GEOLOGIC HAZARDS IN AND NEAR PROPOSED STATE OF ALASKA OIL AND GAS LEASE SALE 79 (CAPE YAKATAGA)

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INTRODUCTION

The proposed Cape Yakataga state oil & gas lease sale occupies onshore and state offshore areas from Icy Bay to Controller Bay along the northern Gulf of Alaska coast (fig. 1). Natural processes in this area will impose severe constraints to exploration, production, and transportation activities associated with possible petroleum development. Geologic maps by Kachadoorian (1959, 1960), and Miller (1971) show the distribution of bedrock and surficial deposits and faults, but do not identify all active faults. Some landslides are shown on Kachadoorian's map, but all except one small landslide near Katalla are outside the proposed lease area.

Primary hazards within the lease area include high earthquake potential associated with the Yakataga seismic gap; active seafloor faulting; tsunamis; ground instability (both onshore and offshore) associated with high influx of unconsolidated, glacially derived sediment; glacial-outburst flooding; snow avalanches near steep terrain; severe storms; and possible future influx of large icebergs. This report provides a brief summary of available information related to these hazards.

EARTHQUAKES

In the region of the proposed lease area, 63 earthquakes of magnitude >5.0 were recorded between 1899 and 1989 (fig. 2). These included two magnitude 8 events near Icy Bay in 1899 and a magnitude 7.7 event near Mount St. Elias in 1979. The 1899 events resulted in as much as 15 m (50 ft) of uplift near Yakutat Bay and triggered large avalanches in the mountains between Icy Bay and Kayak Island (Tarr and Martin, 1912). No great earthquakes (magnitude 7.8 or greater) have occurred in this zone since 1899. Recent earthquakes tend to cluster near the intersection of the Fairweather and Chugach-St. Elias faults near the eastern edge of the map area and in an offshore area south of Cape Yakataga known as the Pamplona fracture zone. Most seismicity in the area is shallow (less than 30 km or 20 mi).

Earthquake Probability

The proposed lease area occupies the Yakataga seismic gap (YSG), which extends from Icy Bay to Kayak Island (McCann and others, 1980; Pérez and Jacob, 1980) along the boundary between the Pacific and North American plates. The YSG is a complex transition zone between right-lateral strike slip motion along the Queen Charlotte-Fairweather fault zone to the east and underthrust motion along the Alaska-Aleutian trench to the west (McCann and others, 1980). This zone is regarded as a seismic gap because of the length of time that has elapsed since it last ruptured in two great earthquakes in 1899.

