# 4.3 SOILS, GEOLOGY, TOPOGRAPHY, AND SEISMICITY

This section incorporates by reference information from the Flora and Fauna Baseline Study of Fort Ord, California; the Soils Baseline Study of Fort Ord, California; and the Other Physical Attributes Baseline Study of Fort Ord, California, which are available at the public information repository established at the Seaside Branch Library (U.S. Army Corps of Engineers, Sacramento District 1992a, 1992d, and 1992e).

## 4.3.1 Soil and Geologic Ecosystem Relationships

Three of the soil types or geologic features underlying Fort Ord are of limited extent and support unique botanical relationships. Recent and relic sand dunes, which cover roughly two-thirds of the facility (Figure 4.3-1), occur in only limited areas of the California coast. Oceano, Baywood, and Arnold soil series developed on the dunes (Figure 4.3-2). The sand dune soils show a generally increasing elevation, age, and soil profile development gradient from the coast to the inland areas. The low fertility and low water-holding capacity of the soils, together with the foggy coastal climate, provide the unusual conditions that restrict habitat to plant communities of limited range and support special-status plant species (U.S. Army Corps of Engineers, Sacramento District 1992a).

Interspersed in depressions between some of the dunes are small, localized vernal pool wetlands (refer to Section 4.11, "Vegetation, Wildlife, and Wetland Resources", for a further discussion of wetlands). The wetland substrate may be relict lagoon deposits. These areas are mapped by the Monterey County soil survey as the Antioch series or Santa Ynez series inclusion within the Arnold mapping unit (Figure 4.3-2) (U.S. Soil Conservation Service 1978a). Based on a preliminary reconnaissance survey of the area, this mapping is incomplete and does not fully describe the actual pedologic (soil) and botanic diversity.

The third soil and geologic feature of limited extent is the Arnold series and Xerorthent soil type formed on the Aromas formation. The distinctive red color of the oxidized iron in the sandstone formation is the result of a pedogenic (soil-forming) process and may be a relict paleosol (i.e., reexposed fossil soil). Such soil types are very rare and important for research in soil formation processes that exist under various climatic conditions and landscape ages. In addition, the Aromas formation soils support a rare maritime chaparral community (U.S. Army Corps of Engineers, Sacramento District 1992a).

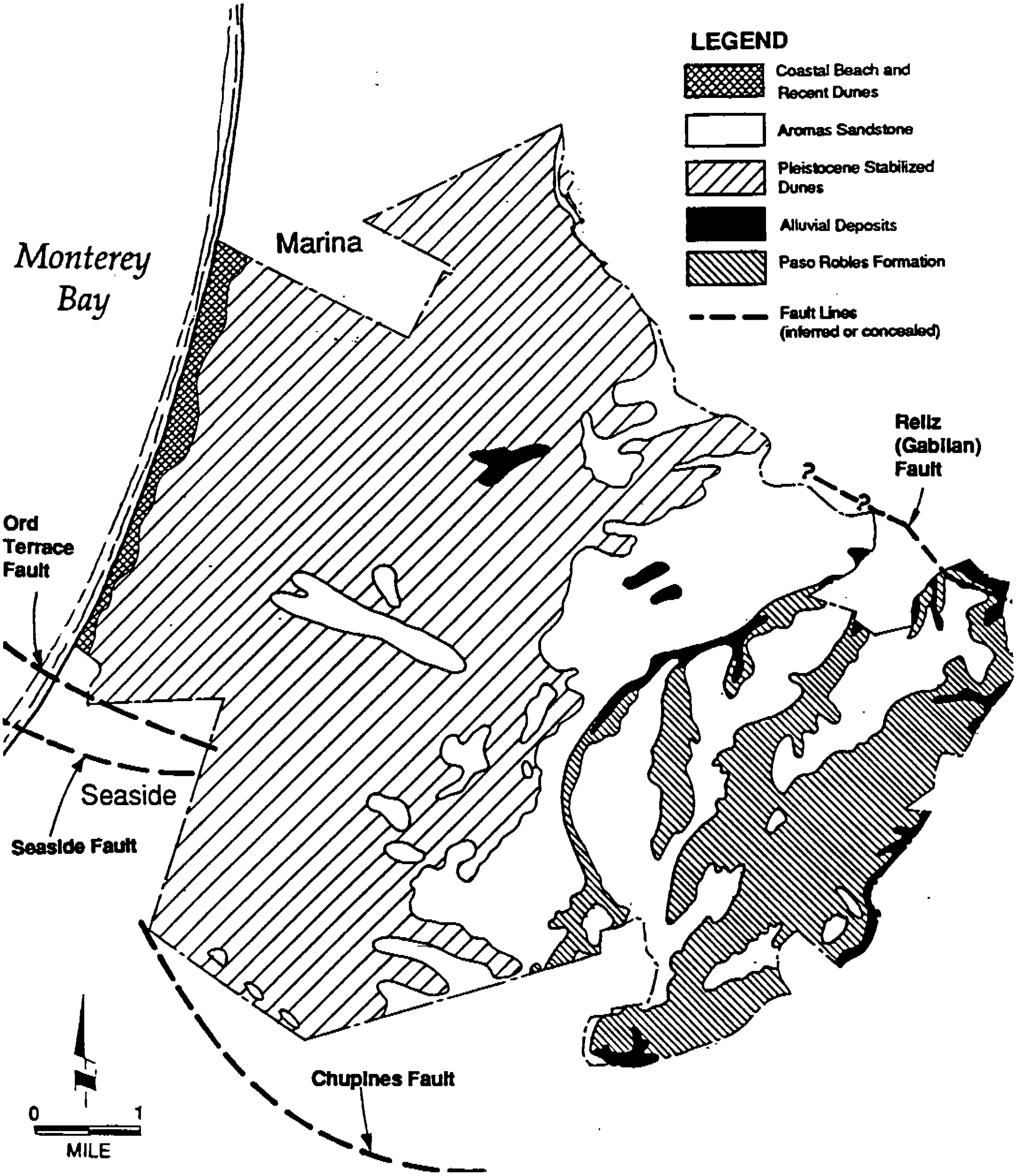
In general, the soil/geologic landscape and correlation with vegetation communities are more complex than existing mapping indicates.

