The Alaska Earthquake
March 27, 1964

Investigations and Reconstruction

GEOLOGICAL SURVEY PROFESSIONAL PAPER 541

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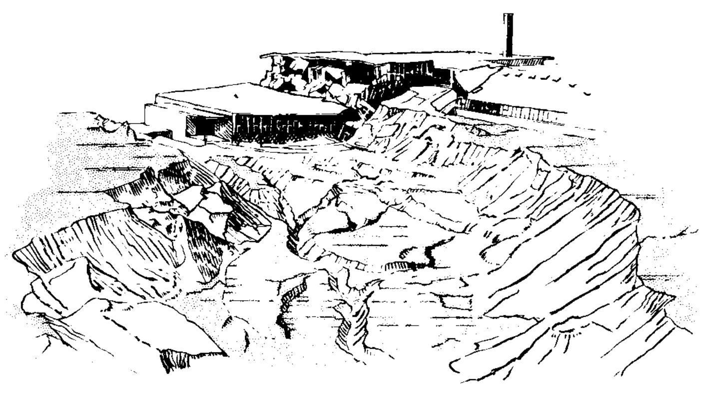
RECONSTRUCTION EFFORT



Aerial view, looking east, of part of Turnagain Heights slide, Anchorage, shortly after earthquake.

The Alaska Earthquake March 27, 1964: Field Investigations and Reconstruction Effort

By WALLACE R. HANSEN, EDWIN B. ECKEL, WILLIAM E. SCHAEM, ROBERT E. LYLE, WARREN GEORGE, AND GENIE CHANCE

An introduction to the story of a great earthquake—its geologic setting and effects, the field investigations, and the public and private reconstruction efforts

GEOLOGICAL SURVEY PROFESSIONAL PAPER 541

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

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FOREWORD

In the late afternoon of Friday, March 27, 1964, one of the most violent earthquakes of all time rocked southern Alaska. Suddenly 114 people were killed, thousands were left homeless, more than 50,000 square miles of the State was tilted to new altitudes, and the resulting property damage disrupted the State's economy.

The response to alleviate the effects of the disaster was immediate. The military forces in Alaska rushed to the aid of the civilian community, providing emergency communications, food, water, and housing. Within 24 hours the U.S. Geological Survey had a team of three geologists in Alaska to begin a reconnaissance survey, and they were but the vanguard of many who arrived to conduct scientific and engineering investigations and to advise on the reconstruction effort. The day after the earthquake the President declared Alaska to be a major disaster area and a wide range of relief and reconstruction work began, much of it sponsored by the Office of Emergency Planning. The Corps of Engineers was given responsibility for large parts of the reconstruction effort. Within a week the President by Executive Order established the Federal Reconstruction and Development Planning Commission for Alaska to coordinate the efforts of many Federal agencies; task forces and field teams moved into action.

At the time of the disaster it was difficult to envision any good proceeding from it, but the unprecedented cooperative efforts of many agencies and institutions, federal, state, and private, and many individuals have enabled the State to recover in large measure and even to move forward. This volume contains the story of the earthquake and the succeeding field investigations and reconstruction efforts in which the Geological Survey is proud to have taken part.

W. T. Pecora,
Director.

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By Wallace R. Hansen and Edwin B. Eckel

INTRODUCTION

One of the greatest geotectonic events of our time occurred in southern Alaska late in the afternoon of March 27, 1964. Beneath a leaden sky, the chill of evening was just settling over the Alaskan countryside. Light snow was falling on some communities. It was Good Friday, schools were closed, and the business day was ending. Suddenly without warning half of Alaska was rocked and jarred by the most violent earthquake to occur in North America this century.

The descriptive summary that follows is based on the work of many investigators. A large and still-growing scientific literature has accumulated since the earthquake, and this literature has been freely drawn upon here. In particular, the writers have relied upon the findings of their colleagues in the Geological Survey. Some of these findings have been published, but some are still being prepared for publication. Moreover, some field investigations are still in progress.

