MARIN COUNTYWIDE PLAN

Geology, Mineral Resources and Hazardous Materials Technical Background Report

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF EXHIBITS

I. PURPOSE AND EXECUTIVE SUMMARY

This technical background report evaluates the existing geologic (seismic and non-seismic) hazards, mineral resource issues and hazardous material issues affecting the County of Marin. This report is provided to assist County staff in updating the previous Countywide Plan (adopted on January 18, 1994) by incorporating more recent and updated information and to provide recently available information that can be incorporated into the County GIS mapping system.

II. GEOLOGIC LEGISLATION

A. Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act was signed into law December 22, 1972, and went into effect March 7, 1973. The Act, codified in the Public Resources Code as Division 2, Chapter 7.5, has been amended eleven times. The Act was enacted to regulate development near active faults in order to mitigate the hazard of surface fault rupture. In general, the Act has two requirements:

- Prohibiting the location of "developments and structures for human occupancy" across the trace of active faults; and,
- Establishing Earthquake Fault Zones as defined by the State Geologist, within which affected cities and counties must establish special procedures for reviewing and approving applications for new building permits within the Zones.

This law initially was designated as the Alquist-Priolo Geologic Hazard Zones Act. The Act was renamed the Alquist-Priolo Special Studies Zone Act effective May 4, 1975 and the Alquist-Priolo Earthquake Fault Zoning Act effective January 1, 1994. The original designation "Special Studies Zones" was changed to "Earthquake Fault Zones" when the Act was last renamed (Hart and Bryant, 1999).

Under the Act, the State Geologist (Chief of the California Geological Survey (CGS)) is required to delineate "Earthquake Fault Zones" along known active faults in California. Cities and counties affected by the zones must regulate certain development "projects" within the zones. They must withhold development permits for sites within the zones until geologic investigations demonstrate that the sites are not threatened by surface displacement from future faulting. The State Mining and Geology Board provides additional regulations (Policies and Criteria) to guide cities and counties in their implementation of the law (California Code of Regulations, Title 14, Div. 2) (Hart and Bryant, 1999). The principal responsibilities and functions for Cities and Counties required by the Alquist-Priolo Act, include:

- Must adopt zoning laws, ordinances, rules, and regulations; primary responsibility for implementing Act (Sec. 2621.5).
- Must post notices of new Earthquake Fault Zone Maps (Sec. 2621.9 and 2622).
- Regulates specified "projects" within Earthquake Fault Zones (Sec. 2623).
  1. Determines need for geologic reports prior to project development.

2. Approves geologic reports prior to issuing development permits.
3. May initiate waiver procedures.

As defined in the Act, an “active fault” is a fault that has had surface displacement within Holocene time (about the last 11,000 years). The San Andreas Fault Zone (SAFZ) is the only known on-land “active fault” and only zoned fault within the boundaries of Marin County. Eight Earthquake Fault Zone maps cover the SAFZ and show the “active” traces of the fault in Marin County. The Earthquake Fault Zones are shown on the following U.S. Geological Survey 1:24,000 scale 7½-minute quadrangles: Bodega Head, Bolinas, Double Point, Drakes Bay, Inverness, Point Reyes, Tomales, and Valley Ford. There have been no changes to the Earthquake Fault Zone Maps within Marin County since all eight quadrangle maps were issued on July 1, 1974 and no new maps have been issued within the County since July 1, 1974 (CDMG, 2000).

B. Seismic Hazards Mapping Act

1. Purpose and Programs

The State Legislature passed the Seismic Hazards mapping Act in 1990, which was codified in the Public Resources Code as Division 2, Chapter 7.8, which became operative on April 1, 1991. The purpose of the Act is to identify areas where earthquakes are likely to cause shaking, liquefaction, landslides, or other ground failure, and to regulate development so as to reduce future earthquake losses (CDMG, 2001a). The Act requires that various governmental agencies and private parties undertake specific responsibilities of the Act (CDMG, 2001b). The following is a list, mostly derived from CDMG (2001a), of the agencies and their responsibilities and functions under the Act.

a. State Mining and Geology Board

- The Seismic Hazards Mapping Act establishes the authority of the State Mining and Geology Board to provide policy and guidance through regulations for a statewide seismic hazard mapping and technical advisory program to assist cities, counties and state agencies in fulfilling their responsibilities for protecting the public health and safety from the effects of strong ground shaking, liquefaction or other ground failure, landslides and other seismic hazards caused by earthquakes, including tsunami and seiche threats.
- The authority includes providing programs to identify and map seismic hazard zones in the State in order for cities and counties to adequately prepare the safety element of their general plans and to encourage land use management policies and regulations to reduce and mitigate those hazards so as to protect public health and safety (State Mining and Geology Board, 2000).

b. State Geologist

- Compile maps identifying Seismic Hazard Zones, for protecting the public health and safety from the effects of strong ground shaking, liquefaction, landslides, or other ground failure and other seismic hazards caused by earthquakes.
- Submit the compiled Seismic Hazard Maps to all affected cities, counties, state agencies, and the State Mining and Geology Board for review and comment. Following this review, the State Geologist may revise the maps, as appropriate, and must provide Official Maps to affected cities, counties, and state agencies, and the appropriate county recorder.

c. Cities and Counties

- Post notices at the offices of the county recorder, county assessor, and county planning commission, and other appropriate sites, identifying the location of any Seismic Hazard Zone Maps issued by the State Geologist that cover their County.
- Record information received: Upon receiving copies of the Official Maps of Seismic Hazard Zones, the county recorder shall record all information transmitted as part of the public record.
- Regulate specified "projects" within Seismic Hazard Zones:
  1. Determine the need for geotechnical reports prior to development projects. The purpose, scope, and requirements for project approval are outlined in CCR Section 3724(c).
  2. Review and determine acceptability of geotechnical reports prior to issuing development permits.
  3. Submit a copy of each acceptable geotechnical report, including the mitigation measures, if any that are to be taken, to the State Geologist within 30 days of report acceptance.
- Take Seismic Hazard Zone Map information into account in the safety element of the general plan and in land-use planning and permitting ordinances.
- Collect building fee and remit to the Department of Conservation. The city or county may retain up to 5 percent for data utilization, certain types of earthquake education, and, under certain circumstances, for improving preparedness for post-earthquake damage assessment.

d. Seismic Safety Commission

- Advise the State Geologist and the State Mining and Geology Board.

e. Sellers of Real Property or Their Agents.

- Disclosure: Sellers of any real property located within a Seismic Hazard Zone must notify prospective buyers of that fact.

The Seismic Hazards Mapping Act requires the State Geologist to establish the regulatory zones titled "Zones of Required Investigation," and to issue appropriate maps titled: "Seismic Hazard Zone maps." The regulatory zones encompass areas prone to liquefaction (failure of water-saturated soil) and earthquake-induced landslides. These maps are distributed to all affected cities, counties, and state agencies for their use in planning and controlling construction and development. Single-family frame dwellings up to two stories not part of a development of four or more units are exempt from the state requirements. However, local agencies can be more restrictive than state law requires. If a property is located in a zone, the state has determined that there may be weak soil and/or rock underlying the property. If present, these weak materials can fail during an earthquake and, unless proper mitigative measures are taken during grading and construction, can cause damage to structures. Before a development permit can be issued or a subdivision approved, cities and counties must require a site-specific investigation to determine whether a significant hazard exists at the site and, if so, recommending mitigating measures to reduce the risk to an acceptable level. The investigation must be performed by state-licensed engineering geologists and/or civil engineers. If the property lies within a mapped Seismic Hazard Zone, that fact must be disclosed by the seller to prospective buyers (CDMG, 2001c).

The CGS has released Official Seismic Hazard Zone Maps, affecting counties and cities in Northern and Southern California (CGS, 2005). At the present time, no maps have been issued in Marin County.

Maps that are created by the CGS use digital data that can be implemented into a GIS system. The raw digital data that is put into the system is made available for public agencies. When maps are completed for portions of Marin County the raw data should be available to be used in the Marin County GIS system.

2. Guidelines for Mitigation

The CDMG released Special Publication 117: "Guidelines for evaluating and mitigating seismic hazards in California," in 1997 to provide specific guidelines for engineering geologists and civil engineers for evaluating and providing mitigation measures for seismic hazards. The objectives of the guidelines include:

- Assisting in the evaluation and mitigation of earthquake-related hazards for projects within designated zones of required investigations; and,
- Promoting uniform and effective statewide implementation of the evaluation and mitigation of the Seismic Hazards Mapping Act.

These guidelines represent the current standard of care for assessing and mitigating seismic hazards in California and are established as the minimum public safety standard for mitigation of earthquake hazards. The minimum level of mitigation for a project should "reduce the risk of ground failure during an earthquake to a level that does not cause the collapse of buildings for human occupancy, but in most cases, not to a level of no ground failure at all."

C. GEOLOGIC HAZARD ABATEMENT DISTRICTS (GHAD)

Geologic Hazard Abatement Districts (GHADs) were enacted by the Beverly Act of 1979 (SB1195) and allow local residents to collectively mitigate geological hazards that pose a threat to their properties. GHADs are designed to handle long-term abatement and maintenance of real property potentially threatened by geologic hazards (Rogers, 2001). They are enabled by Division 17 of the Public Resources Code, Sections 26500 – 26654.

GHADs may be formed for the following purposes:

- Prevention, mitigation, abatement, or control of a geologic hazard; and,
- Mitigation or abatement of structural hazards that are partly or wholly caused by geologic hazards.

A geologic hazard is defined by the Code as "an actual or threatened landslide, land subsidence, soil erosion, earthquake, fault movement, or any other natural or unnatural movement of land or earth. Historically, GHADs have generally been used as a method for mitigating a landslide hazard that crosses several property boundaries. In Marin County, a recently proposed GHAD involves mitigation of large landslides at Easton Point in the Town of Tiburon (Town of Tiburon, 2001). Establishment of a GHAD can provide a useful mechanism to ensure proper inspection and monitoring of the effectiveness of mitigation measures for a geologic hazard and for undertaking routine maintenance of facilities required to minimize the hazard's impacts. Other abatement districts that have worked well in the past have occurred in Blackhawk, Clayton, Moraga, Orinda, Palos Verdes, San Rafael, and San Ramon.

The formation of a GHAD district may be initiated either by a petition signed by owners of not less than 10 percent of the real property to be included within the proposed district; or, by resolution of the legislative body of a local agency; such as, a city or county. Formation must also include a "plan of control." This "plan of control" must include a report prepared by a certified engineering geologist that describes the geologic hazard in detail, including its location and affected area, and a plan for the prevention, mitigation abatement, or control thereof. Olshansky (1986) states:

> "It is a mechanism that responds to the physical realities of landslides, and allows property owners to cooperate in solving a common problem. It removes much of the stigma l of legal liabilities among adjacent landowners and allows them to cooperate rather than litigate. It also provides a cost-effective solution, requiring only one geotechnical engineering firm and one plan to solve the problems of several landowners."

Because of the many geologic hazards within the boundaries of Marin County, especially landslides, GHADs can provide a useful tool for effectively mitigating these hazards.

D. SUMMARY AND ISSUES TO CONSIDER

- The existing County policies regarding the Alquist-Priolo Earthquake Fault Zoning Act should continue to be enforced (Existing policies EH-4.1, EH-4.2, EH-4.3 and EH-4.4 and their supporting programs).
- A similar set of policies should be created to address the future Seismic Hazard Zone maps in Marin County that will eventually be issued under the Seismic Hazards Mapping Act.
- Geologic hazard abatement districts can be an effective tool for managing geologic hazard areas and reducing the risks posed by some hazards, especially landsliding, and therefore should be encouraged.

III. GENERAL GEOLOGIC SETTING

A. REGIONAL TECTONIC FRAMEWORK AND GENERAL GEOLOGIC HISTORY

Marin County is located in the central portion of the Coast Range geomorphic province (Exhibit 1). This province extends about 600 miles along the western edge of California and is bounded to the south by the Transverse Ranges, to the north by the Klamath Mountains and to the east by the Great Valley. The Coast Range geomorphic province is dominated by northwest-southeast trending ridges and valleys. The development of the coast range geomorphic province has been controlled by the dynamics of plate tectonics.

Plate tectonics provides a broad mechanical framework for presenting and understanding the geology and geologic hazards present in Marin County. The upper crust of the earth consists of rigid plates that move relative to each other and interact dynamically with each other at their boundaries. The geology of California has been dominated by the interaction of the Pacific and North American plates. The currently active boundary between these two plates is surficially manifested by the northwest-southeast

Exhibit 1.
Regional Geologic Setting of the Coast Ranges

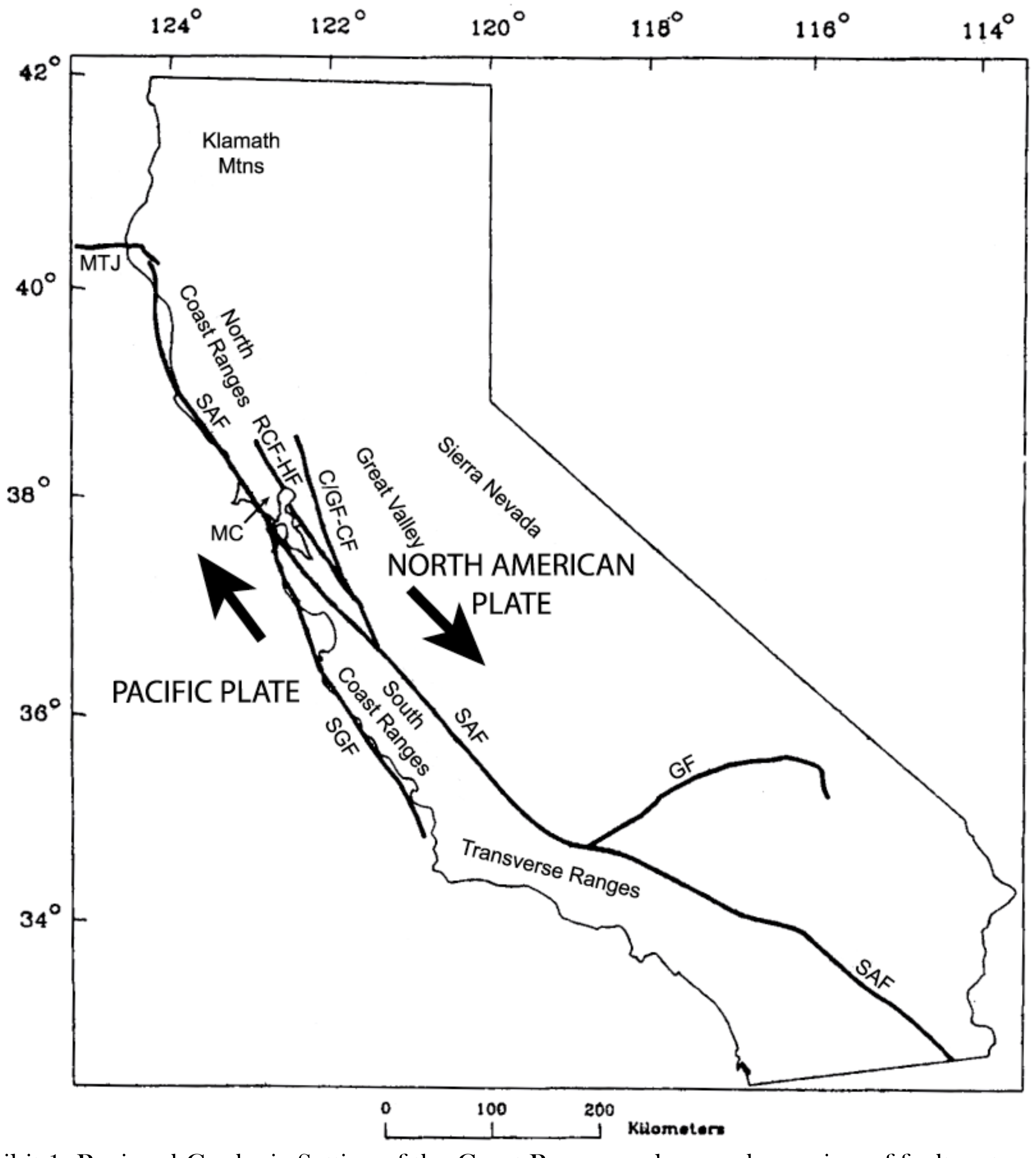


Exhibit 1. Regional Geologic Setting of the Coast Ranges and general overview of fault systems (C/GF-CF, Concord/Green Valley and Calaveras Faults; GF, Garlock Fault; MC, Marin County; MTJ, Mendocino Triple Junction; RCF-HF, Rodgers Creek and Hayward Faults; SAF, San Andreas Fault; SGF, San Gregorio Fault); modified from Jones et al. (1994). Large arrows indicate relative motion of the North American and Pacific plates.

trending San Andreas Fault Zone (SAFZ) that separates the Point Reyes Peninsula from the remaining eastern portion of Marin County. Point Reyes Peninsula is located on the Pacific tectonic plate and that portion of the County east of the SAFZ is located on the North American plate. This dividing zone occurs within the northwest-southeast trending Olema Valley, Tomales Bay and Bolinas Lagoon.

The following general description of the regional geologic history is largely derived from Blake et al. (2000). The bedrock east of the SAFZ consists of Mesozoic (Table 1) rocks unconformably overlain by Tertiary (Miocene and younger) deposits. These rocks represent a complex history that includes late Mesozoic to early Cenozoic subduction and accretion, subsequent uplift and detachment faulting, and Neogene oblique reverse faulting that continues to the present time (Blake et al., 2000). The Mesozoic rocks consist of the Great Valley complex and the Franciscan complex. The Great Valley complex represents the accreted and deformed remnants of Jurassic oceanic crust and a thick sequence of turbidites (disturbed deep ocean sediments). The Franciscan complex rocks were probably Jurassic oceanic crust and Jurassic to Cretaceous pelagic deposits (marine sediments) overlain by Upper Jurassic to Upper Cretaceous turbidites. During Late Cretaceous time, the Franciscan complex was subducted beneath the Coast Range, which resulted in the deformed and sheared rocks that are present. During late Miocene, the regional tectonic regime changed and became dominated by the transform boundary of the San Andreas fault system and deposition of sediments on the older complexes.

The bedrock west of the SAFZ is part of what is known as the Salinian complex. The oldest rocks in this complex consist of Upper Cretaceous granitic rock with pendants of older metamorphic rocks. These rocks are immediately west of the SAFZ. These older rocks are nonconformably overlain by Tertiary rocks comprised of three sedimentary sequences separated by unconformities (break or gap in the geologic record). The portion of the Salinian complex of Point Reyes peninsula appears to have been displaced northward approximately 94 miles on the San Gregorio fault over the last 11 to 12 million years. The granitic rocks, early Eocene conglomerates, and other younger sedimentary rocks are very similar to rocks on the east side of the San Gregorio fault in the Monterey Peninsula region. This northward displacement continues intermittently to this day and the last great movement occurred during the 1906 earthquake where horizontal ground displacements between 13 to 20 feet were recorded in the SAFZ from Bolinas Lagoon to Tomales Bay (Brown and Wolfe, 1972).

The Pleistocene to recent geologic history of Marin County has played a large role in creating the steep topography and recent sedimentation along the boundaries of the upland areas. During the last Pleistocene major high stand of sea level (known as the Sangamon interglacial stage), about 115,000 years ago, The sea level encroached into the San Francisco Bay and deposited Yerba Buena (Old Bay) Mud. Following this last high stand the sea level began to recede during the Wisconsin glacial stage, 90,000 to 11,000 years ago. During the Wisconsin glacial stage the sea level dropped as much as 350 feet below the present elevation. This drained the bay and led to significant erosion due to rejuvenation and increased incisement of stream channels; thereby, cutting steeper topography into the Marin uplands (Helley et al., 1979; Rogers and Figuers, 1991).

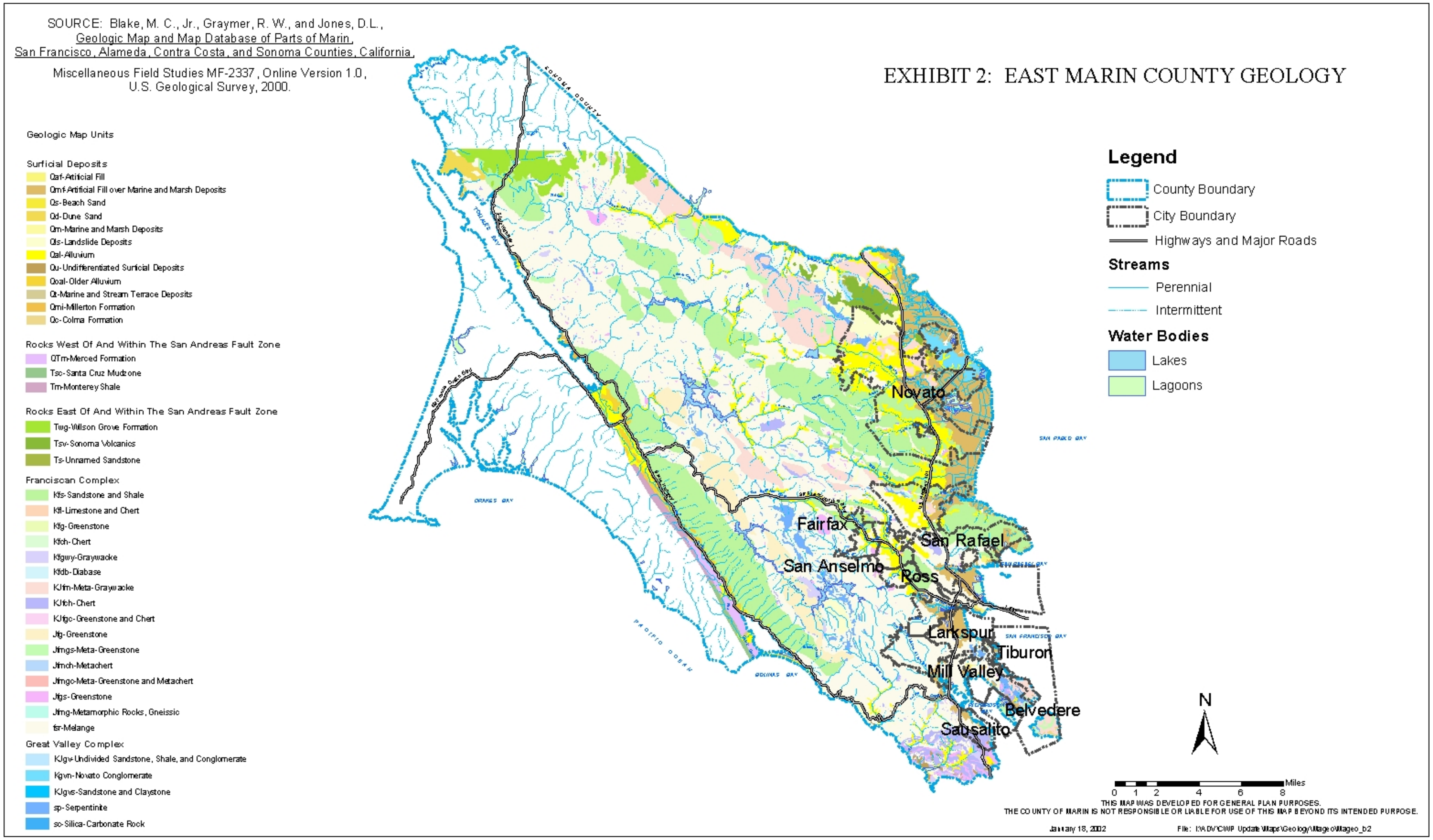
As the Wisconsin glacial stage ended about 11,000 years ago, the rising sea entered through the Golden Gate between 11,000 and 10,000 years ago at a rate of about 1-inch per year and spread across the low-lying flatlands as rapidly as 10 feet/year until 8,000 years ago (Atwater et al., 1977). From 8,000 years ago to the present the shoreline changes have been more gradual. The declining rate of sea-level rise was finally surpassed by the rate of sediment accumulation in the estuaries resulting in growth (progradation) of mudflats and salt marshes by deposition of estuarine Bay Muds. Most of this growth has been within the last several thousand years (Atwater et al., 1977).

Table I –
The Geologic Time Scale

Era	Period	Epoch	Time Interval (in years ago)
Cenozoic	Quaternary	Holocene	10,000 to present
		Pleistocene	1.8 million to 10,000
	Tertiary	Pliocene	5.3 to 1.8 million
		Miocene	23.8 to 5.3 million
		Oligocene	33.7 to 23.8 million
		Eocene	55.5 to 33.7 million
		Paleocene	65 to 55.5 million
Mesozoic	Cretaceous		145 to 65 million
	Jurassic		213 to 145 million
	Triassic		248 to 213 million
Paleozoic			544 to 248 million

Modified from USGS (1999).

EXHIBIT 2: EAST MARIN COUNTY GEOLOGY



B. GEOLOGY EAST OF THE SAN ANDREAS FAULT ZONE

Exhibit 2 presents the general geologic units east of the SAFZ. This map is a compilation of previously published and unpublished maps and new geologic mapping and field checking by Blake et al. (2000) and issued as U.S. Geological Survey Miscellaneous Field Studies Map MF-2337, Version 1.0. The map data was released in digital form so that it could be used in a GIS database. The data for the entire map, including geologic units along the SAFZ (west side of the map) are shown. Some units along the SAFZ overlap or are redundant with units shown in the same area on Exhibit 3 (Geology West of the San Andreas Fault Zone). This is because these maps were prepared separately and by different authors. The list of map units in Exhibit 2 shows all mapped units, their unit name and age (in parentheses). These map units can be separated into two main categories: bedrock and surficial deposits. A general description of the rock types within these main categories is described below and is mostly derived from Blake et al. (2000).

1. Bedrock

Bedrock is the classification for all the rock material that underlies the younger surficial deposits and soil. The bedrock in Marin County east of the SAFZ can be separated into two categories based on time of deposition. The bedrock younger units consist of those rocks that are part of the Tertiary overlap sequence, which rest with an angular unconformity on the older bedrock Mesozoic complexes.

The oldest rocks in Marin County, east of the SAFZ, are those that belong in the Franciscan and Great Valley complexes. The rocks in both of these complexes are Cretaceous and Jurassic in age. The Great Valley complex represents the accreted and deformed remnants of Jurassic oceanic crust, known as the Coast Range ophiolite, and a thick sequence of marine sediments. The Franciscan complex rocks were probably Jurassic oceanic crust and Jurassic and Cretaceous marine sediments that were at least partially subducted and accreted beneath the Coast Range ophiolite (Blake, et al., 2000).

In Marin County, the Great Valley complex underlies portions of northwest Marin County in the vicinity of Burdell Mountain and southeast of Novato. The majority of the rocks consist of conglomerates, sandstones and shales. Southeast of Novato a significant outcrop of conglomerate is present, which is mapped as the Novato conglomerate. The Novato conglomerate is considered to be relatively strong and stable rock (Rice, 1973).

The Franciscan complex underlies the majority of Marin County, east of SAFZ, and many of the rock characteristics of this complex are responsible for many of the hazards discussed. The Franciscan complex is dominated by the mélange, which was first defined by Hsu (1968) as:

> "mappable bodies of deformed rocks characterized by the inclusion of native and exotic blocks, which may range up to several miles long, in a pervasively sheared, commonly pelitic [rock composed of clay] matrix."

Exhibit 2 shows several large zones of northwest-southeast trending blocks of rock bounded by faults and numerous smaller inclusions of rock within the mélange. This geologic terrain is characteristic of the Franciscan complex in the Coast Range and dominates the geology of Marin County. In general, the rocks other than mélange are composed of weakly to strongly metamorphosed sandstone, shale, limestone, chert, greenstone, serpentinite, greywacke, diabase, greenstone and various metamorphic rocks.

The characteristics and behavior of these various rocks are dependent on many variables; such as, the degree of weathering, presence of bedding, extent of fracturing and degree of induration. For example, greenstone in one portion of the County may be highly fractured and weathered relative to greenstone in other portions of the County. This variability of rock characteristics is site-specific and not all-inclusive. Mélange, on the other hand, is relatively consistent throughout the County. It is characteristically inherently weak and pervasively sheared. It is the source of highly expansive soils and the reason for pervasive landsliding east of the SAFZ.

The Pliocene aged Wilson Grove Formation consists of sandstone that underlies much of the north portion of the County and was deposited during the Pliocene. Previous maps in the area questionably labeled this unit as the "Merced" Formation (Blake et al., 1971; Blake et al., 1974). The Pliocene and Miocene aged Sonoma volcanics are generally located at Burdell Mountain and vicinity and are about 12 million years old. The Sonoma volcanic rocks are generally stable; however, large landslides in the Sonoma volcanics are present south and southwest of Burdell Mountain. These landslides failed in the older underlying weaker materials. Miocene aged sandstone is also present in the same vicinity.