## 4.3.2 Erosion

### 4.3.2.1 Coastal Erosion

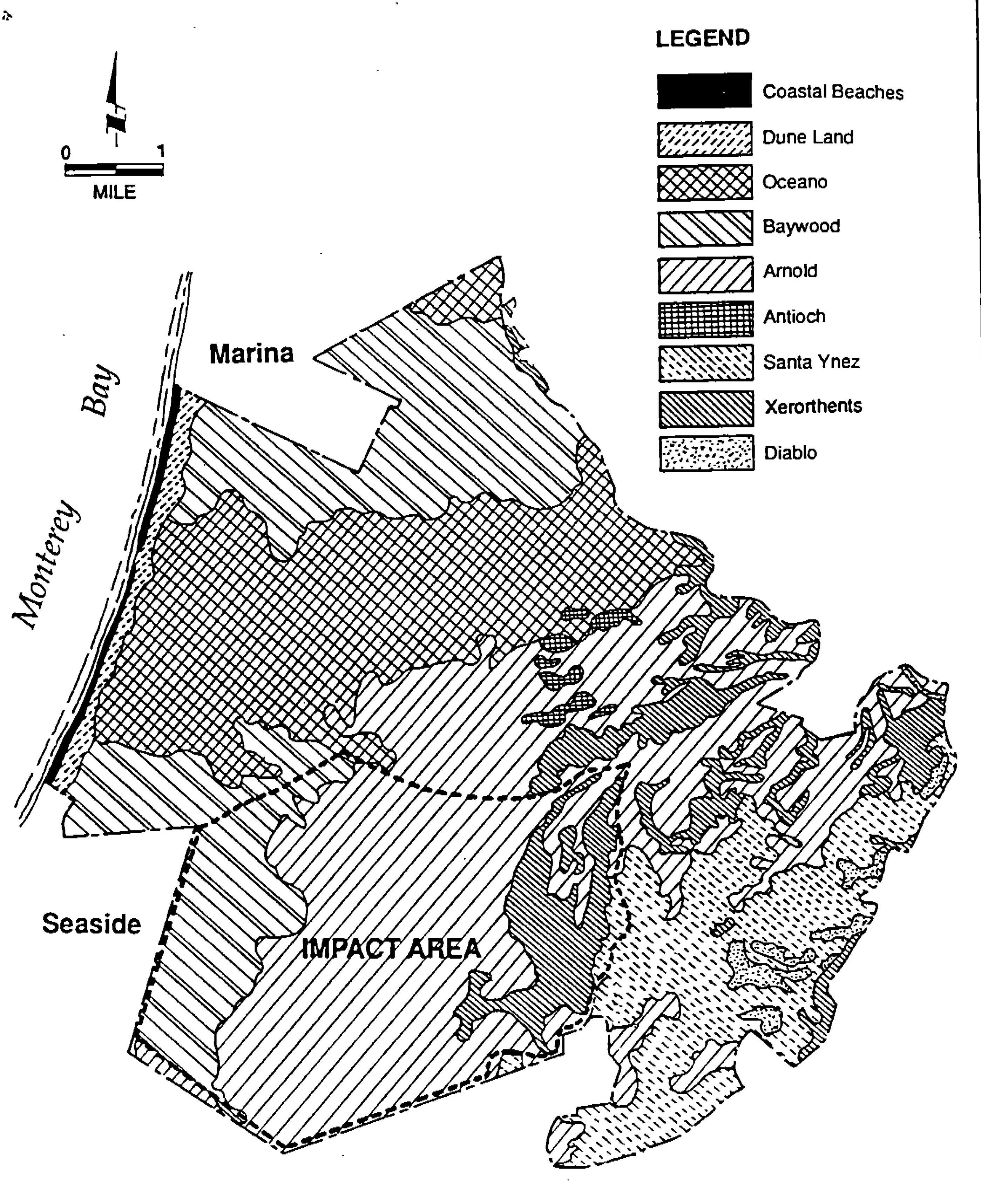
The severe coastal erosion at Fort Ord, which has been occurring for at least several thousand years, is a natural process resulting from the postglacial sea level rise, wave patterns and geomorphic structure of Monterey Bay. The erosion rate has accelerated in this century from about 1.5 feet per year up to 7.0 feet per year in 1983 because of reduced sediment supply (from sand mining along the coast and sediment trapping in reservoirs in the Salinas River watershed) and loss of vegetation on shoreline dunes. A rubble revetment to preserve Stilwell Hall was repaired in 1983 but has since continued to erode on the south side and slip into the ocean. Engineering works proposed in the 1983 U.S. Army Coastal Engineering Research Center Report (Smith 1983) have not been implemented because of the high cost. Pillars supporting storm drainage pipes opening to the ocean are exposed and are likely to collapse. Although the erosion rate has slowed in the last 6 years from a lack of large winter storms, erosion is likely to resume at the previous accelerated rate with suitable storm conditions.

*Figure 4.3-1*
Surficial Geology and Fault Lines of Fort Ord




Sources: Defense Mapping Agency Hydrographic/Topographic Center 1980; Jenkins 1971.

*Figure* 4.3-2
Major Soil Series and Types at Fort Ord




Sources: Defense Mapping Agency 1980; U.S. Soil Conservation Service 1978.

#### 4.3.2.2 Wind Erosion

The portion of Fort Ord comprised of Dune Land and the Oceano, Baywood, and Arnold soil series (Figure 4.3-2) is susceptible to wind erosion if vegetation is removed and the surface is disturbed. Organic matter accumulation or development of soil structure in the surface horizons of the Oceano, Baywood, and Arnold soils retards wind erosion and lowers the erosion hazard unless the topsoil is disturbed or removed. Loose sand, such as in the Oceano, Baywood, and Arnold subsoils, has a wind erosion potential of up to 310 tons per acre per year in open, unvegetated areas, the highest wind erosion potential of any soil type in the Wind Erosion Equation rating system.

Wind erosion is a continuing problem at Fort Ord particularly in areas under development, such as during the construction of Fritzsche Army Airfield. Sand blows from the exposed soil surface, damaging existing and replanted vegetation and accumulating in areas from which it must be removed. Wind erosion continues until the source areas are stabilized and revegetated. Removing trees that act as windbreaks increases the wind erosion potential.