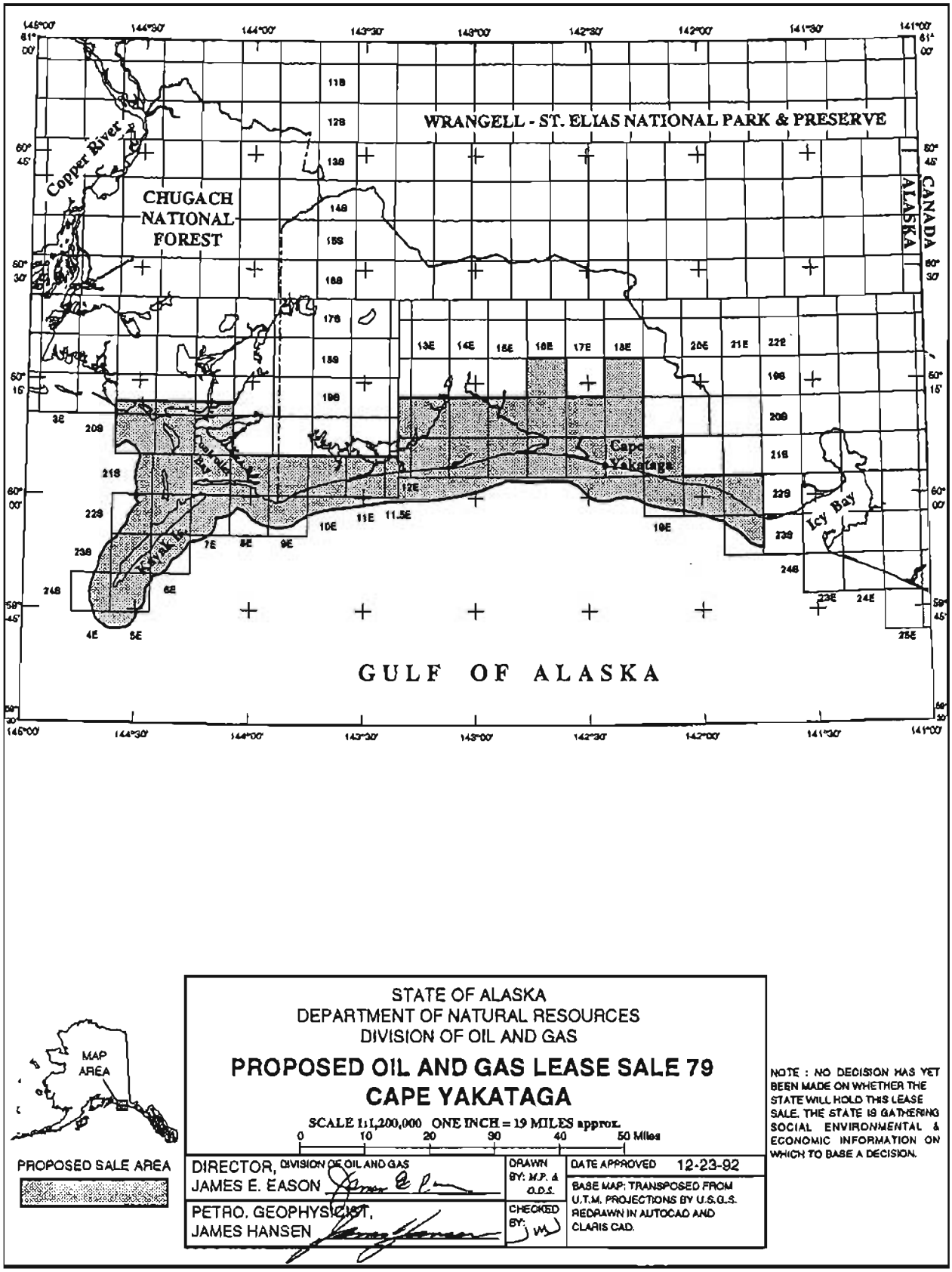

Figure 1. Map of proposed State of Alaska oil and gas lease sale 79 in the Cape Yakataga area.