2. Surficial Deposits

The surficial deposits on the map are deposits that have been deposited within the Quaternary, which is within the last 1.8 million years. The youngest deposits in this category are loose and soft sediments and debris deposited within the last 10,000 years (Holocene). These deposits are typically those that are the most susceptible to seismic shaking, liquefaction and differential settlement. In many locations, deposition of these units is ongoing. These deposits include artificial fill, artificial fill over marine and marsh deposits (young bay mud), beach sand, dune sand, marine and marsh deposits (young bay mud), landslide deposits, alluvium, and slope debris and ravine fill (also labeled as colluvium in portions of the text). The geologic map includes a unit of undifferentiated surficial deposits (Qu) that may include any of the units listed above and older Quaternary deposits.

The older Quaternary deposits are those mapped units that were deposited in the Quaternary, but are no longer actively being deposited. They have been deposited within the Pleistocene Epoch between 10,000 to 1.8 million years ago. These units include: volcanic gravel, older beach deposits, older alluvium, marine and stream terrace deposits, Millerton Formation and the Colma Formation. These older units may also have an increased susceptibility to seismic shaking, liquefaction, differential settlement and landsliding because they have generally not been buried deep or long enough to become well compacted and indurated. However, in general they are less susceptible to geologic hazards than the younger surficial deposits.

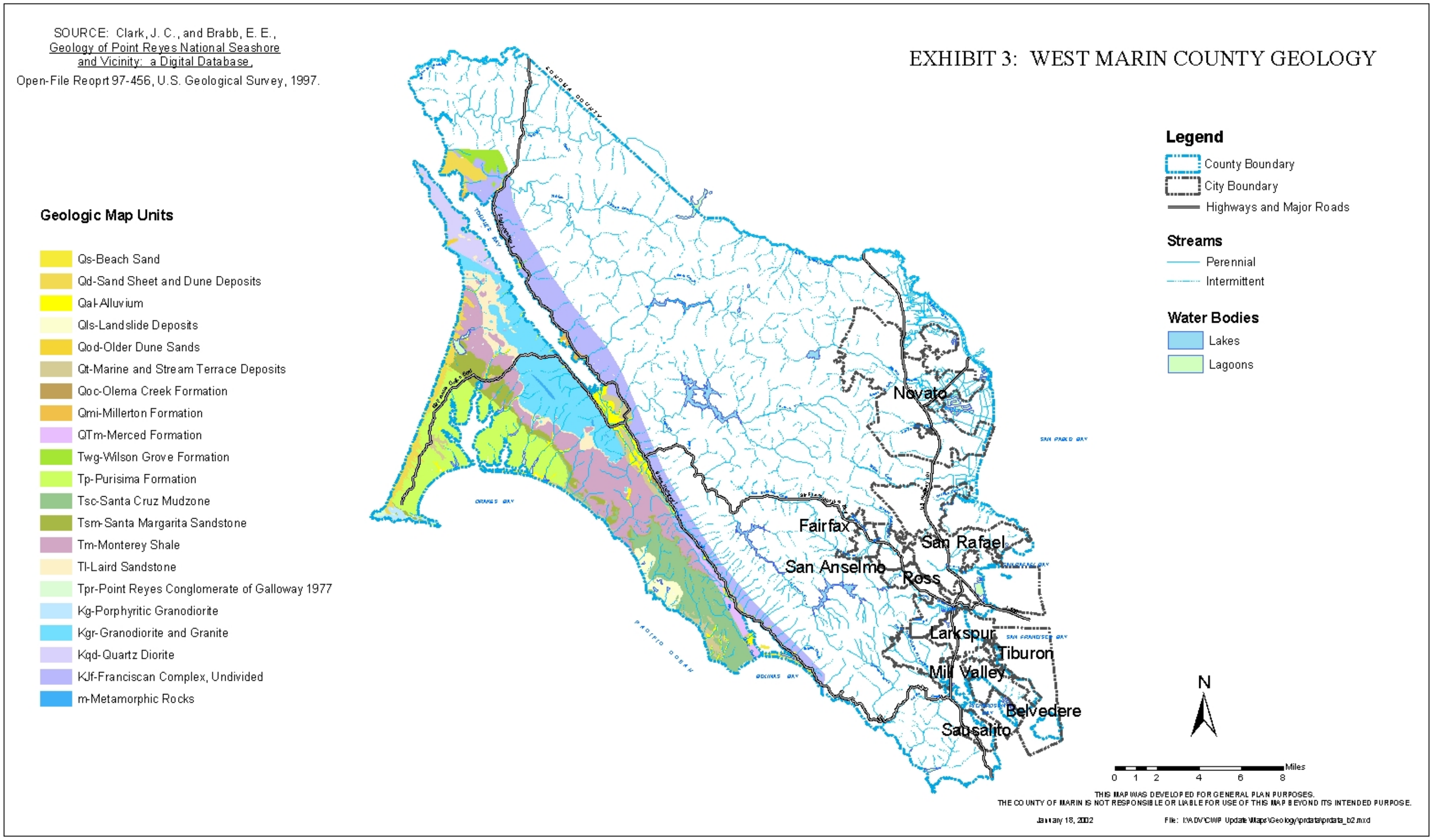
C. GEOLOGY WEST OF THE SAN ANDREAS FAULT ZONE

Exhibit 3 presents the general geologic units west of the SAFZ. This map is a compilation of previously published and unpublished maps and new geologic mapping and field checking by Clark and Brabb (1997) and issued as U.S. Geological Survey Open-File Report 97-456. The map data was released in digital form so that it could be used in a GIS database. The data for the entire map, including geologic units along the SAFZ (west side of the map) are shown. Some units along the SAFZ overlap or are redundant with units shown in the same area on Exhibit 2 (Geology East of the San Andreas Fault Zone). This is because these maps were prepared separately and by different authors. The list of map units in Exhibit 3 shows all mapped units, their unit name, age (in parentheses), and a brief description. These map units can also be separated into two main categories: bedrock and surficial deposits. A general description of the rock types within these main categories is described below and mostly taken from Clark and Brabb (1997).

1. Bedrock

The oldest rocks in Marin County, west of the SAFZ, consist of intrusive igneous rocks of Upper Cretaceous age with inclusions, also known as pendants, of older metamorphic rocks. These rocks are the underlying basement rocks west of the SAFZ, which is known as the Salinian complex. The Porphyritic granodiorite of Point Reyes crops out at the resistant cliffs of Point Reyes. Tonalite of Tomales Point underlies only this portion of the Peninsula. The granitic rocks continue south from Tomales Point and the uplands of Inverness ridge consist of granodiorite and granite.

These Upper Cretaceous rocks are nonconformably overlain by a package of Tertiary sedimentary rocks. The oldest Tertiary rock is the late Eocene Point Reyes Conglomerate, which is present at the west end of the Peninsula, overlying the granodiorite of Point Reyes. Along the eastern side of the Point Reyes Peninsula, the granitic rocks are overlain by the middle Miocene Laird Sandstone. The Laird Sandstone typically consists of light brown, medium to coarse-grained poorly cemented sandstone that rests on the granitic rocks in the northern half of the peninsula. The Monterey Formation, consisting of porcelanite and chert, is predominately in the central portion and southern half of the Peninsula. The retreating cliffs near Bolinas are undercut Monterey Formation rocks that fail along bedding planes. These older sedimentary rocks are up to 5,300 feet thick.


SOURCE: Clark, J. C., and Brabb, E. E.,
Geology of Point Reyes National Seashore
and Vicinity: a Digital Database,
Open-File Reoprt 97-456, U.S. Geological Survey, 1997.
EXHIBIT 3: WEST MARIN COUNTY GEOLOGY
Geologic Map Units
Qs-Beach Sand
Qd-Sand Sheet and Dune Deposits
Qal-Alluvium
Qls-Landslide Deposits
Qod-Older Dune Sands
Qt-Marine and Stream Terrace Deposits
Qoc-Olema Creek Formation
Qmi-Millerton Formation
QTm-Merced Formation
Twg-Wilson Grove Formation
Tp-Purisima Formation
Tsc-Santa Cruz Mudzone
Tsm-Santa Margarita Sandstone
Tm-Monterey Shale
Tl-Laird Sandstone
Tpr-Point Reyes Conglomerate of Galloway 1977
Kg-Porphyritic Granodiorite
Kgr-Granodiorite and Granite
Kqd-Quartz Diorite
KJf-Franciscan Complex, Undivided
m-Metamorphic Rocks
Legend
County Boundary
City Boundary
Highways and Major Roads
Streams
Perennial
Intermittent
Water Bodies
Lakes
Lagoons
Novato
Fairfax
San Rafael
San Anselmo
Ross
Larkspur
Tiburon
Mill Valley
Belvedere
Sausalito
N
0 1 2 4 6 8
Miles
THIS MAP WAS DEVELOPED FOR GENERAL PLAN PURPOSES.
THE COUNTY OF MARIN IS NOT RESPONSIBLE OR LIABLE FOR USE OF THIS MAP BEYOND ITS INTENDED PURPOSE.
January 18, 2002

All of the older rocks described above are unconformably overlain by a sequence of upper Miocene to lower Pliocene sedimentary rocks approximately 8,500 feet thick. The basal unit consists of the Santa Margarita Sandstone, which consists of glauconitic and bituminous arkosic sandstone. This is overlain by a siliceous mudstone unit named the Santa Cruz Mudstone and a siltstone, sandstone and mudstone unit named the Purisima Formation. These three units correlate with rocks in the Santa Cruz Mountains and are given the same formational names because of similar stratigraphic, lithologic, and fossil relationships. As described briefly in the general geology section, they have been horizontally offset from the Santa Cruz Mountain correlative units due to movement on the San Gregorio and SAF.

2. Surficial Deposits

As discussed in the section east of the SAFZ, the surficial deposits on the map are deposits that have been deposited within the Quaternary, which is within the last 1.8 million years. The youngest deposits in this category are loose and soft sediments and debris deposited within the last 10,000 years (Holocene). These deposits are typically those that are the most susceptible to seismic shaking, liquefaction and differential settlement. In many locations, deposition of these units is ongoing. West of the SAFZ, the Holocene deposits include beach sands and dune sands that are located along portions of the coast, alluvium and some landslide deposits. Older Quaternary deposits mapped include some landslide deposits, older dune sands and terrace deposits. The terrace deposits are located in the vicinity of Bolinas Point, along the SAFZ and adjacent to portions of the coastline.

D. GEOLOGIC UNITS WITHIN THE SAN ANDREAS FAULT ZONE

Three distinct units are present within the SAFZ that were deposited from upper Pliocene to Pleistocene (Exhibit 3). The upper Pliocene to Pleistocene Merced Formation is located at the southeast end of the Point Reyes Peninsula within the fault zone along Bolinas lagoon. The weakly consolidated siltstones, sandstones and pebbly conglomerate record coastal and shallow marine sedimentation through much of the Pleistocene (Clifton and Hunter, 1999). The Millerton Formation consists of poorly consolidated and deeply weathered alluvial and estuarine clay, silt, sand and gravel. It is found at Tom's Point, Tomasini and Millerton Points on the east side of Tomales Bay. The Olema Creek Formation consists of granitic sand and gravel interbedded with estuarine mud and peat. It is located within the SAFZ southeast of Olema. The Millerton and Olema Creek Formation are important units in that they record post-130,000 year deposition and deformation within the SAFZ (Grove and Niemi, 1999).

E. SUMMARY AND ISSUES TO CONSIDER

- The geology in Marin County is quite varied and complex and is continually evolving rather quickly (in terms of geologic time) because of its location at an active plate margin. The boundary of this plate margin is the San Andreas Fault.
- Because of long-term strike-slip movement on the San Andreas Fault, the geology on either side of the fault is quite different. East of the fault, the geology is dominated by bedrock of the Franciscan Formation and associated mélange. West of the fault, the bedrock geology is dominated by granitic rocks and overlying sedimentary rocks. The differences in the many types of bedrock materials have an affect on the geologic hazards that are present.

- The surficial deposits located on both sides of and within the San Andreas fault zone, typically have a greater amount of geologic hazards associated with them; Including, liquefaction potential, shaking amplification potential, subsidence and differential settlement and shallow slope failures.
- New data and information on the geology and geologic hazards of Marin County will continue to be generated. It is recommended that the GIS database be maintained and added to as necessary to include new, additional, or updated information as it becomes available. Moreover, where appropriate this information should be made easily accessible to increase public awareness of the geologic hazards in the County. Policy EH-1.1 and EH-1.2 and their associated programs provide a system for collection and dissemination of hazard information. These Policies and programs should be evaluated and refinements should be considered (see Section XIII).

IV. FAULTING AND SEISMIC HAZARDS

A. ACTIVE FAULTING AND FAULT RUPTURE

A fault is defined as a fracture or zone of closely associated fractures along which rocks on one side have been displaced with respect to those on the other side. Most faults are the result of repeated displacement that may have taken place suddenly and/or by slow creep. A fault zone is a zone of related faults that commonly are braided and subparallel, but may be branching and divergent. A fault zone has significant width, ranging from a few feet to several miles (Hart and Bryant, 1999). When a fault comes in contact with the earth's surface it is known as a fault trace. An active fault is defined as one, which has "had surface displacement within Holocene time (about the last 11,000 years as defined by the Alquist-Priolo Earthquake Fault Zoning Act)."

The California Division of Mines and Geology has delineated earthquake fault zones per the policies of the Alquist-Priolo Earthquake Fault Zoning Act. Several faults are present in Marin County; however, only the San Andreas fault zone is considered to be sufficiently active (having ruptured in the Holocene) and well defined within the Marin County boundaries and is zoned under the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant, 1999; Jennings, 1994). In Marin County, the maps delineating the San Andreas fault zone were issued in 1974. These maps include the Bodega Head, Bolinas, Double Point, Drakes Bay, Inverness, Point Reyes, Tomales, and Valley Ford Quadrangles (Exhibit 4).

Exhibit 4 is a compilation of the all the faults in or near the boundaries of Marin County that were compiled by Jennings (1994) in "Fault Activity Map of California and Adjacent Areas." Five types of faults are shown on the map and described in the map explanation and in Table 2. The faults that are considered to be active are the Historic (red) and Holocene (orange) faults.

Table 2.
Explanation of Fault Types Shown in Exhibit 4

Geologic Time Scale			Years Before Present (Approx.)	Fault Symbol	Recency of Movement	DESCRIPTION: ON LAND	DESCRIPTION: OFFSHORE
Quaternary	Late Quaternary	Historic	200			Displacement during historic time (e.g. San Andreas fault 1906). Includes areas of known fault creep.	
Quaternary	Late Quaternary	Holocene	10,000		? ? ?	Displacement during Holocene time.	Fault offsets seafloor sediments or strata of Holocene age.
Quaternary	Late Quaternary	Pleistocene	700,000		? ?	Faults showing evidence of displacement during late Quaternary time.	Fault cuts strata of Pleistocene age.
Quaternary	Early Quaternary	Pleistocene	1,600,000		?	Undivided Quaternary faults - most faults in this category show evidence of displacement during the last 1,600,000 years, possible exceptions are faults which displace rocks of undifferentiated Plio-Pleistocene age.	Fault cuts strata of Quaternary age.
Pre-Quaternary			4.5 billion			Faults without recognized Quaternary displacement or showing evidence of no displacement during Quaternary time. Not necessarily inactive.	Fault cuts strata of Pliocene age or older age.

Source: Jennings (1994).
Note: The question mark shown under "Recency of Movement" indicate that although evidence shows specific faults to have been active within some period of geologic time, they should not be considered inactive. It is not possible to tell if a fault will be reactivated.

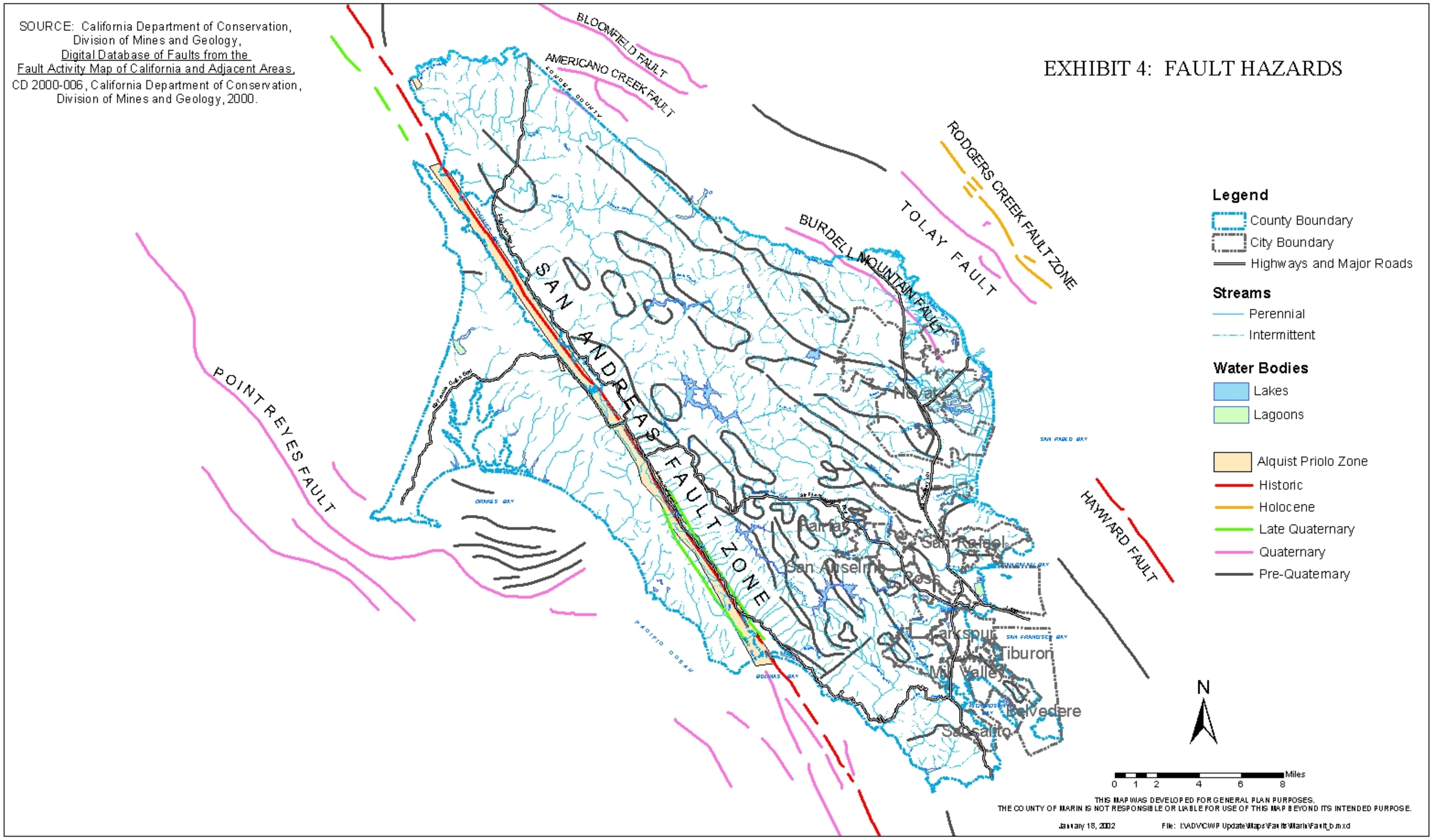


EXHIBIT 4: FAULT HAZARDS
SOURCE: California Department of Conservation, Division of Mines and Geology, Digital Database of Faults from the Fault Activity Map of California and Adjacent Areas, CD 2000-006, California Department of Conservation, Division of Mines and Geology, 2000.
BLOOMFIELD FAULT
AMERICANO CREEK FAULT
RODGERS CREEK FAULT ZONE
TOLAY FAULT
BURDELL MOUNTAIN FAULT
SAN ANDREAS FAULT ZONE
POINT REYES FAULT
HAYWARD FAULT
Novato
Fairfax
San Rafael
San Anselmo
Ross
Larkspur
Tiburon
Mill Valley
Belvedere
Sausalito
Legend
County Boundary
City Boundary
Highways and Major Roads
Streams
Perennial
Intermittent
Water Bodies
Lakes
Lagoons
Alquist Priolo Zone
Historic
Holocene
Late Quaternary
Quaternary
Pre-Quaternary
N
0 1 2 4 6 8 Miles
THIS MAP WAS DEVELOPED FOR GENERAL PLAN PURPOSES.
THE COUNTY OF MARIN IS NOT RESPONSIBLE OR LIABLE FOR USE OF THIS MAP BEYOND ITS INTENDED PURPOSE.

Jennings (1994) shows various mapped faults within the boundaries of Marin County (Exhibit 4). The SAFZ cutting through Point Reyes Peninsula is shown as having surface displacement during historic time (within the last 200 years). This correlates with the M8.3 1906 earthquake, which resulted in a number of recorded surface ruptures in Marin County (Hall and Hughes, 1980). Some segments of the SAFZ only show evidence of displacement some time between 200 to 700,000 years ago. The SAF is a strike-slip fault, meaning that most of its displacement involves horizontal movement in which rocks on opposite sides of the fault plane slide sideways past each other.

The northern end of the active Hayward fault is located within the boundaries of Marin County, but it is in San Pablo Bay where it steps to the right in a complex fault zone transferring strain to the Rodgers Creek fault (McCarthy and Hart, 1993). It is therefore not zoned as an Earthquake Fault Zone within Marin County, but is seismically active.

Three other named faults located near or within the boundaries of Marin County show evidence of displacement during the last 1.6 million years (Jennings, 1994). These include the Burdell Mountain Fault and Americano Creek Fault in the vicinity of the east and northeast boundary of Marin County and the Point Reyes Fault, which is located offshore of the Point Reyes Peninsula. Rice (1973) stated that youthful appearing topographic features are the strongest evidence for geologically recent displacement of the Burdell Mountain Fault zone; however, an age has not been determined. McCulloch and Greene (1989) shows the Point Reyes Fault to be well defined and active or potentially active; however, the age of most recent faulting has not been determined. Late Pleistocene wave-cut terraces on the Point-Reyes Peninsula show formation of an emergent coastline during sea level high stands, suggesting tectonic uplift of the Point Reyes Peninsula (Davis, 2001). Evidence suggests that active folding and uplift is occurring and accommodated, in part, by late Pleistocene and potentially ongoing movement on the Point Reyes thrust (Grove, 2005).

It is also conceivable that earthquakes may occur on faults not previously recognized or on faults that do not have a trace in the ground surface. Recent research indicates the potential for blind thrust fault(s) to be present beneath Marin County (Furlong, 2004). These faults are not exposed at the surface and are typically broadly defined based on the analysis of seismic wave recordings of several hundreds of small earthquakes. In the Bay region, the Mt. Diablo blind thrust fault, which is associated with the Diablo Range, is reported to possibly be capable of a magnitude 6.75 earthquake (Unruh, 2001). Due to the buried nature to these faults, their existence is usually not known until they produce an earthquake. The risk for surface rupture potential for the buried thrust faults is inferred to be low.

B. SEISMICITY

The San Francisco Bay Region is a tectonically active region that has several active faults. Some of these faults have produced significantly large and destructive earthquakes. The most recent being in 1838, 1868, 1906 and 1989 (Table 3). Six strike-slip faults and one thrust fault in the San Francisco Bay area are known to be slipping between 2 to 24 mm/yr. These faults in general release most of the seismic energy in the Bay area and include: the San Andreas, Hayward-Rodgers Creek, Calaveras, San Gregorio, Concord-Green Valley, Greenville, and Mount Diablo Faults (Working Group on California Earthquake Probabilities, 2003).

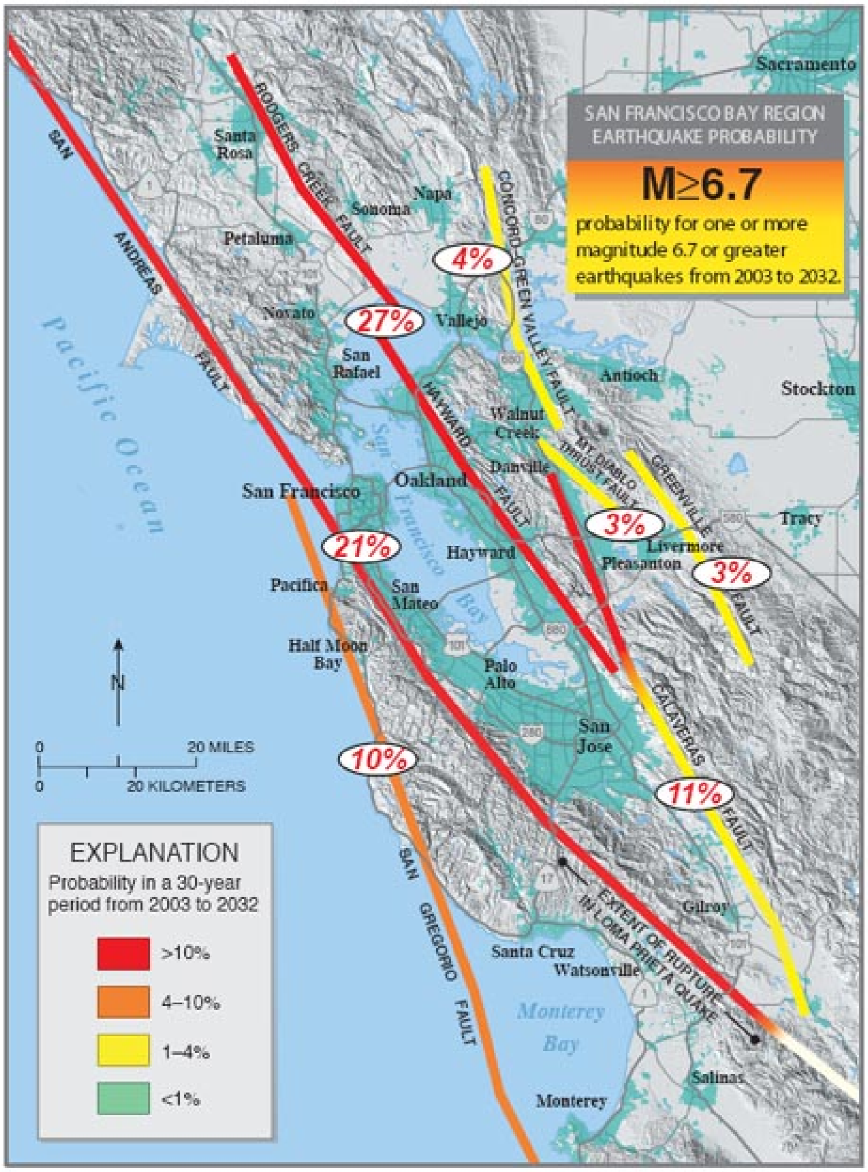
Table 3.
Historical Bay Area Earthquakes Causing Significant Damage

Year	Fault	Epicenter	Richter Magnitude (M)	Modified Mercalli Intensity (MM)*
1836	San Andreas, Calaveras, or Sargent	San Juan Bautista, Hayward	6.3[a]	VII
1838	San Andreas	San Francisco	7.5[a]	X
1852	San Andreas	San Francisco Peninsula	?	VIII
1858	Hayward	San Jose	?	VIII
1861	Calaveras	Livermore	7 +	VIII
1865	San Andreas	Santa Cruz Mountains	7 +	VIII – IX
1868	Hayward	Hayward	6.7	IX – X
1906	San Andreas	San Francisco	8.3	XI
1911	Hayward	San Jose	6.6	VII – VIII
1954	San Andreas	Watsonville	5.2	VIII
1969	Healdsburg	Santa Rosa	5.7	VII-VIII
1989	San Andreas	Santa Cruz Mountains	7.1	IX – X

Source: Montgomery (1990), (a = Toppozada and Borchardt, 1998).
* See Table 4 for definitions of intensities.

The Working Group on California Earthquake Probabilities (WG02) found that there is a 62% probability of at least one magnitude 6.7 or greater earthquake before 2032 within the San Francisco Bay Region (Exhibit 5). This earthquake is likely to occur on one of the seven major fault systems in the bay area. It was determined that the Hayward-Rodgers Creek, San Andreas and Calavares fault systems have the highest probabilities of generating a M≥6.7 earthquake before 2032. The San Andreas and the Hayward-Rodgers Creek fault systems could have the greatest impacts on Marin County because of their proximity to population centers within Marin County and the fact that they have the highest probability of rupture in the San Francisco Bay Region. The WG02 found a 21% probability for the San Andreas fault system and a 27% probability on the Hayward-Rodgers Creek fault system for a M≥6.7 earthquake before 2032. It was also found that an estimated probability of 80% exists for a M6.0 to M6.7 earthquake event in the San Francisco Bay Region.