#### 4.3.2.3 Water Erosion

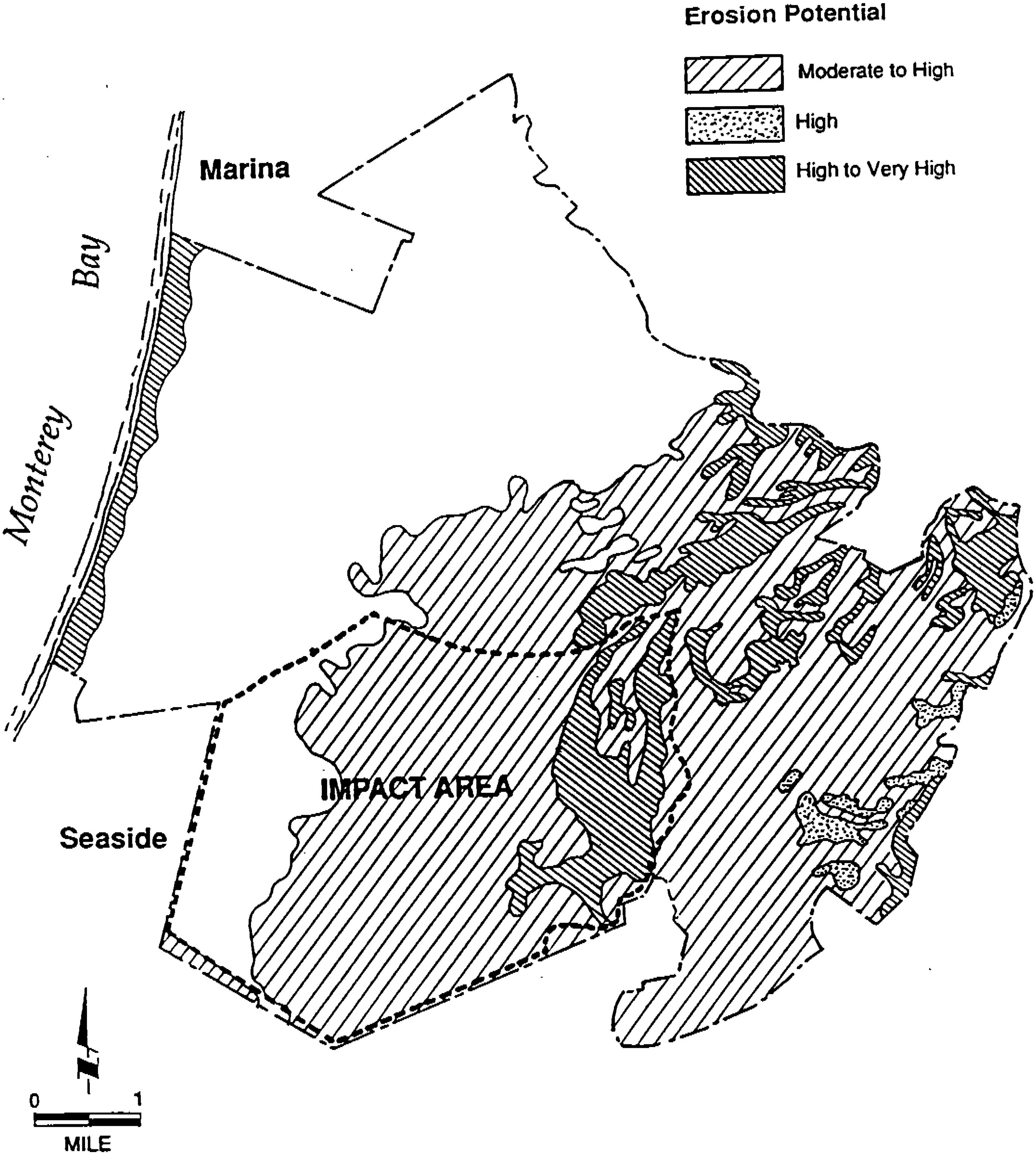
Two regions of Fort Ord are highly susceptible to water erosion: the Arnold and Xerorthent soils on the Aromas formation and the Santa Ynez and Diablo soils on the Paso Robles formation (Figures 4.3-1, 4.3-2, and 4.3-3). The red sandstone layer distinguishing the Aromas formation is 3-15 feet thick and 0-15 feet deep below the soil surface. The sandstone layer is especially evident in ridgetop edge outcrops, which although somewhat resistant, are slowly eroding. Rill and gully erosion sufficient to produce palisade or badland-like features is a naturally occurring process. Although the sandstone layer is weakly consolidated, it is relatively impervious to water compared with the unconsolidated soil; water drains rapidly through the soil profile until it is impeded by the oxidized iron-cemented sandstone layer. Excavations or cuts in this profile produce immediate springs above the sandstone layer where it is exposed. Such induced surface runoff accelerates the natural erosion process. Slopes where eroded material collects are additionally subject to landslides (Dupre 1990).

Erosion on the Aromas formation is exacerbated by disturbance, such as roadcuts. Figure 4.3-4 shows eroded areas on the cutbank and downslope of a roadway. Problems in drainage were also encountered in the construction of the new ammunition supply point. A ditch for an electric line pipe conduit formed a gully breakout where it was excavated below the sandstone layer, and a drainage structure conveying runoff partly downslope from the ridgetop facility induced erosion in spite of riprapping.

The Paso Robles formation also has a high potential erosion hazard. The Santa Ynez soil series mapping unit may include an infiltration-impeding layer of clay accumulation as described in the existing Monterey County soil survey or may be underlain by unconsolidated alluvial deposits and weakly calcium carbonate-cemented sandstone. The Diablo soil series has a clay particle-size class throughout the profile with a consequent low infiltration and high runoff rate. This readily erodible landscape actually formed a more stable, rounded topography under natural conditions, held in place by a nearly continuous grass cover. In contrast, the soils of the Aromas formation are more susceptible to erosion under natural conditions because the native chaparral vegetation cover is noncontinuous.

