_1 were compared to N_{1C} values and the liquefaction potential assessed. The results were assigned a significant, moderate, low, or minimal potential. These results were plotted on soil distribution and ground water maps of the City of Long Beach, and a judgement was made to delineate four zones of liquefaction potential hazard as shown in Plate 7. As noted in Appendix F, the hydraulic fill soil areas for the harbor area and the offshore drilling islands are characterized by loose to medium dense sand to silty sand. As shown in Plate 7, the



LIQUEFACTION POTENTIAL AREAS

LEGEND

-  Liquefaction Potential Minimal
-  Liquefaction Potential Low
-  Liquefaction Potential Moderate
-  Liquefaction Potential Significant

Source: Base Map - Bureau of Engineering - City of Long Beach



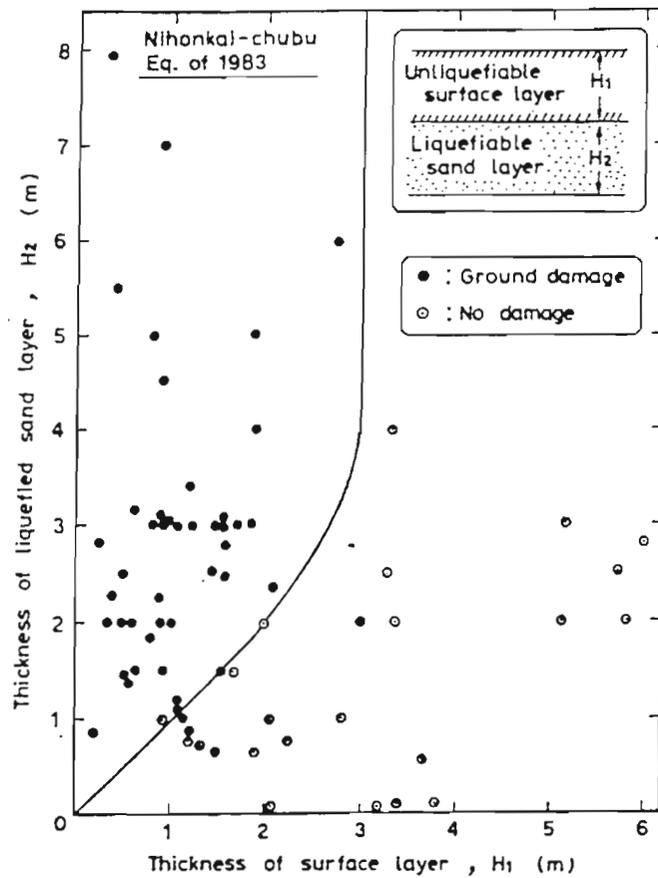
harbor area is in an area characterized as having a significant potential for liquefaction. It is also concluded that the offshore drilling islands should also be characterized as having a high potential for liquefaction.

The consequences for liquefaction in areas designated as having a significant potential for liquefaction includes possible horizontal failure by lateral spreading and instability of containment dikes where they are present, the occurrence of sand boils and differential settlements of the order of several inches to a foot or more. In areas where liquefaction is rated as moderate, the consequences would likely be more subtly characterized by settlements of a few inches and possible sand boils.

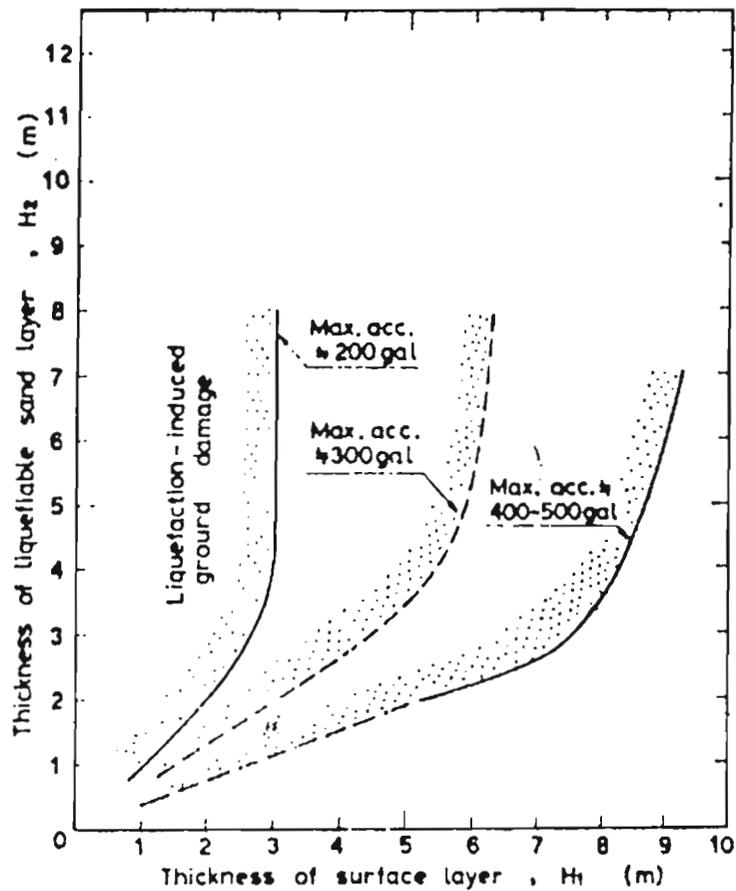
The results of recent observations pertaining to the potential for liquefaction at sites with horizontal ground surface gathered in Japan by Professor K. Ishihara from the University of Tokyo are summarized in Plate 8. Specifically, Plate 8(a) shows the correlation between the thickness of the liquefied soil layer and the thickness of the overlying non-liquefied soil layer as reflecting observed ground damage during an earthquake in 1983. Using these results and similar correlations from other earthquakes in Japan and China, Professor Ishihara proposed the relationship shown in Plate 8(b). The information in Plate 8 is presented as added data on the consequence of liquefaction considering the thickness of a non-liquefied layer over a liquefied layer, which would be important in areas where the water table is well below the ground surface.

6.5 Earthquake-Induced Settlements

Damaging settlements can occur during earthquakes even without the presence of liquefaction. In saturated granular



8(a) SURFACE DAMAGE AS A FUNCTION OF SOIL STRATIFICATION



8(b) PROPOSED BOUNDARY CURVES FOR SITE IDENTIFICATION OF LIQUEFACTION-INDUCED DAMAGE

soils, water pressure between grains that is built up during earthquakes may lead to settlements after the shaking has stopped and the pressure released (Lee and Albaisa, 1974). The areas most susceptible to this potential hazard are the same as those indicated for liquefaction, and damage resulting from such settlements is generally less severe than for liquefaction.

Earthquake-induced settlements can also occur in dry or moist granular materials as a result of shaking without any pore water pressure build-up (Seed and Silver, 1972; Youd, 1973). In general, however, areas of loose, cohesionless soils tend to coincide with areas of high ground water, and potential liquefaction is considered more of a hazard than seismically-induced settlements. Therefore, special delineation was not considered necessary for earthquake-induced settlements.

6.6 Slope Instability

Slope instability during earthquakes can be an important aspect of seismic ground failure. The areas most susceptible to this condition are those where slopes are steep, soils are weak or cohesionless, bedding dips out of the slope, and ground water is present.

Slope instability may also be induced by liquefaction of a supporting stratum. In such cases, very flat slopes on the order of a few degrees can fail. This type of slope instability is considered a liquefaction phenomenon herein.

In general, slopes within the City are not high (less than 50 feet) or steep (generally sloping flatter than 1-1/2:1, horizontal to vertical), and slope instability has not been a significant problem. There were only minor slope failures

noted during the 1933 Long Beach Earthquake. In the consultant's opinion, the potential for seismically induced slope instability that is not associated with liquefaction or dikes should not be considered as a major consideration in land planning concepts. However, certain areas have been identified, where slope stability should be considered for the development of individual sites, see Plate 9. Recommendations for slope stabilization measures are provided in Section 7.4.

6.7 Earthquake-Induced Flooding

Earthquake-induced flooding is the result of failure of water-retaining structures during an earthquake or especially high sea level fluctuations due to a tsunami or seiche. Possible flooding due to structural damage is discussed below.