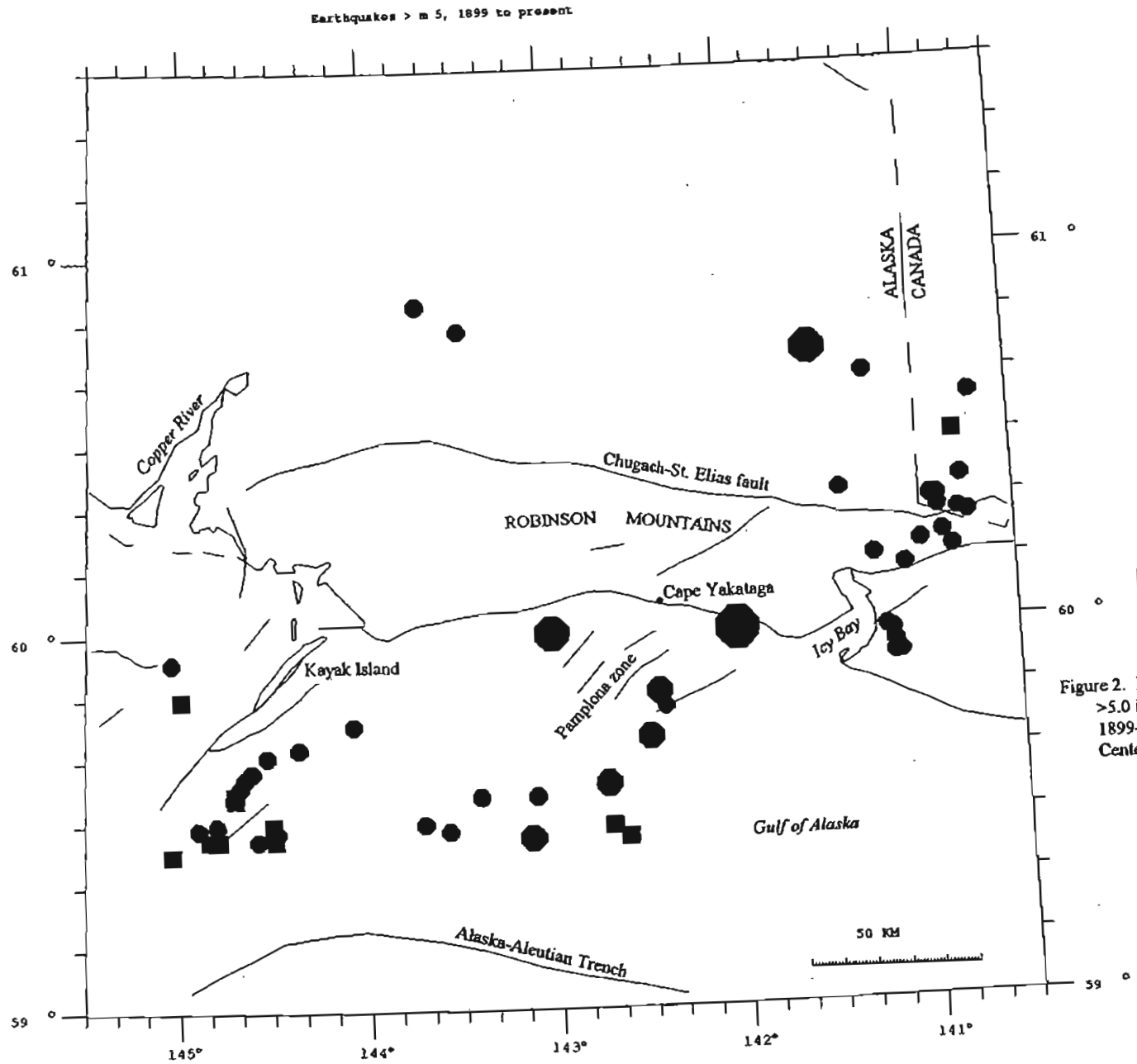

Figure 2. Epicenters of earthquakes with magnitudes >5.0 in the area 59.4-61.1°N, 140.9-145.1°W, 1899-1989 (Alaska Earthquake Information Center, 8/26/93).

A magnitude 7.7 earthquake near Mount St. Elias in 1979 ruptured only a small part of the gap.

Plate motion in the region is accommodated not on a single crustal break but along three primary zones: (1) strike-slip faulting along the northwest-trending Fairweather fault, (2) thrust faulting along the east-west Chugach-St. Elias fault and related faults, which bisect the Chugach and Robinson Mountains, and (3) thrust faulting along the offshore Pamplona fracture zone south of Cape Yakataga. Geologic evidence indicates that the Ragged Mountain fault near Katalla has been active in the recent past (Kachadoorian, 1960), but no historic seismicity has been attributed to offset along the fault. This fault is largely outside the proposed lease area.

Because of the tectonic complexity of this region, hazard estimates using the seismic-gap hypothesis may be less reliable than in other zones along major plate boundaries (Nishenko and Jacob, 1990). Nevertheless, the YSG is one of only three segments along the Alaska-Aleutian seismic zone that have not ruptured during the last 50 yr and are thought to be the most probable locations for the next great earthquake in Alaska (Lahr and others, 1986). Nishenko and Jacob (1990) have estimated a probability of 67% during the next 15 yr for recurrence of the 1899 magnitude 8.2 event and 5% for recurrence of larger events within the YSG. Because of the recent (1958) occurrence of a magnitude 8.2 earthquake along the Fairweather fault to the east, the probability of recurrence of a magnitude 8.2 event along this fault in the next 15 yr is negligible. Although the reliability of these probability estimates may be poor, they give a rough idea of the likelihood of major earthquakes in the vicinity of the Cape Yakataga lease area in the near future.