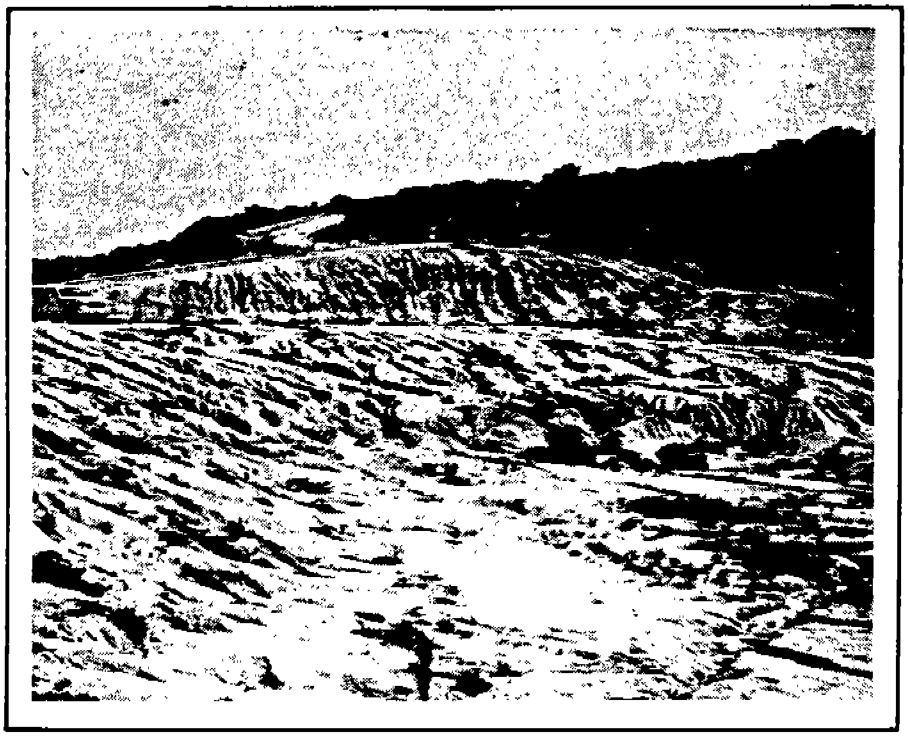
Under disturbed conditions on the Paso Robles formation, such as road or toeslope cuts and grazing pressures, especially when concentrated in stream channels, induced erosion is even more extensive and dramatic than on the Aromas formation. Figure 4.3-5 shows the typical pattern of extensive stream channel gullying that characterizes nearly every stream channel on the Paso Robles formation on Fort Ord. Figure 4.3-6 shows the result of stream channel gullying in conjunction with a road placement (the original roadway is now virtually obliterated). This area of severest erosion has additional complications. The hillside above, although seemingly intact, is laced with piping or internal, subsurface erosion tunnels that open to the surface, indicating widespread slope instability. The Paso Robles formation is highly susceptible to landslides, as indicated by both recent (Figure 4.3-7) and geomorphically identifiable past landslides (Dupre 1990).

*Figure 4.3-3*
Water and Coastal Erosion Potential at Fort Ord



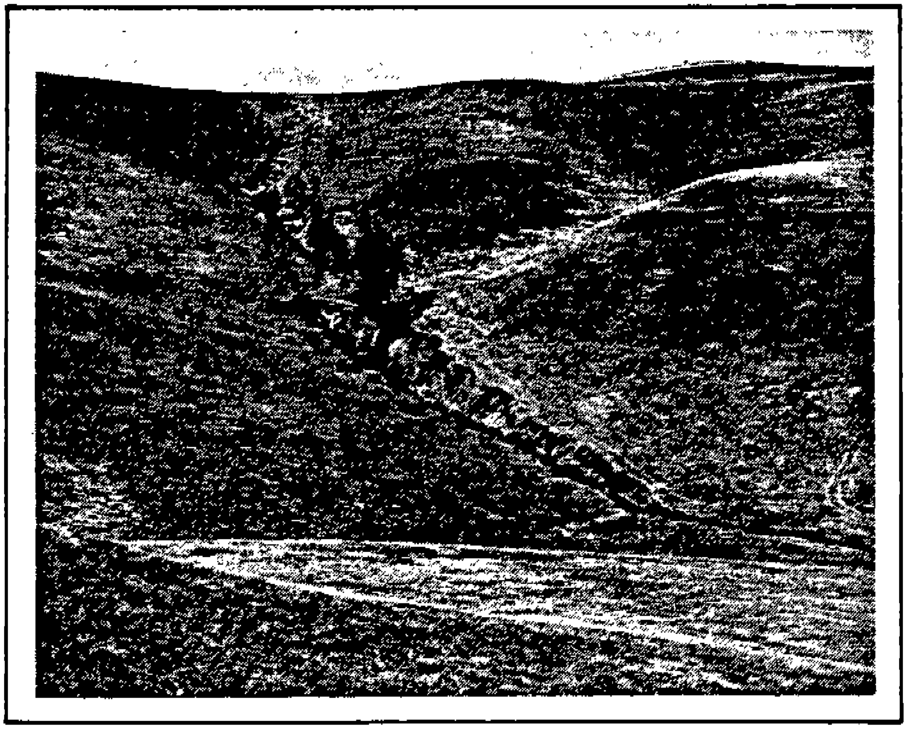

Sources: Defense Mapping Agency 1980; U.S. Soil Conservation Service 1978.

*Figure 4.3-4*



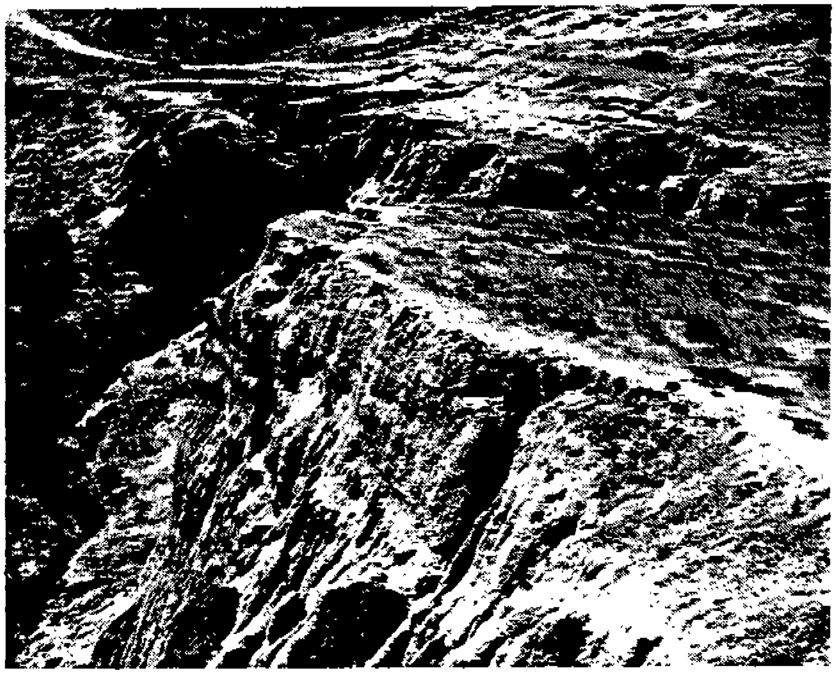
Erosion on cutbank and downslope of a roadway, Aromas formation on Fort Ord.