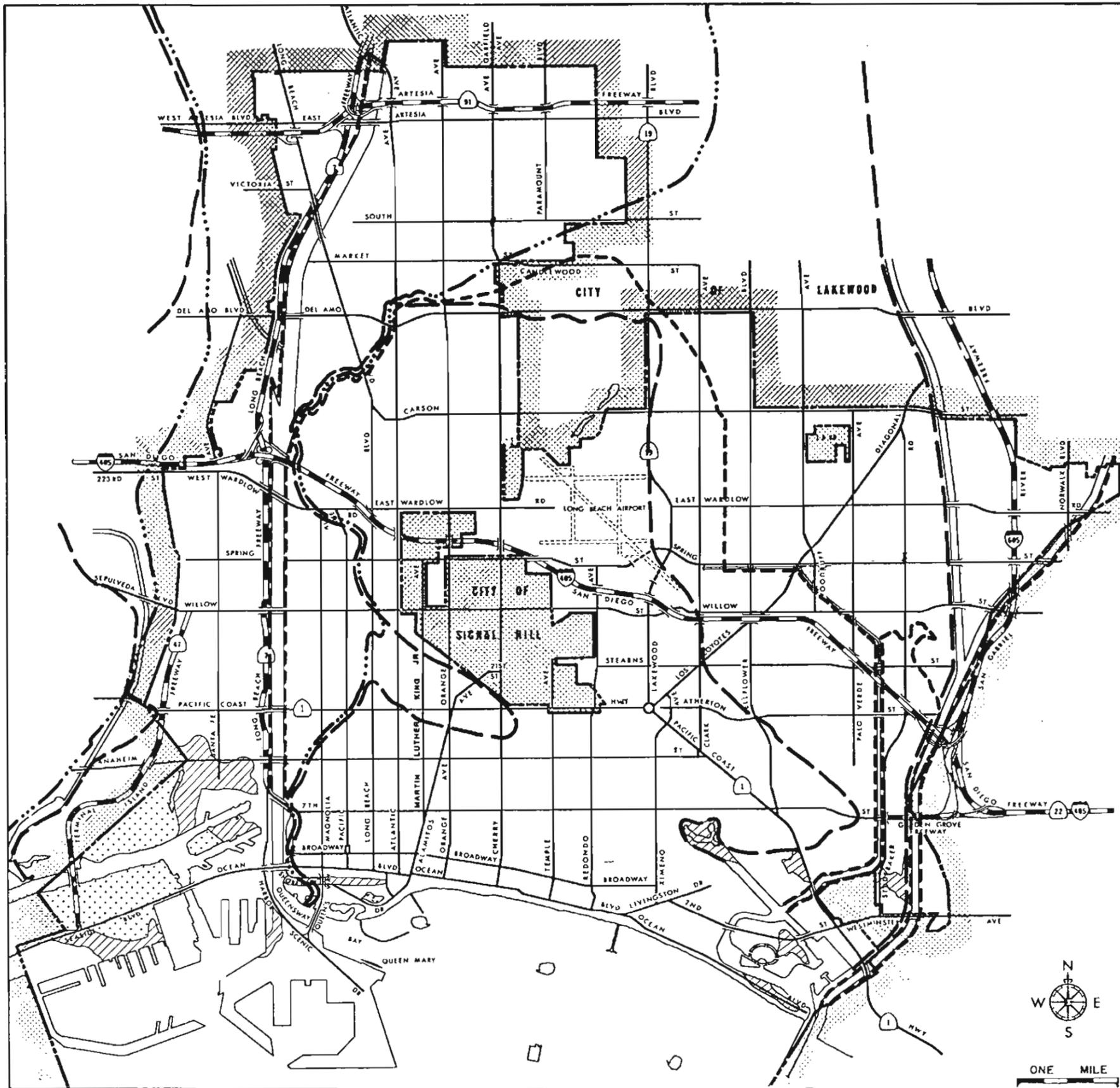
The failure of structures that might cause flooding, are dikes in the waterfront area, flood-control dams upstream from Long Beach, flood control dikes along river courses that pass through Long Beach, and large tanks. In the consultant's opinion, the seismically induced flooding potential for Long Beach is primarily from rupture of dikes during an earthquake.

In the low-lying and harbor areas, two criteria have been established with respect to the potential seismic hazard reflected by dike failure. Areas that are at or below sea level, Mean Lower Low Water (MLLW) are considered most susceptible, and areas up to 5 feet above MLLW sea level are considered vulnerable for flooding at higher tide levels. These areas are approximately delineated on Plate 10 and are

based on U.S. Geological Survey mapping (1964). More precise topographic control is required to estimate accurate flooding potential, especially within the secondary zone.

Four major flood control dams lie upstream from Long Beach. The Sepulveda Basin and Hansen Basin Flood-Control facilities both lie more than 30 miles upstream from Long Beach on the Los Angeles River. The intervening ground through this reach is generally low and flat. Therefore, much of the flood waters, which could result from a dam failure when the reservoirs were full, would be expected to dissipate before reaching Long Beach. However, based on Flood Inundation Maps prepared by the U.S. Army Corps of Engineers (1986), a failure of Hansen Dam could cause extensive flooding in north and west Long Beach. The limits of such flooding are shown on Plate 10. Similar maps prepared by the Corps show that a failure of Sepulveda Dam should be contained within the Los Angeles River Channel by the time the water reaches Long Beach.

The Whittier Narrows and the Santa Fe Basins lie 12 miles and 20 miles, respectively, above the northern boundary of the City. The Whittier Narrows Dam is responsible for control of both the San Gabriel and Rio Hondo rivers, and the Santa Fe Dam provides major control for the San Gabriel River. The San Gabriel River course runs along the eastern side of Long Beach. The Rio Hondo River joins the Los Angeles River about 5 miles north of the City, and then the Los Angeles River runs along the western side of the City. In the event of failure of the Whittier Narrows Dam, while it is full, flooding could occur along both sides of Long Beach but would probably be most severe on the east side.



FLOOD INFLUENCE AREAS

LEGEND

- 
 Surface elevation greater than 0 but less than 5 feet, MLLW
- 
 Surface elevation less than or equal to 0 feet, MLLW
- 
 Maximum Flood Inundation Limits from assumed breach of Hansen Dam - Corps of Engineers, August 1985
- 
 Maximum Flood Inundation Limits from assumed breach of Whittier Narrows Dam - Corps of Engineer, July 1986
- 
 Flood Inundation Limits of 100 year flood - Corps of Engineers, 1987