Exhibit 4a.
Probability of a M≥6.7 earthquake in the San Francisco Bay Region



C. GROUND SHAKING AND SHAKING SUSCEPTIBILITY

1. Hazard Description

The shaking and resulting destruction from earthquakes is caused by seismic waves traveling through the ground. Earthquakes are generated at a rupture point along a fault, which is known as the focus of an earthquake. The seismic waves travel from the focus in all directions. Earthquakes generate two specific types of seismic waves that are responsible for damage to structures. Body waves are waves that travel through the ground and surface waves travel only along the ground surface. The body waves tend to produce the sharp jolting and shaking, while surface waves produce a rolling or swaying motion.

The strength of an earthquake can be measured in two ways. Intensity is a qualitative measurement of the sensations and damages produced by an earthquake. A commonly used intensity scale is the Modified Mercalli Intensity Scale (Table 4). This intensity scale is subjective and if affected by more than just the energy released by an earthquake. Factors affecting the intensity include: distance from the epicenter, focal depth of the earthquake, population density and local geology of the area, type of building construction employed, and duration of shaking.

A quantitative evaluation of the size of an earthquake, known as magnitude, was first developed by Charles F. Richter in 1935 and is known as the Richter Magnitude. This method of measurement determines the energy of an earthquake by measurement of the amplitude of a wave recorded on a seismograph. Table 5 compares Richter Magnitude with the Modified Mercalli Intensity Scale. Other magnitude scales are used for measuring magnitude. A typical scale for large magnitude earthquakes is the Seismic-Moment Magnitude Scale, which is similar but more accurately measures the size of a large earthquake than the Richter Magnitude.

As expected, increasing magnitude results in an increased severity of ground shaking because the energy released by an earthquake is relative to its magnitude. The magnitude scale is logarithmic so each increase in magnitude results in an increase of energy released of approximately 32 times the proceeding magnitude. Ground shaking is the primary cause of damage during an earthquake. The intensity of ground shaking felt by a structure during an earthquake is largely dependent on the type of underlying earth materials. Waves will travel through bedrock differently

Table 4.
Modified Mercalli Intensity Scale

Earthquake Intensity (MM)	Description
I	Not felt by a very few under especially favorable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated.
IV	During the day, felt indoors by many and outdoors by few. At night, some awakened. Dishes, windows, doors disturbed, and walls make cracking sound. Sensation like a heavy truck striking a building. Standing motorcars rocked noticeably.
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motorcars.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. People driving motorcars disturbed.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.

than they will travel through bay mud or unconsolidated alluvium. Structures built on poorly consolidated sediments will experience longer

shaking duration and greater surface wave amplitude than those built on bedrock or other stiffer geologic deposits. Severity of ground shaking damage is also largely dependent on the type and quality of construction of the structures being affected.

A way of determining the seismic intensities that a region will experience is by evaluating the earth materials that will be affected by the seismic waves. Seekins et al. (2000) produced maps of the San Francisco Bay Area that show a general overview of the various earth materials underlying the region and their potential ground shaking amplification effect based on their shear wave velocity (Exhibit 6).

Exhibit 6 shows five soil types that are defined by their shear-wave velocity as determined by the National Earthquake Hazards Reduction Program (NEHRP). The shaking amplification at a particular site is affected by the velocity at which the rock or soil (combined under the term soil type) transmits shear waves. Soil types with a high shear wave velocity do not contribute greatly to amplification, while soil types with low shear wave velocities can greatly amplify the shaking at a particular site. Exhibit 5 is not a representation of how strong the shaking is going to be, but a representation of areas in the County where the shaking can be greatly amplified because of the underlying earth materials. Soil Types A and B with shear wave velocity measurements greater than 750 meters per second are considered to not contribute greatly to shaking amplification. Soil Type C has a shear wave velocity between 350-750 meters per second. Soil Types D and E are those with shear wave velocities of 350 meter per second or less and these materials will significantly contribute to shaking amplification. The areas underlain by soil Type E will have the greatest amplification of shaking.

As an example of what this data shows, if a house on a Type A site was located at the same distance from an earthquake as a house on a Type E site, the house on the Type E site will experience a significantly greater amount of shaking because of the greater amount of amplification. Therefore, it is most likely that a house on the Type E site would likely sustain a greater amount of damage in an earthquake (assuming both houses are of similar design and construction).

In general, the map shows the younger alluvial deposits, especially bay muds, to be the most susceptible to shaking amplification. Areas of particular concern are the Type E soils, which include recent deposits at the southeast end of Tomales Bay, deposits in Bolinas Bay, and those flat lying areas adjacent to San Pablo Bay that are generally underlain by bay muds and fill overlying bay muds. These areas are of greatest risk to experiencing the strongest ground shaking in the County.

Table 5.
Richter Magnitude vs. Modified Mercalli Intensity

Richter Magnitude (M)	Expected Modified Mercalli Maximum Intensity at Epicenter (MM)	
2	I – II	Usually detected only by instruments.
3	III	Felt indoors.
4	IV – V	Felt by most people; slight damage.
5	VI – VII	Felt by all; many frightened and run outdoors; damage minor to moderate.
6	VII – VIII	Everybody runs outdoors; damage moderate to major
7	IX – X	Major damage.
8	X – XII	Total and major damage.

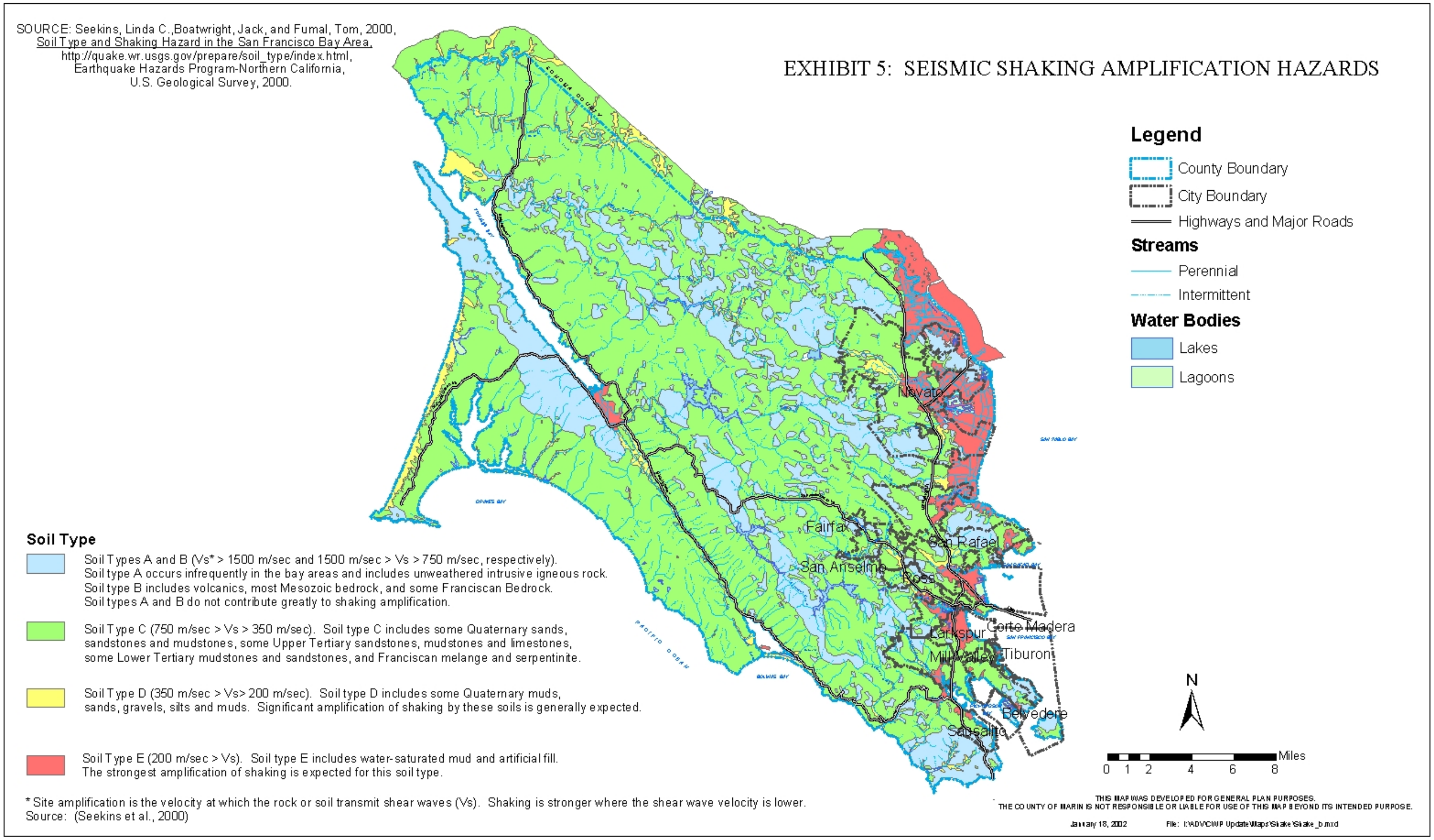
Source: California Department of Conservation, Division of Mines and Geology (1984).

Hypothetical earthquake scenarios (ShakeMaps) for the San Francisco Bay Area have been created by the California Integrated Seismic Network and are available online at www.cisn.org. These scenario events are based on the Working Group (WG02) probability analysis and the current knowledge of potential shaking effects. These maps are not predictions of earthquakes, but are ground shaking models of a hypothetical earthquake. These maps are a useful tool for planning and coordinating emergency response. For Marin County, the two most potentially damaging earthquake scenarios would be a repeat of the 1906 rupture on the San Andreas Fault and rupture of the North Hayward-Rodgers Creek Faults. Exhibits 7 and 8 show the potential shaking effects these scenario events would have on the region (California Integrated Seismic Network, 2003ab). These scenarios are presented here because they are potential events on the fault segments shown by the Working Group (WG02) to have the greatest probability of rupture before 2032.

2. Hazard Mitigation

Because Marin County is located within such a seismically active region and because some areas of development are near the SAFZ, there is a high probability that structures will experience strong ground shaking during the lifetimes of any proposed development. This ground shaking could produce seismically induced liquefaction, landsliding and differential settlement and cause significant damage to structures not designed for intense ground shaking. Exhibit 5 provides a general overview of those deposits in the County that are most susceptible to ground shaking amplification and it can be used to pinpoint areas in the County that have the greatest susceptibility to ground shaking.

The structural damage caused by ground shaking can be lessened by a combination of proper standard of care geotechnical evaluations on a site-specific basis and by compliance with all applicable seismic design provisions of the building code. Geotechnical evaluations of a site can determine the susceptibility of a site to shaking. Design of a structure should consider this geotechnical information and incorporate it into the design to minimize the impact of this hazard.


SOURCE: Seekins, Linda C.,Boatwright, Jack, and Fumal, Tom, 2000,
Soil Type and Shaking Hazard in the San Francisco Bay Area,
http://quake.wr.usgs.gov/prepare/soil_type/index.html,
Earthquake Hazards Program-Northern California,
U.S. Geological Survey, 2000.
EXHIBIT 5: SEISMIC SHAKING AMPLIFICATION HAZARDS
Legend
County Boundary
City Boundary
Highways and Major Roads
Streams
Perennial
Intermittent
Water Bodies
Lakes
Lagoons
Novato
Fairfax
San Rafael
San Anselmo
Ross
Larkspur
Corte Madera
Mill Valley
Tiburon
Belvedere
Sausalito
N
0 1 2 4 6 8 Miles
Soil Type
Soil Types A and B (Vs* > 1500 m/sec and 1500 m/sec > Vs > 750 m/sec, respectively).
Soil type A occurs infrequently in the bay areas and includes unweathered intrusive igneous rock.
Soil type B includes volcanics, most Mesozoic bedrock, and some Franciscan Bedrock.
Soil types A and B do not contribute greatly to shaking amplification.
Soil Type C (750 m/sec > Vs > 350 m/sec). Soil type C includes some Quaternary sands, sandstones and mudstones, some Upper Tertiary sandstones, mudstones and limestones, some Lower Tertiary mudstones and sandstones, and Franciscan melange and serpentinite.
Soil Type D (350 m/sec > Vs> 200 m/sec). Soil type D includes some Quaternary muds, sands, gravels, silts and muds. Significant amplification of shaking by these soils is generally expected.
Soil Type E (200 m/sec > Vs). Soil type E includes water-saturated mud and artificial fill. The strongest amplification of shaking is expected for this soil type.
* Site amplification is the velocity at which the rock or soil transmit shear waves (Vs). Shaking is stronger where the shear wave velocity is lower.
Source: (Seekins et al., 2000)
THIS MAP WAS DEVELOPED FOR GENERAL PLAN PURPOSES.
THE COUNTY OF MARIN IS NOT RESPONSIBLE OR LIABLE FOR USE OF THIS MAP BEYOND ITS INTENDED PURPOSE.
January 18, 2002
File: I:\ADV\CWP Update\Maps\Shake\Shake_b.mxd

D. LIQUEFACTION SUSCEPTIBILITY

1. Hazard Description

Liquefaction is defined as the transformation of a granular material from a solid state into a liquefied state because of increased pore-water pressures (Youd, 1973). Liquefaction and earthquake-induced ground failures, due to liquefaction of underlying materials, has led to significant damage to structures and loss of life throughout the world. Liquefaction features have been located in Marin County following large magnitude earthquakes in the region, including the 1906 San Francisco earthquake and the 1989 Loma Prieta earthquake (Tinsley et al., 1998; Youd and Hoose, 1978). Observed common types of ground failures resulting from liquefaction can include (taken from CDMG, 2001a):

- Lateral Spread – Lateral spread is the lateral (horizontal) displacement of surficial blocks of sediments as a result of liquefaction in a subsurface layer. Once liquefaction transforms the subsurface layer into a fluidized mass, gravity plus inertial forces that result from the earthquake may cause the mass to move downslope towards a cut slope or free face (such as a river channel or a canal). Lateral spreads most commonly occur on gentle slopes that range between 0.3 and 3 degrees, and commonly displace the surface by several to tens of feet. Such movement typically damages pipelines, utilities, bridges, and other structures having shallow foundations. During the 1906 San Francisco earthquake, lateral spreads, causing displacement of only a few feet damaged every major pipeline that broke. Thus, liquefaction compromised the ability to fight the fires that caused about 85 percent of the damage to San Francisco. A lateral spread triggered by the 1989 Loma Prieta earthquake damaged the Moss Landing Marin Laboratory beyond repair and the site was abandoned as unsuitable for a new structure.
- Flow Failure – Flow failure usually occurs on slopes greater than 3 degrees and is the most catastrophic mode of ground failure caused by liquefaction. The flows are principally liquefied soil or blocks of intact material riding on a liquefied subsurface zone. Displacements are commonly tens of miles per hour.
- Ground Oscillation – When liquefaction occurs at depth but the slope is too gentle to permit lateral displacement, the soil blocks that are not liquefied may decouple from one another and oscillate on the liquefied zone. The resulting ground oscillation may be accompanied by the opening and closing of fissures and sand boils, potentially damaging structures and underground utilities.
- Loss of Bearing Strength – When a soil loses strength and liquefies, loss of bearing strength may occur beneath a structure, possibly causing the building to settle and tip. If the structure is buoyant, it may float upward. Earthquake shaking from the 1989 Loma Prieta earthquake caused soil supporting a State Highway 1 bridge to lose bearing strength resulting in collapse of the bridge. Liquefaction also caused pipelines joining structures to break, some of which resulted in fires.

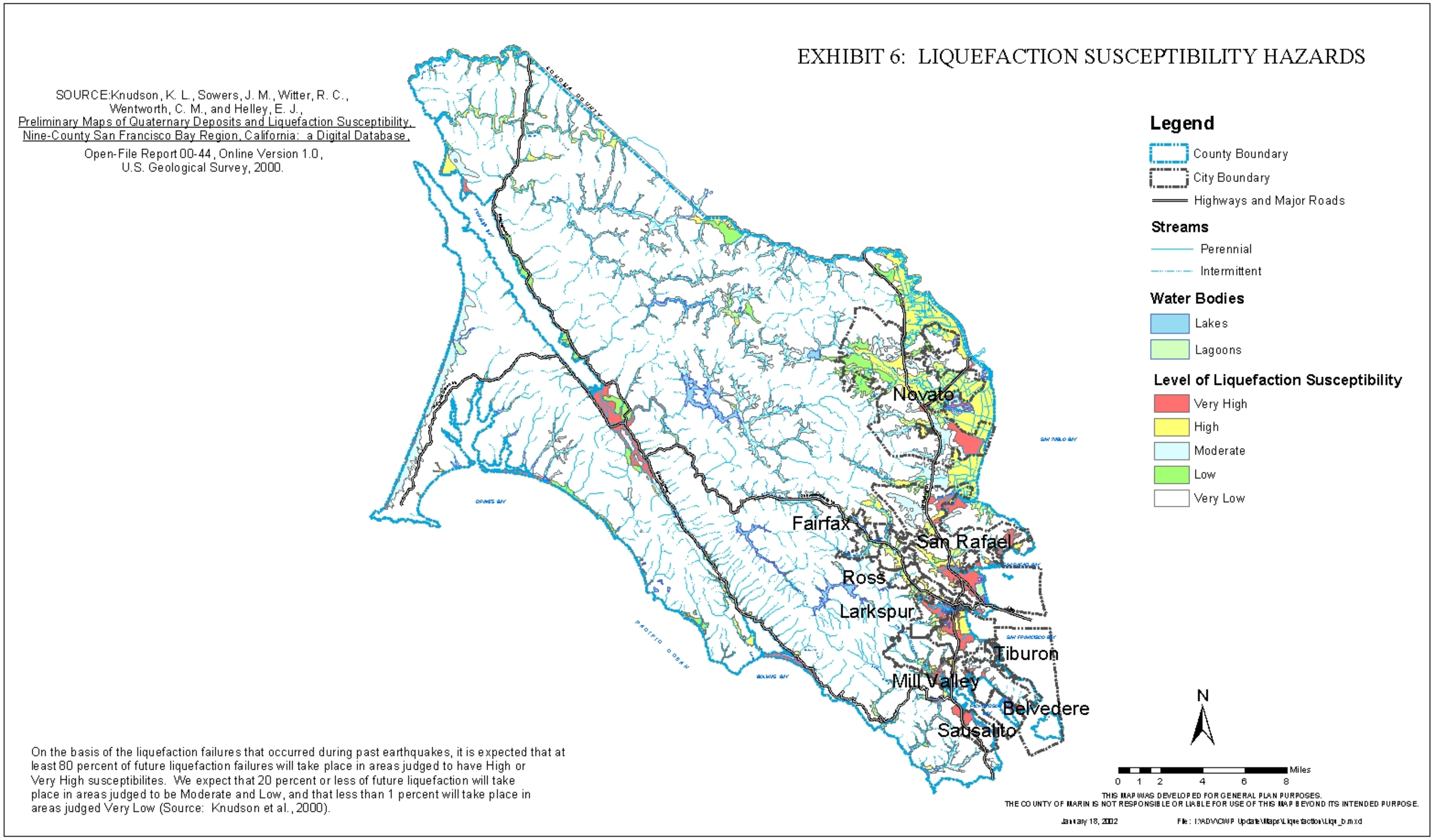
Studies of seismic-induced liquefaction throughout the world have shown that liquefaction occurs in areas underlain by loose, saturated, cohesionless, sand, silt and gravel. Areas that are likely to favor liquefaction include the following:

- Areas known to have experienced liquefaction during historic earthquakes.
- Areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.
- Areas where sufficient existing geotechnical data and analyses indicated that the soils are potentially liquefiable.

- Areas containing young (less than 15,000 years old) soils where there is limited or no geotechnical data.

Relatively recent detailed mapping of Quaternary deposits of the San Francisco Bay region has allowed for a more in-depth analysis of liquefaction susceptibility in Marin County (Knudson et al., 2000). Exhibit 6 shows the results of this in-depth liquefaction susceptibility analysis and shows the liquefaction potential rating for a particular location. This study determined that the geologic materials most susceptible to liquefaction include Holocene stream channel deposits, Holocene beach deposits, and artificial fill overlying Bay Muds (High to Very High Susceptibility). Liquefaction susceptibility units were designated on the basis of a criteria matrix that assigns susceptibility values to all combinations of geologic unit (type and age of the deposit) and ground-water level. The resulting units reflect the likelihood that loose, saturated, granular sediment is present within 50 feet of the ground surface. The matrix was calibrated using information on past occurrences of liquefaction, previous geologic and geotechnical studies, and limited boring log data that includes standard penetration test information (Knudson et al., 2000).

EXHIBIT 6: LIQUEFACTION SUSCEPTIBILITY HAZARDS



Based on liquefaction failures that occurred during past earthquakes, Knudson et al. (2000) expects that at least 80 percent of future liquefaction failures will take place in areas judged to have High or Very High susceptibilities. They expect that 20 percent or less of future liquefaction will take place in areas judged to be Moderate and Low, and less than 1 percent will take place in areas judged Very Low (Exhibit 9).

2. Hazard Mitigation

Liquefaction hazards should be evaluated on a site-specific basis as part of any new development's overall geotechnical investigation. The CDMG Special Publication 117 "Guidelines for Evaluating and Mitigating Seismic Hazards in California," represents the standard of care for assessing and mitigating liquefaction hazards. Exhibit 6 provides a general overview of areas of potential liquefaction and can be used to delineate liquefaction susceptible areas that may require detailed site-specific analysis.

E. TSUNAMIS AND SEICHES

1. Hazard Description

Tsunamis are long-period waves generated by shifting of a large volume of water. They can be triggered by a submarine earthquake, submarine volcanic eruptions, submarine landslides or slumps of large volumes of earth, meteor impacts and onshore slope failures that fail into oceans or bays. Seiches are related to tsunamis and are triggered by the same sources, but occur in enclosed and semi-enclosed bodies of water, such as, bays, inlets, lakes and reservoirs.

Tsunamis and seiches travel outward from the source event and they may be directed in a specific direction depending on the source mechanism. More than one wave is generated in an event. The traveling speed of a tsunami depends on depth of water and it adjusts its speed according to the depth of the water. Wave speeds can reach 500 miles an hour and tsunami crests can be separated by as much as 100 miles. In the open ocean, a tsunami generally produces an unnoticeable rise and fall of the ocean surface, but as it enters coastal areas, the wave increases in height. As the tsunami reaches the coast and the water depth lessens, the speed diminishes and the wave height increases. The first wave may not always be the largest and successive larger waves usually follow.

Tsunamis are generally associated with seismic activity and are a common hazard in tectonically active portions of the world. The west coast of North America is susceptible to this hazard because it is located in the Pacific "Ring of Fire", which includes many zones of tectonic plate interactions resulting in the many earthquakes, volcanic eruptions and landslides that are common in this portion of the world. The sources of tsunamis are prevalent and coastal communities located within the "Ring of Fire" are susceptible to tsunamis.

Seiches could occur in any reservoir located in the County and in San Pablo and San Francisco bays. The extent of potential seiche runup in these bodies of water is unknown. Runup in the bays is thought to be less in magnitude then the runup of potential tsunamis along the Pacific Coast. Since a tsunami is considered a greater potential hazard, it is the focus of the following discussion.

2. Hazard Effects and Potential

Once a tsunami reaches land, the damage and areal extent are determined by the wave runup and the extent of inundation. The runup is the rush of water up a beach or structure. As the runup continues inland, it reaches a maximum runup, which is the maximum vertical height above stillwater (tide level) that the water reaches. The horizontal distance that a runup penetrates inland is known as inundation and inundation height is the maximum runup along a particular transect (Eisner et al., 2001).

As a tsunami approaches, the damages may begin to accumulate. The first sign of an approaching tsunami may be the drawdown of the of the approaching wave trough. A rapid drawdown can create strong currents in harbors and channels resulting in damage to structures and boats. However, the surge of water inland may be the first sign, leading to damage to structures in the path of the runup. The power of the runup can float cars, structures and other debris and transport them inland, sometimes leaving them stranded away from their original location. The surge back toward the body of water can be just as destructive as the surge inland.

Local seismogenic sources may create tsunamis between Cape Mendocino to San Francisco and include the offshore zone of the San Andreas fault and the Point Reyes fault (if active) located offshore of the southwest tip of Marin County. A number of other sources are located offshore the California coast. A tsunami wave up to ¼ to ½-foot high was recorded in 1906 in the vicinity of the Golden Gate as a result of the 1906 earthquake event on the SAFZ. Far source events also can create a tsunami hazard. The 1964 earthquake generated off the south coast of Alaska generated a tsunami that created waves up to 20-feet high, caused more than $11 million dollars in property damage to Crescent City in northern California and produced a measured wave height of 7½ feet in the vicinity of the Golden Gate (Bishop et al., 1973). Reportedly, this event did cause some damage to the Clipperton Yacht Harbor at Sausalito from currents generated by the tsunami (Ritter and Dupre, 1972). More than 20 tsunamis of differing heights have impacted the State of California, in the past two centuries (Eisner, 2001).

The exposure of the Marin coastline to a tsunami hazard will vary locally, depending on the many factors involved. The creation of tsunami runup calculations and inundation maps require complex numerical analysis of source location, source type, local onshore and offshore topography, and other factors. Houston and Garcia (1978) produced an analysis of runup heights for the western coast of the United States. They estimated the runup heights above mean sea level (MSL) for 100 and 500-year return period tsunamis from far-field sources. As an example, their study predicts a 100-year tsunami wave runup varying from 10 feet MSL at the mouth of Bolinas Bay to 10.6 feet MSL at the Stinson Beach State Park boundary. A 500-year tsunami wave runup varies from 17.6 feet MSL at the mouth of Bolinas Bay to 18.8 feet MSL at the Stinson Beach State Park boundary (Johnson, 1983).

The National Tsunami Hazard Mitigation Program (NTHMP) (2001) lists several factors affecting communities to tsunami exposure. This list has been modified to focus on Marin County:

- All or parts of the mainland states are located near active subduction zones (Cascadia and Alaska-Aleutian) or other well-defined tsunami-producing zones. Local tsunamis generated by these zones will reach the coasts extremely quickly (within 5-30 minutes, depending on the distance to the zones.
- Strong earthquakes, whether accompanied by tsunamis or not, are rare events in most low-lying coastal communities (Large earthquake events are common in geological time, but are few and far between in a human lifespan.). With little strong ground shaking experience, these communities have little awareness of earthquake hazards. Yet, even with minimal earthquake activity, the risk of damage from a major tsunami is considered high for these communities.

- Except in Hawaii and a few mainland coastal communities, tsunami awareness is not currently embedded in coastal community "culture."
- Many coastal communities in Marin County are relatively small.
- Marin County has a largely recreational use of its coastline, having short-term and seasonal visitors. This presents a special problem, as losses could be very high if a destructive tsunami occurred at a seasonal peak population time.

3. Tsunami Hazard Mitigation

In 1996, the National Oceanic and Atmospheric Administration (NOAA) formed the Tsunami Hazard Mitigation Federal/State Working Group, which created a Tsunami Hazard Mitigation Implementation Plan for mitigating tsunami hazards threatening coastal communities of the United States (Bernard, 2001). The Plan produced by the working group implemented five specific programs, including: production of inundation maps, improvement of seismic networks, deployment of tsunami detection buoys, development of hazard mitigation programs, and development of state/NOAA coordination and technical support. These programs have been and are being carried out by the Federal/State NTHMP Steering Group.

Currently tsunami inundation maps do not include the Marin County coast; however, a map has been completed for the San Francisco-San Mateo County area (Gonzalez et al., 2001). Tsunami modeling continues to be developed and has reportedly been initiated for areas north of the Golden Gate (Gonzalez et al., 2004). Seismic networks have been installed, which has reduced the time required to locate and determine magnitude of an earthquake event from 8 minutes to 2 minutes. Tsunami detection buoys have been deployed thereby providing faster and more accurate tsunami data. Publications and workshops have been created to educate and inform the public on tsunamis hazards. This includes a "TsunamiReady" program that recognizes communities that have met minimum criteria to properly respond to NOAA tsunami warnings. These programs are ongoing and will continue to improve the ability of the west coast to be prepared for tsunami events (Bernard, 2001).A new plan has been announced for an improved Tsunami Detection and Warning System and it is reported that this will provide the United States with nearly 100% detection capability for a U.S. coastal tsunami (Office of Science and Technology, 2005).