*Figure 4.3-5*



Extensive stream channel gullying, Paso Robles formation on Fort Ord.

*Figure 4.3-6*



Result of stream channel gullying in conjunction with a road, Paso Robles formation on Fort Ord.

*Figure 4.3-7*

Existing landslide, Paso Robles formation on Fort Ord.

Erosion on the Paso Robles formation is causing considerable downstream sedimentation, particularly in Toro Creek, which runs partially on Fort Ord or adjacent to the southeast boundary. The upstream erosion contributes to a potential flooding hazard for existing residences along Toro Creek.

Historically, beginning when Monterey was the capital of California in the Spanish and Mexican periods, heavy cattle grazing may have caused rangeland deterioration and initiated the severe erosion now evident on the grasslands in the southeast quadrant of Fort Ord. In addition, cattle grazing in the old dunes area after the establishment of Fort Ord caused severe wind erosion problems until the grazing was discontinued. An ongoing sheep grazing program may be contributing to the erosion problem because of areas of overgrazing from sheep preferential grazing habits. A new grazing environmental assessment is being prepared. Efforts have been made to control, or at least retard, the active areas of erosion. The installation of drop inlets and planting of willow trees has slowed the deepening of the lower channel gullying, but the headward, upslope gully advance continues.

Water erosion is not as much of a problem on the sandy soil types identified above as the soil's susceptibility to wind erosion, with three exceptions: the high infiltration rate of the sandy soils may be exceeded if runoff or drainage from developed areas is sufficiently concentrated, in which case erosion is rapid; areas of the Arnold soil series on the Aromas formation are susceptible; and the coastal dune cliffs are subject to wave erosion, as well as concentrated runoff or drainage erosion.

### 4.3.3 Topography

Extensive areas of Fort Ord have slopes in excess of 15-30% (Figure 4.3-8). Limited areas have slopes approaching vertical. At present, very little development has occurred in these areas. A slope greater than 15% is considered a severe limitation on almost all development (U.S. Soil Conservation Service 1978a) due to the hazard of erosion and landslides.

### 4.3.4 Agriculture/Horticulture

Before Fort Ord was established, only limited agriculture was practiced on the property. Tomatoes and other vegetables were grown on the alluvial flats along Toro Creek; dryland spring peas were grown on the dunes at the north end of Fort Ord; and hay may have been grown on the grassy flats amidst the sand dunes. Most of the soils on Fort Ord are generally unsuitable and severely limited for agriculture (U.S. Soil Conservation Service 1978a).

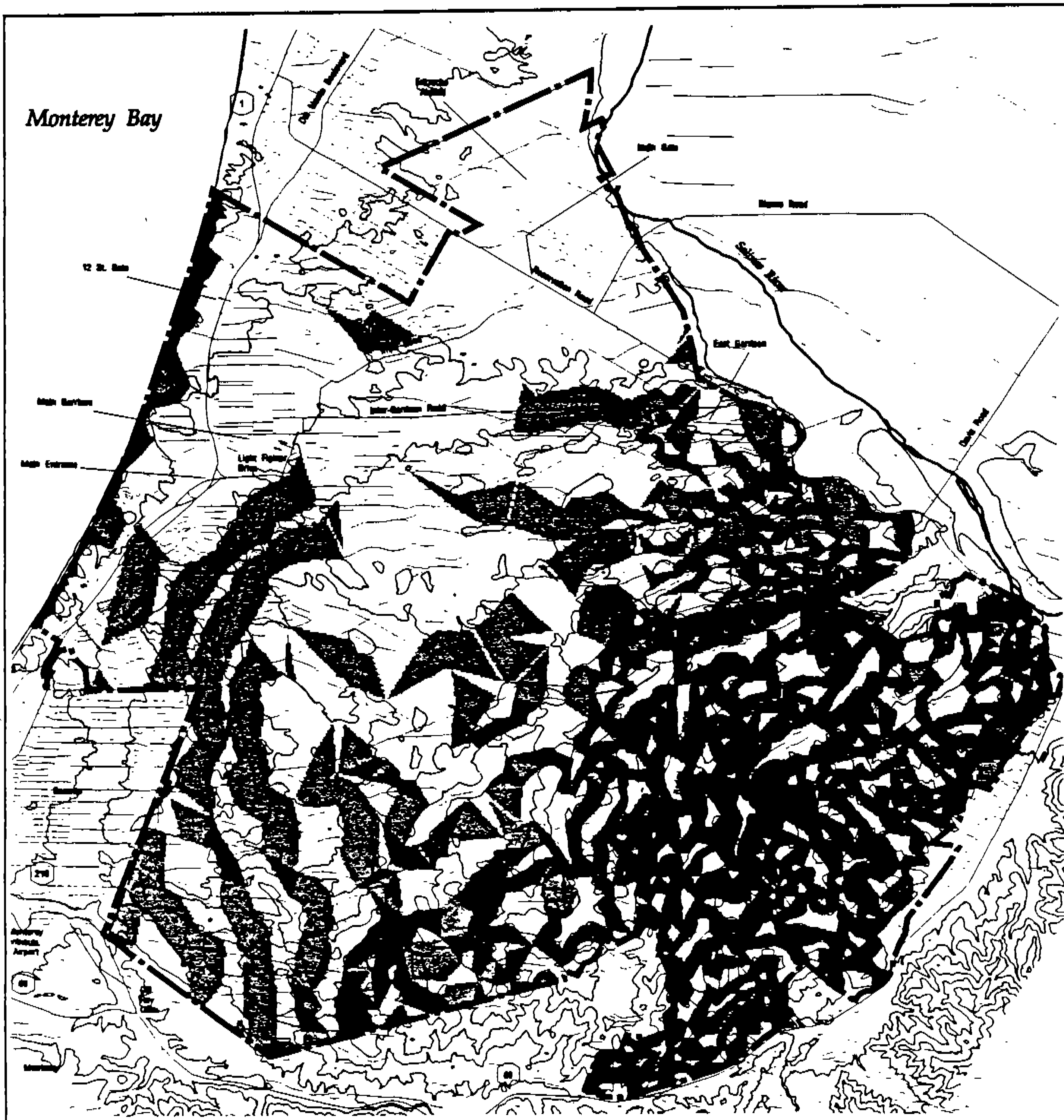
A small portion of Fort Ord, less than 50 acres in the segment along the northeast boundary that extends out to and encompasses the Salinas River, consists of soils suitable for prime farmland. Extensive areas of Oceano soils, and very limited areas of Antioch and Arnold soils, as mapped on Fort Ord are suitable as soils of statewide (farmland) importance (California Department of Conservation 1993). The areas mapped as Antioch soil have a high value as wetlands and rare plant and wildlife habitat. Extensive acreage in the southeast quadrant of Fort Ord has value as grazing land and is presently used for that purpose. No agriculture is currently practiced on Fort Ord.