Geologic study of elevated terraces in the YSG indicates a recurrence interval of 500-1,400 yr for major uplift events during the past 5,000 yr (Plafker, 1990). The events recorded by the terraces probably represent very large great earthquakes like the 1964 magnitude 9.2 event near Prince William Sound. The recurrence interval for "smaller" great earthquakes (magnitude 8-8.5) is probably much shorter.

Earthquake Effects

Thenhaus and others (1985) estimate a 10% probability of exceedance of 0.63 g earthquake-generated horizontal acceleration in rock during a 50-yr period in this area (for comparison, ground acceleration in Anchorage during the great 1964 earthquake was estimated at 0.16 g). Accelerations in areas underlain by soft sediments are likely to be higher than in bedrock areas due to amplification. Thenhaus and his colleagues point out that their estimate was a result of analyses completed in 1978 before the tectonic models of Pérez and Jacob (1980) and McCann and others (1980) were published. Refinements to the acceleration probabilities have not yet been published.

Because of high sediment influx to the region from glacial meltwater streams, most coastal and offshore areas are underlain by thick deposits of unconsolidated sediment (Kachadoorian, 1960; Miller, 1971; Carlson and others, 1975; Carlson and Molnia, 1977; Carlson and others, 1977; Carlson, 1978)(fig. 3). These deposits may amplify earthquake

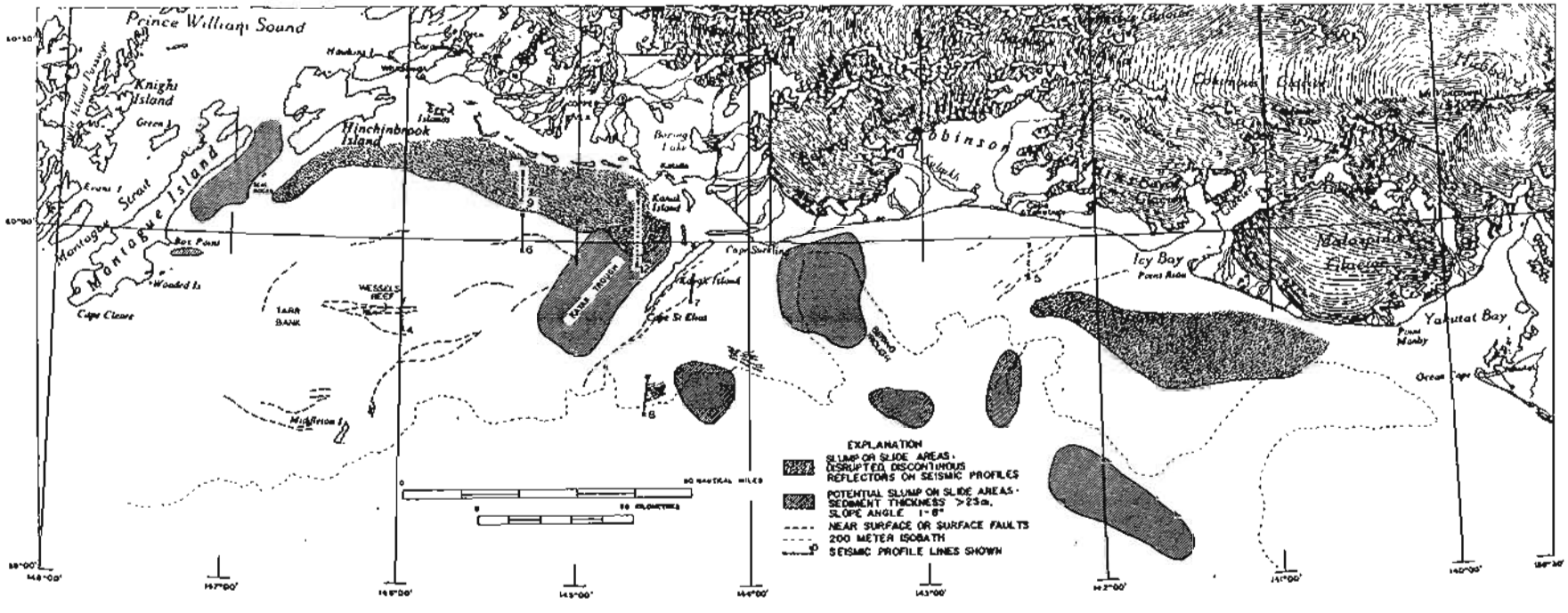

Figure 3. Submarine slides and near-surface faults in the northern Gulf of Alaska (from Carlson and Molnia, 1977).