Tsunami wave runup and inundation should be considered for proposed development along coastal areas of Marin County. Runup calculations, such as those from Houston and Garcia (1978), and any future inundation maps should be utilized for Marin County coastal planning and protection. On a federal/state level, tsunami hazard mitigation is actively being implemented and the County should incorporate new and future tsunami mitigation programs into coastal planning policies.

F. EARTHQUAKE INDUCED LANDSLIDES

Landslides will not be discussed in detail here, but will be discussed thoroughly in the following section "Slope Stability and Landsliding." However, landslides triggered by earthquake ground motion are a significant seismic hazard. Numerous landslides can be triggered by an earthquake and cause substantial damage to a region. It is reported that the 1906 earthquake generated more than 10,000 landslides throughout the Bay area (Keefer, 1984). The more recent 1989 Loma Prieta earthquake triggered thousands of slides throughout approximately 15,000 km^2 of Central California, including some in southern Marin County at Bolinas, Stinson Beach and Muir Beach (Keefer and Mansion, 1998).

Many of the different types of landslides, as described by Varnes (1978), can occur during an earthquake. Some landslides, especially lateral spreads and flows, are associated with soil liquefaction and are therefore more likely triggered by earthquakes than other mechanisms. Ground shaking is one of many triggering mechanisms that can generated a new slide or reactivate an old one. It appears that most earthquake-induced landslides occur in materials that are highly susceptible to earthquake-induced failure, including weakly cemented rocks, artificial fills, uncemented alluvial materials, and both ancient and recent preexisting landslide deposits (Keefer, 1998).

G. SUMMARY AND ISSUES TO CONSIDER

- Several faults are present in Marin County, but the San Andreas Fault is the only land fault considered sufficiently active to be zoned under the Alquist-Priolo Earthquake Fault Zoning Act. The last surface ground rupture was in 1906. The Hayward Fault is also zoned, but in Marin County, it lies offshore.
- The fact that the San Andreas fault is the only land based zoned fault in the County does not rule out the possibility of fault rupture on some of the other known faults or potential unknown faults. Some mapped faults show signs of displacement within the last 1.6 million years (Quaternary); therefore, the potential for rupture on some of these faults cannot be ruled out. Additionally, older potentially active and even inactive faults can move sympathetically during shaking on a nearby active fault.
- Marin County is located in the seismically active San Francisco Bay Region. Fault rupture and strong seismic shaking are inevitable and there is a reported 62% probability of at least one magnitude 6.7 or greater earthquake before 2032 in the region.
- Marin County has within its boundaries the two faults in the region with the reportedly highest probability of rupture: The San Andreas fault and the Hayward fault.
- Enforcement of the existing policies and procedures required for development located within Alquist-Priolo Earthquake Fault Zones must be continued. Existing policies EH-4.1, EH-4.2, EH-4.3 and EH-4.4 and their supporting programs address this issue. Some refinements of these policies and programs are recommended and listed in Section XIII. Existing Policy EH-2.3 is an effective policy at reducing the hazard of potential fault rupture to critical facilities and is still applicable.
- Ground shaking is a geologic hazard that can result in significant damage within the County. Some areas are more susceptible to stronger shaking because of proximity to potential rupture zones and because of the shaking amplification of some underlying soils and rock. These areas have been identified.
- Mitigation of the ground shaking hazard must be addressed to reduce risk associated with this hazard. Those areas underlain by soils and rock prone to significant shaking amplification are considered potentially high-risk zones and should be evaluated properly. Some existing policies and programs address this issue and they need to be continually applied to existing and new structures (Policy EH-5.1, EH-5.2, EH-5.3, and EH-5.4). Further discussion of this hazard in relation to vulnerable structures is in the Structural Hazards section.
- Liquefaction is a potential hazard, especially in areas that are underlain with deposits reported to have a high to very high susceptibility rating. Liquefaction has occurred during past earthquakes within Marin County.
- There are no existing policies that specifically address areas that are susceptible to liquefaction. However, the California Geological Survey (CGS) has prepared guidelines for geotechnical investigations of liquefaction potential. Within Marin County, proposed developments located in

areas of moderate to very high liquefaction susceptibility should be preceded by a thorough, site-specific geotechnical investigation to evaluate liquefaction susceptibility in accordance with CGS guidelines. This will allow for proper mitigation or avoidance of this potential hazard.

- Tsunamis pose a threat to coastal communities and the County coastline is located in an active tsunami producing region of the world.
- When available, tsunami wave runup and inundation maps should be considered in coastal planning and development. Existing County policy (Policy EH-8.1) only addresses the location of critical facilities in tsunami hazard zones. Policy should be considered for all development and existing communities along the coast that could be impacted.
- The County should consider implementation of a tsunami mitigation program that would provide education for those involved in planning, developing or living in coastal communities.

V. SLOPE STABILITY AND LANDSLIDING

A. HAZARD DESCRIPTION

A large portion of Marin county is mapped as having landslides or being near landslide prone areas. A landslide refers to the downslope movement of materials such as rock, soil, or fill under the direct influence of gravity. This downward movement can occur along a surface (glide plane, landslide plane, or discrete slip surface) or without a distinct failure surface. The presence of landslides is due to several influences and factors related to slope stability, including: slope angle, weathering, climate, water content, vegetation, overloading, erosion, earthquakes, and human-induced factors. The interrelationship of these influences create a dynamic equilibrium, in which slopes are subjected to constant changes over time.

Where landslides are present on undeveloped land, movement can occur naturally during prolonged rainstorms when soils are saturated. Ground shaking during an earthquake can also trigger landslides, especially under saturated conditions. When development occurs on or near landslides, both people and property are exposed to these hazards. Without proper repair construction activities and routine use and maintenance, grading and drainage changes caused by development can reactivate long-dormant or more recent landslides, which otherwise would remain stable under static conditions. This can occur because earthmoving changes the ground surface and subsurface and can alter the shape and stability of a slide mass and change drainage and groundwater conditions. Unmitigated dormant landslides also can be reactivated, at least in part, through the effects of residential landscape irrigation, primarily over-watering attributable to lawn care and planting of non-drought tolerant ornamental species. Over the long-term, irrigation generally increases moisture levels sufficiently to precipitate land slippage during years with greater than normal rainfall. A residential subdivision can introduce the equivalent of more than 100 inches of rainfall per year, although use of drip and low-flow irrigation systems and planting of native and drought resistant species substantially mitigates this moisture increase (Rogers, 1992).

Landslides are caused by the dynamics of the previously listed factors, but they are usually triggered by the following forces that disrupt slope equilibrium:

- Adding weight (adding driving force) to the top of a potential slide area,
- Removing mass (removing toe support or resisting force) from the base of a potential slide area,

- Increasing the volume of water to create heightening of pore water pressures within a potential slide area; and,
- Vibrations from earthquakes, which also can serve to heighten pore water pressures.

This overview of landslide hazards in Marin County is intended as a general guide for land use planning purposes. It should not be construed as a site-specific study, which requires detailed engineering geologic and geotechnical investigations for proper evaluation of an individual development project. The information provided discusses the general known slope stability hazards in the County and the recognition that these slope stability issues need to be addressed in regard to land use policy. In general, Marin County is very hilly and combined with the adverse geologic conditions, the numerous slopes in the County are susceptible to landsliding.

The many types of landslides are listed below. The names and description are from a classification system based on the type of movement and the type of material that is failing. All of these landslide types can occur in Marin County; however, slides and flows are relatively common. These definitions are based mainly on the work by Varnes (1978) and taken from Wold and Jochim (1989).

1. Falls

- Falls are abrupt movements of masses of geologic materials that become detached from steep slopes or cliffs. Movement occurs by free-fall, bouncing, and rolling. Depending on the type of earth materials involved, the result is a rockfall, soil fall, debris fall, earth fall or boulder fall. All types of falls are promoted by undercutting, differential weathering, excavation, or stream erosion.

2. Topple

- A topple is a block of rock that tilts or rotates forward on a pivot or hinge point and then separates from the main mass, falling to the slope below, and subsequently bouncing or rolling down the slope.

3. Slides

Slides refer to movements of soil or rock along a distinct surface of rupture, which separates the unstable slide material from more stable underlying material. The two major types of slides are rotational slides and translational slides.

- Rotational Slides – A rotational slide is one in which the surface of the rupture is curved concavely upward (spoon shaped) and the slide movement is more or less rotational about an axis that is parallel to the contour of the slope. A “slump” is a common term used for small rotational slides.
- Translational Slides – In a translational slide the mass moves out, or down and outward along a relatively planar surface and has little rotational movement or backward tilting. The mass commonly slides out on top of the original ground surface. Such a slide may progress over great distances if conditions are right. The slide material may range from loose unconsolidated soils to extensive slabs of rock.
- Block Slide – A block slide is a translational slide in which the moving mass consists of a single unit, or few closely related units that move downslope as a single unit.

4. Lateral Spreads

Lateral spreads are a result of the nearly horizontal movement of geologic materials and are distinctive because they usually occur on very gentle slopes. The failure is caused by liquefaction, the process whereby saturated, loose, cohesionless sediments (usually sands and silts) are transformed from a solid into a liquefied state; or plastic flow of subjacent material. Failure is usually triggered by rapid ground motion such as that experienced during an earthquake, or by slow chemical changes in the pore water and mineral constituents.

5. Flows

- **Creep** – Creep is the imperceptibly slow, steady downward movement of slope-forming soil or rock. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or terracettes.
- **Debris Flow** – A debris flow is a form of rapid mass movement in which loose soils, rocks and organic matter combine with entrained air and water to form a slurry that then flows downslope. Debris flow areas are usually associated with steep gullies. Individual debris flow areas can usually be identified by the presence of debris fans at the termini of the drainage basins.
- **Debris Avalanche** – A debris avalanche is a variety of very rapid to extremely rapid debris flow.
- **Earthflow** – Earthflows have a characteristic "hourglass" shape. A bowl or depression forms at the head where the unstable material collects and flows out. The central area is narrow and usually becomes wider as it reaches the valley floor. Flows generally occur in fine-grained materials or clay-bearing rocks on moderate slopes and with saturated conditions. However, dry flows of granular material are also possible.
- **Mudflow** – A mudflow is an earthflow that consists of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles.
- **Subaqueous Landslide** – Landslides that take place principally or totally underwater in lakes, reservoirs, along river banks, or in coastal and offshore marine areas are called subaqueous landslides. The failure of subaqueous slopes may result from a variety of factors acting singly or together, including rapid lacustrine or marine sedimentation, biogenic methane gas in sediments, surface water storm waves, current scours, water level drawdown, depositional oversteeping, or earthquake stresses. Many different types of subaqueous landslides have been identified in different locations, including rotational and translational slides, debris flows and mudflows, sand and silt liquefaction flows. Subaqueous slides may trigger a tsunami, which could result in coastal damages.

B. HAZARD POTENTIAL

1. Novato Area

Rice (1975) mapped the geology and landslide susceptibility in the region around Novato. In general, the semi-schist and related metamorphic rocks of the Franciscan Formation are associated with expansive soils, resulting in soil creep and soil debris flows. When soils accumulate to a depth of more than 2 to 3 feet on moderately steep slopes the soils tend to exhibit evidence of downslope mobility. The Franciscan mélange is more widespread in other parts of Marin County than in the Novato area. However, some of this terrain is present. The mélange terrain is characterized by scattered prominent sharp outcrops or monument-like masses of hard rock projecting out of smooth natural slopes. The mélange matrix consists of easily eroded materials with a weak shear strength, and show creep and sporadic earth and debris flows. The unsheared coherent rock masses within the matrix commonly act as buttresses at bottoms of slopes, which should be considered before removing during any slope repairs.

The Novato Conglomerate is a relatively strong and stable rock unit and weathering typically yields stable gravelly soils. The bedding is typically defined by sparse lenses of sandstone and they are not significant planes of weakness. In general, the massive sandstone and thinly bedded sandstone and shale bedrock exhibit high stability on natural slopes. However, they produce sandy and/or silty soils prone to erosion. The soils developed on this bedrock are also susceptible to liquefaction when saturated and when they accumulate in thick masses, they are potential sources of rapid, liquid-flow type landslides (debris avalanches).

The volcanic rocks in the Burdell Mountain area are abundant and large landslides are present in the vicinity of Burdell Mountain. These landslides resulted not from failure of the volcanic rocks, but from the underlying metamorphic rocks in the area and are likely unstable masses.

Colluvium is present throughout the upland areas. A blanket-like accumulation many feet thick occurs on steep heavily wooded north facing slopes. The south slopes are commonly grass covered, more gently inclined and have a thinner alluvial cover. This should be considered before removing any forest vegetation, which could greatly impact the slope stability and increase the amount of failures. Most debris flows and debris avalanches develop in the thick colluvium, which is highly susceptible to slope instability if subjected to grading or clearing.

2. Southeastern and Central Marin County

Relatively detailed mapping of the geology and landslide susceptibility has been performed in and around several communities in southeastern and central Marin County (Rice et al., 1976). The slope stability issues in this portion of Marin County are similar to those in other areas previously mapped. Most landslide damages are reported to have taken place within pre-existing landslide deposits from continued or renewed movement. The majority of slope failures that occur are soil and rock debris flows.

The Franciscan mélange and semi-schist and related metamorphics typically develop soil profiles that have a high clay content, usually montmorillonite, which has a high shrink-swell potential. These soils have little shear strength when they become wet and are susceptible to significant downslope creep. An accumulation of more than 2 to 3 feet of this type of soil increases the probability of soil debris and earth flows.

Other rock types in the area are usually relatively stable if they are in a massive and unweathered state. Metamorphic volcanic rock (also known as Greenstone) has a high strength and is erosion resistant when it is not sheared. However, if it is sheared and greatly fractured it weathers to clay that is relatively weak and susceptible to rapid erosion and landsliding. Sandstone and shale bedrock, which is the most common rock type in central Marin, is generally stable except where it has been sheared or closely fractured and deeply weathered.

Soil debris avalanches are common usually during periods of heavy rainfall. These failures are typically only in sandy and silty soil with little clay content and when the soil is completely saturated. Many of the debris avalanches in southeast Marin County occur in colluvium. A blanket like accumulation many feet thick are common on steep heavily-wooded north facing slopes. The dense tree cover inhibits erosion of the colluvium and stabilizes it.

3. Western Marin County

Wagner (1977) and Wagner and Smith (1977) mapped the geology and landslide susceptibility in portions of western Marin; specifically, in and around Bolinas and the area around the southeast end of Tomales Bay; including, areas around Inverness, Inverness Park, Point Reyes Station, and Olema. As discussed previously in the General Geologic Setting portion of this report the general geology west of the SAFZ consists of Late Cenozoic marine and continental rocks resting upon Cretaceous granitic basement (Salinian Block). East of the fault, the Franciscan complex is overlain by the Pleistocene Millerton Formation and other Quaternary deposits. Therefore, the slope stability problems are different on each side of the SAFZ, because the geology is different.

The general slope stability issues are reported by Wagner (1977). Landslides are prevalent along the coast and resulting in rapidly retreating sea cliffs in the coastline around Bolinas. Slope failures are present in moderate to steep slopes underlain by the Merced Formation. Debris flows are common in areas underlain by mélange matrix.

In the Bolinas Peninsula slope stability problems are associated with the different geologic units. Slope failures are common in the Monterey Formation, which has bedding that generally strikes about N 40° W and usually dips 40 to 60 degrees to the west. This bedding orientation has resulted in unstable conditions and large landslides on the coastline. The younger Merced Formation underlies the east part of Bolinas peninsula. This formation consists of poorly consolidated sediments that erode easily and are very susceptible to debris flow landslides and falls. The terrace deposits are generally in level terrain; however, they are easily erodible, have a low shear strength resulting in small slumps and gullying. The older alluvium in the area also contains unconsolidated material and is prone to slumping on the steep sides of deeply incised streams.

In the Tomales Bay area slope stability problems are common, but vary depending on which side of the SAFZ the failure occurs. East of the SAFZ, the Franciscan complex is the major unit and most slope failures occur in it. As discussed previously, slope creep and earth flows are common types of failures typical of the mélange matrix of the Franciscan. The Late Pleistocene Millerton Formation exposed in the cliffs on the east side of Tomales Bay typically slumps. West of the SAF zone, the ground is covered by thick vegetation that likely has a stabilizing effect on the steep slopes. This area is generally underlain by granitic rocks. These granitic rocks are deeply weathered and the weathered profile and overlying soil are likely prone to failure. Removing the vegetation by clearing and grading could likely result in activating new landslides or reactivating old landslides.

4. Countywide Landslide Potential

Wentworth and Frizzell (1975) performed photo-reconnaissance mapping of landslide deposits for a major portion of Marin County. These maps were based solely on photo interpretation methods and are at a smaller scale than the more detailed mapping discussed above (Rice, 1975; Rice et al., 1976; Wagner, 1977). However, they provide a general overview of the landsliding present in Marin County. These 7.5-minute quadrangle maps show that the Marin County uplands are significantly affected by some form of landsliding. The distribution of landslides varies and is controlled by the many causal factors discussed previously.

Landslides, especially debris flows and debris avalanches have been widespread and common in Marin County during times of heavy intense rainfall. Following the January 3-5, 1982 storm 4,600 debris flows were mapped just within Marin County (Ellen et al., 1988). Direct cost damage from landslides within Marin County were estimated to be $18,464,000 (Creasey, 1988). The mapping found several associations of debris flows and the natural landscape:

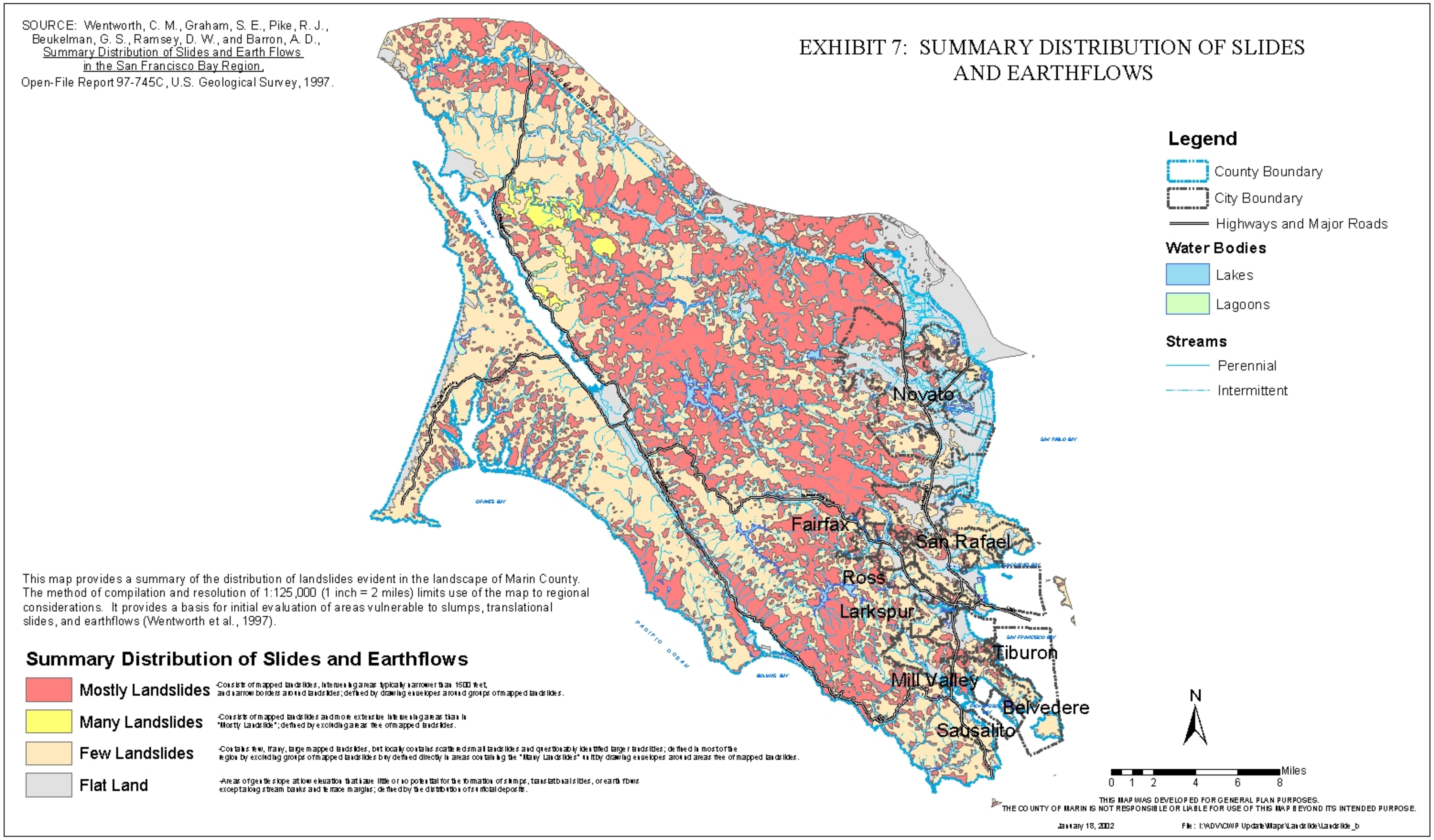
- Steep slopes (80 percent occurred on slopes steeper than 27.5 degrees.
- Granular soil mantle.
- Granular soil mantle with both bedrock contacts and materials that have contrasts in permeability.
- They are closely associated with drainages.
- They are associated with intense rainstorms.

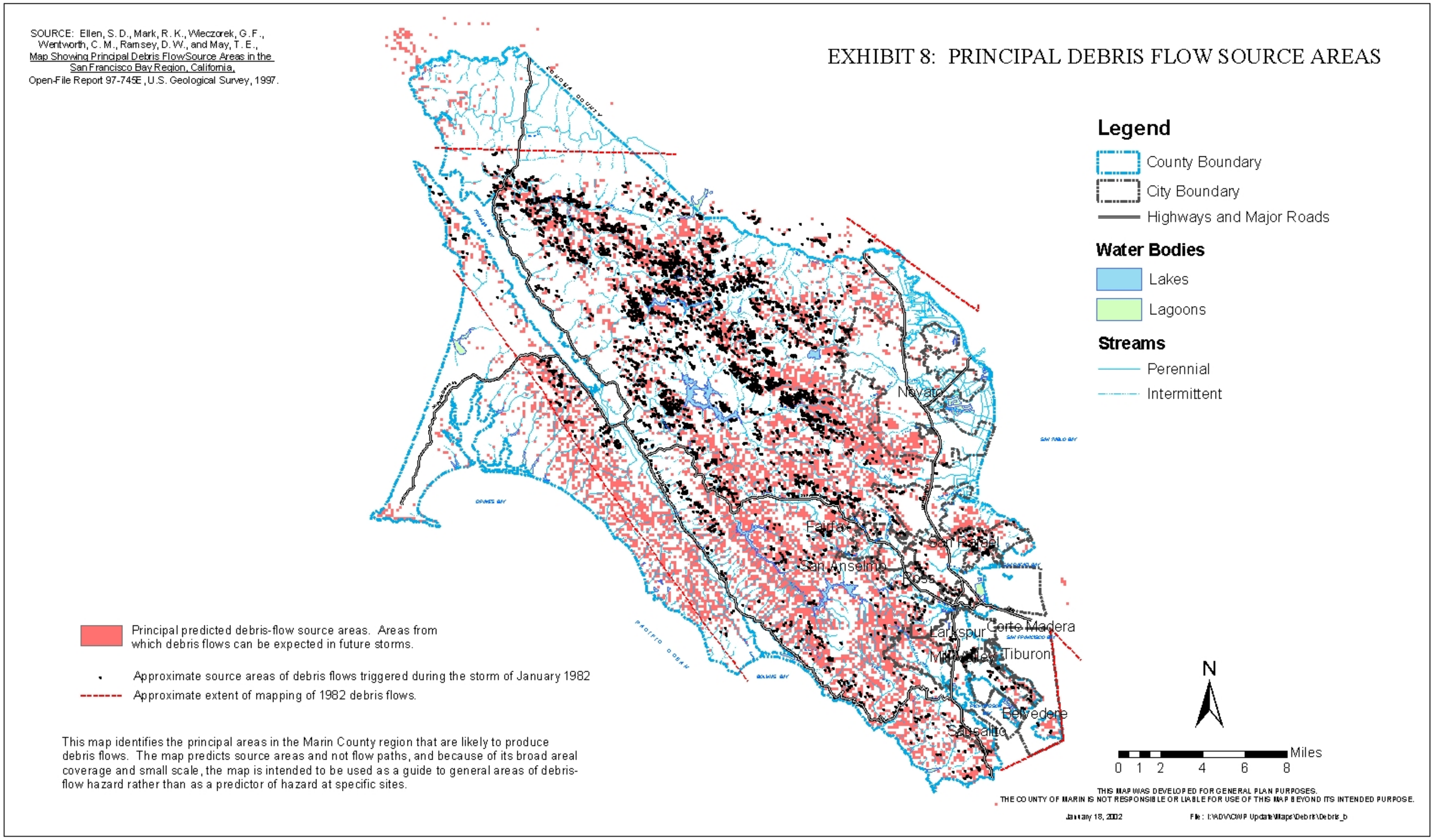
Reconnaissance landslide mapping has been performed in Marin County several times following periods of intense rainfall. The first published map by the U.S. Geological Survey was performed following the 1968-69 winter season (Taylor and Brabb, 1972). Above average rainfall occurred that season and 66 landslides were recorded with total public and private costs estimated at $1,054,950. Another published map was for the 1972-73 winter season (Taylor and Nilsen, 1975) shows that 153 landslides were reported in Marin County with a high concentration in Mill Valley and the Fairfax-San Anselmo area. The total public and private costs were estimated to total $3,064, 490.

Following the 1997-98 El Nino winter season Godt (1999) shows that near-record rainfall levels in the region caused landslides throughout the 10 County San Francisco Bay region during the first week of February 1998. Some counties received as much as 240 percent of normal rainfall. Several known landslides were located in Marin County and the majority were located near the cities of Tomales, Mill Valley and Novato (Morrissey et al., 1999). The total cost was estimated to be at least $2,540,000 in damage to public and private properties. Fifty eight percent of the total costs were related to damage caused by earth and debris slides. In Marin County over 65 percent of the recorded slides were debris flows.

Exhibit 10 shows the summary distribution of landslides evident in the landscape of Marin County. This map is a compilation of previous detailed mapping. The method of compilation and resolution of 1:125,000 (1 inch = 2 miles) limits the use of the map for regional considerations and is not to be used for site-specific evaluations. The red and yellow areas are locations that consist of mostly or many landslides, respectively. The orange areas contain few if any large mapped landslides, but locally contains scattered small landslides and questionably identified larger landslides. The gray areas are flat lands where landslide potential is low, except along stream banks and terrace margins. As can be seen from the map, a majority of the upland areas in Marin County may be potentially susceptible to landslide hazards.