The sandy, drought-affected soils of Fort Ord limit landscaping and make lawns difficult and expensive to maintain.

### 4.3.5 Engineering Uses

Different soil types may have various limitations as substrates for engineering or construction purposes. In addition to limitations caused by erosion, slope, landslides, and sedimentation, some soils on Fort Ord have limitations of low strength, shrink-swell potential, excavation caving, and piping (Figures 4.3-9, 4.3-10, and 4.3-11).

*Figure 4.3-8*
## Slope Map at Fort Ord



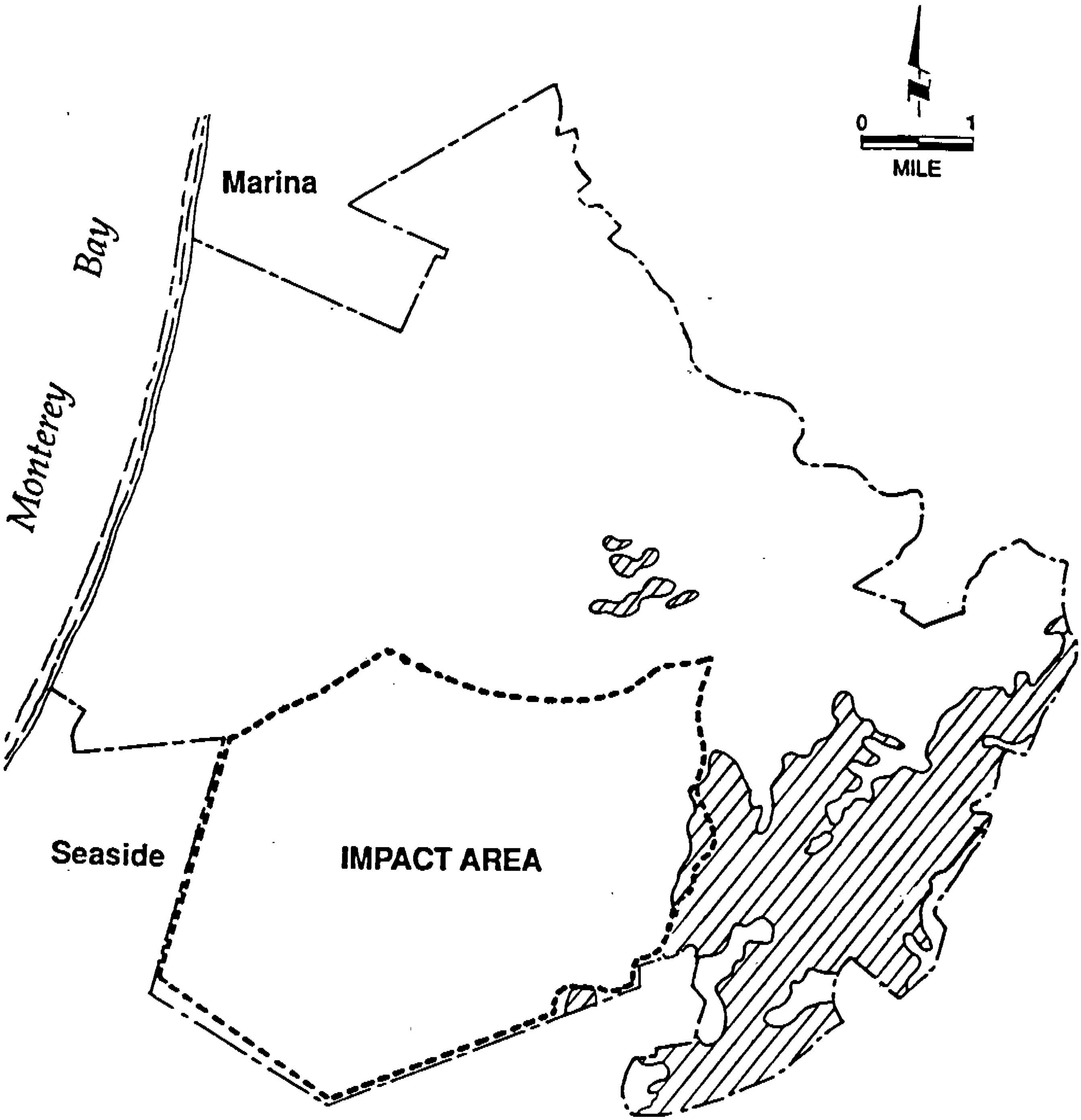

0 1 2 3 miles
0 2,500 5,000 7,500 10,000
0 1 2 3 kilometers

0 to 10% Slope

15 to 30% Slope

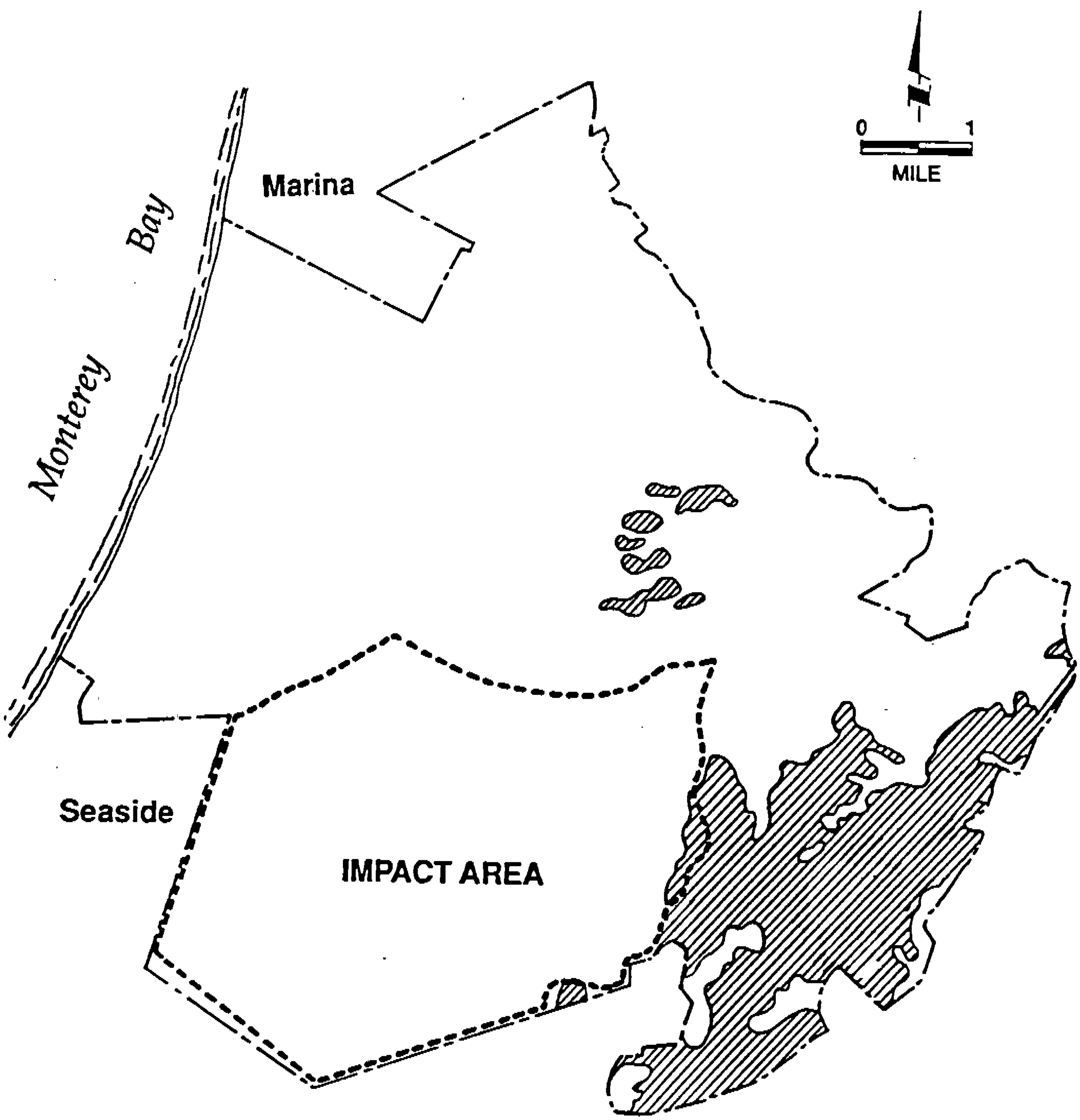
Greater Than 30% Slope

*Figure 4.3-9*
Soils with Low Strength at Fort Ord



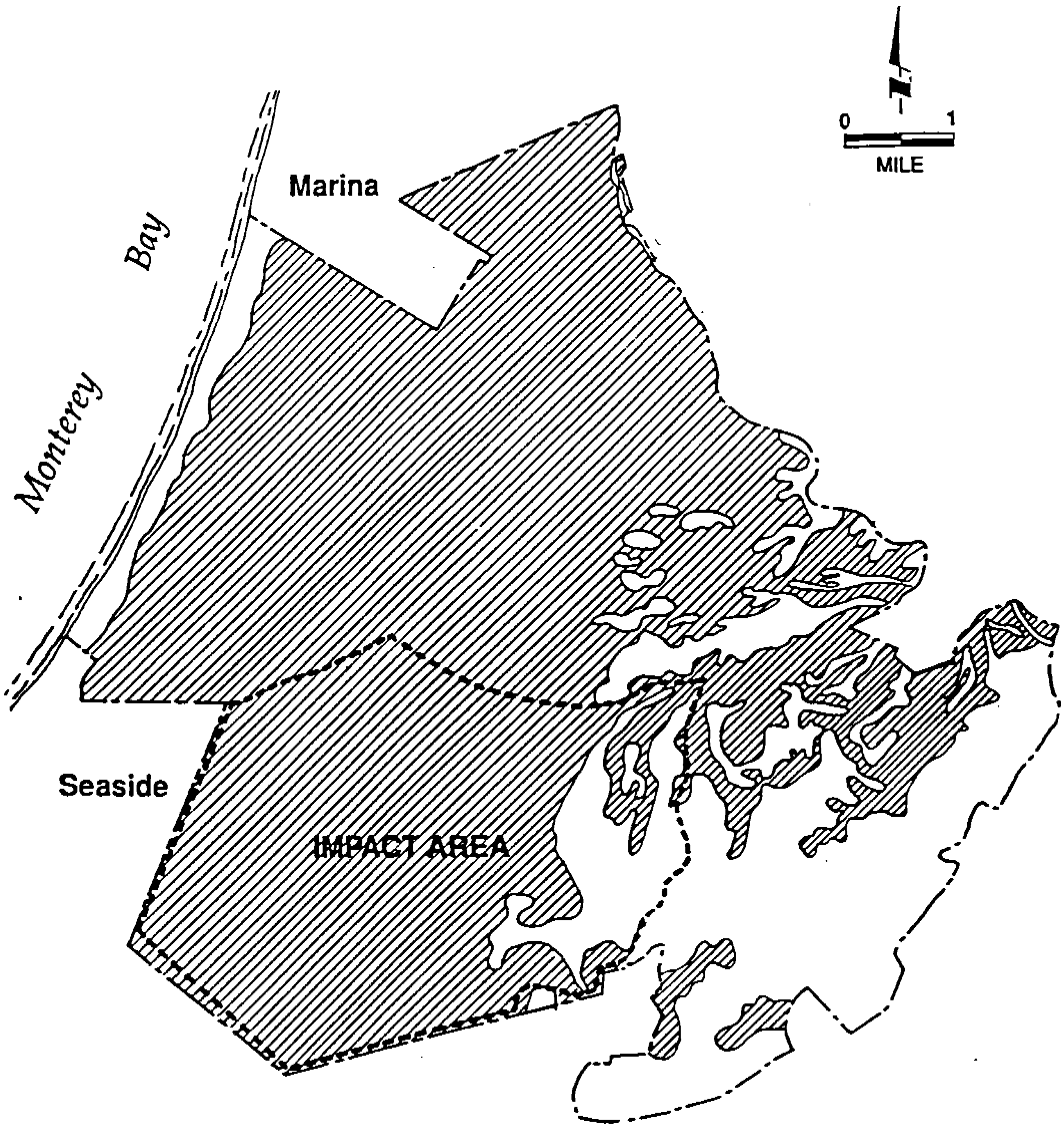

Sources: Defense Mapping Agency 1980; U.S. Soil Conservation Service 1978.

*Figure 4.3-10*
Soils with High Shrink-Swell Potential at Fort Ord




Sources: Defense Mapping Agency 1980; U.S. Soil Conservation Service 1978.

*Figure 4.3-11*
Soils with Excavation Caving and Piping Potential at Fort Ord




Sources: Defense Mapping Agency 1980; U.S. Soil Conservation Service 1978.

Two soil series with high clay contents are rated as having severe limitations for low strength: Diablo for buildings, and both Diablo and Santa Ynez for roads, streets, and embankments. The same two soil series have a severe limitation of shrink-swell potential for buildings and roads and streets. Three poorly aggregated sandy soil series, Baywood, Oceano, and Arnold, have severe limitations for shallow excavation caving and for piping in embankments. Severe piping was observed in areas mapped as the Santa Ynez soil series.

A severe limitation exists for reservoir construction on Oceano, Baywood, and non-Aromas formation Arnold soil series because of very high permeability and seepage and piping potential in earthen dam embankments.

