APPENDIX B

ENVIRONMENTAL SAFETY TECHNICAL APPENDIX

This appendix contains technical background material related to the seismicity and seismic hazards issues addressed in the Environmental Safety Element.

Specifically, Appendix B contains:

B.1 Modified Mercali Scale of Earthquake Intensities

B.2 Distribution of Hazards

B.3 Levels of Acceptable Risk and Damage Related to Kind of Facility and Occupancy

B.4 Geotechnical Evaluation Map

B.1 MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITIES

THE MERCALLI INTENSITY SCALE
(As modified by Charles F. Richter in 1956 and rearranged)

If most of these effects are observed	*then the intensity is:*
Earthquake shaking not felt. But people may observe marginal effects of large distance earthquakes without identifying these effects as earthquake-caused. Among them: trees, structures, liquids, bodies of water sway slowly, or doors swing slowly.	*I*
Effect on people: Shaking felt by those at rest, especially if they are indoors, and by those on upper floors.	*II*
Effect on people: Felt by most people indoors. Some can estimate duration of shaking. But many may not recognize shaking of building as caused by an earthquake; the shaking is like that caused by the passing of light trucks.	*III*
Other effects: Hanging objects swing. *Structural effects:* Windows or doors rattle. Wooden walls and frames creak.	*IV*
Effect on people: Felt by everyone indoors. Many estimate duration of shaking. But they still may not recognize it as caused by an earthquake. The shaking is like that caused by the passing of heavy trucks, though sometimes, instead, people may feel the sensation of a jolt, as if a heavy ball had struck the walls. *Other effects:* Hanging objects swing. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. *Structural effects:* Doors close, open or swing. Windows rattle.	*V*
Effect on people: Felt by everyone indoors and by most people outdoors. Many now estimate not only the duration of shaking but also its direction and have no doubt as to its cause. Sleepers wakened. *Other effects:* Hanging objects swing. Shutters or pictures move. Pendulum clocks stop, start or change rate. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. Liquids disturbed, some spilled. Small unstable objects displaced or upset. *Structural effects:* Weak plaster and Masonry D* crack. Windows break. Doors close, open or swing.	*VI*
Effect on people: Felt by everyone. Many are frightened and run outdoors. People walk unsteadily. *Other effects:* Small church or school bells ring. Pictures thrown off walls, knicknacks and books off shelves. Dishes or glasses broken. Furniture moved or overturned. Trees, bushes shaken visibly, or heard to rustle. *Structural effects:* Masonry D* damaged; some cracks in Masonry C*. Weak chimneys break at roof line. Plaster, loose bricks, stones, tiles, cornices, unbraced parapets and architectural ornaments fall. Concrete irrigation ditches damaged.	*VII*
Effect on people: Difficult to stand. Shaking noticed by auto drivers. *Other effects:* Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Furniture broken. Hanging objects quiver. *Structural effects:* Masonry D* heavily damaged; Masonry C* damaged, partially collapses in some cases; some damage to Masonry B*; none to Masonry A*. Stucco and some masonry walls fall. Chimneys, factory stacks, monuments, towers, elevated tanks twist or fall. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off.	*VIII*
Effect on people: General fright. People thrown to ground. *Other effects:* Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes. Steering of autos affected. Branches broken from trees. *Structural effects:* Masonry D* destroyed; Masonry C* heavily damaged, sometimes with complete collapse; Masonry B* is seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Reservoirs seriously damaged. Underground pipes broken.	*IX*
Effect on people: General Panic. *Other effects:* Conspicuous cracks in ground. In areas of soft ground, sand is ejected through holes and piles up into a small crater, and, in muddy areas, water fountains are formed. *Structural effects:* Most masonry and frame structures destroyed along with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes and embankments. Railroads bent slightly.	*X*
Effect on people: General panic. *Other effects:* Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. *Structural effects:* General destruction of buildings. Underground pipelines completely out of service. Railroads bent greatly.	*XI*
Effect on people: General panic. *Other effects:* Same as for Intensity X. *Structural effects:* Damage nearly total, the ultimate catastrophe. *Other effects:* Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.	*XII*

* Masonry A: Good workmanship and mortar, reinforced, designed to resist lateral forces.
Masonry B: Good workmanship and mortar, reinforced.
Masonry C: Good workmanship and mortar, unreinforced.
Masonry D: Poor workmanship and mortar and weak materials, like adobe.

Source: California Division of Mines and Geology, Bulletin 198.