Sources: 1) Base Map - Bureau of Engineers - City of Long Beach
 2) USGS, 1981

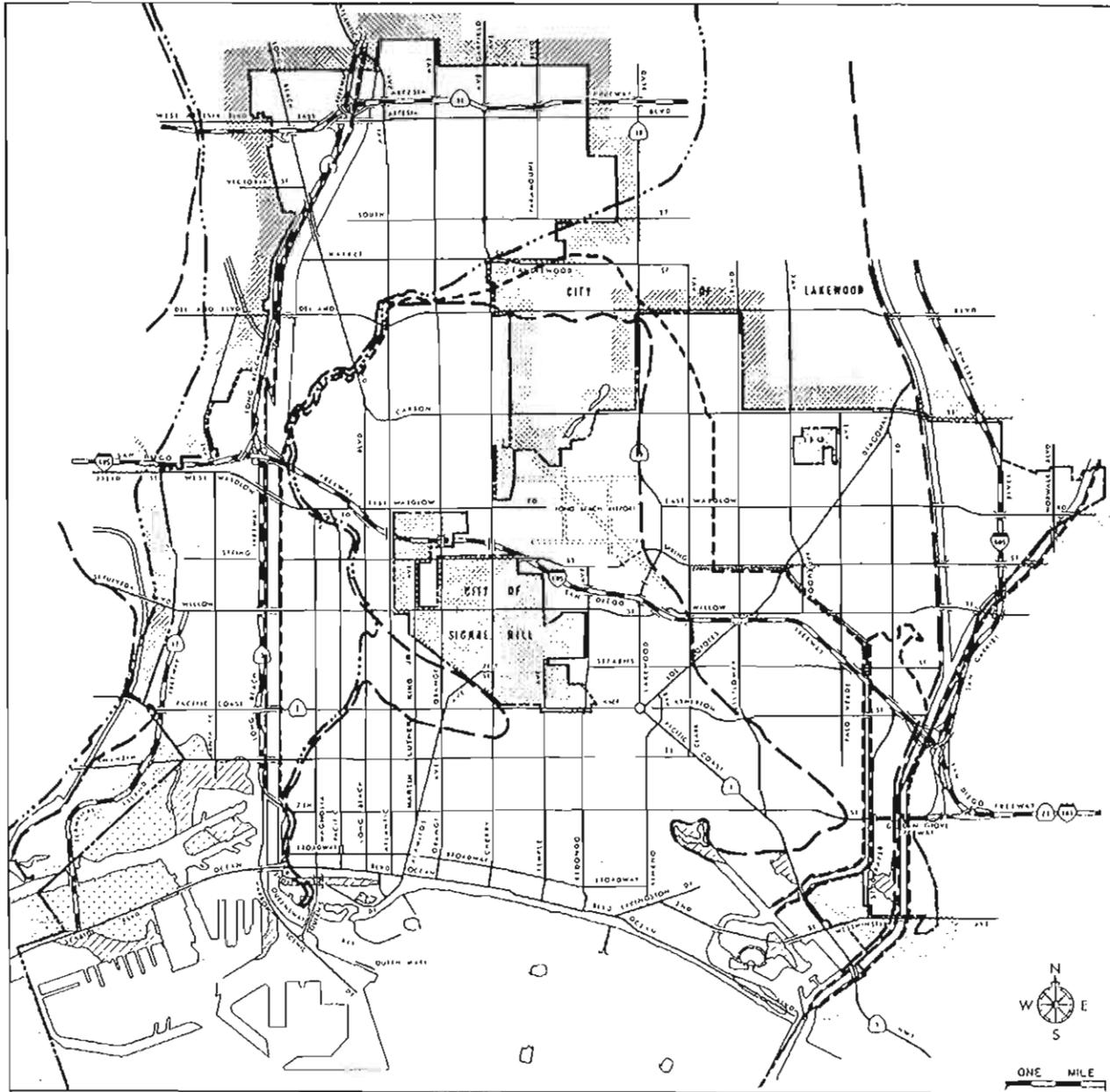


ONE MILE

Plate 10 shows the extent of flooding that could occur by the failure of Whittier Narrows Dam (Corps of Engineers, 1985). The Corps has not prepared a map showing the extent of possible downstream flooding from a failure of Santa Fe Dam, however, they state that it could not be completely retained by the Whittier Narrows Dam. This type of a failure and overtopping or bypassing of the Whittier Narrow Dam could be expected to cause extensive flooding in Long Beach, and could cover an area similar to that of a failure of the Whittier Narrows Dam as shown on Plate 10.

Because these dams impound water only during periods of infrequent high, seasonal precipitation, the probability of flooding due to coincident seismically induced failure of these structures is considered very low. As stated on the inundation maps prepared by the Corps, the preparation of the maps and the discussion here are not in any way intended to reflect upon the integrity of the dams discussed. Additionally, because the periods of high river flow are short, the probability of flooding due to the failure of river dikes is considered very low.

In order to place the potential for earthquake-induced flooding in perspective, the extent of flooding, based on the Corps of Engineers' "100 Year Flood", is also shown on Plate 10 (COE, 1987). The extent of flooding estimated for the 100 year flood exceeds, in most areas, that caused by the possible failure of any of the upstream dams. Therefore, the hazards are similar as to the possible extent of flooding but, as stated above, the probability of flooding due to coincident seismically induced failure of a dam is considered to be very low and less probable than the 100 year flood.



FLOOD INFLUENCE AREAS

LEGEND

- 
 Surface elevation greater than 0 but less than 5 feet, MLLW
- 
 Surface elevation less than or equal to 0 feet, MLLW
- 
 Maximum Flood Inundation Limits from assumed breach of Hanson Dam - Corps of Engineers, August 1905
- 
 Maximum Flood Inundation Limits from assumed breach of Whittier Narrows Dam - Corps of Engineer, July 1908
- 
 Flood inundation Limits of 100 year flood - Corps of Engineers, 1907

Sources: 1) Base Map - Bureau of Engineers - City of Long Beach
 2) USGS, 1901

Another potential for earthquake induced flooding is from large tanks. In the City of Long Beach there are a number of water and oil storage tanks located throughout the City. However, the largest concentration of water tanks is on Reservoir Hill. These tanks are operated by the Long Beach Water Department which has prepared an earthquake action plan. In the event of an earthquake, the plan calls for an immediate site inspection by a designated field engineer. In addition to this plan, the Water Department has recently installed new shut-off valves on all the tanks.

With regard to the large oil storage tanks in the area, the oil companies are required to maintain dikes around the tanks that are capable of containing any spill from the tanks.

6.8 Tsunamis and Seiches

A tsunami is a sea wave generated by a submarine earthquake, landslide or volcanic action. "Tsunami" is a Japanese word meaning harbor wave and has replaced the popular but inaccurate word "tidal wave" in most literature relating to earthquake generated waves. A major tsunami from either a landslide or volcanic event is considered extremely remote for Long Beach. The most likely tsunami source is a submarine earthquake. Submarine earthquakes are common around the edges of the Pacific Ocean. Therefore, all of the Pacific Coastal areas are subject to this potential hazard to a greater or lesser degree.

Tsunamis are long period, low amplitude ocean waves. The distance between wave crests in the ocean may be 50 miles and the wave height probably no more than 2 feet (Steinbrugge, 1982). Traveling at almost 500 mph in the Pacific, such a wave in the open ocean causes no problems,

and in fact may be imperceptible to a ship at sea. However, as the tsunami waves approach the coastline, they are affected by shallow bottom topography and the configuration of the coastline, which transforms the waves into very high and potentially devastating waves. Even small tsunamis can cause extensive damage by developing extreme "tidal fluctuations" and strong currents in harbors and bays.

Observable tsunamis are usually only caused by large earthquakes with a magnitude of about M 7.0 or greater. Smaller tsunamis are usually only recorded in the form of exaggerated tides.

California has had two historic locally generated tsunamis. The 1812 Santa Barbara Earthquake generated a tsunami with variously reported heights, but it seems likely that the runup height was not more than 10 or 12 feet at Gaviota. The second local tsunami was caused by the Point Arguello Earthquake of 1927; this magnitude 7.3 earthquake was accompanied by a 6-foot wave at the town of Surf (Steinbrugge, 1982).

California has been struck by five significant tsunamis during the past 50 years, which were generated elsewhere in the Pacific Ocean (Welday, 1974). Four tsunamis were from the north Pacific. These are the 1946 tsunami from the Aleutians, the 1952 tsunami from Kamchatka, the 1957 event from the Aleutians, and the very devastating tsunami from the Gulf of Alaska in 1964. The other recorded tsunami was generated by the 1960 Earthquake in Chile.

The most damaging tsunami along the California coast accompanied the 28 March 1964 Alaska Earthquake. A tsunami of 20 feet in height hit Crescent City, as a result of a

magnitude 8 earthquake and caused damages of approximately \$11,000,000. Most of the loss was due to harbor and boat damage. The run-up inundated about 30 city blocks, in the area of about 100 acres. The majority of one-story, wood-frame buildings that were situated in areas where the water depth exceeded about 4 feet were either destroyed outright or were so badly damaged that they had to be demolished later. This destruction extended over approximately half the area inundated. Losses in the remaining half were due primarily to water damage. There was also some damage at the Los Angeles (\$275,000) and Long Beach (\$100,000) harbors.

In southern California, the most serious recorded tsunami was generated by the 1960 Earthquake in Chile. Damage was estimated at between one-half to over one million dollars, and primarily related to boats and harbor facilities. The greatest damage occurred in the Long Beach-Los Angeles Harbor where 5 foot waves surged back and forth in the Channels. Currents of 12 knots were reported as the water rose and fell rapidly. A 5.8 foot drop in water level occurred in one minute at Long Beach and 3 feet in 5 minutes along the Cerritos Channel. The currents tore some 300 small boats and yachts from the slips, and as many as 30 were sunk (Weldey, 1974). Both the 1960 and 1964 tsunamis arrived in the southern California area at periods of low tides. If the tsunamis had occurred during periods of higher tides, tsunami damage would have been significantly increased.

There are little data available to evaluate the potential for destructive tsunamis due to nearby sources. There are conflicting interpretations as to the significance of tsunami damage resulting from significant offshore earthquakes occurring in 1812 and 1927. The 1933 Long Beach

Earthquake (M 6.3) on the Newport-Inglewood Fault Zone did not result in tsunami damage along the Long Beach coastline. Movement along the Newport-Inglewood Fault Zone would be expected to be primarily horizontal, and it is questionable whether such movement could cause a significant tsunami.