Exhibit 11 shows the principal debris flow source areas in Marin County at a resolution of 1:125,000 (1 inch = 2 miles). Debris flows can be expected to originate largely in the areas shown on this map. Debris flows in a given storm originate from a number of source areas scattered throughout steep parts of the landscape, such as, old colluvial (soil) filled ravines. During subsequent storms, new debris flows


SOURCE: Wentworth, C. M., Graham, S. E., Pike, R. J., Beukelman, G. S., Ramsey, D. W., and Barron, A. D., Summary Distribution of Slides and Earth Flows in the San Francisco Bay Region, Open-File Report 97-745C, U.S. Geological Survey, 1997.
EXHIBIT 7: SUMMARY DISTRIBUTION OF SLIDES AND EARTHFLOWS
Legend
County Boundary
City Boundary
Highways and Major Roads
Water Bodies
Lakes
Lagoons
Streams
Perennial
Intermittent
Novato
Fairfax
San Rafael
Ross
Larkspur
Tiburon
Mill Valley
Belvedere
Sausalito
This map provides a summary of the distribution of landslides evident in the landscape of Marin County. The method of compilation and resolution of 1:125,000 (1 inch = 2 miles) limits use of the map to regional considerations. It provides a basis for initial evaluation of areas vulnerable to slumps, translational slides, and earthflows (Wentworth et al., 1997).
Summary Distribution of Slides and Earthflows
Mostly Landslides
-Consists of mapped landslides, intervening areas typically narrower than 1500 feet, and narrow borders around landslides; defined by drawing envelopes around groups of mapped landslides.
Many Landslides
-Consists of mapped landslides and more extensive intervening areas than in "Mostly Landslide"; defined by excluding areas free of mapped landslides.
Few Landslides
-Contains few, if any, large mapped landslides, but locally contains scattered small landslides and questionably identified larger landslides; defined in most of the region by excluding groups of mapped landslides but defined directly in areas containing the "Many Landslides" unit by drawing envelopes around areas free of mapped landslides.
Flat Land
-Areas of gentle slope at low elevation that have little or no potential for the formation of slumps, translational slides, or earth flows except along stream banks and terrace margins; defined by the distribution of surficial deposits.
N
0 1 2 4 6 8 Miles
THIS MAP WAS DEVELOPED FOR GENERAL PLAN PURPOSES.
THE COUNTY OF MARIN IS NOT RESPONSIBLE OR LIABLE FOR USE OF THIS MAP BEYOND ITS INTENDED PURPOSE.
January 18, 2002
File: I:\ADV\CWP Update\Maps\Landslide\Landslide_b


SOURCE: Ellen, S. D., Mark, R. K., Wieczorek, G. F., Wentworth, C. M., Ramsey, D. W., and May, T. E., Map Showing Principal Debris Flow Source Areas in the San Francisco Bay Region, California, Open-File Report 97-745E, U.S. Geological Survey, 1997.
EXHIBIT 8: PRINCIPAL DEBRIS FLOW SOURCE AREAS
Legend
County Boundary
City Boundary
Highways and Major Roads
Water Bodies
Lakes
Lagoons
Streams
Perennial
Intermittent
Novato
Fairfax
San Anselmo
San Rafael
Ross
Larkspur
Corte Madera
Mill Valley
Tiburon
Belvedere
Sausalito
N
Miles
0 1 2 4 6 8
Principal predicted debris-flow source areas. Areas from which debris flows can be expected in future storms.
Approximate source areas of debris flows triggered during the storm of January 1982
Approximate extent of mapping of 1982 debris flows.
This map identifies the principal areas in the Marin County region that are likely to produce debris flows. The map predicts source areas and not flow paths, and because of its broad areal coverage and small scale, the map is intended to be used as a guide to general areas of debris-flow hazard rather than as a predictor of hazard at specific sites.
THIS MAP WAS DEVELOPED FOR GENERAL PLAN PURPOSES.
THE COUNTY OF MARIN IS NOT RESPONSIBLE OR LIABLE FOR USE OF THIS MAP BEYOND ITS INTENDED PURPOSE.
January 18, 2002
File: I:\ADV\CWP Update\Maps\Debris\Debris_b

originate from various sources when the soils become saturated. These various sources, however, are similar in topographic form because debris flow initiation requires steep slopes and prefers concave parts of hillsides, such as, soil filled ravines. These topographic characteristics were used to compile the map in order to predict the likely future source areas shown (Ellen et al., 1997).

The red zones in Exhibit 11 are the principal areas from which debris flows can be expected during future storms. The black dots represent the debris-flow sources mapped after the heavy rain events in January 1982 and during the 1997-98 El Nino winter season. The dots provide an example of the abundance of debris flows that might be expected during a major rainstorm, and they illustrate that approximate nature of this predictive map (Ellen et al., 1997).

Because debris flows start in upland areas, they travel downslope and downstream from the source areas. This results in hazardous conditions that extend beyond the red zones on the map. These hazard areas can be near the base of steep hillsides, near the mouths of steep hillside drainages, and in and near the mouths of canyons that drain steep terrain. The hazards at the edges of the red zones should be considered. Debris flows are of the greatest concern during times of heavy rainfall, as shown in the historical record and because they typically move rapidly downslope and without warning. Because the map depicts potential source areas and not flow paths, and because of its broad areal coverage and small scale, the map is intended to be used as a guide to general areas of debris-flow hazard rather than as a predictor of a hazard at specific sites. Appropriate uses include storm-preparedness planning for emergency access and response (Ellen et al., 1997).

C. HAZARD MITIGATION

1. Reasons for Mitigation

The direct and indirect economic losses from landsliding throughout the State of California have been enormous. And, as shown by previous landslide mapping and economic loss estimates, the costs have been significant in Marin County. Schuster and Fleming (1986) define direct costs as those related to replacement, repair, or maintenance due to damage of property or facilities within the boundaries of a landslide. The indirect costs include:

- Reduced real estate values,
- Loss of productivity of agricultural or forest lands,
- Loss of tax revenues from properties devalued as a result of landslides,
- Costs of measures to prevent or mitigate future landslide damage,
- Adverse effects on the water quality and biology in streams,
- Loss of human productivity due to injury or death,
- Costs of litigation.

It has been determined that landslides in developing areas are largely caused by human activity, usually construction activity. Nilsen and Turner (1975) estimated that approximately 80 percent of landslides in Contra Costa County were due to human activity. This indicates the importance of effective enforcement of grading and construction codes in reducing landslide hazards. In addition, in Marin County the historical record has shown that a majority of landslides are due to two triggering mechanisms that have always been present and will continue to trigger landslides in the County:

- Earthquakes; and,

- Intense Rainfall

Combined with the adverse geologic conditions these triggering mechanisms pose a great threat to the slope stability in the County.

2. Methods of Mitigation

In order to reduce the direct and indirect costs and mitigate the causal factors of landsliding an effective mitigative plan is necessary. The USGS found that communities that achieved landslide loss reductions implemented four conditions that led to successful mitigative programs (USGS, 1982):

- An adequate base of technical information about the local landslide problem,
- An "able and concerned" local government,
- A technical community able to apply and add to the technical planning base; and,
- An informed population that supports a mitigation program objective.

Wold and Jochim (1989) state: "The key to achieving loss reduction is the identification and implementation of specific mitigation initiatives, as agreed upon and set forth in a local or state landslide hazard mitigation plan." They also propose that achievement can be obtained by applying the following techniques:

- Preventing or minimizing the exposure of populations and facilities to landsliding,
- Preventing, reducing, or managing the actual occurrence of landslides,
- Physically controlling landslide-prone slopes; and,
- Protecting existing structures.

Wold and Jochim (1989) recommend the following planning process steps that are involved in developing a landslide hazard mitigation plan (adopted for Countywide mitigation):

- Analysis of the types of landslide hazards in the County and a general assessment of the vulnerability of people and property to the County's landslides hazards,
- Identification of specific areas of the County where landslides have the most serious or immediate potential impacts and a detailed analysis of their vulnerabilities,
- Translation and transfer of technical information on hazards and vulnerabilities to users such as decision makers, community planners, and emergency management officials,
- Assessment of resources and mitigation programs available in the public and private sectors to deal with the identified potential impacts,
- Determination of local capability shortfalls and unmet needs in order to apply technical and financial assistance where it can best contribute to the reduction of future losses,
- Formulation of goals and objectives for County landslide hazard mitigation plans, and the development of cost-effective mitigation projects that address identified vulnerabilities,
- Establishment of a permanent County hazard mitigation system to prioritize and promote mitigation goals and objectives and to secure and direct funding for implementation; and,
- Periodic evaluation and modification of the plan and planning process.

D. SUMMARY AND ISSUES TO CONSIDER

- Landslide and slope stability hazards are prevalent throughout Marin County due to the existing adverse geologic conditions. The potential threat of a significant number of failures occurring at the same time is great during strong seismic shaking or during intense rainfall events. Landsliding during causative events such as these could cause significant levels of damage and significantly impact structures, utilities, services, roads, etc.
- Studies of landslides, especially debris flows, triggered by significant rain events over the last three decades have shown that millions of dollars in damage occur in Marin County during these events. Reducing this cost should be a key goal of landslide hazard mitigation.
- Evaluation of landsliding and slope stability should be done through additional detailed and large scale mapping studies. This would help in reducing the potential hazards. This type of evaluation study could be conducted with other public agencies, such as the Division of Mines and Geology and the U.S. Geological Survey, as was done with the previous studies in the 1970's. The information from these studies is still currently used. Adding to and improving upon past studies should provide additional and more refined knowledge to be used in mitigating this hazard. A future source of information will be the upcoming Seismic Hazard Zone Maps and their accompanying reports. These maps will provide valuable information with respect to areas that may be susceptible to earthquake-induced landslides.
- The definition of what constitutes a landslide hazard area should be reevaluated. A landslide hazard area is currently defined by stability zones 3 and 4 on County slope stability maps. These maps do not cover some areas of the County and more detailed studies could redefine stability zones based on new updated information.
- Regular review and reevaluation of existing County policies and building code regulations should be done. Continued improvement of hillside safety and hazard prevention measures can contribute to reducing the cost of damage.
- Increased education and awareness of the landslide and slope stability issues by public officials, consultants, developers, homeowners, and contractors will encourage proper geotechnical and engineering geologic investigations and effective mitigative efforts. Information concerning landslide and slope stability issues should be accessible to homeowners and incentives and disincentives should be created to promote mitigation efforts.
- Development of a hillside safety and hazard mitigation program would lead to creating an effective vehicle in dealing with this ongoing long-term issue. This issue will only grow as continued development encroaches on the hilly "marginal" areas within the County.
- Effective grading policies, regulations and enforcement play a vital role in mitigating this hazard and they are at the core of any hillside safety and hazard mitigation program.
- Both a geotechnical engineer and a certified engineering geologist should perform any slope stability investigation and analysis. Existing County landslide and slopes stability policies (Policies EH-6.1, EH-6.2, and EH-6.3) should be refined and include the combined efforts of a geotechnical engineer and engineering geologist. Development of all hillside properties should be preceded by a detailed engineering geologic and geotechnical engineering investigation. Those properties found to have landslide and/or debris flow deposits should be analyzed thoroughly and properly mitigated prior to development.

VI. EXPANSIVE AND CREEPING SOILS

A. HAZARD DESCRIPTION

Many of the soils present in Marin County have moderate to high expansion potential. Such soils generally are cohesive, have a high clay content, and shrink when dried. Montmorillonite or other smectite group clay minerals are usually present in expansive soils. Expansive soils are naturally prone to large volume changes through the absorption of pore water. The physical manifestation of such moisture change most often is expansion or swelling during the winter and subsequent shrinkage due to drying or desiccation in the summer. This cyclic volume change can exert large forces on nearby structures, causing damage to concrete slabs and foundation elements and cosmetic damage to interior and exterior wall surfaces, tilted posts, fences, retaining walls, and ruptured utility lines. Thick soil accumulations of expansive soils are responsible for the numerous earth flows that are present throughout the hillsides of the County, particularly in areas underlain by Franciscan mélange. The thickness and depth to an expansive soil layer will influence the degree of shrinking and swelling that may take place. On a hillside, expansive soils are adversely affected by gravity and cyclically creep downhill. This type of creep movement typically occurs during the drying cycle.

Exhibit 12 shows the soil units that are listed in the 1985 Soil Survey of Marin County prepared by the United States Department of Agriculture, Soil Conservation Service as having low, moderate and high expansion potential components in their soil profile (Kashiwagi, 1985). Due to the scale of the mapping, the map units are typically composed of more than one soil type within their boundaries. Individual profiles for a specific soil type may have different expansion potentials. For example, a single soil type may have low, medium and high expansion potential layers in its profile. Therefore, the highest expansion potential designation determined for a specific map unit is shown on Exhibit 12. This provides a conservative overview of the soil expansion potential in the County.

The soil survey indicates that laboratory measurements of swelling undisturbed clods were made for many soils; and, for others swelling was estimated on the basis of the kind and amount of clay minerals in the soils and on measurements of similar soils. If the shrink-swell potential is rated from moderate to very high, shrinking and swelling can cause damage to

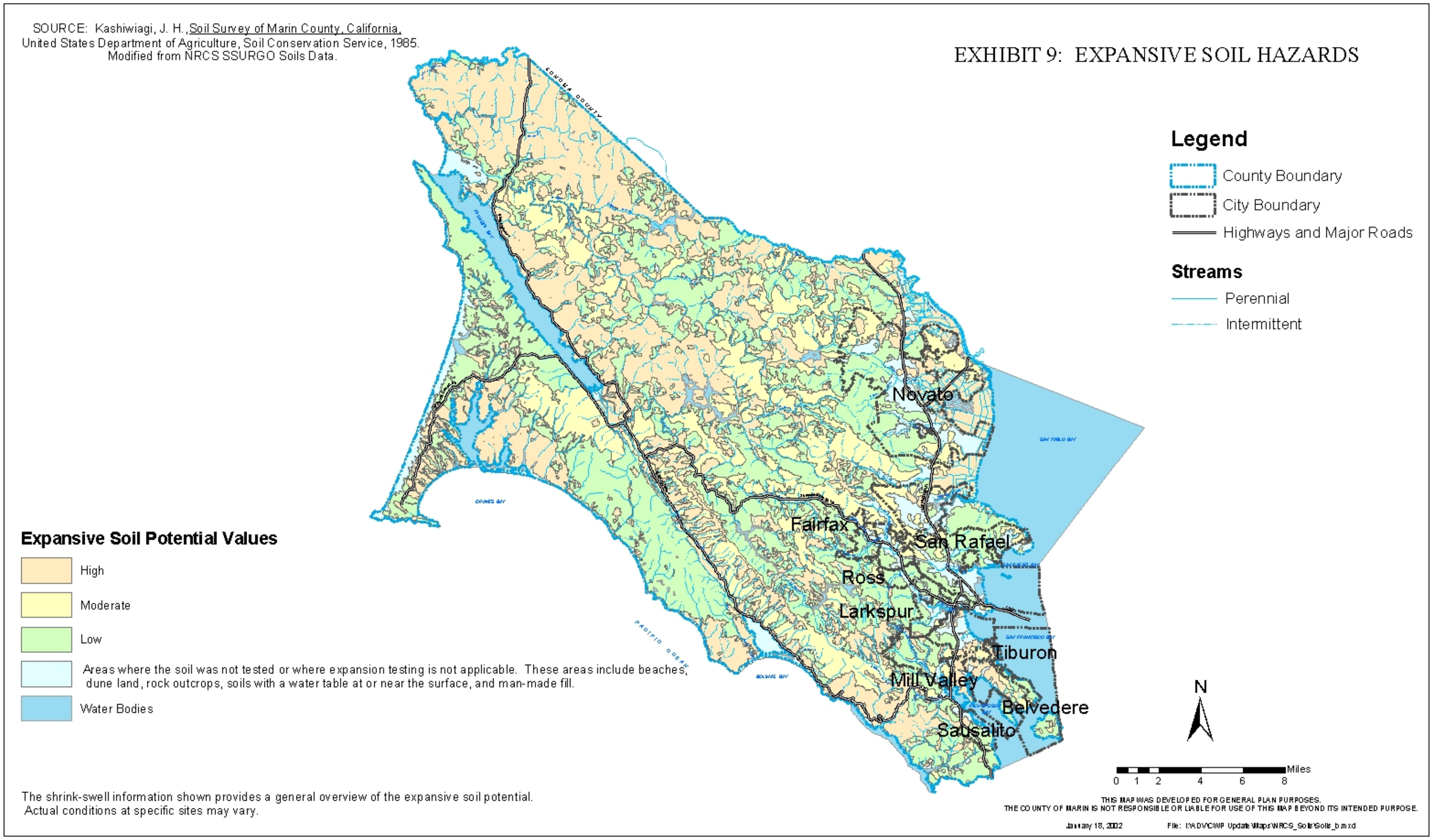


EXHIBIT 9: EXPANSIVE SOIL HAZARDS

buildings, roads and other structures. The shrink-swell potential classes in the table and used in the exhibit are based on the change in length of an unconfined clod as moisture content is increased from air-dry to field capacity. The change is based on the soil fraction less than 2 millimeters in diameter. The classes are: low, a change of less than 3 percent; moderate, 3 to 6 percent; high, more than 6 percent, and; very high, greater than 9 percent (Kashiwagi, 1985). There are no soils in the survey listed as very high. Those areas not given a designation of high, moderate or low are areas where the soil was not tested or where expansion testing is not applicable. These areas include beaches, dune land, rock outcrops, soils with a water table at or near the surface, and man-made fill.

The shrink-swell data from the soil survey shown in Exhibit 12 provides a general overview of the expansive soil conditions in the County. Actual conditions for a specific development may vary; therefore, site-specific geotechnical investigations and testing of expansive soil potential should be performed in areas where there is a potential concern.

B. HAZARD MITIGATION

Several mitigative measures are available for expansive soils. For site-specific conditions, a soils engineer must recommend specific design criteria; notably, the minimum embedment depth of footings, pressure on retaining walls, reinforcement in footings, etc. Use of minimum standards of the Building Code or more conservative design parameters should be implemented on a case-by-case basis.

Typical mitigative measures for treatment of expansive soils include:

- Pre-saturating fill soils and wet placement of fill soils above optimum moisture content.
- Placing a non-expansive imported soil in the upper part of the building pad.
- Burying expansive soils deep in the fill.
- Treating soil with lime.
- Mixing expansive soils with less expansive soils.
- Designing foundation systems to incorporate measured variation of soil swell with effective confinement (dead weight).

Mitigative Measures typically incorporated in building design include:

- Strengthening of foundations and use of suspended wood floors.
- Drilling pier and grade beam foundations with sufficient embedment.
- Building floating slabs and pre-stressed (post-tensioned) slabs-on-grade.
- Chemical treatment.
- Proper drainage control.
- A combination of these techniques.

C. SUMMARY AND ISSUES TO CONSIDER

- Expansive soils are present throughout Marin County and are responsible for a large amount of surficial creep and slope failure in upland areas. Expansive soils are also responsible for damage to structures in upland and flatland areas.
- Increased education and awareness of the hazards resulting from expansive soils by public officials, consultants, developers, homeowners, and contractors will encourage proper geotechnical and engineering geologic investigations, effective foundation design, grading and drainage policies.

- Methods provided in the Uniform Building Code and future codes used by Marin County for addressing this hazard are minimum standards that should be effectively enforced to mitigate this issue.
- The existing County policies and methodologies for mitigating expansive soil hazards should be regularly reevaluated for improvements as new information is obtained and new design methods are created.
- Existing County policies do not specifically address the issue of expansive soils; however, some existing policies should be refined to include expansive soils in their text (see Section XIII). Specific policies tailored toward expansive soils should be considered. New developments located in known or mapped high to moderate expansion potential zones should be preceded by a thorough, site-specific geotechnical investigation to evaluate expansion hazard. Laboratory testing for expansion potential should be performed at finished grade on a lot by lot basis as deemed appropriate by the project geotechnical engineer. This will allow for proper mitigation or avoidance of this potential hazard.

VII. GRADING

A. INTRODUCTION

Grading operations are used consistently throughout California to mitigate adverse soil conditions and repair landslides. Grading with site-specific under-construction input from engineering geologists historically has lowered the incidence of influence by adverse geologic conditions, such as, compressible soils and landslides. Without mitigative grading in affected terrain, the potential for developments being impacted is increased substantially.

Specific conditions of individual sites dictate how much grading is necessary to successfully mitigate adverse geological conditions and typically include minimal grading and mass grading, although it is the depth and volume of earthmoving activities which define these types of grading, not necessarily the areal extent of surface disturbance.

The type and location of grading operations required to mitigate adverse geological conditions successfully for the long-term cannot be determined before completion of subsurface investigations, which are necessary to provide sufficient detailed information to characterize the extent of adverse conditions and to design measures suitable to remediate site-specific conditions. Once site-specific conditions are determined, the appropriateness of the following techniques can be considered on a case-by-case basis for inclusion in the design and implementation of projects:

- Mechanically stabilize embankments, construct toe buttresses, and infill incising creek channels (creek channel incisions are geologic "triggers" that spawn landsliding) to reduce the amount of grading. Such techniques can permit minimal grading with the degree of long-term safety normally associated with conventional buttress repairs.
- Use passive mitigation to reduce the potential for landslide induced hazards in the area of large landslides. This technique would involve setting development back or relocating structures away from large identified potential landslide features to avoid damage or destruction from sliding. Physical avoidance to mitigate potential slide impacts on proposed improvements would eliminate the zone of disturbance caused by grading.

- Both mechanical stabilization and passive mitigation would be effective in reducing the magnitude of grading. However, if not planned properly to reduce the corridor of disturbance, grading could impact a large area adversely in a number of ways. Secondary impacts caused by grading include dust control, traffic, noise, erosion and water needs during construction.

B. TYPES OF GRADING

1. Minimal Grading

Minimal site grading may involve a large area in plan view but generally is shallow and involves the least amount of earthmoving necessary to reach the desired finished building grades. Because minimal grading may not stabilize all major geologic hazards (such as bedrock landslides), it is usually most appropriate on sites with generally favorable geologic conditions or where landslides are relatively shallow. Minimal grading can also involve the use of retaining structures, mechanically stabilized embankments and surface and subsurface drainage, to further stabilize sites with a limited grading concept.

2. Mass Grading

Mass mitigative grading (such as that used in buttress fill slope reconstruction) involves the removal and recompaction of thousands of cubic yards of earth material in order to stabilize an unstable or unsupported slope or to repair large landslide deposits. While mass grading may ultimately produce a safer site, it usually creates a much greater corridor of disturbance than minimal grading techniques. Mass grading also can produce many secondary effects, such as biotic, dust, noise and traffic concerns. This type of grading is best performed only in areas, which are not environmentally sensitive.

C. HISTORY OF GRADING CODES

The numerous problems, procedures, trials, and errors suffered by governmental agencies and hillside-development in California during the period from 1956 through 1961 inadvertently became the basis of Chapter 70 of the Uniform Building Code (UBC) published by the International Conference of Building Officials (ICBO). A regrettable lack of uniformity had persisted in the existing grading codes. The codes lacked integrity because they had been pieced together as particular problems arose rather than developed comprehensibly. The only valuable geotechnical field supervision of grading during that period was by soil-testing companies and governmental grading inspectors. The lack of uniform code requirements and the limited grading code enforcement personnel understandably failed to require a quality of performance that insured safe construction (Scullin, 1983). Chapter 70 of the UBC was written in 1962 and developed out of the grading codes for the County of Los Angeles. It was adopted and added to the UBC as an appendix in 1964. The section was later revised several times and the final version was incorporated into the 1969 UBC. Research has shown that modern grading codes have reduced rain-induced damages to structures in graded tracts by as much as 90 percent (Scullin, 1983).

D. GRADING CODE ADMINISTRATION AND ENFORCEMENT

Effective grading code enforcement has clearly been shown as an effective way to reduce losses due to natural geologic hazards. Potential natural hazards do not become community risks until urban development and population encroachment hinder the natural geologic processes. Interruptions of natural processes without knowledgeable technical management have the potential to induce financial and human losses. Public administrators challenged by systems management with reduced funding, and professional and technical industries faced with higher liability and relatively less compensation, are often being required to define "acceptable risk" and "cost benefit" programs commensurate with population increases into "marginal" land areas. Public involvement and support, administrative awareness and management skills, geotechnical professions, and industrial progress within our urban development fields will all play important roles as communities grow into potentially hazardous terrain. Effective grading code enforcement can and should provide cost benefit programs that will mitigate losses due to geologic hazards (Scullin, 1983).

E. GRADING INSPECTION AND THE REVIEW PROCESS

The modern review process is designed to assure public safety and welfare through comprehensive site evaluation prior to issuing building permits, and through quality control inspection during construction. The application of site knowledge to planning, design and grading construction is absolutely essential to ensure a safe building site. The inclusion of grading supervision, control, and code enforcement is a recent sophistication of the review process. The grading review process applies from site planning through plan check, the actual grading of the site, and the rough and fine grade stages of construction.

F. CONSULTING REVIEWERS

Geologic and soil engineering consultants have been retained by builders, developers, and large construction companies to evaluate the soils and geologic conditions on proposed building sites. There have been cases when conflicts of opinion between private consultants and governmental staff has resulted in outside geotechnical reviewers being hired to provide an independent review of the geologic conditions and peer review of the consultant's work. Geotechnical review has contributed safe development of graded sites in grading projects, improvement projects, and both major and minor divisions of land. Geotechnical reviewers act as consultants regarding environmental impact reports (EIR), seismic safety elements of the general plan, planning department projects, geologic hazard areas, waste disposal sites, and as expert witnesses to legal departments.

G. SUMMARY AND ISSUES TO CONSIDER

- Grading can be an effective means for successfully mitigating adverse geologic conditions and hazards. The input from an engineering geologist can be effective in mitigating geologic hazards and should be considered when refining any existing policies.
- In order for proper grading to be performed, oversight by adequate grading code administration and enforcement is necessary. This is especially true now that continued development will encroach on "marginal" lands where significant geologic hazards will likely be encountered. Continual reevaluation of grading code administration and enforcement should be done in order to enhance and improve existing County standards.
- Existing Policy EQ-3.16 addresses the issue of minimizing grading; however, this policy should be refined to include the importance of a stable development site. Minimizing grading is fine as long as geologic hazard mitigation is performed properly.

VIII. SUBSIDENCE AND DIFFERENTIAL SETTLEMENT

A. HAZARD DESCRIPTION

Subsidence is the vertical displacement of the ground surface, which can be localized or over a broad region. Subsidence can be affected by different processes at work and can be naturally induced or human-induced. Regional scale human-induced subsidence generally results from withdrawal of fluids (water, oil or gas) from underground reservoirs. More localized human-induced subsidence can be caused by placement of fills and structures on collapsible soils, saturation of collapsible soils by the human introduction of water into the subsurface, and mining operations. This can be done by pipe breaks, over irrigation and on-site sewage disposal systems. Naturally induced subsidence can also be related to localized settling caused by seismic shaking. Seismic shaking can cause liquefaction or compaction of soils prone to collapse. Differential (uneven) settlement refers to the vertical movement of an engineered structure due to subsidence of the underlying unconsolidated materials.

The most prominent and well-known significant subsidence hazard in Marin County is subsidence of the young bay muds. The placement of fills and structures on bay muds has resulted in human-induced subsidence and seismic shaking has caused naturally induced subsidence of bay muds. In general, bay mud is a soft, slightly organic silty clay containing occasional thins seams or lenses of silt and sand. Its high water content and low pre-consolidation pressure cause it to undergo substantial long-term settlement under sustained loads (Seed, 1969). The upper layer of younger bay mud is unconsolidated and in a semi-fluid state that is sensitive to seismic shaking and an increase in vertical loading (Lee and Praszker, 1969).

Subsidence of natural materials over a time span that would be noticeable in engineered works generally occurs in the low-lying flatland deposits in valley basins and along bays. In Marin County, these areas are located in the flats and valleys on the east side of Marin County adjacent to the Bay and in the flats and valleys associated with drainage outlets to Tomales and Bolinas Bays and outlets to the Pacific Ocean (Exhibits 2 and 3). The areas most susceptible to subsidence and differential settlement in Marin County are in those areas underlain by young Holocene unconsolidated alluvial and colluvial sediments and estuarine muds. Development of these areas should be evaluated and mitigated using appropriate engineering methods. Differential settlement of engineered structures may also occur in upland areas if the slope materials are collapsible or on landslides that are unstable or potentially unstable. The deposits on Exhibits 2 and 3 that may likely be prone to localized subsidence and differential settlement include, East of the SAFZ (Exhibit 2): artificial fill (Qaf), artificial fill over marine and marsh deposits (Qmf), beach sand (Qs), dune sand (Qd), marine and marsh deposits (Qm), landslide deposits (Qls), alluvium (Qal), slope debris and ravine fill (Qar), Undifferentiated surficial deposits (Qu). West of the SAFZ (Exhibit 3): beach sand (Qs), dune sands (Qd), alluvium (Qal) and landslide deposits (Qls). However, other collapsible soils may be present at other locations in the County.

B. HAZARD MITIGATION

The consequences of improper utilization of land prone to subsidence and differential settlement will likely result in significant economic losses. In certain extremely subsidence prone areas, complete avoidance is likely the best mitigative measure. However, this can include usage of the susceptible land to uses that would not be greatly impacted; such as, using the land for agriculture, parkland, open spaces, or other suitable usages. If the economic cost is not detrimental, developments can be engineered to prevent subsidence and differential settlement. This would require site-specific detailed engineering and geological analysis to properly evaluate and mitigate the unfavorable site conditions.

C. SUMMARY AND ISSUES TO CONSIDER

- Collapsible soils are present in Marin County and are generally located in the low-lying flatland deposits in valley basins and along bays. The most susceptible areas are those underlain by young Holocene unconsolidated alluvial and colluvial sediments and estuarine muds, especially younger bay muds.
- Both human-induced processes and naturally induced processes can cause subsidence and differential settlement of collapsible soils.
- Increased education and awareness of the hazards resulting from collapsible soils by public officials, consultants, developers, homeowners, and contractors will encourage proper geotechnical and engineering geologic investigations, effective foundation design, grading and drainage policies.
- The existing County policies and methodologies for mitigating hazards posed by collapsible soils should be regularly reevaluated for improvements as new information is obtained and new design methods are created.
- Existing Policies EQ-2.62 and EQ-2.62 address the hazard of differential settlement within the Bayfront Conservation Zone as posed by the young bay muds. These policies are still applicable; however, some refinement of these policies, as discussed in Section XIII, should be considered.
- Existing Policies EH-7.1, EH-7.2, EH-7.3 and EH-7.4 and their associated programs specifically address this hazard and are still applicable; however, some refinement of these policies, as discussed in Section XIII, should be considered.