DEFINITIONS OF EARTHQUAKE SEVERITY AND FAULTS

Earthquake severity is usually measured in terms of magnitude and intensity. Magnitude is an instrumental measure of the amplitude of the seismic waves and is related to the amount of energy release--an amount that can be estimated from seismographic recordings. Magnitude assigns a value to the calculated energy release, this system can rank earthquakes and compare them one to another. By this method, an earthquake is rated independently of the place of observation. In the United States, the magnitude of earthquakes is expressed according to the Richter Magnitude Scale.

Intensity is a subjective measure of the force of an earthquake at a particular place as determined by the physical manifestation (i.e., its effects on persons, structures, and earth materials). The intensity of an earthquake related to local soil, groundwater, foundation conditions, type and design of structures, and duration of shaking. Intensity ratings, therefore, are based on visual observation and are not measured with instruments. The principal scale in use, today, in the United States is the Modified Mercalli, reproduced in Table B-1.

ACTIVE, POTENTIALLY ACTIVE AND INACTIVE FAULTS. The definitions of the categories active, potentially active, and inactive faults used by the California Division of Mines and Geology and adopted in the Environmental Safety Element are:

Active: Those faults which have moved or have shown activity within the last 11,000 years.

Potentially Active: Those faults which have moved or have shown activity within the last three million years.

Inactive: Those faults that have not moved or shown activity within the last 3,000,000 years.

DEFINITIONS OF SEISMIC HAZARDS

The principal seismic hazards are described in further detail in this section.

Faulting and Ground Rupture. One of the primary concerns for public safety along active and potentially active faults is the possibility of sudden ground rupture during an earthquake. This occurs during an earthquake when fault movement intersects the ground surface. Surface rupture does not occur every time a fault moves. In the event of an earthquake of high magnitude along the San Andreas Fault, displacement of several feet is possible with accompanying ground rupture. Most of the displacement would probably be in a horizontal direction though some vertical movement might also occur. Ground rupture may not be confined to a single line but could be manifest in a zone as much as several hundred feet wide along the surface traces as mapped.

While many faults run through Monterey County, each fault does not in itself indicate a surface rupture hazard. The fault must also be active or potentially active. Therefore, an evaluation of the possibility of surface rupture must include both fault identification and delineation, and classification of the fault with respect to activity.

Satisfying these two requirements is generally not simple. The existence of the fault is either known or suspected, based on geological reconnaissance or other mapping techniques, but its precise location may not be defined, and its activity status may be either unknown or in question. This situation commonly occurs because classification of faults with respect to activity often requires detailed subsurface exploration which is time consuming, costly and not part of commonly conducted geologic studies.

Ground Shaking. It has been long recognized that the intensity of ground shaking and the potential for building and structural damage due to this cause are profoundly influenced by local soil conditions. There is now considerable evidence to show that structural damage due to shaking is not simply a function of soil depth but also, the engineering properties of the soil deposit. Damage is particularly likely to occur when the natural period of vibration of a building is similar to that of the soil deposit on which it is constructed. Thus low, short period buildings tend to suffer major damage due to earthquake shaking when they are located in shallow short period soil deposits. Conversely, tall multi story buildings tend to suffer greater damage when they are located on deeper, long period deposits. In such cases, a quasi resonance condition between a structure and the underlying soil deposits can develop, producing very strong shaking in the structure.

Damage to structures from ground shaking is caused by the transmission of earthquake vibrations from the ground into structures. The variables which determine the extent of damage are: 1) the characteristics of the underlying soils and/or rocks; 2) the design and configuration of the structure; 3) the quality of materials and workmanship used in construction; 4) the location of the epicenter and magnitude of the earthquake; and 5) the duration and character of the ground motion. The potential for damage to existing structures due to ground shaking in the Carmel area is considered greatest in the areas of saturated soils along the Carmel River. It is least in areas where bedrock is near the surface.

Ground shaking caused by an earthquake will affect all of the structures in Carmel, to some degree. It is the intent of the various building regulations to provide some measure of protection against this hazard, but many of the older buildings were constructed before earthquake resistant provisions were included in the Building Codes. Other newer buildings may have been built at times when code enforcement was not very rigid or demanding. Since design standards for seismic resistance have been changing rapidly, some structures that were constructed to what were considered to be high standards at one time may be more vulnerable to damage than was anticipated.

Ground Failure. Ground failure potential is related to the duration and intensity of shaking, the location and magnitude of the quake, and the characteristics and condition of the ground at the time. The longer the shaking goes on, the greater the potential for ground failures to occur.