Steinbrugge (1982) points out the lack of historic record as a major problem in trying to estimate the tsunami hazard at any one location. He discussed one useful system developed by J. R. Houston (1979) at the U.S. Army Engineer Waterways Experiment Station. This system divides the coastlines around the world into five zones with ranges of estimated run up of up to 50 feet. The City and Harbor of Long Beach are shown to lie in Zone 2, indicating 5 to 15 feet of run up.

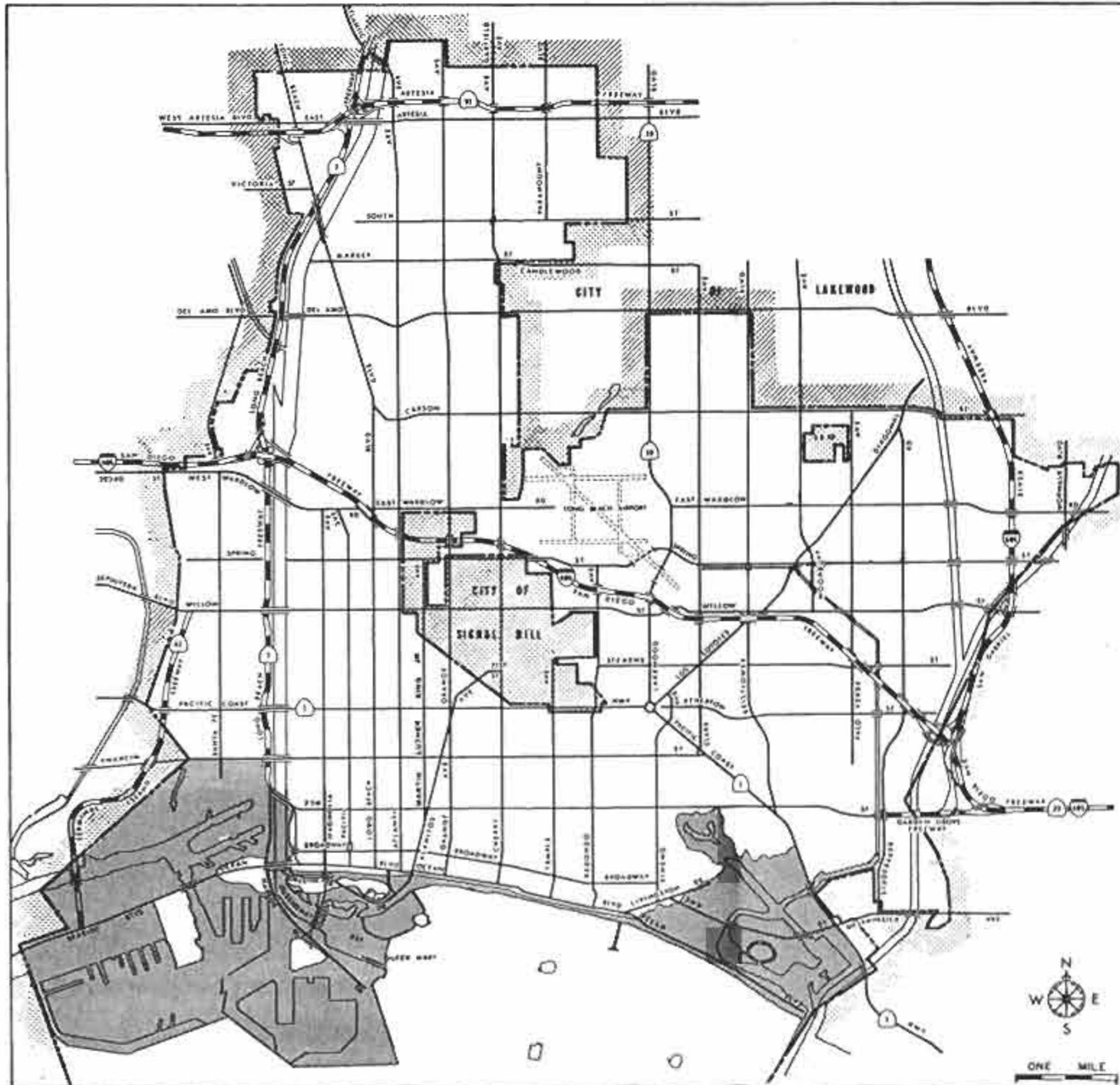
Due to the presence of the Palos Verdes Peninsula, Channel Islands, and the harbor breakwater, the Long Beach coastline and harbor are somewhat protected (especially to the north and west). However, due to the more open exposure to the south, the harbor and coastline are more vulnerable to tsunamis generated in the south seas and offshore southern California. Published estimates of recurrence intervals indicate maximum wave heights of 3 to 6 feet for 50 and 100 year recurrence intervals (Weldey, 1974). Such events are not expected to cause major damage to on-shore features. However, there is considerable potential for damage to boats, harbor facilities, and light, seafront structures during such events. Warning time in terms of perhaps 6 to 12 hours would be expected for distant events. The potential for death or injury from this source is not considered great, although shoreline property damage could be substantial.

A seiche is another earthquake or slide-induced wave that can be generated in an enclosed body of water of any size from a swimming pool to a harbor or lake. Historically, seiches have not caused as much damage as tsunamis.

The seismic hazards map, Plate 11, showing tsunami and seiche influence areas is based on the combined criteria of there being an elevation of less than 10 feet and within 100 feet of the beach. In the harbor area, the influence would be expected to drop off rapidly as it moved inland and would not be expected to be severe north of Anaheim Street, even in the low-lying areas to the north. Similarly in the Alamitos Bay area, damage would not be expected to be severe north of Pacific Coast Highway.

6.9 Seismic Response Zoning

Long Beach has been divided into smaller areas in such a manner that the potential for each seismic hazard may be considered relatively constant over each "sub area". The "sub areas" are called Seismic Response Areas (SRA) because they reflect differences from one area to another in the estimated potential for each seismic hazard. These SRAs are presented on Plate 12, and each hazards' potential for occurrence is summarized for each SRA in Table 4. An evaluation of structure compatibility with the different SRA is presented in Section 8.0. Siting and design recommendations consistent with the SRAs and their identified seismic hazards are presented in Section 9.0.

