Table 1. Potential hazards from future eruptions in California

| | FLOWAGE PHENOMENA | | | | | | | | ERUPTION OF TEPHRA | EMISSION OF VOLCANIC GASES |
|---|---|---|---|---|---|---|---|---|---|---|
| | Debris avalanches | Pyroclastic flows | Lateral blasts | Pyroclastic surges | Lava flows | Lava domes | Debris flows | Floods | | |
| ORIGIN AND CHARACTERISTICS | Result from failure of volcanic edifice. Move downslope away from volcano at high speed. Distribution is partly controlled by topography. | Can be caused by direct eruption of fragments of molten or hot solid rock or by explosion or collapse of a lava dome or flow. Commonly occur suddenly and move away from volcano at tens of km to more than 100 km per hour. Distribution is mostly controlled by topography. | Result from explosive ejection of rock fragments with or without magma and steam. Commonly occur suddenly; ejected debris moves away from vent at hundreds of km per hour. Distribution controlled by direction of blast, only slightly influenced by topography. | Result from explosive magmatic or phreatic expulsion of rock fragments with steam or other hot gases. Pyroclastic surges commonly occur suddenly and ejected debris moves away from vent at hundreds of km per hour. Distribution controlled only slightly by topography. | Result from nonexplosive eruption of molten lava. Flows move down slope slowly, usually no faster than a person can walk. Distribution is controlled by topography. | Result from nonexplosive eruption of molten lava. Lava is erupted slowly and accumulates above the vent. Distribution limited to above and within a few km laterally from vent. | Commonly result from eruption of hot material onto snow and ice and from eruptive displacement of crater lakes. May also be derived from debris avalanches from volcano. Debris flows commonly originate suddenly and move at tens of km per hour. Distribution controlled by topography. | Origin similar to origin of debris flows. Debris flows may grade downstream to floods. Commonly move at speeds of <20 km per hour. Distribution controlled by topography. | Produced by vertical expulsion of columns of fragments and gas into the air; materials can be carried great distances by wind. Commonly is erupted suddenly, and is carried away from vent at speeds of tens of km per hour. Distribution controlled by height to which erupted and wind direction and speed. | Produced by explosive or nonexplosive emission of gases from vent; gases may be hot and commonly contain sulfur and other harmful compounds. Gases commonly are carried by wind away from vent at speeds of tens of km per hour. Distribution controlled by wind direction and speed. |
| EFFECTS ON LAND AND OBJECTS | Burial, destruction by impact, or dislocation. | Burning, burial, impact damage, and dislodgement. | Burning, burial, impact damage, and dislodgement. | Burning, burial, impact damage, and dislodgement. | Burial or destruction. May start fires. | Near-vent areas subject to burning, burial, or destruction; distant land and objects may be destroyed by pyroclastic flows generated by explosion or collapse of dome. | Burial, dislodgement, and impact damage. | Dislodgement, impact damage, and inundation by water. | Near-vent areas subject to burial, loading, and infiltration by abrasive rock particles. Blanketing and infiltration effects can reach hundreds of km downwind. | Structures, equipment, people, animals, and vegetation can be damaged or destroyed by corrosive gases. Odor, "haze," and mild effects can extend hundreds of km downwind. |
| DEGREE OF RISK IN AFFECTED AREA | Extreme for both people and property near and downslope from source. Risk decreases gradually away from volcano. | Extreme for both people and property near erupting volcano. Risk to people high because of possible sudden origin and high speeds. Risk decreases gradually with distance from vent, and more abruptly with increasing height above valley floor. | Extreme for both people and property within 30 km of vent because of sudden onset and very high speeds. Risk decreases gradually away from vent but does not depend on topographic position. | High for both people and property because of sudden onset and high speeds. Risk decreases gradually away from vent. | Low for people; high for property. | Low for people; high for property. Risk is greatest at vent and decreases rapidly away from the vent. Risk from dome-related pyroclastic flows may extend 15 km beyond vent. | Moderate to high for both people and property near erupting volcano. Risk decreases gradually with distance from vent and abruptly with increasing height above valley floor. | Low to moderate for both people and property. Risk decreases gradually downvalley and abruptly with increasing height above valley floor. | Moderate to people and property near erupting volcano. Risk decreases rapidly upwind and gradually downwind from vent. | Low to people and property. Risk decreases rapidly upwind and gradually downwind from vent. |