Ground failure resulting from shaking can take the general form of liquefaction, lurch cracking and lateral spreading, all forms of slope failure including landslides, differential compaction and localized settlement. Another possible form of ground failure is regional tilting and warping which generally would occur only during large earthquakes as a result of major tectonic displacements.

Liquefaction. Liquefaction is the loss of strength of soil due to the seismic forces acting on water saturated granular soils. This loss of strength leads to a quicksand condition and is a mechanism causing many types of ground failure. Where the liquified granular layer occurs at the surface objects can either sink or float depending on their density. The evaluation of potential for liquefaction is complex and must consider soil type, soil density, groundwater table and the duration and intensity of shaking. Liquefaction occurred during the 1906 earthquake in the lower Carmel Valley, and other portions of Monterey County.

Available data indicate that liquefaction will most likely occur in deposits of saturated unconsolidated alluvium or similar deposits of artificial fills. The most likely places for liquefaction to occur are in the area adjacent to the Carmel River, and in beach and sand dune areas.

Lurch Cracking and Lateral Spreading. Ground shaking, settling, compaction of soil, and sliding produce irregular fractures, cracks, and fissures from a few inches to many feet in length, often collectively termed lurch cracking. Such fractures may displace soil and earth in a manner similar to faults. Fractures are rare in solid rock; most significant in weathered rock, alluvium and soil. Lateral spreading with accompanying cracking and soil displacements, is the near horizontal movement of soil masses, generally toward an open face such as stream banks or the open side of fill embankments.

Fracture patterns from lurch cracking and lateral spreading may be controlled by the configuration of shallow bedrock structures, by highway surfacing, by the margins of fill, and engineering structures. Fractures are often accompanied by sand boils and mud volcanoes which are evidence of liquefaction. Fracturing may cause damage many miles from the epicenter of an earthquake. Another effect is the extensive rippling and fracturing of pavements and curbs. These effects are characteristic of earthquakes large enough for significant ground motion to occur. The larger the earthquake magnitude the more extensive are these effects.

The available data indicate that these forms of ground failures are more likely to occur in areas underlain by deep, relatively loose saturated alluvium. The ground shaking resulting from the 1906 earthquake, produced numerous examples of fracturing, cracking, fissuring, and/or lateral spreading in the Carmel Valley.

Slope Failure. Mass movements of loose rock, soil, and water saturated, weathered materials are common occurrences in all earthquakes large enough to be felt. They consist of rock falls, landslides, rock avalanches, mud and debris flows, and all other types of gravitational earth movement from very minor landslides to massive slides involving millions of cubic yards. Steep slopes favor such mass movements. That is why slides occur so frequently in highway cuts and on downhill road shoulders. However, liquefaction of fine sandy sediments may lead to failures on very gentle slopes (lateral spreading). High rainfall and saturation by water are also contributory to mass earth movements.

In a major earthquake, there are usually large mass movements of rock and earth over wide areas, and many hundreds of landslides. There can be severe landslide damage, particularly to highways, up to 75 miles or more from the earthquake epicenter. There can be mass movements of earth, rock, and pavement at bridges and overpasses; repaired movements may be redamaged by aftershocks. Old landslides in or near fault zones may be reactivated. In addition, aftershocks may trigger successive slides for weeks or even months after a major or great earthquake.

Although groundwater saturation favors gravity propelled movements of earth and rock, sliding also occurs in dry materials. Inadequately compacted fills, and fills placed over weak materials are particularly susceptible to sliding.

Landslides may occur on gently sloping ground. Many failures along creek banks are a form of landslide called lateral spreading. This form of landslide can affect areas many hundreds of feet back from the top of the creek bank.

Other Forms of Failure. Tectonic subsidence and/or uplift (regional tilting and warping) may occur over several square miles in larger earthquakes. In sizeable earthquakes, groundwater and surface water regimes are also often disrupted. No estimate of the probability of these events occurring in Carmel or Monterey County is possible with data presently available.

Seismically Induced Water Waves. The seismic sea wave, or tsunami, is produced by subsidence or large areal displacement of the ocean bottom or earth movement along the coast. Tsunamis move at velocities of 350 to 500 miles per hour in deep open water and may be up to 100 miles in length. Approaching the shore, at a slower speed, the wave may reach a height of 50 feet.

There is no record of any tsunami more than ten feet high occurring along the Monterey County Coast, but major to great Pacific Ocean earthquakes have caused damage along the California Coast. Twelve people lost their lives in a tsunami affecting Crescent City at the time of the Alaskan earthquake of 1964. There also was damage in boat harbors, and to other marine installations.