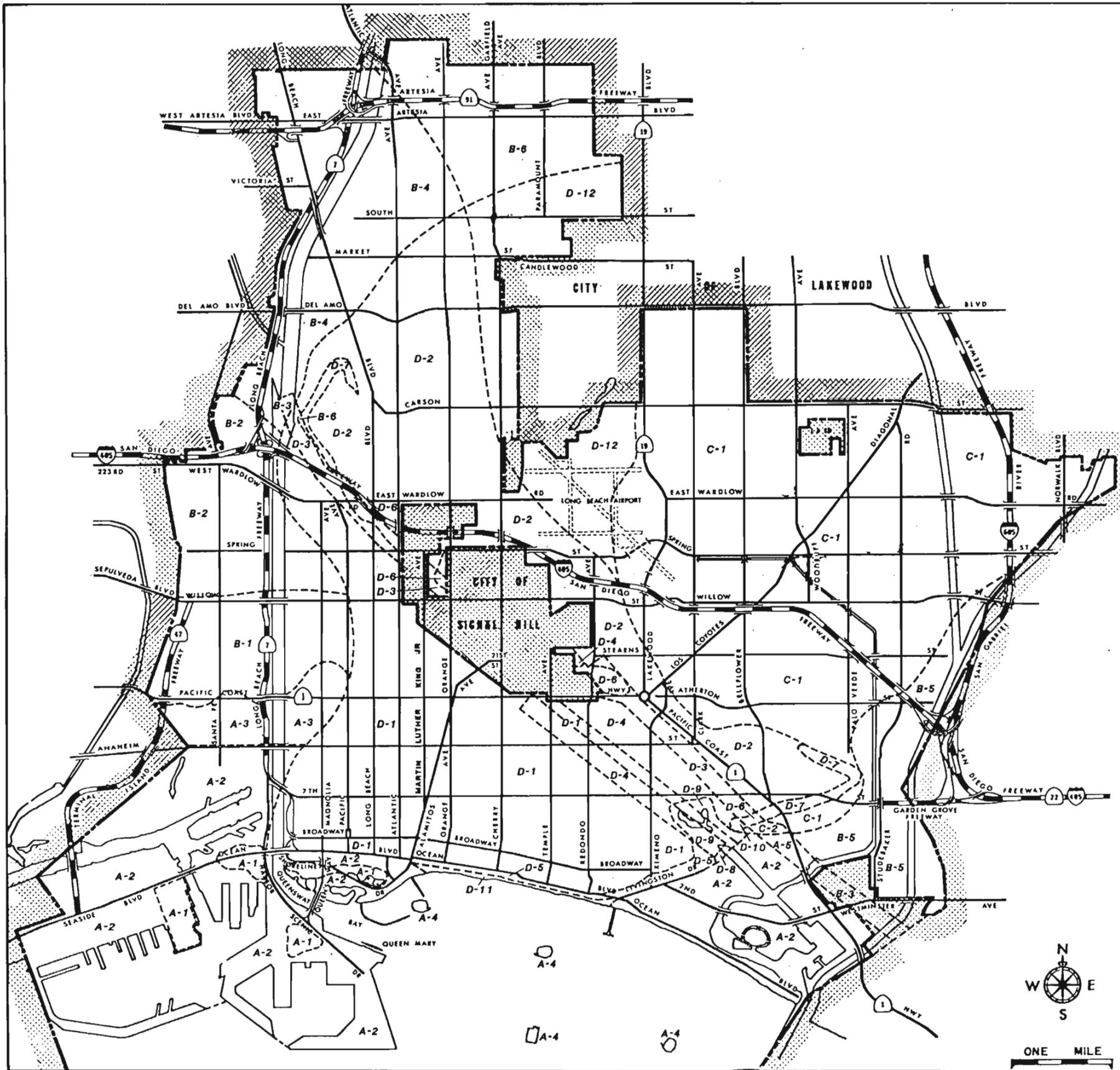


TSUNAMI AND SEICHE INFLUENCE AREAS



Shaded land areas are susceptible to Tsunami run up and Harbor and Channels areas are susceptible to seiche and strong currents.

Source: 1) Base Map - Bureau of Engineers - City of Long Beach
 2) USGS, 1981
 3) Steinbrugge, 1982



SEISMIC RESPONSE AREAS

LEGEND

A-1 SEISMIC RESPONSE AREA

Letters refer to soil profile

Numbers refer to areas with different combinations of Potential Seismic Hazards

See Table 4 for details

SOIL PROFILES

A - Man Made Fill

B - Sandy and Clayey Alluvium overlying Gaspar and Recent Aquifers

C - Sandy and Clayey Alluvium overlying Pleistocene sediments at shallow depth

D - Granular Terrace deposits overlying Pleistocene sediments at shallow depths

Source: Base Map - Bureau of Engineering - City of Long Beach

TABLE 4

SEISMIC HAZARD EVALUATION BY SEISMIC RESPONSE AREA

Seismic Response Area	Soil Profile	Seismic Hazard Potential					
		Fault Rupture	Ground Shaking	Liquefaction	Slope Stability	Tsunami	Flooding*
A-1	A	A	1	D	A	B	D
A-2	A	A	1	D	A	C	C
A-3	A	A	1	D	A	A	D
A-4	A	A	2	D	A	B	A
A-5	A	B	1	D	A	C	B
B-1	B	A	1	D	A	A	D
B-2	B	A	1	B	A	A	D
B-3	B	B	3	A	A	A	D
B-4	B	A	3	A	A	A	D
B-5	B	A	3	D	A	A	D
B-6	B	A	3	B	A	A	D
C-1	C	A	3	B	A	A	D
C-2	C	B	2	B	A	C	A
D-1	D	A	2	A	A	A	A
D-2	D	A	3	A	A	A	A
D-3	D	B	2	A	A	A	A
D-4	D	C	2	A	A	A	A
D-5	D	A	2	A	B	B	A
D-6	D	B	2	A	B	A	A
D-7	D	A	3	A	B	A	A
D-8	D	A	2	C	A	B	B
D-9	D	C	2	C	A	B	B
D-10	D	C	2	A	B	A	A
D-11	D	A	2	A	A	C	A
D-12	D	A	3	B	A	A	A

*Flooding may not affect all of area, see Plate 10.

TABLE 4 LEGEND

Soil Profile:

- A. Predominantly man-made fill areas consisting of hydraulic-fills assorted man-made fills, and soils of questionable origin, generally composed of fine sand and silt, includes drilling islands.
- B. Sandy and clayey alluvial materials composed of interlayered lenses of cohesionless and cohesive material overlying the shallow Gaspar or Recent aquifers; includes some local filled areas.
- C. Sandy and clayey alluvial material overlying Pleistocene granular marine sediments at shallow depths.
- D. Predominantly cohesionless, granular non-marine terrace deposits overlying Pleistocene granular marine sediments at shallow depths; includes adjacent beach areas.

Fault Rupture Potential:

- A. Fault rupture potential remote.
- B. Newport-Inglewood Fault, Alquist-Priolo Special Studies Zone.
- C. Possible Newport-Inglewood Fault, caution zone for critical structures.

Ground Shaking Areas:

- 1. Deep-firm soil conditions based on deep alluvium in gap areas.
- 2. Deep-stiff soil conditions south of Newport-Inglewood Faults.
- 3. Deep-stiff soil conditions north of Newport-Inglewood Faults.

Liquefaction Potential:

- A. Liquefaction potential minimal.
- B. Liquefaction potential low.
- C. Liquefaction potential moderate.
- D. Liquefaction potential significant.

Slope Stability:

- A. Area predominantly flat, slope stability problems minimal.
- B. Slope stability study area where slopes are steeper than 2:1 (horizontal to vertical).

Tsunamis Hazard Potential:

- A. Tsunamis and Seiches hazard potential remote.
- B. Tsunamis and Seiches hazard potential low.
- C. Potential for tsunamis and Seiches.

Seismic Induced Flooding Potential:

- A. Flooding potential considered minimal.
- B. Portion of area with surface elevations less than 5 feet MLLW, secondary flood influence area.
- C. Portion of area with surface elevations below MLLW sea level, primary flooding influence area.
- D. Within Corps of Engineers Inundation Area, see Plate 10.

7.0 RECOMMENDED GUIDELINES

7.1 Surface Fault Rupture

It is usually not economically feasible to design and construct foundations for structures that will remain intact across faults if the fault ruptures the ground surface. Therefore, fault zones subject to potential surface rupture should be avoided and construction of buildings for human occupancy over or across such faults should be prohibited.

In the areas where the State Geologist, California Division of Mines and Geology, has designated the Alquist-Priolo Special Study Zones, the State has established criteria for special geologic/seismic investigations prior to construction. These criteria for the investigations and ensuing reports are presented in Appendix A. The primary purpose of the Special Studies Zones Act is to prohibit the location of structures for human occupancy across the traces of active faults.

In addition to the Special Study Zones established by the State Geologist we recommend that some additional potential surface fault rupture "Caution Zones" be established that essentially extend the Special Study Zones as illustrated in Plate 2. We recommend that the following guidelines be implemented for these Caution Zones. These guidelines are not as stringent as those required by the Alquist-Priolo Act. They are intended to provide an awareness of the possibility of surface rupture hazards until additional data are collected that increases our knowledge of the level of surface fault rupture hazard that these faults might impose. The recommendations are as follows:

- o For construction of essential facilities, such as hospitals, schools, police and fire stations,

communication centers, etc. and hazardous facilities involving sufficient quantities of toxic or explosive materials presenting a danger to the general public safety if released: A subsurface investigation supervised by an engineering geologist, shall be undertaken to evaluate the presence or absence of an active fault zone underneath that proposed structure. If active faults are encountered, the construction shall be avoided at the proposed site or the structure moved to an adequate offset from the fault trace, as considered appropriate by the engineering geologist conducting the study.

- o For all other facilities: If a subsurface excavation is made, the excavation shall be inspected and logged by an engineering geologist to evaluate the presence or absence of faulting in the near-surface materials. If an active fault is found, the risk associated with surface displacement shall be evaluated by the engineering geologist. Depending on the level of the risk and consequences of potential surface faulting, a decision can then be made to construct the structure with proper design requirements at the proposed site, or to relocate the structure.

7.2 Seismic Shaking

The results of the analysis of ground shaking are described in Section 6.3 and presented in Plate 6. The intensity of ground shaking, as represented by tabulations of peak ground acceleration versus return period in Appendix D, indicates high seismicity for the Long Beach area. To mitigate the consequences of this high level of seismicity in terms of ground shaking, requires significant design strengthening of

structures to resist earthquake loading. One rational means for design, considering the frequency response of structures and the intensity of ground shaking, is the use of response spectrum. An evaluation of response spectrum for the City of Long Beach for each of the three ground shaking zones shown on Plate 6 was made, and the results are tabulated in Appendix E. These values were developed for general information and to define the ground shaking zone only. It is important that individual designs of structures take into account the specific subsurface conditions of a site, and that the response spectra used should be developed on a case-by-case basis. The spectra data listed in Appendix E should be used for comparison purposes only.