### 4.3.6 Seismic Hazards

Several inferred or concealed earthquake faults (i.e., the Reliz or Gabilan, Chupines, Ord Terrace, and Seaside faults) either cross or are adjacent to Fort Ord (Figure 4.3-1). The first has possibly been active in the last 0.7 million years, and the latter three have possibly been active in the last 1.6 million years. None show activity in the last 10,000 years, but the potential cannot be ruled out (California Division of Mines and Geology 1992). The San Andreas fault, historically active in the last 200 years, is within 25 miles of Fort Ord.

The Palo Colorado-San Gregorio fault, 14 miles southwest of Fort Ord, and the Monterey Bay fault zone, directly offshore of Fort Ord, both show evidence of Holocene movement and recent earthquake activity (Greene 1989). The Monterey Bay fault zone extends seaward of the Ord Terrace, Seaside, and Chupines faults (Figure 4.3-1). The maximum credible earthquake magnitude is greater than 6 for the Monterey Bay fault zone, greater than 7 for the Palo Colorado-San Gregorio fault, and greater than 8 for the San Andreas fault (Greene 1973, California Department of Conservation 1980).

The potential of earthquake damage from ground shaking is moderate to very high, with the highest potential in the coastal dune zone. Only minor earthquake damage was sustained at Fort Ord in the Loma Prieta earthquake of 1989. Cracks appeared in the concrete between Stilwell Hall and the dune cliffs because of the unstable condition of the cliffs, and a few cracks occurred in the Silas B. Hays Army Community Hospital because of ground shaking.

Approximately 8,000 buildings exist on Fort Ord. Most buildings on Fort Ord were not constructed to comply with current local building codes relating to seismic safety because most were built before modern seismic safety provisions were incorporated into California building codes and Department of the Army technical manuals.

Seismic safety provisions of California building codes focus on buildings that receive concentrated public use or house sensitive uses, such as schools and hospitals. Schools on Fort Ord are owned and operated by the Monterey Peninsula Unified School District on land leased from the federal government, and are required to be in compliance with current building codes relating to seismic safety. The Silas B. Hays