Minor damage was experienced along the California coast at the time of the 1960 earthquake in Chile.

Tsunami inundation could occur along the margins of Monterey and Carmel Bays and surrounding beach areas. The following properties of a tsunami are important and should be understood.

- A tsunami is not a single wave but a series of waves, and the first wave is not necessarily the largest.
- The swift currents generated by receding or incoming waves are an additional hazard, and these can damage moored boats and marinas.
- Before a tsunami, or after the first wave, water may withdraw from the coast, exposing large areas of the shore.

The U.S. Army Corps of Engineers is presently studying methods of tsunami long range forecasting for Pacific coastal communities. The U.S. Government has established a tsunami warning system to alert potentially effected coastal communities.

B.2 DISTRIBUTION OF HAZARDS

Applies to Figure B-1 Carmel-by-the-Sea and Vicinity

	ENGINEERING					SEISMIC					
	SLOPE STABILITY	EROSION	EXCAVATION	GROUND WATER	EXPANSIVE SOIL	LURCH CRACKING	LATERAL SPREADING	VIBRATION DAMAGE	SUBSIDENCE & UPLIFT	GROUND RUPTURE	LIQUE-FACTION
I	NA	□+	□ TO ○+	△+	△ TO □+	NA	NA	△ TO □+	NA	NA	NA
II	△ TO □+	□+	△ TO ○+	□ TO ○+	△ TO □+	□ TO ○+	□ TO ○+	□ TO ○+	○+	NA	□ TO ○+
III	□ TO ○+	□ TO ○+	△ TO □+	△+	△ TO □+	□+	□+	□+	□+	NA	□+
IV	○ TO □+	□ TO ○+	NA	△ TO □+	□ TO ○+	△+	NA	□ TO ○+	NA	NA	NA
V	△ TO ○+	△ TO ○+	△ TO ○+	△ TO ○+	△+	△ TO ○+	△ TO ○+	○+	□ TO ○+	○+	○+
VI	○	○	□+	□+	○+	○+	○+	○	□ TO ○+	○+	○+

Source: Spangle and Associates, 1975

△ MINOR   □ MODERATE   ○ MAJOR   + LOCALLY

NA GENERALLY NOT APPLICABLE

The triangles indicate that the potential geotechnical hazard is of concern in less than about 10 percent of the zone so designated. The squares indicate that the potential hazard is of concern in less than about 40 percent of that zone, whereas the circles indicate that the potential hazard is of concern in more than about 40 percent of that zone. A cross is used as a modifier to indicate that a particular geotechnical hazard is a localized one as well as being a potential problem throughout the zone. The symbols, then, are intended to indicate the potential for distribution within a zone rather than the severity of the hazard within that zone. In the case of slope stability in Zone IV, the sequence of symbols is reversed from that in all other cases to emphasize that slope instability is a major potential hazard in many parts of this zone.

B.3. LEVELS OF ACCEPTABLE RISK AND DAMAGE RELATED TO KIND OF FACILITY AND OCCUPANCY

RISK CLASS 1 - HIGHLY CRITICAL STRUCTURES AND OCCUPANCIES

Structures whose continued functioning is critical, or whose failure might be catastrophic: large dams, power intertie systems, nuclear reactors, plants manufacturing or storing explosives or toxic materials.

Acceptable Damage: None which would expose large population to death or serious injury or impair the safety of the facility or disrupt its function.

Acceptable Location: Areas of low environmental hazard, unless it can be shown through specific site studies that the hazards associated with location in a moderate or high risk area can be mitigated to the point that the level of risk is negligible.

RISK CLASS 2 - STRUCTURES CRITICALLY NEEDED AFTER DISASTER

Structures whose use is critically needed after a disaster: important utility centers; hospitals; fire, police, and emergency communication facilities; fire stations; and critical transportation elements such as bridges and overpasses; also smaller dams.

Acceptable Damage: Minor nonstructural; facility should remain operational and safe, or be susceptible to quick restoration of service.

Acceptable Location: Areas of low environmental hazard, unless it can be shown through site studies that the hazards associated with location in a moderate or high risk area can be mitigated to the point that the level of risk is negligible.

RISK CLASS 3 - HIGH OCCUPANCY STRUCTURES

Structures of high occupancy, or whose use after a disaster would be particularly convenient: schools, churches, theaters, large hotels, and other high-rise buildings housing large numbers of people; other places normally attracting large concentrations of people; civic buildings, such as fire stations; secondary utility structures; extremely large commercial enterprises; most roads and alternative or noncritical bridges and overpasses.