shaking and are susceptible to earthquake-induced failure. West of Kayak Island, large volumes of sediment are also supplied to the continental shelf by the Copper River. Onshore, ground cracking and lateral spreading in glaciofluvial deposits, former beach ridges, and other unconsolidated deposits extended from Controller Bay to the Cape Yakataga area as a result of the 1964 magnitude 9.2 earthquake, centered nearly 200 mi to the east (Plafker and others, 1969).

Despite the tectonic complexity and uncertainty about earthquake probabilities and accelerations in the Cape Yakataga region, the area is generally recognized as having higher likelihood of a great earthquake in the next few decades than most other areas along active plate boundaries. All structures should be designed to meet or exceed the Uniform Building Code requirements for seismic zone 4 (highest earthquake hazard). Builders should take special precautions to prevent damage from higher accelerations and earthquake-induced ground failure in areas underlain by thick, soft sediments.

SEAFLOOR HAZARDS

Detailed shipboard seismic profiling in the 1970's revealed numerous areas of unstable sediment on the continental shelf in northern Gulf of Alaska (Carlson and Molnia, 1977)(fig. 3). Large submarine slides south of Icy Bay and west of Kayak Island were probably triggered by earthquakes. Surface or near-surface faults were also identified in several areas, including the Pamplona fracture zone south of Cape Yakataga and a zone parallel to the southeastern shore of Kayak Island. The ongoing activity of these faults is demonstrated by recent seismicity (fig. 2).

In addition to the earthquake hazards described above, man-made structures on or near active surface faults may be subject to extreme ground accelerations, catastrophic ground failure, or direct displacement due to fault offset at the ground surface. Although these seafloor faults and slides were mapped largely in the federal Outer Continental Shelf (OCS) area, similar instability and active faulting probably extends shoreward into state-owned waters. The most effective means of mitigating against possible damage to offshore structures due to seafloor instability or active faulting is by careful mapping and avoidance of these features.

TSUNAMIS

Because of the high likelihood of a local great earthquake and exposure of the northern Gulf of Alaska coast to nearly the entire Pacific Ocean, tsunami hazard in the Cape Yakataga lease sale area is high. A tsunami generated by a local earthquake could be very severe and allow very little warning. A tsunami generated by a distant source would allow public officials more time to warn inhabitants and evacuate coastal lowlands, but the physical effects could be equally severe. The primary hazards from tsunamis, or seismic sea waves, are personal injury and inundation of structures in coastal lowlands and shallow offshore areas, particularly if the tsunami occurs at high tide.

The Gulf of Alaska coast east of Prince William Sound was not seriously affected by a tsunami as a result of the 1964 great earthquake. Erratic tides, swift currents, and surges of 1-3 ft were observed at Cape Yakataga and Yakutat, but none exceeded normal extreme high tide (Plafker and others, 1969). A large earthquake involving offshore fault displacement or major tilting of the seafloor in the Gulf of Alaska could generate a large tsunami that would be very destructive to coastal facilities.

VOLCANIC ERUPTIONS

Although the Cape Yakataga lease area is more than 200 mi east of the active Cook Inlet and Aleutian volcanoes and 100 mi south of the Wrangell volcanic center, eruptions of these volcanoes can result in ash fallout in the area. A tephra plume from the August 18, 1992, eruption of Mt. Spurr, 75 mi west of Anchorage, blew east over the Chugach Mountains, followed the northern Gulf of Alaska coast over the proposed lease area, and caused significant ash fall at Yakutat (Alaska Volcano Observatory, 1993). Such ash falls can be a serious hazard to aircraft, vehicles, and machinery.