| LOCATION OF HAZARD | Areas downslope and downvalley from volcano. Large-volume debris avalanches, which occur only at large steep-sided volcanoes, may extend as far as 45 km. | Beyond volcano flanks, effects may extend as far as 40 km downslope and 65 km downvalleys. Areas adjacent to pyroclastic flows may be affected for a distance of several km by clouds of hot ash. | Beyond volcano in a sector as wide as 180° that extends as far as 30 km from volcano. Ridge crests and valley floors may be affected about equally. | Areas within a distance of 10 km of vent. Topographically high and low areas may be affected about equally. | Restricted to areas downslope from vents, and most will reach distances <10 km. Flows occur repeatedly at central-vent volcanoes, but successive eruptions may affect different flanks. Elsewhere, flows occur at widely scattered sites, mostly within volcanic fields. | At vent and within a few km of vent. Pyroclastic flows resulting from collapse or explosion may extend downslope or downvalley as far as 15 km. | Beyond volcano flanks, effects mostly confined to floors of valleys and basins that head on volcanoes. Large, snow-covered volcanoes are principal sources. May extend tens to hundreds of km from source volcanoes. | Confined primarily to floors of valleys and basins that head on large, snow-covered volcanoes. May extend for hundreds of km downstream. | Areas near and downwind from volcanoes are susceptible. Zones X and Y (see text and explanation) surround volcanoes that have been explosively active during the last 10,000 yr. | All areas at and within a few hundred km downwind from erupting volcanoes or other gas emitting vents. |
| PREDICTABILITY OF LOCATION OF ENDANGERED AREAS | Relatively predictable, because most originate at large, steep-sided volcanoes and are restricted to flanks of volcanoes, immediately adjacent areas, and valleys leading from them. | Relatively predictable, because most originate at central-vent volcanoes or areas of past silicic volcanism. Pyroclastic flows are restricted to flanks of volcanoes and valleys leading from them. | Difficult to predict; may be predictable after eruption precursors begin. Deformation of volcano may indicate sector most likely to be affected. | Difficult to predict. May occur wherever magma or hot rock reaches the water table or standing water, whether or not magma has erupted there before. | Relatively predictable near large central-vent volcanoes. Only general locations predictable within volcanic fields. | Relatively predictable, because most originate in areas of past silicic volcanism and are restricted to small areas near vent. | Relatively predictable, because most originate at snow-covered volcanoes and are restricted to flanks of volcanoes and valleys leading from them. | Relatively predictable, because most originate at snow-covered volcanoes and are restricted to valley bottoms leading from them. | Moderately predictable. Voluminous tephra originates mostly at silicic volcanoes; its distribution depends mostly on winds. Tephra can be carried in any direction; probability of dispersal in various directions can be judged from wind records. | Moderately predictable, because most serious effects occur at or near erupting volcanoes. Distribution of gases away from vent depends on wind directions. |
| SIZE OF AREA AFFECTED BY SINGE EVENT | May cover areas ranging from a few tens to several hundred square km. | Generally cover a few square km to a few hundred square km. | Generally cover a few tens of square km to as much as 600 $km^2$. | Generally cover a few square km to several tens of square km. | Most cover no more than a few square km. Relatively large and rare flows probably would cover no more than a few tens of square km. | Generally cover no more than a few square km. Domes that spread farther considered to be lava flows. | Generally cover a few square km to a few hundred square km. | May affect a few square km to a few hundred square km. | An eruption with a volume of several $km^3$ could affect tens of thousands of square km and spread tephra over many states. An eruption of moderate volume (0.1-1.0 $km^3$) could affect many thousands of square km. | May affect several hundred square km. However, severe effects will be limited to a smaller area near the volcano. |