Acceptable Damage: No structural damage which would materially impair safety; structures should remain usable; some impairment of function acceptable.

B.3 (CONTINUED). LEVELS OF ACCEPTABLE RISK AND DAMAGE RELATED TO KIND OF FACILITY AND OCCUPANCY

Acceptable Location: Areas of low or moderate environmental hazard, unless it can be shown through site studies that the hazards associated with location in a high risk area can be mitigated to the point that structures remain safe and usable.

RISK CLASS 4 - ORDINARY RISK TOLERANCE

The vast majority of structures in urban areas: most commercial and industrial buildings, small hotels, and apartment buildings, and single family residences.

Acceptable Damage: Some structural as well as nonstructural damage excluding collapse.

Acceptable Location: Areas of low or moderate environmental hazard, unless it can be shown through site studies that the hazards associated with location in a high risk area can be mitigated to the point that structures will remain standing.

RISK CLASS 5 - MODERATE TO HIGH RISK TOLERANCE

Open space uses, such as farms, ranches, and parks without high occupancy structures; warehouses with low intensity employment storing nonhazardous materials.

Acceptable Damage: Not applicable.

Acceptable Location: Areas of low, moderate, or high environmental hazard.

DEFINITION OF ACCEPTABLE RISK

This section: (a) defines the term acceptable risk, (b) assigns various structures, occupancies, and land uses to risk classees, (c) defines what constitutes acceptable damage to structures in each risk class, and (d) defines high hazard areas.

Acceptable Risk. The term acceptable risk is used to describe the level of risk that the majority of citizens will accept without asking for governmental action to provide protection.

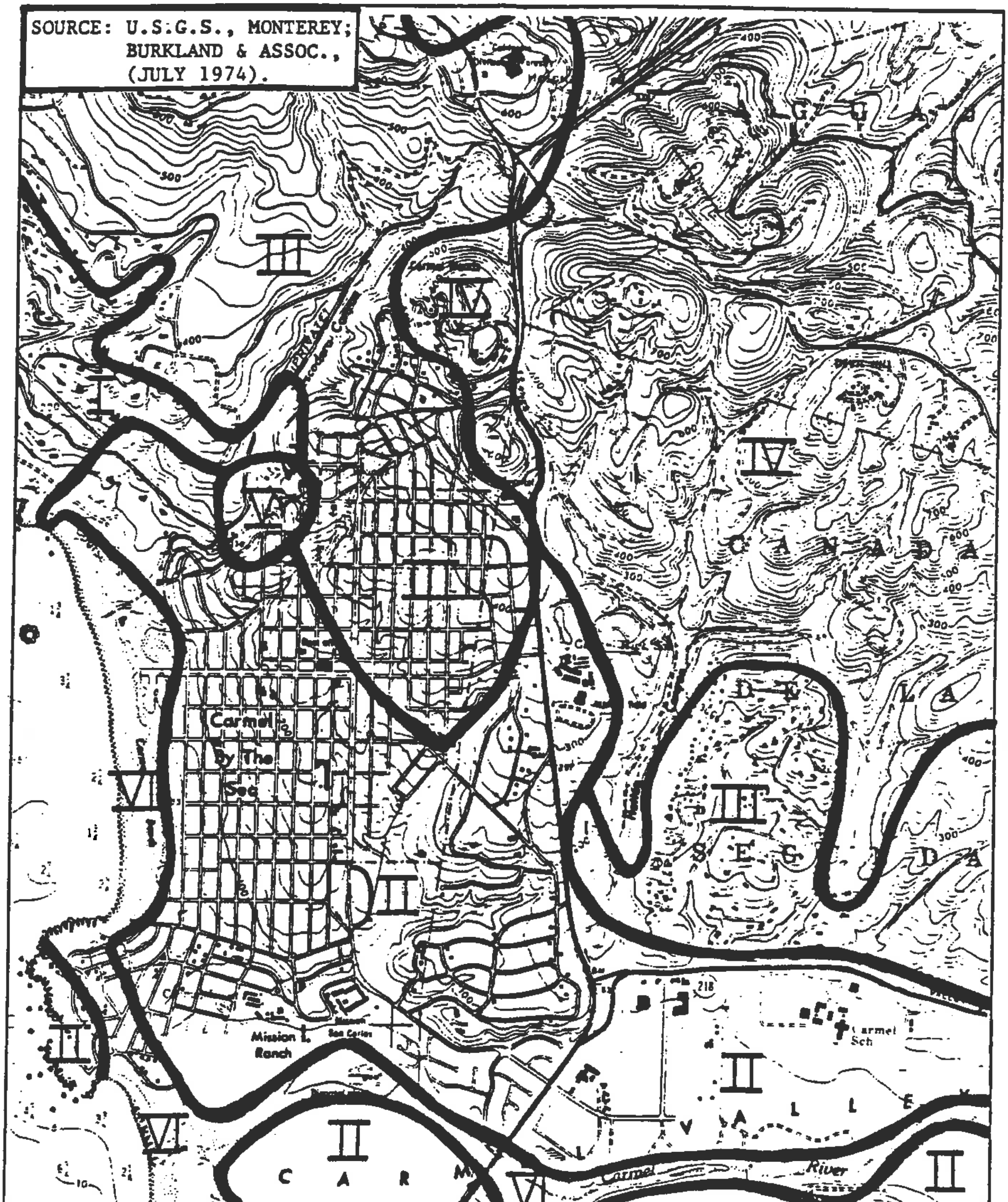
Classification of Structures and Occupancies. Five classes of structures and occupancies are established for the purpose of risk rating. The first two classes include critical facilities and occupancies: those structures and occupancies which are especially important for the preservation of life, the protection of property, or for the continuing functioning of society. Less critical structures and occupancies are include in Classes 3, 4, and 5.