The actual method of design against shaking should consider the importance of the structure, the complexity of the structure, and the occupancy requirements of the structure. To provide guidelines for design, structures have been divided into groups on Table 6, relating structure type and location to the minimum design procedures that should be used. In some cases, the actual minimum design procedures may be more critical than indicated in Table 6, as dictated by other jurisdictional authorities. Because of the high seismicity of the area, it is prudent for the structural engineer and geotechnical engineer to consider innovative aseismic design procedures and mitigation. For ground shaking, this could include the use of base isolation or time-history analysis of the structure to develop the plastic response and identify areas of the structure where strengthening is important.

7.3 Liquefaction

The results of the analysis of earthquake induced liquefaction are described in Section 6.4 and in Plate 7. The consequences of liquefaction were also discussed in

Section 6.4, along with the aid of Plate 8 showing the affects of the thickness of unliquefied soil above a liquefied zone. Because of the potentially significant affects of liquefaction, it should be treated as a significant hazard for which a site should be investigated if the potential is moderate or significant as in the case for faulting. Therefore, similar guidelines have been developed for liquefaction as was done for surface faulting. The guidelines recommended below should be implemented in the moderate and significant zones identified on Plate 7.

- o For construction of essential facilities, such as hospitals, schools, police and fire stations, communication centers, etc. and hazardous facilities involving sufficient quantities of toxic or explosive materials presenting a danger to the general public safety if released: A subsurface investigation, logged, and supervised by a Geotechnical Engineer should be undertaken to evaluate the potential for liquefaction beneath that structure. If the liquefaction potential is found to be high and the consequence severe, mitigation measures shall be implemented or construction shall be avoided at the proposed site. Potential mitigation measures are discussed below.

- o For all other facilities: If the subsurface investigation indicates the potential for liquefaction, the consequences of liquefaction shall be identified and the structure strengthened to reduce the chance of building collapse.

In general, mitigation of the consequences of liquefaction can be accomplished in three different ways: (1) regional lowering of the ground water table; (2) structural

foundation treatment; and (3) individual site subsurface soil improvements. Regional lowering of surface water is generally not practicable in Long Beach because of cost and the potential for inducing settlement of adjacent surface structures. The other two methods may be practicable but should be considered on a case-by-case basis. In considering the use of soil improvement, the effects of site improvement on adjacent structures should be evaluated (ie, the effects of vibrations from dynamic compaction or vibroflotation can be detrimental to existing adjacent structures).

7.4 Slope Instability

Although slopes within the City of Long Beach are generally low, certain areas have been identified where slope stability should be considered, see Plate 9. Compared to liquefaction, slope stability problems are easier to analyze, and in most cases, prudent design can minimize this potential hazard without excessive cost. Because of the lack of adequate subsurface information, no specific recommendations can be made about the stability of specific slopes. For areas designated to have moderate to high slope instability potential in Plate 9, a seismic slope stability investigation may be required for the development of the individual sites, and the appropriate remedial measures may be needed to improve the stability of slopes under seismic loading.

Seismic stability of slopes can be improved by increasing the safety margin of the slopes under static loading conditions. This will provide a higher resistance to seismically induced deformations and failures. Several remedial measures may be considered to reduce seismically induced slope instability potential. These are listed as follows:

- o Reducing slope angle
- o Improving surface drainage through surface sealing, diversion ditches, interceptor drains, and surface vegetation
- o Improving subsurface drainage by installing horizontal drains or drainage tunnels
- o Constructing retaining walls near the base or toe of the slope
- o Planting trees, driving piles, and installing earth anchors, all of these can improve the stability of slopes by reinforcing them.

A site specific investigation is required for each case to evaluate the most effective and feasible alternative for a given site.

7.5 Seismically Induced Flooding

Seismically induced flooding can come from two major directions: (1) earthquake generated tsunamis, causing rapid rises in sea level, strong currents in the channels, and possible failure of levees; and (2) failure of dams upstream from Long Beach on either the Los Angeles or San Gabriel rivers causing the river levees either to be overtopped, to fail, or both. Tsunamis are discussed in the following Section 7.6. A third but more local flooding potential exists adjacent to large water tanks, which are not surrounded by containment dikes.

The flood control dams and channels that lie upstream from the City of Long Beach are operated and maintained by either the Corps of Engineers or the Los Angeles Department of Public Works, each one having jurisdiction over certain dams and reaches of flood control channels. Therefore, for

assessment and mitigation of the flood hazard, both aseismic and seismic, coordination is necessary with each of the governmental agencies. As stated in Section 6 and illustrated on Plate 10, the area of potential flood inundation from seismically induced failure of structures is similar in potential total area to that outlined by the Corps for the 100 year flood. Therefore, flood hazard evaluations and emergency procedures should be coordinated with those for the 100 year flood hazard. The general guidelines that should be considered in developing these emergency procedures should include the following:

- o If surface elevations are lower than high tide level, or if the property lies within the COE dam failure inundation areas, the project must be designed to mitigate the flood hazard or must be justified considering the potential for flooding.
- o Large water tanks and reservoirs should be evaluated as to their seismic safety and mitigation measures undertaken where necessary.
- o All property owners should be made aware of the potential hazards that could affect their property.

7.6 Tsunamis

Although the Long Beach Harbor is somewhat protected by the Palos Verdes Peninsula and Channel Islands from tsunamis originating from the Pacific northwest, it is not protected from tsunamis originating in the South Pacific, especially those generated along the western South American Coast. Therefore, there is the potential for considerable damage to boats, harbor facilities, and lowlying, unprotected seafront

structures. The most likely results in the harbor would be from rapid rise and fall of water levels and strong currents in the channels.

Mitigation of the threat of the tsunami hazard can be approached on two fronts: (1) strengthen and protect seafront structures, and (2) provide an emergency warning system.

Since 1948, the seismic Sea-Wave Warning System for the Pacific Ocean has been in operation through a cooperative program among nations around the Pacific rim. The System has worked successfully for the 1953, 1960, and 1964 tsunamis that hit Hawaii (Steinbrugge, 1982). Depending on the distance from Long Beach to the causative earthquake, the warning time can range from 6 to 12 hours. This time can be used to notify port authorities, move boats out to sea, and evacuate people from threatened areas.

Tsunami warnings for earthquakes occurring along coastal British Columbia, Washington, Oregon, and California are issued from the Alaska Tsunami Warning Center, (A.T.W.C.), operated by the National Weather Service, (D. S. McCulloch, 1985). Both Alaska and Hawaii have rapid-response regional-warning networks that issue tsunami warnings on the basis of reported earthquake magnitudes reported from around the Pacific. At the present time, California has no similar warning system that can respond rapidly to a locally generated tsunami, however, the Seismic Sea-wave Warning System can provide a warning for distant tsunami producing earthquake.

8.0 SEISMIC RESPONSE AREA - STRUCTURE COMPATIBILITY

8.1 Structure Types

The structure types evaluated are indicated in Table 5. The divisions of structures are intended to encompass general land uses, and to divide structure types with respect to differences in response to earthquakes.

8.2 Compatibility

Table 5 provides an extension of the earlier 1975 studies relating the relative damage potential of the various seismic hazards to structures. The earlier studies were completed with the aid of a structural engineer who judgementally assessed the relative damage potential. In the current study the response areas were simplified from 74 areas to 25 areas and the compatibility ratings were assigned based on the previous work. It is important that a more rigorous assessment be made with a qualified structural engineer working together with the engineering seismologist to make the judgements on relative damage potential. The numerical values need to be consistent with the new seismic response zones and current structural design philosophy and practices. When finalized with the input of a structural engineer, the values in Table 5 should reflect estimates of the relative susceptibility to structural damage from primary potential hazards resulting from an earthquake.

Comparing the values horizontally across any row provides an identification of the least risk structure type (lowest number) for each SRA. By comparing the values vertically, allows an evaluation of the most suitable siting area(s) for any particular type of structure. The following comments would be pertinent to Table 5, reviewed as indicated above.