ICEBERGS

Icebergs from Bering Glacier presently pose a hazard to coastal small boat traffic in the Gulf of Alaska. Large icebergs could become a hazard to man-made structures and shipping if a narrow barrier beach holding the icebergs in Vitus Lake erodes further or is breached by storm waves or a tsunami. The Bering Glacier has begun retreating rapidly, releasing giant icebergs into Vitus Lake (R.J. Motyka, personal communication, 1993). The icebergs, some as long as 500 m (1,600 ft), are trapped in the lake by the shallow outlet at Seal River. Breaching the outlet could allow Vitus Lake to become a fjord open to the sea, releasing the large icebergs to the Pacific Ocean.

Although the Bering Glacier is presently retreating, a potentially major surge began recently that may result in a major temporary advance of the terminus (Molnia, 1993). The surge probably would not extend far enough to impact coastal facilities, but terminal retreat after the surge could be accompanied by a higher than usual rate of calving, exacerbating the potential iceberg hazard if the Seal River outlet to the Gulf of Alaska is breached.

GLACIAL-OUTBURST FLOODING

Onshore facilities near streams that drain some glaciers in or near the lease area may be at risk from glacial-outburst flooding. The Bering, Yakataga, and White River Glaciers all impound lakes with the potential of draining catastrophically as the physical character of the impounding glaciers changes (Post and Mayo, 1971). Berg Lake, which is impounded by the Stellar lobe of Bering Glacier, presents an extreme hazard on the Bering River lowland. Other streams with outburst potential are Campbell River, Seal River, White River, and all channels of Yakataga River. Outburst floods have not been documented on these streams, so their frequency and severity are unknown. These potential

flood areas should be avoided where practical. Any structures placed along these rivers should be engineered to withstand stream erosion, deposition, and severe flooding.

LANDSLIDES AND SNOW AVALANCHES

Steep terrain in the eastern portion of the Cape Yakataga lease area (east of Kaliakh River) presents potentially serious hazards due to slope instability, particularly debris slides, debris avalanches, and snow avalanches. High relief combined with heavy, wet snowfall, cold temperatures, and erratic strong winds in this area create conditions favorable for major snow-avalanche activity (Hackett and Santeford, 1980). Earthquakes can trigger large slope failures and snow avalanches, as they did in the mountains west of Icy Bay during the 1899 events (Tarr and Martin, 1912). These hazards are highly localized, however, and can be mitigated by careful evaluation and avoidance of susceptible slopes.

SEVERE STORMS

Low-pressure systems that develop in the northwestern Pacific Ocean typically track eastward into the Gulf of Alaska, causing strong southerly or southeasterly winds along the northern gulf coast. Pressure gradients are strengthened by the packing of air along the mountain barrier, resulting in even stronger inland winds. Venturi effects cause these winds to be erratic and locally intense near rough terrain. Average annual wind speed is 12 mph at Middleton Island and 8 mph at Yakutat, with maximums reaching 68 mph and 75 mph, respectively, during the winter months (Searby, 1969). Sustained gusts up to 109 mph have been recorded at Middleton Island, southwest of the proposed lease area (U.S. Dept. of Commerce, 1953). In addition to adverse loading effects of these strong winds, a secondary hazard to offshore or coastal installations is structural icing caused by water spray adhering and freezing on structural elements when the temperature is near freezing. These weather hazards are significant in the Gulf of Alaska but can be mitigated with proper engineering.

CONCLUSIONS

Development in the proposed Cape Yakataga lease area will be subject to potentially severe geologic hazards, including earthquake shaking, earthquake-induced ground failure, tsunamis, seafloor instability and faulting, volcanic ash fall, possible large icebergs, glacial-outburst flooding, slope instability, and severe storms. All structures should be built to minimum requirements of the Uniform Building Code for seismic zone 4. Additional precautions should be take to identify and accomodate special conditions such as unstable ground, active faults, flooding, and other localized hazards. Proper siting and engineering will minimize the detrimental effects of these natural processes.

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