Table B.3, describes the kinds of facilities and occupancies in each class. Except where otherwise indicated, damage relates to that which could be expected from an earthquake of magnitude 8.3 on the Richter scale with an epicenter within 50 miles. This is similar in magnitude to the 1906 earthquake on the San Andreas Fault (and is defined as a great earthquake) (Spangle, 1975)

High Hazard Areas. For the purpose of applying seismic safety policy, the following areas are defined as high hazard areas:

- zones one eighth mile each side of active or potentially active faults;
- areas of tsunami hazard;
- areas on Figure 7.1 indicated as subject to liquefaction, strong ground shaking, and landsliding; and
- geotechnical evaluation zones IV, V, and VI of Figure B-1.

Acceptable damage is damage incurred during the maximum possible event such as the 100 year flood or the maximum probable earthquake. Acceptable locations for each class of structures are also given based on the environmental hazard classification of the site upon which the building is planned. Geotechnical evaluation zones II and III may be considered generally moderate hazard areas, and zone I may be considered a generally low hazard area. Proposed building sites must be considered on an individual basis, however, since local variations exist at scales smaller than is indicated on the accompanying maps. Boundaries shown are only approximate and units are generalized as explained earlier.



Carmel-by-the-Sea

N
SCALE
1" = 2000'

FIGURE B.1 GEOTECHNICAL EVALUATION MAP

Refer to TABLE B.2 DISTRIBUTION OF HAZARDS

GEOTECHNICAL EVALUATION MAP

Figure B-1 indicates six classes of zones ranging in prevalence of seismic hazards from Zone I (least) to Zone VI (greatest). Table B.2. illustrates the extent of the hazards within each zone. It is possible to zone and describe the seismic hazards through a single chart because of the similarity of physical conditions prevailing throughout this area. The hazard ratings noted on the geotechnical maps are general, indicating the distribution of conditions to be expected within the areas in each class of zone shown on the map. The ratings of the several hazards should be used with caution in making judgments regarding the relative capability of lands to support any particular use, existing or prospective. Although the maps should be helpful in preliminary evaluation of sites for specific facilities and uses, extreme caution is needed to avoid drawing erroneous conclusions because of the generality of the basic information.

The boundaries shown on the Geotechnical Evaluation map are only approximate and the units shown are necessarily generalized on the basis of topographic, geologic, and soil data available for interpretation. The boundaries, then, are subject to modification and adjustment in the event of more detailed studies in those locations. The maps can be utilized for planning purposes to determine areas of relatively low geotechnical hazard potential for development in relation to areas of greater or high hazard potential. Certain high hazard areas may be unavoidable, so it is important to require sufficiently detailed geotechnical studies to properly identify the extent of the hazards and provide mitigating measures for the planned land usage or proposed development in such areas.

In making recommendations for future geotechnical investigations, it is necessary to take into account the type of planned land usage and the geotechnical conditions affecting each site. Recommended procedures for determining the type and extent of future geotechnical investigations are included later in this element.