IX. COASTAL BLUFF EROSION

A. HAZARD DESCRIPTION

Much of the Marin County coastline is dominated by erosional processes that predominate over depositional processes; thereby, resulting in coastal bluff erosion. This erosion is a continually on-going process that is more pronounced during periods of intense storm activity. Bluff erosion is a complex erosion process involving many aspects that can vary greatly along the coast (Hampton and Dingler, 1998). The primary component of this process, and the greatest single factor in the erosion rate of a bluff as compared to another, involves the physical characteristics of the bluff materials (Benumof and Griggs, 1999). Different soil and rock materials are susceptible to erosion to varying degrees. Benumof and Griggs (1999) label these physical characteristics of eroding materials as the intrinsic variables involved in bluff erosion, and include the strength of the material, the severity of joints and fractures, and the susceptibility of a material to weathering. Therefore, given the same external influences, a bluff composed of strong, weather resistant rock with no fractures will erode at a slower rate than a weak rock with extensive fracturing that is highly susceptible to weathering. The secondary component of the bluff erosion process involves the extrinsic variables that impact the intrinsic variables. These include wave erosion, amount of precipitation, surface runoff, groundwater seepage, and seismic shaking. The bluffs of Marin County are susceptible, in varying degrees, to all of these intrinsic and extrinsic variables.

The degree of erosion varies over time and significant erosion appears to be episodic in nature when greater than normal storm events cause the greatest erosion. This was observed and well documented during the 1982-83 and 1997-98 El Niño winter storms (Storlazzi and Griggs, 1998; Cannon et al., 1998). These greater than normal storm events result in larger wave heights, higher sea surface elevations and increased precipitation relative to average storm events. As expected, these greater than normal extrinsic variables have a greater impact on the intrinsic variables; thereby, increasing the erosion rates for a limited period. This is an important point when considering the length of time that is evaluated for determining setback lines from eroding bluffs.

Reported bluff erosion rates for the Marin coastline are mostly limited to the Bolinas Peninsula. Erosion rates for the Bolinas Peninsula have been reported in various sources and range from 0.4 to 36 inches per year, which is dependent on the location (Marin County, 2003). Coastal bluff erosion can be more pronounced during periods of heavy storm activity as during El Nino winters; thereby, increasing these retreat rates in a shorter time span (Cannon et al., 1998).

B. HAZARD MITIGATION

The best mitigative measures for bluff erosion is not permitting development near the top of actively eroding coastal bluffs and providing a significant enough setback from the top of bluffs to prevent damage to any structures and their foundations by bluff erosion. Setbacks should be based on known bluff erosion studies and site-specific studies providing design recommendations for development. Setbacks should be determined on a case-by-case basis because of the varying retreat rates along the coast.

New development must be sited far enough away from a bluff so that it is not at risk during its expected economic lifetime and that measures are employed during development to prevent any adverse impacts to the bluffs or adjacent properties. The following two setback methodologies are used by the staff of the California Coastal Commission in evaluating setbacks for bluff top development (Johnsson, 2005). The first method that can be used is based on determining the stability of a bluff; if a bluff is not stable then a setback line can be determined with a slope stability analysis. This setback line, derived from slope stability analysis, is the line that meets the minimum factor of safety deemed appropriate. For residential and commercial structures, this is typically a factor-of-safety of 1.5 (ratio of driving force to resisting force). This type of analysis is very effective for a site-specific study and should include evaluation of the subsurface conditions and the potential for landsliding along planes of weakness.

The second method of determining a setback line is by measuring the long-term bluff retreat rates from historical data and creating setbacks based on the expected economic lifetime of proposed new development. This approach requires determining the maximum erosion rate for a bluff and plugging it into the following formula:

Setback = (expected economic life of structure) x (rate of retreat)

Because of the uncertainty involved in the actual analysis of bluff erosion, it is common for an additional distance to be added to the setback as a safety factor. This can been done using various methods, which are outlined in Johnsson (2005). As an example, the Bolinas Gridded Mesa Plan incorporates an additional safety factor of 45 feet to the above formula:

Setback = (expected economic life of structure) x (rate of retreat) + (safety factor 45 feet)

Uncertainties that are beyond control and difficult to determine, include the effects of sea level rise, the number and severity of future large storm events and the number and severity of future earthquake events. A method useful for addressing some uncertainty and for refining a setback line over time is the use of a rolling setback. A rolling setback is based on the use of updated coastline change information that is reexamined and adjusted as necessary. This ensures that the location of new development evolves with the ever-changing coastline.

C. SUMMARY AND ISSUES TO CONSIDER

- Bluff erosion and landsliding along the coast are due to ongoing active erosional processes on the Marin County coastline and are a potential geologic hazard that must be addressed.
- Any development within the vicinity of a coastal bluff should be preceded by a detailed engineering geologic and geotechnical engineering investigation, which will accurately characterize the site geologic conditions and determine the stability of the slope and bluff retreat rates. This will allow proper setback and/or mitigative recommendations by the project geotechnical engineer.
- A countywide plan policy does not exist regarding coastal bluff erosion and coastal landslide hazards; however, these issues are addressed in the Marin County Development Code for coastal zones.
- The coastal resource management standards, used to implement policies of the Coastal Act and Local Coastal Plans, provide minimum standards that address this issue (Marin County Code – Title 22, Development Code, Chapter 22.70, Coastal Resource Management Standards).
- The minimum standards described in the Coastal Resource Management Standards section 22.70.130 – Shoreline Protection, addresses the issue of slope stability and blufftop retreat rates and provides potentially effective requirement standards for addressing this issue.
- The minimum standards described in the Coastal Resource Management Standards section 22.70.060 – Hazard Areas, should be evaluated in order to determine if the standard can be raised. Currently, a coastal permit application for a site in a designated geologic hazard area requires a report by a qualified registered civil or structural engineer describing the extent of potential geologic hazards at a site. A report requiring the combined knowledge of an engineering geologist with the design and mitigation knowledge of a civil, geotechnical or structural engineer would be a more effective report for addressing coastal geologic hazards.

X. STRUCTURAL HAZARDS DUE TO EARTHQUAKES

A. HAZARD DESCRIPTION

Bertero (2000) states that the philosophy of earthquake design for most structures is well established, and defined by:

- Preventing non-structural damage in frequent minor ground shaking,
- Preventing structural damage and minimizing non-structural damage in occasional moderate ground shaking; and,
- Avoiding collapse or serious damage in rare major ground shaking.

However, the implementation of this philosophy is difficult because of current design methodologies, problems with quantifying the different types of structural and non-structural damage and defining what constitutes frequent minor, occasional moderate and rare major earthquake ground shaking.

A comprehensive design approach should consider the fact that many, if not most, of the previously discussed geologic hazards can result in damage to structures and facilities, including:

- Ground failures (or instabilities due to ground failures)
- Surficial fault rupture
- Vibration of soil (including earthquake generated ground shaking)
- Ground cracking
- Liquefaction
- Ground lurching
- Differential settlement
- Lateral spreading
- Landslides
- Vibrations transmitted from the ground to the structure
- Tsunamis
- Seiches
- Landslides
- Floods
- Fires

From this list it becomes apparent that the design of a structure is influenced by where the structure is to be located and that adequate design methodologies should be considered when evaluating the potential impact these effects may have. The effect of vibration from earthquake shaking is usually what is of greatest concern to the structural engineer, and its effect on common structures is discussed in this section and is taken from Bertero (2000) and the California Seismic Safety Commission (CSSC) (1999). Ground shaking can result in structural failure and possible collapse but usually results in non-structural damage. It also causes building elements and equipment within and outside of a structure to become potential hazards.

The dynamic response of a structure to ground shaking is a very complex behavior that is dependent on a number of inter-related parameters that are often very difficult, if not impossible, to precisely predict. These include: the exact character of the ground shaking that the building will experience; the extent to which the structure will be excited by and respond to the ground shaking; the strength of the materials in the structure; the quality of construction and condition of individual structural elements; the interaction of the structural and non-structural elements of the building; the weight of furnishings and contents present in the building at the time of the earthquake; and other factors. Most of these factors can be estimated, but never precisely known (CSSC, 1999). Thus, it is quite difficult to determine the potential vulnerability that a specific structure will have to ground shaking. However, an approximate vulnerability estimate can be developed by a structural engineer with specialized knowledge of earthquake engineering.

The numerous failures of structures over the years have resulted in development of regulations and guidelines that if used properly result in an effective seismic-resistant design. Proper use of the Uniform Building Code (UBC) in design should result in a structure that will not collapse in the event of an earthquake; however, this does not rule out the possibility of some non-structural damage. Many buildings in Marin County were built before development of modern codes and therefore may become a hazard during seismic shaking.

The building code sets minimum criteria for the structural design of buildings. For many years, the codes enforced by local governments in California have been based on the UBC, which has been published by the International Conference of Building Officials (ICBO). Since, 1991, California cities and counties have been required to adopt the same edition of this code, as is adapted by the State of California. With the publication of the 1997 edition of the UBC, the ICBO ceased publication of this model code (CSSC, 1999). The code adopted by the State is the California Building Code (CBC), which is also known as Title 24 of the California Code of Regulations. The publication dates of the CBC are established by the California Building Standards Commission (BSC), which is updated and republished in a 3-year cycle. In 2000, the BSC voted to re-adopt the 1997 Uniform Building Code (UBC) as the 2001 California Building Code. All parts of the 2001 CBC became effective November 1, 2002. Currently, the BSC is reviewing the 2004 proposed code changes.

The earthquake design provisions contained in the UBC have traditionally been based on recommendations developed by the Structural Engineers Association of California (SEAOC). These recommendations have adopted a seismic design philosophy intended to protect life safety, but allow for some structural and potentially significant nonstructural damage from earthquake levels as severe as can be expected in active seismic regions such as Marin County. This philosophy was briefly stated in the beginning of this section.

Buildings designed in accordance with the UBC are anticipated to experience significant damage loss, when affected by a major earthquake. Further, the design provisions of the UBC primarily address damage caused by ground shaking. They do not address the effects of other site hazards, such as liquefaction, ground lurching, landslides, ground surface rupture, etc. Any of these types of ground failure can result in excessive damage and potentially, even collapse of buildings meeting the code criteria. Because of the continual experience, California has had with earthquakes over the past few decades major UBC code changes have been made, following the 1994 Northridge earthquake, 1989 Loma Prieta earthquake, and the 1971 San Fernando earthquake.

The following is a general list of some building types and a brief description of some issues related to their earthquake performance (portions of the following are taken from Bertero (2000) and CSSC (1999)):

1. Wood-Frame Structures

Among the materials that are used for construction, wood is considered the most efficient earthquake resistant material for low-rise buildings. During seismic shaking, the response of a structure's foundation greatly depends on the intensity of inertia forces. These forces are the product of mass and acceleration; therefore, it is important to reduce the mass of a structure to a minimum. Thus, wood is a useful material in achieving this goal.

Based on past earthquake experiences the greatest considerations for wood-frame structures are that they should be carefully designed and constructed, provided with lateral bracing and all of their components should be tied together from the roof down to the foundation. A major cause of failure in older wood-frame structures is failure at the framing/foundation junction in which, the framing is not properly connected to the foundation or the lower portions of the framing are not adequately braced.

2. Unreinforced Masonry Structures (URMs)

It is a well-known fact, based on the historical record of performance in earthquakes that unreinforced masonry is very susceptible to ground shaking. Solid brick masonry is very heavy and its tensile strength is low. Old unreinforced masonry buildings, whose walls are not properly connected to floors, roof, and interior and exterior transverse walls, are an extreme seismic hazard. However, if masonry is properly reinforced it can be used in seismic-resistant construction.

California passed the URM law in 1986 requiring local governments in the highest Seismic Zone 4, which includes Marin County, to provide three things:

- Inventory of URM buildings in their jurisdiction,
- Establish loss reduction programs for URM buildings by 1990; and,
- Report progress to the California Seismic Safety Commission.

The law also recommended that local governments:

- Adopt mandatory strengthening programs by ordinance,
- Establish seismic retrofit standards; and,
- Enact measures to reduce the number of occupants in URM buildings.

The Seismic Safety Commission (2005) reports a total inventory of 118 unreinforced masonry buildings in Marin County and cities within the County boundaries (Table 6). Table 6 shows the number of URMSs for each jurisdiction that satisfy retrofitting in accordance with the 1997 Uniform Code for Building Conservation (UCBC) and those that satisfy requirements in jurisdiction programs. The Building Department for Marin County reported only one unreinforced masonry building in Marin County and that it has been retrofitted (personal communication, Steve Jensen, 2001).

Table 6. URM Inventories within Marin County

Jurisdictions	Inventory Completed	URM's	Mitigation Program Established	UCBC Compliance	Compliance with Jurisdication Program	Partial Compliance/Under Construction	Type of Loss Reduction Program
Belvedere	Yes	0	N/A	N/A	N/A	N/A	N/A
Corte Madera	Yes	3	Yes	/	/	/	Notification Only
Fairfax	Yes	4	Yes	/	4	/	Voluntary Strengthening
Larkspur	Yes	12	Yes	5	5	/	Mandatory Strengthening
Marin County	Yes	1	Yes	/	1	/	Order to strengthen or demolish
Mill Valley	Yes	18	Yes	23	23	1	Mandatory Strengthening
Novato	Yes	1	No	1	/	/	Owner Notified
Ross	Yes	1	Yes	1	/	/	Mandatory Strengthening
San Anselmo	Yes	21	Yes	21	/	/	Mandatory Strengthening
San Rafael	Yes	44	Yes	/	44	/	Partial Mandatory Strengthening
Sausalito	Yes	12	No	1	11	/	Compliance with Jurisdiction Program
Tiburon	Yes	1	No	/	1	/	Compliance with Jurisdiction Program

3. Concrete Structures

Concrete is a relatively heavy material and it has a low tensile strength. It is usually reinforced with steel and when done properly reinforced concrete can be used in seismic-resistant construction. It is very important that beam/column connections be designed, detailed and constructed with the proper amount and type of reinforcing steel to provide ductility. If not constructed properly, drastic failure of a structure may occur during earthquake ground shaking.

Common types of damage during earthquakes include shearing of concrete columns that results from the lack of adequate steel reinforcement and severe cracking of concrete walls, which is common in older, lightly reinforced structures. Multi-story concrete frame buildings built from the 1950s to early 1970s often have inadequate reinforcing in their columns. Consequently, these buildings have the potential for a pancake type collapse (CSSC, 1999).

4. Steel Structures

The strength, ductility and toughness per unit weight are significantly higher than concrete and masonry materials. This makes it a useful construction material. However, because of its high strength per unit weight, the slenderness of steel structural members could result in failure during seismic shaking. Buckling failure of steel members is a common phenomenon during earthquake shaking. Another issue in steel design is the connection of the structural member, the most common being welds. If steel members are not connected properly to each other then failure may occur. For an effective seismic-resistant design, it is imperative that the compactness requirements for the cross section of the critical regions of steel structural members be greater than those that would be used in a design for normal (non-seismic) loading conditions and the design of connections should take into account seismic loading conditions. The steel frames should be designed with strong column beams such that the ultimate failure mode would be in beams yielding and not columns.

5. Light-Gauge Steel Structures

Light gauge steel is also a very good material for low rise buildings and is now being used exclusively in may new housing tracts in the southwest and midwest. It is lighter than wood, it will not dry rot, it is insect proof, it is noncombustible and because it is a manufactured item made to strict tolerances, framing members remain true when assembled. This eliminates the problems associated with wood products that undergo distortion and volumetric changes that affect finish materials such as drywall and plaster.

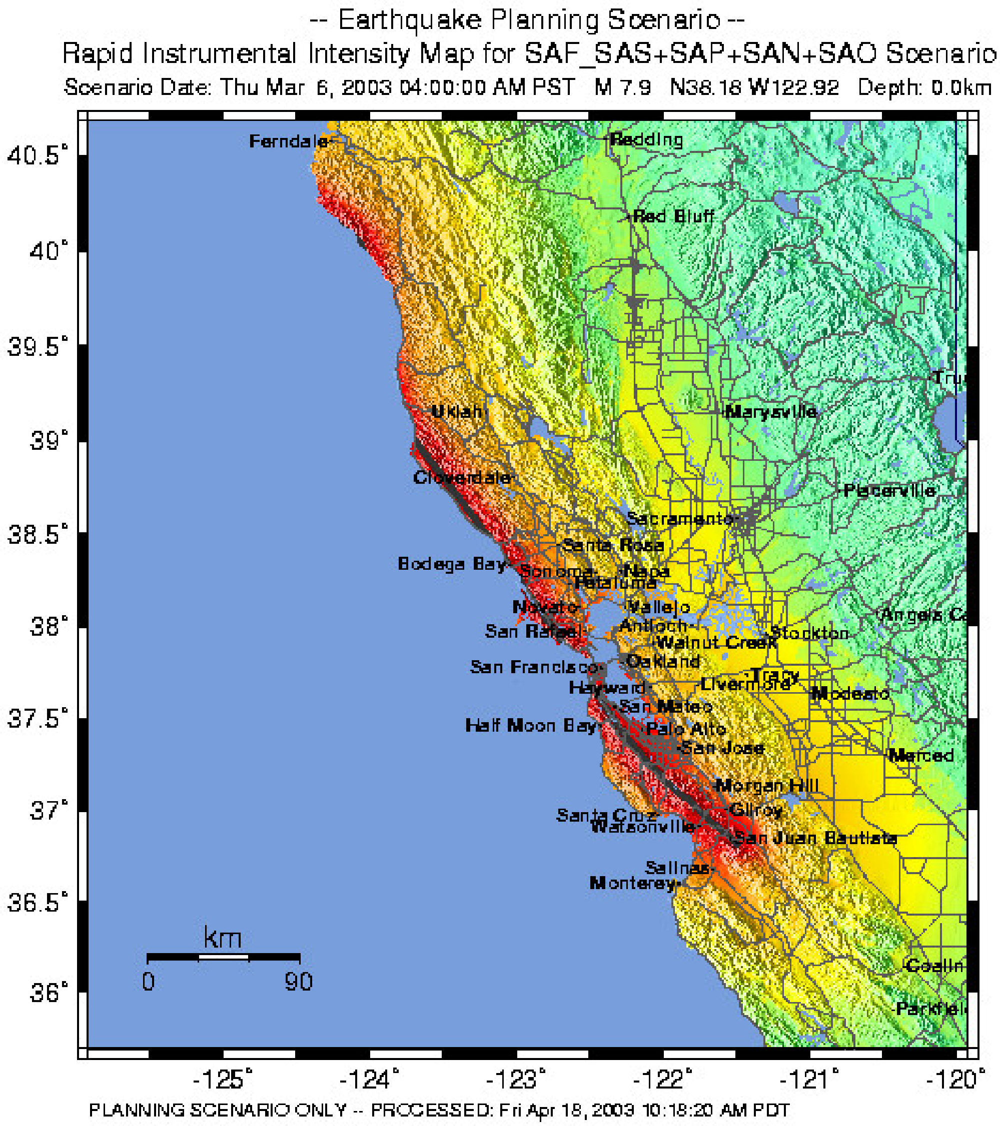
The assembly is similar to wood framing except the members are connected with self-drilling, self-threading screws instead of nails. The lateral strength is developed similarly with plywood diaphragms and shear walls, but may also be strengthened with diagonal steel straps. As with steel structures discussed previously, if members are not connected properly to each other then failure may occur.

Structural Damage Based on Scenario Earthquakes

As discussed in the Fault and Hazards Section of this report several active faults are present in the Bay Region. The degree of shaking varies depending on the magnitude and distance from Marin County of an earthquake event. The following table lists the predicted uninhabitable units for Main County due to rupture of specific earthquake scenarios. The bold entries are those earthquake scenario events shown in Exhibits 7 and 8.

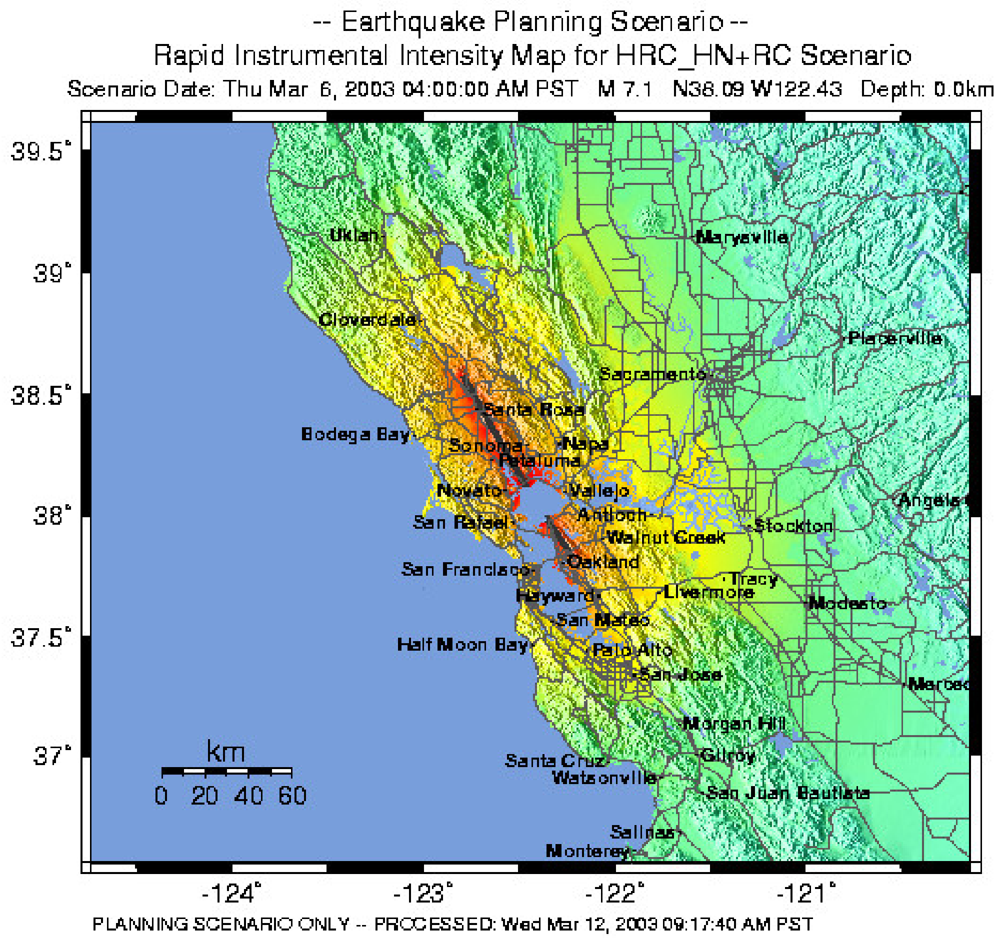
Table 7 is based on Association of Bay Area Government (ABAG)'s modeling of uninhabitable housing units in future earthquake scenarios. This modeling is based on an extensive statistical analysis of the housing damage which occurred as a result of the 1989 Loma Prieta and 1994 Northridge earthquakes. However, the expected percentage of pre-1940 single-family homes rendered uninhabitable used to generate this table is larger than published in 1996. New data on lack of retrofitting and reasons for low damage in the Northridge earthquake cause ABAG to increase the uninhabitable percentages used to create this table for pre-1940 single-family homes to 19% and 25% for MMI IX and X, respectively. The earthquake fault segments listed are based on the ground shaking information published by the USGS in 2003 (ABAG, 2003).

Exhibit 10.
Scenario Earthquake and Potential Groundshaking of a Repeat of the 1906 Earthquake



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Exhibit 11.
Scenario Earthquake and Potential Groundshaking of Rupture on the North Hayward-Rodgers Creek Faults



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Table 7.
Predicted Uninhabitable Units in Marin County and Selected Earthquake Scenarios

Earthquake Scenario	Predicted Number of Uninhabitable Units Following Earthquake event
Santa Cruz Mountains San Andreas	297
Peninsula-Golden Gate San Andreas	1,485
Northern Golden Gate San Andreas	2,988
Entire Bay Area San Andreas	**3,495**
Northern San Gregorio	1,176
South Hayward	1,030
North Hayward	1,653
North and South Hayward	2,125
Rodgers Creek	1,549
Rodgers Creek – North Hayward	**2,691**
South Mayacama	27
West Napa	27
Concord - Green Valley	29
North Calaveras	27
Central Calaveras	27
Mt. Diablo	751
Greenville	27
Monte Vista	16

B. SUMMARY AND ISSUES TO CONSIDER

The following is from the "Existing Buildings Element" and the "New Buildings Element" of the CSSC draft (July 27, 2001) of their "California Earthquake Loss Reduction Plan 2002-2006 (CSSC, 2002):

> "Many existing buildings, including homes, are vulnerable to damage or collapse from earthquakes. Most seismic retrofit projects to date have focused appropriately on life safety and have not significantly reduced the potential loss to property, personal disruption, and productivity. Continuing occurrence of earthquake damage to older and recently constructed buildings clearly demonstrates the need for heightened awareness of the benefit of increased performance levels beyond that of life safety;"
>
> "Earthquake protection of new buildings based on providing life-safety and collapse resistant structures has been reasonably successful in moderate earthquakes. Protection of property and economic loss control has not received as much emphasis and is not yet as successful. As a result, property and economic loss due to earthquake damage to recently completed buildings and contents has been unacceptable. Losses have been due to: 1) limited knowledge of the performance of materials and systems; 2) lack of a complete approach to seismic design including all elements of buildings and their contents; and 3)

inadequate quality control of design construction. The damage from recent earthquakes clearly demonstrates the need for continued improvement in these three areas to achieve cost-effective seismic performance of new construction."

These two paragraphs provide a summary of the structural hazards due to earthquakes that are present in the State of California and in Marin County and they demonstrate the need for continued reduction of the vulnerability of structures to seismic hazards. The following is a list of structural hazard issues to consider in development of new policies that address this specific issue:

- Many of the buildings throughout Marin County, both existing and new are most likely vulnerable to damage caused by ground shaking and other geologic hazards and could be potentially hazardous.
- The hazard from unreinforced masonry buildings (URM's) has reportedly been mitigated in unincorporated Marin County. However, hazard reduction through retrofitting or removal of some URM buildings under the jurisdiction of local cities and towns in the County has not been conducted.
- As an example of other potentially hazardous buildings: Older concrete tilt-up buildings, constructed without embedded steel ties to roof framing members other than the plywood perimeter nailing to wood ledgers, are also hazards. The walls pull away from the roof diaphragm during moderate to large seismic events. The purlins and rafters are pulled out of their hangers and the roof can collapse at the perimeter bearing walls. Tilt-up buildings permitted prior to 1975 may not have positive steel hardware tying concrete walls to purlins, rafters and girders and should be retrofitted. Retrofitting can be implemented by adopting a mandatory strengthening program by ordinance for these structures.
- Several strategies considered by the CSSC (2002), could be effectively applied in Marin County to reduce the vulnerability of existing and new structures to seismic hazards, and are listed below.
- Providing incentives to retrofitting structural and nonstructural elements of existing buildings in accordance with standards that improve seismic performance.
- Initiate educational efforts for those involved in the retrofit design and construction process about the benefit of retrofitting existing buildings for improved performance including basic structures, non structural components, and operational elements.
- Develop reliable and practical methodologies and codes for minimum prescriptive retrofit standards; and enhanced performance-based retrofit standards for the structural and non-structural elements of all types of existing buildings.
- Upgrade seismically vulnerable buildings by establishing an effective risk reduction program. Buildings providing essential services, schools and hospitals and those buildings located in geologically hazardous areas may be considered first in developing the prioritizing process of a risk reduction program.
- New construction should conform to state-of-the-art seismic safety provisions and state-of-the-art model building codes and amendments in order to reduce vulnerability.
- The design of new structures should be based on an intergrated approach considering all elements of construction (structural and nonstructural) that contribute to seismic performance. Design should also consider the many potential geologic hazards that may be present at a specific location.
- Policies EH-5.1, EH-5.2, EH-5.3, EH-5.4, and their supporting programs address some of the issues discussed above and are still applicable policies toward reducing structural hazards in the County. Some refinements to these policies should be considered. Program EH-5.3b, which deals with URM's, has been effective in reducing this hazard in unincorporated county areas and similar

programs addressing other potentially hazardous structures (e.g. older tilt-up buildings) would be useful for reducing structural hazards.