TABLE 5

SEISMIC RESPONSE AREA/STRUCTURE TYPE COMPATIBILITY

Seismic Response Areas	1-story, wood frame, without fixed partitions (commercial or industrial)	1-story, shear wall, without fixed partitions (often high ceiling tilt-up or masonry)	1-story, steel frame, without fixed partitions (commercial or industrial)	1- and 2-story, wood frame, with fixed partitions (typical residential)	3- to 8-story, wood frame, with fixed partitions (commercial or industrial)	3- to 8-story, shear wall	8-story to 160 foot, moment resisting steel frame	Buildings greater than 160 feet in height	Underground structures (parking structures, etc.)	Tanks	Piping at or below grade, roadways	Long-period, thin structure (elevated tanks, stacks, transmission line towers, etc.)				
A-1	4	5	4	3	6	5	3	7	7	7	3	2	4	5	3	7
A-2	4	5	4	3	6	5	3	7	7	7	3	2	4	7	3	7
A-3	3	4	3	3	6	5	3	7	7	7	3	2	4	5	3	7
A-4	4	5	4	3	6	5	3	7	7	7	3	2	4	5	3	7
A-5	3	4	4	3	6	5	3	7	8	7	3	2	7	7	5	7
B-1	3	4	3	3	6	5	3	7	7	7	3	2	4	5	3	7
B-2	2	2	2	1	2	2	2	3	3	3	1	1	2	2	1	2
B-3	2	3	3	2	3	2	3	3	3	3	1	1	7	2	5	3
B-4	2	2	2	1	2	2	2	3	3	3	1	1	2	2	1	3
B-5	3	4	4	3	6	5	3	7	7	7	3	2	4	7	3	7
B-6	2	2	2	1	2	2	2	3	3	3	1	1	2	2	1	2
C-1	2	2	2	1	2	2	2	3	3	3	1	1	2	2	1	2
C-2	3	3	4	2	3	2	4	3	3	3	1	1	2	2	5	2
D-1	3	3	4	2	2	2	3	2	2	2	1	1	2	1	1	1
D-2	3	3	4	2	2	2	3	2	2	2	1	1	2	1	1	1
D-3	3	3	4	2	2	2	4	3	3	3	1	1	5	2	5	2
D-4	3	3	4	2	2	2	4	3	3	3	1	1	5	2	5	2
D-5	3	3	4	2	2	2	3	2	2	2	1	1	2	1	1	1
D-6	3	3	4	2	2	2	4	3	3	3	1	1	2	2	1	2
D-7	3	3	4	2	2	2	3	2	2	2	1	1	2	1	1	1
D-8	3	4	4	3	4	5	3	7	8	7	3	2	4	7	1	7
D-9	3	4	4	3	4	5	3	7	8	7	3	2	5	7	5	7
D-10	3	3	4	2	2	2	4	3	3	3	1	1	5	2	5	2
D-11	4	4	4	3	6	5	3	7	7	7	3	2	4	7	1	7
D-12	2	2	2	1	2	2	2	3	3	3	1	1	2	2	1	2

Note: 1) Lower number indicates better compatibility.
 2) Modified from Table 4, Long Beach City Planning Department, 1975.

TABLE 6 LEGEND

1. No special fault study required.
2. Geology and earthquake hazard report required in accordance to Guidelines to Geologic/Seismic Reports, Appendix A to this report. Report should consider all potential seismic hazards.
3. Special fault study required. Structures not permitted across potentially active fault traces. Siting policy to be in agreement with policies and criteria of the State Mining and Geology Board with Reference to the Alquist-Priolo Special Studies Zone Act, Appendix A to this report.
4. Building Code requirements considered minimum design.
5. Site specific dynamic analysis required. Design should provide for little or no damage from the design earthquake. Design should minimize structural damage and provide for public safety for maximum earthquake.
6. No special liquefaction study required.
7. Liquefaction study required if ground water level shallower than 50 feet. Siting must be justified considering liquefaction potential from maximum probable earthquake.
8. No special slope stability study required.
9. For slopes greater than 20 feet in height and steeper than 2:1 (horizontal to vertical), slope stability analysis required based on maximum earthquake.
10. No special flood studies required.
11. If surface elevation lower than high tide level, or if within COE Inundation Area, see Plate 10, project must be designed to eliminate flood hazard or be justified considering potential for flooding. All property owners to be made aware of potential hazard.
12. No special tsunami/seiche study required.
13. Project must be justified based on potential for tsunami hazard. All property owners to be made aware of potential hazard.

1. The compatibility values do not consider structure size or cost. Equal compatibility numbers reflect estimated equal structural damage relative to present market values (i.e., different structure types with the same compatibility number would have different damage costs but the same percentage damage cost in terms of market value).
2. The compatibility numbers do not consider occupancy or secondary effects of damage such as the effects of broken utility lines.
3. The values presented are based on the opinion of the consultant group as per present design standards. Other knowledgeable consultants would not necessarily derive the same values if the same approach was used. The overall results are considered as indicative. However, careful design can, of course, increase structure/land use compatibility.
4. The compatibility numbers are most strongly affected by ground shaking and liquefaction potentials.

By identifying the relationships between structure types and land uses, structure type/SRA compatibility can be incorporated in land use planning.

9.0 SITING AND DESIGN RECOMMENDATIONS

9.1 Siting and Design Considerations

It is the intent of this section to provide the building official with information to evaluate the levels of earthquake investigation and design considerations required for various types of structures according to their proposed location within the City. It is not intended to eliminate certain types of structures from various areas through zoning, but instead to set the level of seismic safety requirements prior to design and construction. The level of consideration will vary according to the type of structure contemplated. For example, light residential structures that will be constructed on flat ground would probably not need any significant additional consideration over what is conventionally required. For the design of essential structures, which must be able to function after a large earthquake or hazardous facilities which present a danger to the general public safety, stringent requirements for earthquake consideration and design shall be levied. Requirements for earthquake consideration and design of structures intermediate to the two extreme examples cited above vary according to the size, occupancy, and function.

The data and recommendations presented should discourage unfavorable site/structure combinations. They should not forbid a type of development if proper design and construction are assured, and if the development is consistent with normal zoning ordinances. Table 6 presents recommended siting and design recommendations by structure type and seismic hazard potential as discussed in Section 7.

9.2 Pre-1933 Buildings

The structures most vulnerable to collapse and/or damage during an earthquake are those that do not comply with the

provisions of the Field and Riley Acts of 1933. The City of Long Beach has a special problem with respect to these old, unreinforced structures. Many of the older sections of the City, particularly the downtown area and along the major corridors such as Broadway, 4th, 7th, 10th, Anaheim, Atlantic, and Long Beach Boulevard, have an abundance of such structures. The rapid implementation of Chapter 18.68, Earthquake Hazards Regulations (Subdivision 80) of the Long Beach Municipal Code is a rational remedial measure for reducing the potential risk. Subdivision 80 relates to the rehabilitation of pre-1933 buildings. Economically, such rehabilitation and renovation is expensive. For an existing hazardous structure, the cost of remedial work can amount to a relatively large percentage of total value of a structure, and the benefit-cost ratio, therefore, may be relatively small when considering property improvements for earthquake resistance. However, the social value in reduction to the threat of life loss justifies the existence of Subdivision 80. Furthermore, Subdivision 80 provides interim measures that can be instituted to reduce occupancy and use of such buildings.

9.3 Essential and Emergency Facilities

In addition to the recommendations presented in Table 6, future site studies and designs for essential and emergency facilities should be done more carefully and thoroughly than has been the general standard of practice in the past. The City should require a thorough and complete study of the site and building design for all public and private facilities, which are of the essential and emergency type. Such buildings or structures could include, but not be limited to:

- a) Hospitals, and other medical facilities that have surgery or emergency treatment areas

- b) Fire and police stations
- c) Municipal government centers
- d) Public utility service centers and storage facilities
- e) Designated civilian emergency centers
- f) Power facilities.

The thorough studies referred to for the above-listed structures should include but not necessarily be limited to the following considerations:

- a) Adequate geologic seismic studies and reports following guidelines of CDMG Note 37 and the Alquist-Priolo Special Study Zones Act, see Appendix A.
- b) Adequate boring and field and laboratory testing to determine accurately the subsurface profile and the static/dynamic properties of the soil/rock materials.
- c) Thorough regional studies of all possible causative faults and fault systems that could generate motions at the site.
- d) Studies to determine the character of ground motions at the site.