Table 2. Summary of Holocene eruptive activity and probable greatest hazards from future eruptions at volcanic centers in California
[~, about; >, more than; ≥, greater than or equal to; <, less than]

| Volcanic center (reference) | Recognized products of recent eruptions of major volcanic centers[1,2]: Lava flows and cinder cones | Domes | Tephra | Pyroclastic flows | Blasts and pyroclastic surges | Debris avalanches and debris flows | Most recent eruption (reference) | Most probable future[3] potential hazard |
|---|---|---|---|---|---|---|---|---|
| Mount Shasta (10,000 yr). (Christiansen, 1985; Miller, 1978; Miller, 1980) | Many lava flows and 1 cinder cone erupted at several vents between 10,000 and ~2,000 yr ago. | Two domes formed between ~10,000 and 9,000 yr ago; one formed during the last ~2,000 yr. | Two tephra eruptions of small volume between ~10,000 and 9,000 yr ago; probable volume 0.001-0.1 $km^3$. | Many pyroclastic flows down all sides of the volcano; some traveled ≥20 km from summit. | None recognized | Many debris flows down all sides of the volcano; many reached >30 km from volcano; one reached more than 40 km from volcano. | Small pyroclastic flows, associated ash clouds and debris flows ~200 $^{14}C$ yrs ago. (Miller, 1980) | Formation of large pyroclastic flows and debris flows. |
| MEDICINE LAKE HIGHLAND REGION: Rhyolite center (1,500 yr). (Chesterman, 1955; Fink and Pollard, 1983; Heiken, 1978; Ives and others, 1964, 1967; Mertzman, 1977) | At least four lava flows during the last 1,500 yr. | Many small silicic domes formed within the last 1,500 yr. | Two tephra eruptions of small volume during the last 1,500 yr; one slightly older; probable volume 0.05-0.1 $km^3$. | None recognized | None recognized | None recognized | Lava flows erupted within the last 1,500 yr. (Heiken, 1978) | Formation of relatively small pyroclastic flows; eruption of tephra. |
| MEDICINE LAKE HIGHLAND REGION: Basalt field (10,000 yr). (Finch, 1933) | At least 15 lava flows and (or) cinder cones within about the last 10,000 yr. | None recognized | Small volumes of mafic tephra erupted with cinder cones and flows. | None recognized | None recognized | None recognized | Several lava flows probably erupted during the last few hundred years. (Finch, 1933) | Formation of cinder cones, small volumes of tephra, and lava flows. |
| LASSEN PEAK REGION: Lassen area dacites (12,000 yr). (Clynne, 1985; Crandell, and others, 1974; Day and Allen, 1925; Heath, 1959; Rubin and Alexander, 1960) | At least one small lava flow in A.D. 1915. | At least eight silicic domes within the last 12,000 yr; four between ~12,000 and 11,000 yr; three ~1,000 yr ago; one ~350 yr ago. | Tephra eruption ~1,100 yr ago. | Two pyroclastic flows between ~12,000 and 11,000 yr ago; three pyroclastic flows ~1,100 yr ago; two pyroclastic flows ~300 yr ago. | Two small directed blasts (or pyroclastic flows) in A.D. 1915; effects extend to distance of 5 km from summit. | Dozens of debris flows were generated during eruptions at Lassen Peak dome ~11,000 yr ago; several debris avalanches ~300 yr ago; two small debris flows in A.D. 1915. | Lava flow, tephra fall, hot debris flows, and two small blasts in A.D. 1914-1917. (Clynne, 1985; Day and Allen, 1925) | Formation of pyroclastic flows; small to moderate-size debris flows. |
| LASSEN PEAK REGION: Basalt field (10,000 yr). (Anderson, 1940; Finch, 1937; Williams, 1928) | Eruption of >20 mafic centers producing lava flows and (or) cinder cones during the last 10,000 yr. | None recognized | Small volumes of mafic tephra erupted at many centers during Holocene time. ~80 $km^2$ covered with ash from Cinder Cone about 400 yr ago. | None recognized | None recognized | None recognized | Lava flows, tephra and cinder cone erupted in A.D. 1851. (Clynne, 1985; Finch, 1937; Williams. 1928) | Formation of cinder cones, small volumes of tephra, and lava flows. |
| Clear Lake (10,000 yr). (Berry and others, 1976; Hearn and others, 1976; Sims and Rymer, 1975) | None recognized | None recognized | Numerous mafic tephras were erupted during phreatomagmatic eruptions as recently as ~10,000 yr ago. | None recognized | Numerous phreatic eruptions, hydromagmatic explosions, and base-surge events. | None recognized | Mafic tephra from phreatomagmatic eruption ~10,000 yr ago. (Sims and Rymer, 1975) | Phreatic and phreatomagmatic explosions, base surges, and small-volume tephra eruptions. |