Army Community Hospital, which was completed in 1971, would require extensive modifications to comply with local and state seismic safety building codes required of in-patient healthcare facilities. The Army has conducted extensive studies of the modifications that would be required to bring this building into compliance with current regulations and has estimated the cost of such modifications to be greater than $50 million. Other buildings, such as theaters, recreational facilities, and community centers, were generally constructed before 1973 and may also require substantial modifications to comply with current seismic regulations.

Other earthquake hazards of concern include liquefaction and landslides. High to very high liquefaction potential exists on recent alluvial sediments along Toro Creek. The same potential may exist in other small, localized areas along creeks; near existing ponds and reservoirs; and in isolated, water-retaining basins amidst the sand dunes. Landslide potential as an earthquake effect is present in the landslide-prone areas described above, including the Aromas formation and the shoreline dune cliffs.

Past studies have indicated that tsunamis and seiches (California Division of Mines and Geology 1980), large seismically induced and potentially destructive open ocean and bay waves, are of relatively minor concern in Monterey Bay (U.S. Army Corps of Engineers, Sacramento District 1992e) and would add only a somewhat increased hazard of coastal erosion at Fort Ord.

### 4.3.7 Toxic Contaminants and Live Ordnance

The known sites of toxic contamination and live ordnance are found on the sandy soils of the Dune Lands and the Oceano, Baywood, and Arnold soil series. These soils are characterized by their high permeability and infiltration rates, low fertility and water-holding capacity, and high susceptibility to wind erosion if vegetation is removed or the surface is otherwise disturbed. Areas of Xerorthents and Arnold series underlain by sandstone are also highly susceptible to water erosion. (Refer to Section 4.10, "Hazardous and Toxic Waste Site Remediation", for further discussion.)