- e) Determination of design response spectra or earthquake time-histories for dynamic design of structures.
- f) Careful dynamic design of a cohesive structure, each element of which works as a part of the entire structural system.
- g) Thorough study of the ways in which the structure might disassemble if it were to fail, and inclusion of redundant backup features to control disassembly so that outright collapse cannot occur.
- h) Design of a damage control plan for emergencies.
- i) Design of anchorage and bracing for all critical in structure systems (ie, emergency power, heat, light, oxygen supply, etc.), based on factors derived from dynamic analysis, providing generous and conservative safety factors. The manufactured equipment and appurtenances purchases for such a facility should be designed likewise.
- j) Selection of architectural details and fixtures that aid structural response and will not be hazardous.
- k) Planning and policing of inside space use so that rolling or sliding furniture and fixtures will not be hazardous, and so that caustic or critical chemicals will remain intact.

- l) Thorough inspection of construction to ensure that designs are complied with, to include a written certification by the Contractor that all work was done in strict accordance with the Plans and Specifications.

- m) Periodic inspection of all structures and systems to determine that no detrimental modifications are made, and that proper maintenance is provided.

10.0 DATA RETRIEVAL

One of the important results of the implementation of the recommendations included in this study would be the development of a significantly expanded seismic safety data bank. In order to make full utilization of this information in planning and evaluating land uses, and to prevent redundant data gathering, a data retrieval system is recommended. The data retrieval system would be of great assistance to the Environmental Studies Division of the City Planning Department in evaluating studies initiated by the requirements outlined in Table 6. However, all departments of the City could use a centralized data retrieval system. This system would employ a Data Source and Location Sheet or a similar form, to catalogue all site-specific seismic safety related information by location and type (as per the coordinate system shown on City maps). The file of boring logs presently maintained by the Engineering Department of the City is an excellent source of soil data and should be maintained as an important part of the data retrieval system.

The retrieval system should be referenced by location so that all pertinent existing information regarding any site could be found easily. Furthermore, the data could be made into a public file as a service to all interested parties.

11.0 DISASTER PLANNING AND OPERATIONS

Most people living in the greater Los Angeles area will experience a nearby, major earthquake during their lifetime. To date, most local communities have been less than thorough in preparing for that event. In other areas which face a similar problem, Tokyo for instance, very detailed emergency plans are in effect and people can even purchase kits which contain emergency supplies and instructions.

The City's Fire Department Bureau of Support Services is currently revising our policy for disaster operations. This was necessitated by the abandonment of the previous Emergency Operating Center and the need to bring our policies into concert with those established within the California State Office of Emergency Services Basic Plan. The completion of this document and the subsequent approval of the Emergency Plan by the City Council is expected to occur by the end of this year, 1988. The provisions contained within this policy which relate to seismic disasters will be incorporated into the City of Long Beach Seismic Safety Element by reference.

12.0 RECOMMENDATIONS

This Seismic Safety Element is an attempt to gain insight and explore avenues of improved seismic safety through a systematized analysis of seismic factors. Adherence to the technical guidelines and recommended principles contained herein should assure that progress is made toward achieving a safer environment. While economic, social, and legal constraints must be appropriately considered, implementation of seismic safety controls is imperative for the long-term benefits of the community.

In terms of an implementation timetable, the recommendations are short, intermediate, and long range. For discussion purposes, however, the proposed actions are divided into two major categories: immediate action recommendations; and advanced planning recommendations. The former relate to matters of immediate interest, while the latter type are more policy oriented and serve primarily as guidelines for future land use allocations and continued urban development. While the immediate action recommendations may have a greater impact upon current City activities, the advance planning recommendations often relate to developmental policy and may have a more significant effect upon the City's future.

Advance Planning Recommendations

Land Use:

1. The Seismic Response Area/Structure Compatibility Matrix (Table 5) should be utilized as a means of allocating the most appropriate land uses for various areas of the City. An attempt should be made to locate low risk structure types in every response area of the City.

2. Priority should be given to low risk type projects such as low rise buildings and open space in areas of known seismic hazards.
3. Density is a seismic safety consideration in that higher occupancy results in greater risk exposure to more people should an earthquake occur. Therefore, from a seismic safety perspective, lower densities are often preferred.
4. Hazardous activities, such as petroleum operations, should be buffered to the extent possible from other types of land uses. This isolation of activities would serve to lessen exposure of such operations to the general public.
5. As seismicity and its relationship to land use planning is in its infancy, the City should keep abreast of new information in the field and respond to new sources of information.

Structural Safety:

6. As potential structural damage and loss of life is associated with the condition and age of structures, an effort should be made to recycle areas, supplanting deteriorated structures with new developments.
7. Pre-1933 high occupancy buildings should continue to be the first priority for recycling, as these structures constitute the most serious threat to public safety because of the probability of their failure during a major earthquake.

8. An incentive program should be explored to encourage voluntary renovation or replacement of pre-1933 buildings.

Public Information:

9. Through the media, public education programs, citizen participation, and other lines of communication, a greater dissemination of seismic safety information should be implemented.

Immediate Action Recommendations

Land Use:

10. The City is urged to continue to utilize redevelopment project areas as an opportunity to condemn, demolish, and replace unreinforced, unsafe buildings.

Structure and Design:

11. The siting and design recommendations, as specified in Table 6, should be seriously considered for implementation. Special siting and design studies must be completed for specified structural types in specified Seismic Response Zones.
12. The creation of new unfavorable site/structure combinations should be discouraged, unless adequate site dynamic studies are made and sufficient seismic safety measures are built into the structure.
13. No structures for human occupancy defined as a "project" within the Alquist-Priolo Special

Studies Zones Act and essential facilities and hazardous facilities involving sufficient quantities of toxic or explosive materials presenting a danger to the public safety if released and located within the delineated Caution Zones shall be approved without geologic and earthquake hazard reports. These report should be completed in accordance with the "Guidelines to Geologic/Seismic Reports", as provided by the State Division of Mines and Geology, and/or in accordance with the policies and criteria of the State Mining and Geology Board with reference to the Alquist-Priolo Geologic Hazards Zones Act. (These guidelines, policies, and criteria are provided in Appendix A.)

14. The City should require a thorough and complete study of the site and building design for all public and private facilities which are of the essential and emergency type. These geologic studies should include the considerations listed in Section 9.0.
15. No structure for human occupancy shall be permitted to be placed across the trace of an active fault, i.e., the Newport-Inglewood Fault.

Codes:

16. The present earthquake resistive requirements for new buildings in Long Beach are contained in the 1985 Uniform Building Code.

Insurance:

17. Earthquake insurance should be made readily available to the homeowner by its inclusion in extended-coverage riders on "standard homeowners insurance" and on "standard fire" policies. It is recommended that the City conduct an in-depth study into the existing earthquake insurance situation in Long Beach to assure the property owner the opportunity to purchase such coverage. Furthermore, loan programs available to rebuild in the event of a disastrous earthquake should be explored.

Personnel:

18. Implementation of the development policies as suggested in Table 6, should be coordinated between the Building and Safety Bureau and the Environmental Division of the Planning and Building Department. Personnel in these departments of the City should notify applicants when special seismic hazard studies are required and review the provided information as to its accuracy, veracity, and reliability. A geologist registered in the State of California would be technically qualified to evaluate geologic reports. Employment of an individual(s) with these qualifications should be considered for this purpose. In any event, a geologist should work closely with structural engineers in the Building and Safety Department to verify that proposed structures are resistive.

Enforcement:

19. Consideration should be given to instituting a program through the Building and Safety Bureau of the Planning and Building Department to inspect and identify all buildings constructed after January 9, 1934 which are of the structural types that have exhibited poor histories of performance during past earthquake episodes. Buildings constructed after this date are exempted from the earthquake hazard mitigation provisions contained within Chapter 18.68 (Subdivision 80) of the Long Beach Municipal Code Earthquake Hazard Regulations. They are, however vulnerable to structural damage or collapse associated with earthquake activity and present a real threat to human life and property as well as jeopardizing the economy of the City. Systematic and practical procedures similar to those contained within Subdivision 80 should be developed and incorporated into the Long Beach Municipal Code in order to correct these known deficiencies to an acceptable tolerable risk level. Examples of building types that have a poor history of performance are:

- o Concrete frame buildings built prior to 1947
- o Certain tilt-up concrete and masonry buildings
- o Buildings with long spans, irregular shapes or weak or soft first story construction
- o Poorly maintained buildings or those weakened by modifications

- o Buildings located in geologically hazardous areas subject to earthquake fault displacement, landslide or soil liquefaction.

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APPENDICES

Appendices referred to in the text of the Seismic Safety Element are available for review at the Department of Planning and Building, Long Beach, California.