| MONO LAKE-LONG VALLEY AREA: Silicic vents (10,000 yr). (Bailey and others, 1976; Dalrymple, 1967; Mankinen and others, 1986; Miller, 1985; Miller and others, 1982; Reinhart and Huber, 1965; Tadduci and others, 1968; Wood, 1983) | Many silicic lava flows erupted at numerous vents between 10,000 yr ago and ~500 yr ago; possible flows younger than 500 yr B.P. | Many silicic domes erupted at numerous vents between 10,000 yr ago and ~500 yr ago. | Many silicic tephras erupted from numerous vents; volumes ranged from <0.02 $km^3$ to >0.2 $km^3$. | Many pyroclastic flows from numerous vents. Some have flowed 10-15 km from vents. | Many phreatic, phreatomagmatic and pyroclastic surge events have occurred at numerous vents. | Small debris flows have originated at several vents. | A series of explosive magmatic and phreatic eruptions and emplacement of lava flows occurred at several vents at the Inyo volcanoes ~550 yr ago. (Miller, 1983; 1985; Miller and others, 1982; Wood, 1983) | Small- to moderate-volume silicic pyroclastic eruptions that will form pyroclastic flows and small to moderate volumes of tephra. |
| MONO LAKE-LONG VALLEY AREA: Mafic vents (13,000 yr). (Bailey and others, 1976; Lajoie, 1968) | Sublacustrine mafic eruptions in Mono Lake ~13,000 yr ago; eruption of cinder cones and flows at two vents 1,200-5,000 yr ago. | None recognized | Mafic cinders erupted at two vents 1,200-~5,000 yr ago. | None recognized | None recognized | None recognized | Mafic cinder cone and lava flow eruptions at two vents. 1,200-~5,000 yr ago. (Miller, this report) | Formation of cinder cones, small volumes of tephra, and lava flows; phreatic explosions. |
| Amboy Crater-Lavic Lake basalt fields (~10,000 yr). | Several mafic lava flows and cinder cones from several vents during last ~10,000 yr. | None recognized | Mafic tephra erupted at several vents during past ~10,000 yr. | None recognized | None recognized | None recognized | Mafic cinder cones and lava flows of apparent early Holocene age. (Miller, this report) | Formation of cinder cones, small volumes of tephra, and lava flows; phreatic explosions. |
| Salton Buttes rhyolite center (16,000 yr). (Muffler and White, 1969; Robinson and others, 1976) | At least one silicic flow associated with rhyolite dome ~16,000 yr ago. | Five silicic domes erupted from four vents ~16,000 yr ago. | Probable small-volume pyroclastic eruptions associated with dome emplacement at several vents. | None recognized but may have occurred at several vents. | Products of subaqueous pyroclastic eruptions at least one vent. | None recognized | Silicic pyroclastic and extrusive eruptions at four vents ~16,000 K/Ar yr ago. Robinson and others, 1976) | Explosive and extrusive rhyolitic eruptions; phreatic and phreatomagmatic eruptions. |
| Ubehebe Crater area (~10,000 yr). (Crowe and Fisher, 1973) | None recognized | None recognized | Several mafic phreatomagmatic tephra eruptions in Holocene time. | None recognized | Base-surge and phreatomagmatic tephra deposits associated with ~13 maar-crater eruptions. | None recognized | Formation of maar craters and deposition of phreatomagmatic tephra and base-surge deposits in early Holocene time. (Crowe and Fisher, 1973) | Phreatomagmatic eruptions associated with base surges and small volumes of tephra. |
| Golden Trout Creek volcanic field (~10,000 yr). (Moore and Lanphere, 1983) | One mafic cinder cone and lava flow ~10,000-5,000 yr ago. | None recognized | Mafic cinders erupted at one vent ~10,000-5,000 yr ago. | None recognized | None recognized | None recognized | Mafic cinder cone and lava flow ~10,000-5,000 yr ago. (Moore and Lanpherė, 1983) | Formation of cinder cones, small volumes of tephra and lava flows. |

[1]Time interval evaluated shown in parentheses for each volcano.

[2]Much of these data resulted from this study; other references are cited.

[3]Based on consideration of size, frequency, and severity of event.

# TABLES OF VOLCANIC HAZARDS IN CALIFORNIA