XI. MINERAL RESOURCES

A. INTRODUCTION

The State Mining and Reclamation Act of 1975 requires that the County adopt policies to protect certain State-designated mineral resource sites from land uses which preclude or inhibit mineral extraction needed for satisfying local market demand on a timely basis. The purpose of the Act is to ensure that construction materials will be available to all areas of the State at a reasonable cost. Eight sites in Marin County have been "designated" by the California State Department of Conservation Division of Mines and Geology as having significant mineral resources for the North Bay region. Sites were designated which contained deposits that were l) suitable as marketable commodities, and 2) meeting a threshold value defined as a gross selling price of at least $5 million in 1978 dollars.

B. POTENTIAL MINERAL RESOURCE SITES

Of the eight mineral resource sites designated in Marin County, two no longer meet the minimum threshold requirements and are exempt from application of mineral resource policies. Of the remaining six sites, four are located within incorporated areas. The State has designated one of the resource sites, Ring Mountain, as a scientific resource zone and 300 acres have been preserved as open space.

The North San Francisco Bay Production-Consumption Region includes Sonoma, Marin and Napa Counties. The Region is dependant upon both crushed stone and alluvial deposits for construction, in particular asphaltic concrete, aggregate, road base or subbase materials and Portland Cement Concrete. Total aggregate consumption through the year 2030 is estimated to 478 million tons for the North Bay region based on consumption records and population estimates from the past 28 years.

Ring Mountain is considered to be a Scientific Resource Zone (SZ) rather than a production site due to the rare geologic formations found there. Seven other sites in Marin County have been identified as Mineral Resource Zone Class 2 or MRZ-2. The eight sites include:

1. Ring Mountain, Tiburon

This 190-acre site is located at the base of the Tiburon Peninsula and would be precluded from further development as a result of these policies. It contains rare, colorful and enigmatic metamorphic rock as well as many species of rare plants. This preserve is the type location for the mineral Lawsonite. Lawsonite was named in honor of Professor Andrew Lawson of the University of California. Lawsonite is known for its hardness and is a mineral of the glaucophane schist facies associated with chlorite, epidote, sphene, glaucophane, garnet, and quartz. It is formed under low temperature and high pressure. One of the mineral resource sites (near Pt. Reyes) is located in the unincorporated county and subject to the policies of this plan.

2. (Sector D-1) Novato Conglomerate-Black Point

This site is located within the city limits of Novato and is an alluvial resource, which contains a thick accumulation of well-rounded pebbles, cobbles and boulders in a well-cemented sandy matrix. This material has been found to be suitable for the use of Portland Concrete Cement. It is calculated that this deposit could potentially yield 18.47 million tons of material. The high degree of weathering in the deposit has required a thorough washing of the aggregate. Field geologic mapping indicates that this mineral deposit is relatively evenly distributed over the subject area. This deposit is primarily urbanized except for outcroppings located to each distal edge. This sector would be subject to mineral resource policies adopted into the Novato General Plan only.

3. (Sector D-2) Novato Conglomerate-Black Point

This site is located at the Renaissance Faire/Living History Centre and was once quarried for the conglomerate it contains. The material in this sector is a similar alluvial deposit as in Sector D-1. This supply is estimated to have the potential yield of 10.64 million tons. It is also subject to mineral resource policies adopted into the Novato General Plan only.

4. (Sector I) Franciscan Complex Sandstone – San Pedro Hill

This site is located at the tip of the San Pedro Peninsula just outside San Rafael City limits and has been mined since the turn of the century. The site has yielded crushed stone suitable for Portland Cement Concrete aggregate and rip rap. Shale deposits are also present and these materials have been developed by several quarries throughout the years to supply bricks, tile and lightweight aggregate. A reclamation plan was filed in 1976 and amended in 1982. San Rafael's policies for the reclamation of the site are expressed in the City's Peacock Gap Neighborhood Plan.

5. (Sector J) Sonoma Volcanics Andesite – Burdell Mountain

This 50-acre site is located on the east side of Mount Burdell and contains a large block of andesite, which occurs within landslide debris. Crushed rock from this mass has been shown to be suitable for asphaltic concrete aggregate or road base material. The presence of sufficient andesite was disputed by the owner, Mt. Burdell Partners, who presented a study by a qualified geologist confirming that most of this material had already been extracted over a 20-year period ending in 1977. After considering this testimony, the Planning Commission has recommended that this site be exempted from the application of Mineral Resource Preservation Policies.

6. (Sector L) Franciscan Complex – Borello Quarry

This site is located 3.5 miles north of Point Reyes Station and contains sandstone, shale, greenstone, chert and pillow lavas. Greenstone and pillow lavas are mined and sold for road base material and drain rock.

7. (Sector M) Franciscan Complex Serpentinite – Ghilotti Quarry

Located on the southwest slope of Burdell Mountain and 3 miles northwest of downtown Novato, this site contains serpentinite, dark green to grayish-green in color, suitable for subbase material after crushing. The State Division of Mines and Geology confirmed in their letter of April 20, 1988, that this site no longer contains sufficient mineral deposits to meet the minimum to be designated as a regionally significant deposit. The Board of Supervisors has therefore, exempted this site from the application of Mineral Resource Preservation Policies.

8. (Sector V) Sonoma Volcanics Andesite – Burdell Mountain Open Space Preserve

Adjacent to Sector J., this site also contains hard, dense andesite suitable for asphaltic concrete aggregate. It is owned by the Marin County Open Space District and located within Novato city limits. It is a management policy of the District to prohibit the collection or exploitation of minerals from its lands, as these activities are incompatible with the Open Space use of the land.

C. ADDITIONAL POLICY DISCUSSION

The policy framework recommended in a previous technical report (*Environmental Quality Element Technical Report #2 Mining Resource Preservation in Marin*) for general plan amendment serves to protect the above listed mineral resource sites from untimely development and incompatible land uses while ensuring that all mining operations provide adequate reclamation plans. Implementation measures would apply a new overlay zone "Designated Mineral Resource" to the identified sites in unincorporated Marin County.

The overlay zone would prohibit any temporary or permanent land uses, which would preclude eventual extraction of the mineral resource and would require the creation of buffer land uses between the potential extraction areas and surrounding areas. Notice would be recorded on property titles identifying the presence of important mineral resources. Implementation would also include amendments to Chapter 23.06 of the Marin County Code to require quarry permit applications to report how nuisances, hazards and adverse environmental impacts created by the mining operation would be mitigated including the protection of wetlands and the reduction of negative visual impacts. All new quarry permit applications would be subject to an Initial Study to determine if an Environmental Impact Report should be required.

Once a site is mined and satisfactory evidence is presented to the Planning Department that it no longer contains the threshold amount of mineral resource, the County shall institute action to remove the site from the application of its Mineral Resource Preservation Policies.

D. SUMMARY AND ISSUES TO CONSIDER

- There are six potential mineral resource sites in the County. Four of these sites are located in unincorporated Marin County.
- Two sites were “designated” as having significant mineral resources, but are now exempt from application of mineral resource policies.
- The current County policies and associated programs regarding mineral resource areas are still applicable (Policies EQ-2.81, EQ-2.82, EQ-2.83, EQ-2.84, EQ-2.85, EQ-2.86).

XII. HAZARDOUS MATERIALS

A. Introduction

Environmental hazards are not the only public safety risk in Marin County. Man-made safety risks have resulted from the use and disposal of hazardous materials. These man-made conditions can be encroached upon by development, and conditions that are otherwise secure, can become destabilized by environmental hazards such as geologic, seismic, flood and fire hazards.

Within Marin County's Department of Public Works is the Certified Unified Program Agency (CUPA). CUPA was established to provide a unified hazardous waste and hazardous materials management program. This program deals with most of the day-to-day programs required to protect the public from unsafe use practices and provide a coordinated emergency response in the case of an accidental release.

This section of the technical background report gives a brief overview of hazardous materials relative to planning issues in Marin County. It also emphasizes their management based on the greatest potential for impact on land development within Marin County. The greatest potential for impact is:

- Development encroachment on exiting sites, and
- Releases of hazardous materials caused by environmental hazards.

1. Relationship to other County Wide Plan Elements

The nature of hazardous materials and increased public concerns about them has made them one of the most intensely scrutinized and highly regulated classes of materials in California. Because of this, they are relevant to many sections of the Marin Countywide Plan.

The discussion of hazardous materials is relevant to other Marin Countywide Plan Elements that address hazardous materials issues in the following manners:

- Community Facilities Element: Discusses the urban wastewater services and rural septic system issues.
- Environmental Hazards Element: Discusses hazards that can trigger hazardous material releases.
- Environmental Quality Element: Discusses the concept of different environmental corridors and resource conservation areas. Resources most relevant to accidental hazardous material releases in Marin County are the air and surface waters.
- Transportation Element: Discusses the movement of hazardous materials.
- Agriculture Element: Discusses livestock and farm management issues.

2. Excluded Hazards

Other public safety issues relating to hazardous materials do exist, but are not covered in this technical background report. This report does not discuss the planning issues related to nuclear radiation or military ordinance, which come under federal regulation. Site-specific hazards such as asbestos, lead paint or biohazards are not relevant to planning issues. Those seeking information on site-specific hazards should contact the appropriate County office.

B. Background

1. Introduction To Hazardous Materials And Wastes

Reflected in Marin County's lifestyle and local economy are the types and quantities of materials found there. The benefits of a modern industrialized County are significant, but with this benefit come the responsibility of proper management of some substances that can cause health, safety, and environmental impacts.

a. Hazardous materials defined

Presently, the U. S. Environmental Protection Agency (USEPA) tracks approximately 75,000 named industrial chemicals used in the United States (USEPA, 1999). A hazardous material is defined in Marin County's Hazardous Waste Management Plan (HWMP) as: "A substance or combination of substances which, because of its quantity, concentration, or physical, chemical or infectious characteristics, may either:

- Cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
- Pose a substantial present or potential hazard to human health or environment when improperly treated, stored, transported or disposed of or otherwise managed." (Marin County, 1988)

A hazardous material becomes a hazardous waste when either of the following occurs:

- The material has been used for its original intended purpose, and
- When there is no use or intended use for the material and it is to be discarded.

A non-hazardous substance can become a hazardous waste if during its normal use it comes to meet the definition of a hazardous material or hazardous substance. Hazardous substances are substances that have been designated in government codes and regulations or that exhibit certain characteristics such as being toxic, corrosive, flammable, reactive, or explosive. Thus, there can be more hazardous waste generated in an area than there are hazardous materials consumed.

Since hazardous wastes and hazardous substances fit the definition of being a hazardous material, the broader term hazardous material will be used throughout this technical background report.

b. Waste streams

Because people continue to recognize additional interrelationships between society and the earth's four environmental spheres, new wastes and waste streams will also continue to be identified (CIWMB, 2001).

Recently the federal and state authorities have formally recognized a new waste stream by creating the "Universal Waste" designation. Universal Wastes are "lower risk hazardous wastes that are generated by a wide variety of people rather than the industrial businesses" (CalEPA, 2000). As an example of societies increasing recognition of environmental interrelationships, California Environmental Protection Agency, Department of Toxic Substances Control recently designated cathode ray tubes (CRTs – television and computer monitor screens) as a universal waste because they can contain between 2 and 5 pounds of the toxic element lead (CalEPA, 2001). This lead, which is particularly harmful to young children, could potentially contaminate soil and groundwater if CRTs are disposed of in a municipal landfill.

Additionally, unexpected wastes, waste streams, or consequences should be expected to result from new industries or industrial processes. A recent example of this has been the contamination of groundwater wells from the relatively recent introduction of metratetrabutylether (MTBE) as a gasoline additive.

C. LEGISLATION AND REGULATION OVERVIEW

Industry, agriculture, and even household activities have contributed to the amount of hazardous materials present everyday in Marin County. Because of the vastness of their use and the range in their physical properties, there is no one organization that can create a "one size fits all" set of regulations. As the volume of hazardous materials increased, actual damages caused by them increased as well as the public's recognition of their potential hazards. This increase in public concern about hazardous materials leads to a desire for tighter controls.

The result has been the formation of a complex web of law, code, policies, rules and regulations that has created many overlapping jurisdictions. Additionally, much of the hazardous materials regulations are indirect, being contained in laws and programs addressing other issues.

Presently, most hazardous materials regulations originate at the State and Federal level, with local County and City agencies enforcing these regulations. The State and Federal level provides a consistent level of control, while the use of County or City agencies allows for more effective enforcement since they better understand the local conditions.

This summary is not intended to be a complete review of the existing hazardous materials regulations. It presents some of the more common agencies and regulations.

1. Federal Agencies and Legislation

The USEPA is the federal agency designated to oversee hazardous materials. The USEPA derives legal basis through more than a dozen major statues and laws (USEPA, 2001). Several of the policies relevant to hazardous materials are:

- Toxic Substances Control Act (TSCA) of 1976 (15 U.S.C. s/s 2601 et seq.): This gives the USEPA the ability to screen, track and control chemicals as necessary to protect public safety and the environment.
- Resource Conservation and Recovery Act (RCRA) of 1976 (42 U.S.C s/s 6901 et seq.). This act gives the USEPA authority to regulate all aspects of hazardous waste including generation, transportation, treatment, storage and disposal ("cradle-to-grave"). The disposal section of this act deals only with active and future disposal sites.
- The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) created broad federal authority to respond directly to hazardous materials releases or threatened releases that would affect public safety. Commonly known as Superfund, it establishes hazardous waste site closure standards, creates liability for waste site operators and uses a trust fund to clean up abandoned sites.

- The Superfund Amendments and Reauthorization Act (SARA) amended CERCLA in 1986. SARA extended the life of CERCLA and made revisions that allows CERCLA to better meet its goals.
- Emergency Planning and Community Right-to-Know Act (EPCRA) is a part of SARA. It is designed as a national legislation to help local communities protect public safety and the environment from hazardous substances.

2. State Agencies and Legislation

The California Environmental Protections Agency (Cal/EPA) was created in 1991. It acts as a centralized environmental concerns (umbrella) agency for six environmentally related boards and agencies created in the State of California (Cal/EPA, 2003). These agencies and their duties include:

- The Air Resources Board (ARB) is responsible for reducing air pollution in the state.
- The Department of Pesticide Regulation (DPR) protects human health and the environment by regulating pesticide sales and use and fostering reduced-risk pest management. DPR's strict oversight includes product evaluation and registration, environmental monitoring, residue testing of fresh produce, and local use enforcement through the County agricultural commissioners (DPR, 2003).
- The Department of Toxic Substances Control (DTSC) regulates those who produce, transport or store toxic substances including hazardous waste facilities (DTSC, 2003). Through its Hazardous Waste Management Program, DTSC implements the Federal RCRA regulations. Through DTSC's Hazardous Waste Facility Permits, it implements a five-tiered permitting program. This program "matches the statutory/regulatory requirements imposed upon each category of hazardous waste facility to the degree of risk posed by them" (DTCS, 1998). The DTSC's permitting process includes all RCRA wastes and some non-RCRA wastes added by the state of California.
- The California Integrated Waste Management Board (CIWMB) is responsible for managing the state's solid waste. CIWMB "works in partnership with local government, industry, and the public to reduce waste disposal and ensure environmentally safe landfills" (CIWMB, 2001).
- The State Water Resources Control Board (SWRCB) protects all water resources in California (SWRCB, 2000). The SWRCB is organized into nine Regional Water Quality Control Boards (RWQCB) that perform the actual protection through the use of region specific plans.
- The Office of Environmental Health Hazard Assessment (OEHHA) works to protect public health and the environment by objectively using "scientific evaluation of risks posed by hazardous substances" (OEHHA, 1999).

3. Marin County

Regulation and enforcement of hazardous materials in Marin County fall primarily under the Department of Public Works and the Community Development agency. The Certified Unified Program Agency (CUPA) and Waste Management are within the Department of Public Works while Environmental Health is within the Community Development Agency.

- CUPA consolidates, coordinates and makes consistent" portions of six existing programs pertinent to hazardous substances (Marin County CUPA, 2004). CUPA is the local agency that "regulates, inspects and permits over 500 Marin businesses" (Marin County CUPA, 2004). Emergency response, as coordinated with the State Office of Emergency Services (OES), is also included under CUPA.

- The Waste Management division administers solid waste franchises and provides staff for the regional waste agency. This regional waste agency, The Marin County Solid and Hazardous Waste Joint Powers Authority (JPA), was created to reduce landfill disposal and encourage recycling. JPA also develops and implements Marin County's Regional Integrated Waste Management Plan.
- The Department of Public Works also administers Marin County's Hazardous Waste Management Plan (HWMP), which shoulders the responsibility for managing hazardous wastes in accordance with legislated regulations (Marin County, 1988). The HWMP focuses on regulating hazardous wastes by permitting, enforcement, and the unified program activities to assure the safe storage, treatment, transportation and disposal of hazardous wastes. The HWMP also provides for the management of hazardous wastes through waste reduction, siting criteria, and projected handling need policies and programs.
- Environmental Health Services (EHS) protects the public health through a series of programs designed to control hazardous materials and other risks (Marin County EHS, 2005). The Solid Waste Program has been certified by the CIWMB as Local Enforcement Agency (LEA) for Marin County. EHS's LEA certification allows it to permit, inspect, and enforce regulations at solid waste disposal sites, transformation stations, transfer and processing stations, and material recovery facilities. EHS also oversees septic systems and medical wastes within the county.

4. Future Trends

In recent years, the State of California has attempted to reduce overlap and redundancy within the hazardous materials regulations and enforcement efforts. Since the formation of Cal/EPA, the State has made improvements in protecting the public health and environment while maintaining the State's economic vitality. The creation of a simplified tiered permitting processes and allowing health based risk analysis signal that the improvements will continue. Cal/EPA has formed CalGOLD, an online permitting assistance providing businesses the information they need to comply with environmental and other regulatory and permitting requirements (CalGold, 2005). The formation of OEHHA will likely allow the widespread determination of site-specific health based risk analysis cleanup standards, rather than using the broad and necessarily conservative regulation standards.

D. PRESENT CONDITIONS IN MARIN COUNTY

1. Summary of Existing Conditions

This section summarizes existing Marin County conditions in terms of their potential for impact on planning.

One of the goals of the Marin County Board of Supervisors has been to retain clean business and industry (Marin County, 2001). Coupled with the existing hazardous materials policies of other agencies, the result is that there are relatively few serious hazardous materials issues present in the county. Marin County has also begun to reduce overlap and redundancy in its hazardous materials regulations and enforcement similar to the State by creating CUPA. Therefore, the threat of serious hazardous materials impacts are minimal, but several planning issues still exist.

2. Summary of Existing Hazardous Materials Sites

This summary is not intended to be a complete list of every site relevant to this section of the technical background report. If interested, the reader can consult the local agency or division for additional information.

a. Solid Waste

Information provided by County and State agencies indicated that there are approximately 20 known solid waste sites in Marin County. Planning should expect this number to increase as described below. A list of known sites is available from the Integrated Waste Management Board at their website: http://www.ciwmb.ca.gov/SWIS/.

Presently, there are two active solid waste landfills, two active composting facilities and one active large volume transfer and processing facility.

There is one known inactive solid waste disposal sites The remaining sites are closed solid waste sites. Two of the closed sites were used as burn dump facilities and at least three appear to have been encroached upon by development (Janofsky, 2001). A query of the USEPA's Superfund database returned three sites listed as active Superfund sites (USEPA, 2005).

Due to its rural and agricultural nature, unknown sites will most likely be identified in Marin County's future. These sites will be identified as urban development occurs in rural and agricultural areas, as sites abandoned long before the introduction of solid waste regulations are encountered during construction. It is expected that these new sites will be small private family and farm sites.

b. Hazardous Wastes and Materials Use

The vast majority of Marin County's hazardous waste is produced by "small quantity generators" which are defined as solid quantities of less than 500 pounds or liquid quantities of less than 55 gallons of any one type or a total aggregate amount of 275 gallons (Unidocs, 2002). These wastes are "primarily generated by the businesses in the retail, manufacturing and services sectors" with waste oil being the primary constituent (Marin County, 1988).

Marin County's CUPA currently regulates, inspects and permits over 500 Marin County businesses (Marin County CUPA, 2004). These businesses have been identified based on their hazardous material registration forms and hazardous materials business plans (HMBP). A list of business sites with HMBPs can be obtained from Marin County Department of Public Works, Certified Unified Program Agency.

Relevant classifications for businesses on this list include those:

- With underground storage tanks (USTs),
- With above ground storage tanks (ASTs),
- In the Accidental Release Program (Cal/ARP),
- Required to complete a HMBP,
- That generate hazardous waste and/or
- Required to complete a tiered permit.

c. Rural Issues

Approximately 40% of Marin County is in agricultural use with dairy farming being the major activity (Marin Count, 1994). Hazardous materials issues related to agriculture include:

- nuisance items such as odors and noise, and

- health hazards such as impacted soil, surface water, groundwater, vector control, and dust suppression.
- Locations of abandoned and existing aboveground diesel tanks for fueling farm vehicles.

Although three small municipal sewer systems are present, most homes and communities with in rural west Marin County rely on private water wells and septic systems (Marin County, 1994). Failure of septic systems can pollute the soil and groundwater. Although extremely limited, the possibility exists that private homes could also have heating oil USTs present in rural areas.

3. Types Of Hazardous Material Threats

a. Types of impacts

The types of impacts created in Marin County by hazardous materials are public health concerns and a degraded environment.

Public health in Marin County can be threatened by hazardous materials in two ways:

- By long term exposure to a contaminated medium, and
- By releases of highly mobile hazardous materials to highly mobile mediums. Called secondary disasters, these events can be triggered by hazardous material releases caused by accidents and natural disasters within or adjacent to Marin County.

When hazardous materials have previously degraded Marin County's environment, it has often been the result of a long-term condition resulting from the improper use, storage or disposal of these materials. Most of these past conditions have been identified and mitigated by the present regulations.

b. Impacted mediums

Based on the hazardous materials present in Marin County, they could be released as gases, liquids and/or solids. Depending on how they are released, hazardous materials could affect the following mediums:

- The air,
- Surface waters such as streams, lakes, and the bay,
- Groundwater and watersheds, and
- The soil.

These impacted mediums could degrade the natural resource of Marin County and affect the County's public health.

c. Area of impact and degree of planning importance

The area impacted by a hazardous material release in Marin County would depend on many controlling factors. Most important of these are the quantity and toxicity of the material released and the medium that has been impacted.

Most of the hazardous materials present in the County are in small quantities and of relatively low toxicity. The environment is able to rebound rather quickly and threats to public health are often easily mitigated from impacts associated with these types of releases.

The impacted media also greatly influences the area of impact. Air is the most vulnerable media in Marin County. Hazardous materials released into the air will result in rapid movement of the material, with rates being measured in minutes and hours. However, for small amounts, these releases typically dissipate rapidly resulting in relatively small area being impacted.

The spreading rate of hazardous materials released to Marin County's surface and ground waters depends on if the material dissolves in (mixes with) the water or remains in its "pure" form and flows on the surface. Dissolved materials move at about the same rate as the water. Immiscible liquids (liquid materials that slowly dissolve in water) will spread out on the water surface at a rate dependant upon their viscosity and the surface's slope. Surface water and immiscible liquid movements will also be measured in terms of minutes and hours, however groundwater movement is typically measured in terms of days to millennium. Releases to surface waters would produce the second most critical situation of a hazardous materials release in Marin County, especially in remote rural areas.

Since soils are a solid, they are essentially immobile. However, if the hazardous material can be transported by another medium, then the impacted area can be larger. Both air and water do penetrate Marin County's soil and thus could enlarge the area of impact. Releases to soil are considered to have minimal impact on Marin County in terms of planning except for large releases and waste disposal sites.

d. General examples relevant to planning

Hazardous materials releases are relevant to planning issues because of their threat to public health and the environment. Examples of some releases spreading in different mediums and ecosystems present within Marin County include:

- A gaseous hazardous material is released to the atmosphere, mixes with the air and drifts down wind from the release site.
- A hazardous material is released to a surface water body. This material spreads out on the surface and is also carried along as the water flows. This material can also dissolve in and contaminate the water, spreading beyond the visibly impacted area as the water flows.
- An immiscible liquid hazardous material (such as gasoline) is released to the soil. It flows downward under the influence of gravity until it reaches the groundwater. At the groundwater surface it begins to spread laterally and begins slowly dissolving in the groundwater. If this liquid is volatile (evaporates quickly and easily), it can also evaporate into the soil atmosphere and contaminate it.
- A hazardous material is released to a soil surface. It can spread as wind blown dust and by tracking on people, animals and equipment. Water can flow across the contaminated soil spreading it out on the surface and washing it into stream channels and surface water bodies.
- A hazardous material is buried in the ground. Water percolating through the soil (moving down under the influence of gravity) can leach the hazardous material out of the soil and into the groundwater. Once in the groundwater, the hazardous material can spread laterally with the groundwater as it flows.

- A hazardous material is released to the environment where living organisms absorb or ingest the material. As the organisms become sick or die, other organisms are indirectly impacted by changes to the areas food web.

4. Relationship of Hazardous Material Sites to Marin County's Three Environmental Corridors

The 1973 Marin Countywide Plan established three environmental corridors that were based on the County's natural features and existing land uses (Marin County, 1994). Based on the designated use, each corridor has a predisposition towards certain hazard material uses and their associated risks. These risks should be considered in the planning process.

a. The City-Centered Corridor:

Although most of the land in this corridor lies outside of the jurisdiction of the county, it is adjacent to the county and movement of a hazardous material onto county land is a concern. This corridor is considered most susceptible to public health concerns and environmental degradation caused by long-term conditions and by secondary disasters.

By design, this corridor has the greatest concentration of people and industry in the county. As population density and industrial activities increase, so do the use of hazardous materials. Businesses and activities expected to be present in this corridor would include:

- Industrial manufacturing businesses that use and produce hazardous materials and wastes.
- Fuel storage facilities that use ASTs and USTs for commercial, County, and private vehicles.
- Commercial service business such as automotive service facilities and dry cleaners.
- Retail supply businesses such as hardware, paint, and drug stores.
- The transportation of bulk quantities of hazardous materials by truck, rail, or pipelines.
- Infrastructure support services that use ASTs and USTs for emergency power backup sources.
- Waste treatment and disposal sites.

b. The Inland Rural Corridor

This corridor is considered most susceptible to public health concerns and environmental degradation caused by long-term conditions. However, one of the greatest risks for hazardous materials releases in Marin County is the transportation of these materials. This is especially true of the Rural Inland corridor where response times would be great, sensitive environmental receptors are abundant, and the roads are often narrow and twisty.

Businesses and activities expected to be present in this corridor would include:

- The transportation of bulk quantities of hazardous materials by truck, rail, or pipelines.
- Waste treatment and disposal sites.
- Agricultural farming activities that store and use fertilizers and pesticides.
- Agriculture livestock (dairy farms) and recreational animal (horse stables) activities where large numbers of animals are contained in unlined yards or holding areas.
- Rural residential living that use septic systems and heating oil tanks.
- Rural recreational facilities that use septic systems.

- Recreational facilities that have motorized vehicle use.

Smaller pockets of some businesses found in the City-Centered Corridor could expect to be found in this corridor as well.

c. The Coastal Recreation Corridor

This corridor is most susceptible to public health concerns and environmental degradation caused by long-term conditions.

Business and activities expected to be present in this corridor would include:

- Rural residential living that use septic systems and heating oil tanks.
- Rural recreational facilities that use septic systems.
- Recreational facilities that have motorized vehicle use.

E. ADDITIONAL POLICY DISCUSSION

Hazardous materials and land planning issues in Marin County can be viewed in terms of limiting the threat to public health and safety and protecting the environment. Consideration should be given to the adoption of countywide policies that would promote the following:

1. Reduce the potential for public and natural resource exposure to hazardous materials

The preferred method for reducing exposure to hazardous materials is to reduce the use of these materials. All levels of regulation are pursuing this method wherever possible. Development plans should support the existing regulations prepared by other entities.

Screening of rural areas prior to development for abandoned waste sites and other potential hazards is a second way to reduce the potential for public and natural resource exposure to hazardous materials.

2. Reduce the potential for public exposure to hazardous material releases following emergencies

In the event that a major damaging environmental hazard triggered one or more hazardous materials releases in Marin County, the coordinated emergency response established by other agencies could be expected to be at or near peak demand. Safety factors could be added at the county level by planning for this situation in cooperation with the adjacent cities by:

- Preventing the use of seismically unsafe buildings for hazardous materials storage or use,
- Promoting compatible development, and
- Monitoring county adjacent projects for the potential for air impacts associated with secondary disasters.

As mixed-use developments become more common, Countywide policies should be considered that would encourage coordination with the cities to prevent placement of hazardous materials near sensitive receptors such as schools, hospitals, high occupancy buildings or nursing homes.

Marin's Countywide Plan should also support existing regulations by other entities and encourage public education of the possible hazards present.

3. Promote Safe Transportation of Hazardous Materials

Since transportation routes are already established, Countywide policies should be considered to prevent placement of sensitive receptors near them. Plans should also support existing regulations, encourage the ability for a coordinated regional response, and encourage public education of possible hazards present.

4. Promote the Safe Use and Storage of Hazardous Substances to Protect the Public and Environment

Countywide policies should be considered to identify hazardous material storage areas in unsuitable buildings. Plans should also support existing regulations, encourage the ability for a coordinated response, and encourage public education of possible hazards present.

5. Encourage Regional Disposal Solutions

Countywide policies should recognize the need for regional disposal solutions following fair share principles. Plans should support Marin County's Regional Integrated Waste Management Plan.

F. Development Scenarios

The following development scenarios involve hazardous materials impacts that could occur within the county. They are presented in the order of the most- to least- likely to occur. They are based on the urban service area concept, which states that the areas within an existing city's sphere of influence will be the most likely to be developed in the immediate future (Marin County, 1994).

Each scenario has been created using a combination of what is currently present and what is a logical future development pattern. The negative impacts of each of these scenarios can be reduced by advanced land planning controls, as presented in the "Development Considerations" section. Some of these controls will involve coordinating planning efforts with the adjacent cities, especially for potential impacts involving the air medium.

1. Solid Waste Site – Closed Site with Encroaching Development

As urban service areas are developed, the potential exists that closed solid waste sites will be encroached upon. The resulting impacts could be significant depending upon the nature of the waste and the planned land use. An unidentified burn dump planned to become a school will require more effort to remediate than an inert construction debris dump becoming a parking lot.

An encroached waste site could be either an identified or unidentified solid waste location. When this occurs, a hazard mitigation plan should be prepared to evaluate and minimize the hazards present. The hazard mitigation plan should be based on what is present in the encroached site. For well-documented sites, the hazard mitigation plan could be developed based on existing information. For sites with little or no information, the contents and the nature of the materials in the site will need to be evaluated before a hazard mitigation plan can be made.

Hazard mitigation plans could include removing the impacted materials, designing engineered controls, or leaving appropriate buffer zones from the encroaching development.

Advanced planning with the Department of Public Works could identify areas where the potential for this type of scenario exists before development begins. Once identified, Planning should work with other departments to assure that the existing requirements are met.

2. Agricultural Impacts – Dairy Farm Site With Encroaching Development

As urban service areas are developed, the potential exists that diary farm sites could be encroached upon. In this case, advance planning should consider nuisance and health hazard issues.

Nuisance issues could include such items as odors and noise. Health hazard issues could include:

- Impacted soil, surface water, and groundwater
- Vector control, and
- Dust suppression.

If nuisance or health hazard issues are present, mitigation efforts should be undertaken.

Advanced planning in the diary agriculture regions of Marin County could identify potential locations where mitigation efforts may be required. The planning should be coordinated with the policies and programs established in the agricultural section of the Countywide Plan.

3. Rural Impacts – Septic System Failures

Most of rural Marin County populations are served by septic tank systems. Contaminates associated with previous Marin County septic system failures include nitrates and microorganisms in the soil and groundwater. As the rural population of Marin County increases, so does the likelihood that there will be failures. Historically, where one system fails, others typically fail too compounding the impacts.

Planning controls can limit the density of such development and work with other agencies to ensure enforcement of existing regulations. Planning can also cautiously encourage the use of alternative wastewater systems. Although there have been significant advances in alternative wastewater systems, they are by nature experimental and lack a long-term record.

4. Secondary Disasters – Seismic Event

Hazardous materials secondary disasters will occur in Marin County at a time of stressed emergency response due to poor communication, distressed roadways, and overloaded care facilities.

RCRA permitted facilities are required to evaluate this as part of their permit but smaller facilities may be exempt from this requirement. However, these facilities can still have a significant impact because of the potential for a cumulative effect from multiple smaller facilities. A release of hazardous material to the highly mobile air media of Marin County would be one of the greatest concerns.

This scenario also has the increased potential for producing releases to soil or water media that would not be immediately addressed. Damaged storage or containment structures in Marin County and adjacent areas could release hazardous materials in an undetectable manner while emergency response crews were addressing more visible hazards.

Although the prevailing wind patterns would allow some predictability of impact direction, planning controls could ensure that sensitive receptors are not developed adjacent to or in the direction of Marin County's prevailing downwind air patterns. A scenario like this should be considered when planning mixed-use developments and in evaluating the concentrations of hazardous material businesses in county areas adjacent to the City-Centered Corridor.

5. Secondary Disaster – Industrial Fire

Similar to a secondary disaster triggered by an environmental hazard, an industrial fire could release hazardous materials to the highly mobile air media. It too could release hazardous materials in an undetectable manner while emergency response crews were addressing more visible hazards.

Most RCRA permitted facilities are required to evaluate this as part of their permitting process. However, smaller business may not be required.

Although the prevailing wind patterns would allow some predictability of impact direction, planning controls could ensure that sensitive receptors are not developed adjacent to or in the direction of prevailing downwind air patterns. A scenario like this should be considered when planning mixed-use developments and in evaluating the concentrations of hazardous material businesses in a given area.

G. SUMMARY AND ISSUES TO CONSIDER

Hazardous Materials are already one of the most regulated items in Marin County. Business complaints of over regulation are being met by current trends of consolidating hazardous materials regulations into a single coordinating agency such as CUPA wherever possible. However, the huge amount of concern about hazardous materials and their all encompassing use in a modern industrialized society, all but guarantees that a single agency will never be able to address all of the issues related to hazardous materials.

Marin County's greatest concerns relative to planning issues about hazardous materials are:

- Encroachment by development of abandoned waste or agricultural sites, and
- Secondary disasters caused by accidental releases.

As county land in Marin County's 11 cites' sphere of influence and particularly within their Urban Service areas is considered for development, a review for potential development issues should be performed as outlined below.

Hazardous Materials Review Policy

Hazardous materials issues should be identified in the County's planning and development review process. Appropriate modifications and mitigation measures should be required.

The following issues should be reviewed for each proposed development:
- Proximity to known solid waste sites,
- Proximity to known agricultural sites, and:

- Proximity to hazardous materials locations.

Known solid waste sites: As part of the permitting or planning process, the relationship of proposed development to known solid waste sites should be identified. Any potential impacts should be discussed and mitigating plans should be made.

Known agricultural sites: As part of the planning process, the potential impacts of known agricultural sites should be identified and mitigating plans made. Agricultural sites being developed should be reviewed for potential impacts to the soils and waters such as unknown solid waste disposal locations and/or nitrates or microorganisms. Development adjacent to active agricultural sites should review the possibility that nuisance issues could arise such as odors and noise.

Proximity to hazardous materials locations: To reduce the potential for public exposure to hazardous materials County policy should promote compatible development (preventing sensitive receptors from being located near hazardous materials and vice versa), and monitor county adjacent projects for compatible development.

XIII. MARIN COUNTYWIDE PLAN REVIEW

Existing County policies of the 1994 Marin Countywide Plan are reviewed in this section and suggestions are provided for those policies that need refinement.

Table 8.
Evaluation of Existing Countywide Plan Geology, Mineral Resources and Hazardous Materials Policies and Programs

Environmental Quality Element

RESOURCE CONSERVATION AREAS	
1. Stream and Creekside Conservation Areas	
Policy EQ-2.37 Geologic Hazards. Geologic hazards in locations where dams, ponds, and other water impoundments exist or are proposed should be identified in the environmental review process. Appropriate modifications and mitigation measures should be required.	Needs Refinement – Should include a geotechnical investigation as a requirement.
Policy EQ-2.49 Planned District Development Review with Environmental Assessment. The County shall review all proposed development within the Bayfront Conservation Zone in accordance with the planned district review procedure in order to ensure maximum possible habitat restoration and protection. An Environmental Assessment of existing environmental conditions (biologic, geologic, hazard, and aesthetic) shall be required prior to submittal of development plans.	Still Applicable.
Program EQ-2.49a Environmental Assessment of Bayfront Lands. Environmental assessment (biologic, geologic, hazard, and aesthetic) of existing conditions on proposed development sites will be completed prior to preparation of master plans and development plans. These assessments will include recommendations for siting and design that will avoid adverse environmental impacts. When it is not possible to avoid impact, recommendations shall include provisions for minimizing environmental impact. The assessment should serve as a portion of the Environmental Impact Report on the project and recommendations should be incorporated into the project itself. Refer to Program 2.43a for detailed criteria to be used in formulating recommendations for siting and design.	Needs Refinement – Discussion of assessments should include reference to appropriate investigations for siting and design.

Policy EQ-2.61 Consistency with Environmental Hazards Element. Any development proposed for lands within the Bayfront Conservation Zone must be consistent with policies and proposals of the Environmental Hazards Element, including avoidance of areas that pose hazards such as: • differential settlement • slope instability • liquefaction • ground shaking • ground rupture • tsunami, and • other types of ground failures.	Still Applicable.
Policy EQ-2.62 Areas Underlain by Deposits of Bay Muds. Those areas underlain by deposits of "young muds" should be reserved for water-related recreational opportunities, habitat, open space, or limited development subject to approval by the Corps of Engineers and other trustee agencies.	Needs Refinement – Should mention the use of detailed geotechnical investigation for limited development.
Policy EQ-2.63 Sites with Poor Soil Conditions or Seismically Active. Any development (within the watershed areas) proposed for sites that have poor soil conditions for construction or that are seismically active should be designed to minimize: • earth disturbance • erosion • water pollution, and • hazards to public safety.	Needs Refinement – Should indicate the use of proper investigation for determining design parameters and minimizing the listed impacts.
5. Mineral Resources	
Policy EQ-2.81 Protection of Designated Mineral Resource Sites. The County shall protect designated sites from temporary or permanent land uses which would preclude or inhibit timely mineral extraction to meet market demand.	Still Applicable.
Program EQ-2.81a Designated Mineral Resource Sites Identified. The County shall assign the label "Designated Mineral Resource" and shall create and map an overlay zoning district for all Sectors designated by the California Division of Mines and Geology within unincorporated Marin County. These sites include all or portions of the following parcels, identified by Assessor Parcel Numbers: 184-01-15,16,52 (San Pedro Hill), 125-180-62 (Mt. Burdell), 119-010-08 and 119-060-12 (Borello), 125-150-26 (Ghilotti). Further reference may be found in Part III. Classification of Aggregate Resource Areas North San Francisco Bay Production-Consumption Region. Special Report 146 by the California Department of Conservation, Division of Mines and Geology, 1983. Designated Sector J (APN 125-180-62, Mt. Burdell) and Sector M (APN 125-150-26, Ghilotti Quarry) have been exempted from these policies because convincing evidence has been presented to indicate that these sites do not contain sufficient material to meet the state defined thresholds for designated MRZ-2 sites.	Still Applicable.

Program EQ-2.81b Ring Mountain, Designated Mineral Resource – Scientific Zone. The County shall assign the label "Designated Mineral Resource-Scientific Zone" to all or portions of the following parcels (Ring Mountain) 038-182-31,32,36,37 to preclude future development or mining operations on this unique resource and indicate affected areas on County zoning maps.	Still Applicable – Should mention that the mineral Lawsonite is being protected.
Program EQ-2.81c Notice on Property Titles of Mineral Resource Areas. The County shall record the presence of important mineral resources on property titles in mineral resource areas.	Still Applicable.
Policy EQ-2.82 Buffer Between Potential Mineral Extraction Areas and Incompatible Land Uses. The County shall further protect designated mineral resource sites by creating a buffer of land uses between potential mineral extraction areas and areas with land uses incompatible with mining.	Still Applicable.
Program EQ-2.82a Designated Mineral Resource Overlay Zone District. The County shall include requirements in its "Designated Mineral Resource" overlay zone district to require a sufficient buffer between mining and land uses incompatible with mining.	Still Applicable.
Policy EQ-2.83 Nuisances, Hazards or Adverse Environmental Impacts of Mining Operations. The County shall assure that, after mitigation measures are taken, a proposed mining operation will not create significant nuisances, hazards, or adverse environmental impacts.	Still Applicable.
Program EQ-2.83a Mitigation to Address Nuisances. The County shall amend Marin County Code Section 23.06.040 application (for mining permit) to require applicants to list what mitigation will be taken to address nuisances to neighboring properties for proposed mining operations.	Still Applicable.
Program EQ-2.83b Environmental Review. The County shall require an Initial Study and may require an Environmental Impact Report on all mining or quarrying permits requested after the date of adoption of these policies.	Still Applicable.
Policy EQ-2.84 Reclamation of Mined Lands. The County shall assure that all mining operations provide for adequate reclamation of mined lands before issuing mining or quarrying permits.	Still Applicable.
Program EQ-2.84a Reclamation Requirements. The County shall continue to enforce the reclamation requirements of Marin County Code Section 23.06.	Still Applicable.
Program EQ-2.84b Wetlands. The County shall augment Section 23.06.40(5) Application to require Reclamation Plans to include a) protection of wetlands, if any and b) reduction of negative visual impacts.	Still Applicable.
Policy EQ-2.85 Excavation of Wetlands. Wetlands proposed for excavation shall be reviewed for significant habitat value and will be protected in lieu of mining where significant mineral resources have been identified.	Still Applicable.
Program EQ-2.85a Return to Wetland Status. Wetlands that are mined shall be reclaimed and returned to wetland status after conclusion of mining operations.	Still Applicable.

Policy EQ-2.86 Removing a Site from Application of these Policies. When a site is mined and satisfactory evidence is presented that it no longer contains the threshold amount of resource, the County shall institute action to remove the site from the application of these mineral resource preservation policies.	Still Applicable.
THE BUILT ENVIRONMENT	
1. General Policies	
Policy EQ-3.7 Avoidance of Hazards from Earthquake, Erosion, Landslide, Floods, and Fires. Construction and operations shall be located and designed to avoid or minimize the hazards from earthquake, erosion, landslides, floods, fire, and accidents consistent with policies and programs in the Environmental Hazards Element.	Needs Refinement – Should mention use of proper investigation and list expansive soils as a hazard.
Policy EQ-3.16 Minimize Excavating, Grading, and Filling. New development in the County shall adhere to the standards of the Department of Public Works in order to minimize excavating, grading, and filling, while allowing for adequate access.	Needs Refinement – Needs to indicate that minimizing does not preclude a stable development site. Hazards still need to be properly mitigated.
Environmental Hazards Element	
Policy EH-l.l Support for Public Awareness. The County should advise citizens on the availability of countywide and local area environmental hazards studies, sources of hazard information, and public services.	Still Applicable.
Program EH-l.la Public Information. The County should prepare a handout informing prospective property owners about safety hazards that may exist on properties within Marin County .This document could be distributed by members of the Marin Association of Realtors to prospective and existing Marin residents.	Still Applicable.
Program EH-l.lb Maps Available. Maps depicting the areas covered by the Alquist-Priolo Special Studies Zone Act should be made publicly available at County offices and the County Community Development Agency.	Needs Refinement – "Special Studies Zone" needs to be replaced with "Earthquake Fault Zoning" and policy must include the Seismic Hazards Mapping Act.
Program EH-l.lc Improve Soils Information. The County should develop a systematic and accessible compilation of existing drilling log data in filled and bay mud areas.	Needs Refinement – This information should be provided to the CDMG for their use.
Policy EH-l.2 Support Scientific Geologic Investigations. The County should continue to support scientific geologic investigations, which refine, enlarge and improve the body of knowledge on active fault zones, unstable areas, severe ground shaking, and similar hazardous conditions in Marin County.	Needs Refinement – Should provide access to public lands as deemed appropriate to allow scientific studies.
Policy EH-2.1 Location of Public Structures. Structures necessary for the protection of public safety and/or the provision of emergency services should not be located in areas subject to inundation, subsidence, slope failure, or ground failure in a seismic event. An exception to this policy may be granted if the only alternative location would be so distant as to jeopardize the safety of the community, given that adequate precautions are taken to protect the facility.	Still Applicable.

Program EH-2.1a Project Review Procedures. The County Community Development Agency shall facilitate project review by providing reference maps on seismic study areas. Public structures shall be located outside such study areas.	Need Refinement – Unclear what studies areas are and should include maps of Earthquake Fault Zones and Seismic Hazard Zones. Public structures should be located outside these zones or adequately investigated and sited in accordance with state guidelines.
Policy EH-2.2 Emergency Building Design. Emergency buildings and vital utilities, communication systems, streets and other public facilities should be designed in a manner which allows them to remain operational during and after an earthquake, or any other disaster .	Needs Refinement – Needs to be investigated properly and in accordance with State regulations and guidelines.
Policy EH-2.3 Critical Facilities. Within designated fault zones, the following critical public uses should be prohibited: schools, hospitals, utility and public safety facilities, high density housing and reservoirs.	Still Applicable.
Policy EH-3.1 Location of Future Development. New development shall be sited in a manner which avoids or minimizes the potential of hazards from earthquake, erosion, landslide, floods and fire. Development should not be endangered by nor contribute to hazardous conditions on the site or on adjoining properties.	Needs Refinement – Expansive soils should be listed as a hazard. Assessments of hazards should be based upon a detailed geotechnical investigation.
Program EH-3.1a Protect Review. The Community Development Agency shall continue to review the impact of a project on the site and surrounding properties potentially affected by the development.	Still Applicable.
Policy EH-3.2 New Development Approval. New development will be approved in identified geologic hazard areas only if the hazards can be reduced to acceptable levels through mitigation measures which are appropriate [at] the site, and consistent with other policies in the Countywide Plan.	Still Applicable – typo. Should be fixed: [at].
Program EH-3 .2a Mitigation. The County Community Development agency should continue to require mitigation measures for projects proposed in areas with identified geologic hazards.	Needs Refinement – should require a geotechnical investigation in order to assess hazards.
Policy EH-3.3 Disaster Protection Measures. At places of employment, residence, and public gatherings, safety measures shall be taken to protect the public health and safety during and following a disaster. These measures shall include provisions for the health and safety of people with disabilities.	Still Applicable
Program EH-3.3a Protect Review. Criteria for project review should provide for the health and safety of members of the public.	Still Applicable
Policy EH-4.1 Alquist-Priolo Special Study Zones. The Alquist-Priolo Special Studies Zone Act shall continue to be implemented by the County and efforts should be made to inform applicants early in the development process of the existence of known fault traces which might affect their property , site development, and design.	Needs Refinement – "Special Studies Zones" needs to be replaced with "Earthquake Fault Zones (Zoning)". A new policy must be implemented to include Seismic Hazards Zones as defined by the Seismic Hazards Mapping Act.

Policy EH-4.2 Location of Structures. No public or private structure built for human occupancy, or with the potential to imperil structures built for human occupancy, shall be permitted to be placed across the trace of a confirmed active fault. This policy shall not be interpreted as being more restrictive of single-family residential construction than the Alquist-Priolo Act. It is assumed that the area within fifty (50) feet of an active fault is underlain by active branches of that fault unless and until proven otherwise by an appropriate geologic investigation.	Still Applicable- "Alquist-Priolo Act" should be listed by its full name "Alquist-Priolo Earthquake Fault Zoning Act."
Program EH-4.2a Protect Review Procedures. The Department of Public Works should continue to determine the applicability of the Alquist-Priolo Act, and if necessary, require a site investigation report by a registered geologist.	Still Applicable- "Alquist-Priolo Act" should be listed by its full name "Alquist-Priolo Earthquake Fault Zoning Act." Also should be noted that determination is made by CDA, not DPW.
Policy EH-4.3 Public Financing Support. Public financing or support should be withheld from buildings located in an Alquist-Priolo Special Studies Zone with a confirmed fault trace, unless there is no possibility of surface fault displacement or ground rupture that would injure the public investment.	Needs Refinement – "Special Studies Zone" needs to be replaced with "Earthquake Fault Zone." Should indicate that this is determined by an appropriate investigation by a registered geologist.
Policy EH-4.4 Geologic Investigation Requirement. No new building sites should be created within the Alquist-Priolo Special Studies Zone, unless an appropriate geologic investigation establishes sufficient and suitable land area for development according to existing zoning and other applicable County ordinances.	Needs Refinement – "Special Studies Zone" needs to be replaced with "Earthquake Fault Zone." Should indicate that this is determined by an appropriate investigation by a registered geologist.
Program EH-4.4a Applications for Development. Applicants proposing to develop land or divide land into two or more parcels located within the Alquist-Priolo Special Studies Zone must submit a geologic report to the County. The report shall be prepared by an engineering geologist and directed to the problem of potential surface fault displacement through the project site unless a waiver has been approved by the State Geologist.	Needs Refinement – "Special Studies Zone" needs to be replaced with "Earthquake Fault Zone." Should indicate that a report is to be prepared by a certified engineering geologist.
Policy EH-5.1 Mitigation of Risk. Construction of all new habitable structures, including those for residential, commercial, and industrial use, shall employ engineering measures that mitigate against life safety risks from ground shaking. At minimum, new structures shall meet standards specified in Title 19, Marin County Code.	Still Applicable – should mention the Uniform Building Code in addition to Title 19.
Policy EH-5.2 Geotechnical Investigation Requirements. Applications for proposed developments sited on landslide deposits, non- engineered fill, or bay mud shall be accompanied by a geotechnical engineering investigation which focuses on the problem of ground shaking and ground failure.	Needs refinement – should include term engineering geologic as part of investigation and mention deposits with high susceptibility to ground shaking and high susceptibility to liquefaction.
Program EH-5.2a Requirements for Soils and Geologic Reports. The Community Development Agency shall require that soils and geologic reports be submitted with master plan applications, and that soils and/or geologic reports accompany subdivision applications.	Still Applicable.

Policy EH-5.3 Potential Earthquake Hazard in Existing Buildings. The County should minimize potential earthquake damage from existing publicly owned buildings through strengthening building structure, eliminating hazardous features, or relocating buildings.	Still Applicable.
Program EH-5.3a Structural Improvements. The Department of Public Works should identify structural improvements needed for safety in public buildings and develop measures to institute the necessary improvements.	Needs refinement. "Public buildings is very broad. DPW can undertake this only in "county buildings"..
Program EH-5.3b Compliance with SB 547. In compliance with SB 547, the Department of Public Works should identify unreinforced masonry buildings in unincorporated county areas and require strengthening of structurally unsound buildings.	Needs refinement. Chief Building Official, who is in CDA handles this, not DPW..
Policy EH-5.4 Location and Design of High-Occupancy Structures. The design and siting of structures occupied by a large number of people, such as restaurants and hotels, shall consider site constraints. Site constraints and appropriate safety measures for design and siting shall be determined by the engineering geologist and civil engineer conducting the site investigation.	Still Applicable.
Program EH-5.4a High Density Structures. The Department of Public Works should determine that structures which are to be occupied by a large number of people (as described in Policy EH-5.4) are designed to be as safe as similar structures in locations not subject to excessive ground shaking or other geologic hazard.	Needs refinement. This determination is not made by DPW, probably made by the Chief Building Official during the permit review process.
Policy EH-6.1 Evaluate Projects in Stability Zones 3 or 4. Prior to consideration of site design or use, the Department of Public Works shall evaluate projects proposed in zones 3 or 4 (see EH II.B.l) in stability and landslide potential according to the California Division of Mines and Geology Classification 9. Project proposals shall be accompanied by a report prepared by a civil engineer with soils engineering expertise or a soils certified engineering geologist. The soils evaluation should address the structural foundation engineering of the actual site, the impact of the project on adjacent lands, and impacts of off- site conditions on the site. Project applicants may need to consult with a soils engineer to determine whether their parcel falls within Stability Zones 3 or 4.	Needs Refinement – Should mention that proposals should be based upon a detailed subsurface investigation and that reports should be signed by both a civil engineer and engineering geologist. Perhaps policy should be less specific as to who conducts studies. The Countywide Plan should be a framework and actual specifics should be contained in the Marin County code.
Policy EH-6.2 Construction Observation and Certification. For work undertaken to correct slope instability, the County should require that the work is supervised and certified by a geotechnical engineer and, when necessary, an engineering geologist.	Needs Refinement – Work should be by a geotechnical engineer and an engineering geologist. Perhaps policy should be less specific as to who conducts studies. The Countywide Plan should be a framework and actual specifics should be contained in the Marin County code

Policy EH-6.3 Projects on Known Landslides and Landslide-Prone Deposits. New development should not occur on known landslides and landslide-prone deposits on steep slopes, except where an engineering geologic site investigation indicates that such sites are stable, or can be made stable through appropriate mitigation measures. In such cases, it must be shown that the risk to persons, property, or public liability can be minimized to a degree acceptable to the County.	Needs Refinement – Should include an engineering geologic and geotechnical engineering investigation.
Program EH-6.3a Project Review. The County should continue project review procedures that may require soils and/or geologic reports to be reviewed by the Department of Public Works.	Still Applicable.
Policy EH-7.1 Filled Land Underlain by Compressible Materials. Soils investigations for projects on filled land underlain by compressible materials (bay mud, marsh, slough) should delineate those areas where settlement will be greatest and subsidence may occur. Soils investigations should include: recommended site preparation techniques employed to preclude hazard; borings; identification of former sloughs; and a list of other factors which would accentuate differential settlement.	Still Applicable.
Policy EH-7.2 Minimize Differential Settlement. In the areas with great potential for differential settlement, uses should be planned which would not be damaged by settlement and which would provide minimum inducement to settlement that is detrimental to persons, property and public investment.	Needs Refinement – Need to list some potential sites, such as, those areas underlain by bay mud.
Program EH- 7 .2a Soils Report Requirement. The County shall continue to address differential settlement and subsidence in required geologic reports.	Needs Refinement – "Soils" and "geologic" should be replaced with "geotechnical/engineering geologic."
Program EH-7 .2b Findings Requirement. The Public Works staff must make a finding that the proposed fill, excavation, or grading will not unduly or unnecessarily create a safety hazard in areas susceptible to differential settlement. The staff finding may be appealed to the Planning Commission.	Needs Refinement. Should be revised as follows: *Requirement.* Proposed fill, excavation, or grading shall not unduly or unnecessarily create a safety hazards in areas susceptible to differential settlement.
Program EH-7 .2c Site Preparation Requirements. When recommended by the consulting geotechnical engineer, site preparation shall include settlement monitoring for a period of time sufficient for evaluating the particular site characteristics as needed for detailed foundation engineering and site planning.	Still Applicable.
Policy EH- 7.3 Structural Design of Foundations and Utilities. The structural design of foundations and utilities shall recognize the potential for differential settlement and subsidence.	Needs Refinement – Include potential for expansive soil movement.
Program EH- 7 .3a Enforce Development Standards. The Department of Public Works should continue to enforce development standards with regard to minimum elevations and ultimate settlement. The Building Inspection Department should continue to enforce building code requirements for structural design of foundations and utilities.	Still Applicable.
Program EH 7 .3b Augmented Expertise. The Department of Public Works should continue to hire consultants in soils engineering as necessary for evaluating specific developments proposed on bay mud and fill.	Still Applicable.

Policy EH- 7.4 Identify Inadequately Engineered Fills. The Department of Public Works should continue to determine the adequacy of engineered fills prior to the construction of structures.	Still Applicable.
Policy EH-8.1 Location of Critical Facilities. Public safety structures should not be located within the range of a tsunami.	Still Applicable.
Program EH-8.1a Review Procedures. The County should utilize the California Environmental Quality Act environmental review procedure to review and direct the siting of critical facilities structures in tsunami hazard areas.	Still Applicable.
Policy EH-9.1 Dam and Levee Design. The design and location of dams and levees shall be in accordance with all applicable design standards and specifications and accepted state of the art design and construction practices.	Still Applicable.
Program EH-9.1a Enforce County ~The County shall continue to enforce the provisions of Title 11.04 (Dams) and Title 23:08 (Excavation) which allow the County to review applications for dam permits when the dam size is smaller than the minimum size requiring a permit from the State of California.	Still Applicable.
Program EH-9.1b Inspect Levees. The County should continue to review new levees for seismic and hydrologic safety.	Still Applicable.
Policy EH-9.2 Notify property Owners. Property owners who are located in areas of possible inundation from failure at one of eight major dams should be notified regarding susceptibility to flood hazard.	Still Applicable.
Program EH-9.2a Public Information Regarding Dam Inundation Areas. Information on the location of dam inundation areas, for the eight major dams, should be made publicly available in the County Community Development Agency.	Still Applicable.

XIV. APPENDIX – REFERENCES

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Linda Seekins, U.S. Geological Survey

Chris J. Wills, California Department of Conservation, Division of Mines and Geology

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