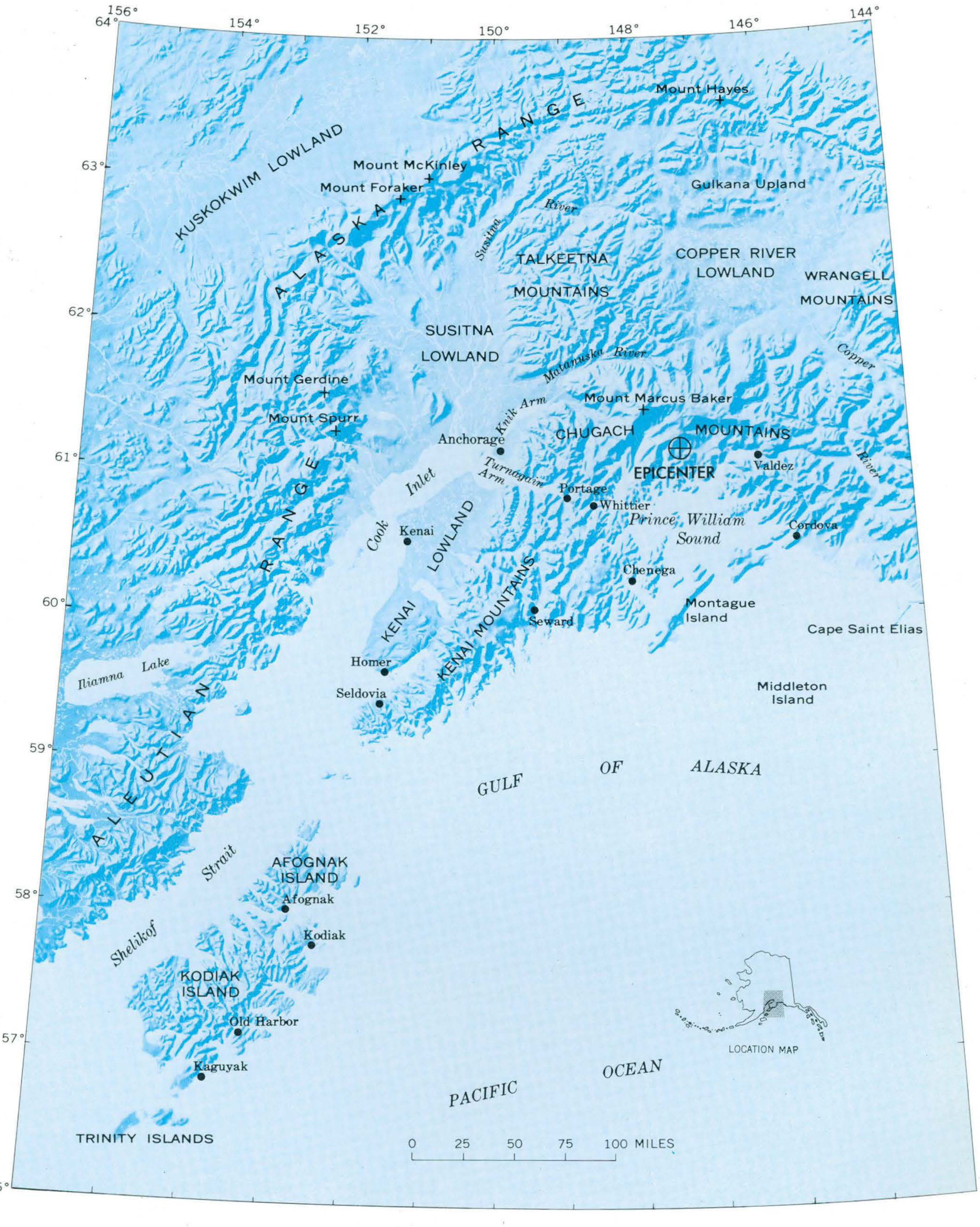
TIME AND MAGNITUDE

Seismologic events such as earthquakes are normally recorded in the scientific literature in Greenwich mean time. Greenwich time provides a worldwide standard of reference that obviates the difficulties of converting one local time to another. The Alaskan earthquake of 1964 thus began at about 5:36 p.m., Friday, March 27, 1964, Alaska standard time, but its onset is officially recorded in the seismological literature as 03:36:11.9 to 12.4, Saturday, March 28, 1964, Greenwich mean time (U.S. Coast and Geodetic Survey, 1964, p. 30).

This earthquake has become renowned for its savage destructiveness, for its long duration, and for the great breadth of its damage zone. Its magnitude has been computed by the U.S. Coast and Geodetic Survey as 8.3–8.4 on the Richter scale. Other observatories have calculated its magnitude as 8.4 (Pasadena) and 8.5–8.75 (Berkeley). These computations indicate something of the great size of the earthquake. Few earthquakes in history have been as large. In minutes, thousands of people were made homeless, 114 lives were lost, and the economy of an entire State was disrupted. Seismic sea waves swept the Pacific Ocean from the Gulf of Alaska to Antarctica; they caused extensive damage in British Columbia and California and took 12 lives in Crescent City, Calif., and 4 in Oregon. Unusually large waves, probably seiches, were recorded in the Gulf of Mexico. The entire earth vibrated like a tuning fork.

EPICENTER

The epicenter of this great earthquake has been located in a forlorn wilderness of craggy peaks, glaciers, and fjords at the head of Prince William Sound, on the south flank of the rugged Chugach Mountains, about 80 miles east-southeast of Anchorage (fig. 1, next page). Computations by the Coast and Geodetic Survey fix the epicenter at lat 61.1° N., long 147.7° W. ±15 km. The hypocenter, or point of origin, was at a depth of 20–50 km. However, it is not meant to imply that the earthquake had a point source: During the quake, energy was released from a broad area south and southwest of the epicenter underlying and adjacent to Prince William Sound and the Gulf of Alaska (U.S. Coast and Geodetic Survey, 1964, p. 31; Grantz and others, 1964, p. 3). Epicenters of most aftershocks were dispersed throughout an area of about 100,000 square miles, mainly along the continental margin of the Aleutian Trench between Prince



1.—Physiographic setting of south-central Alaska, including the area principally involved in the Alaska earthquake of 1964. The epicenter of the main shock is near the north end of Prince William Sound.

William Sound and the seaward side of Kodiak Island (fig. 9). This area coincides with a zone of tectonic uplift (Plafker, 1965).

DURATION AND EXTENT

The total effect of the earthquake was intensified by the long duration of strong ground motion. The elapsed time can only be surmised from the estimates of eyewitnesses, inasmuch as no recording instruments capable of measuring the duration of the shock were in the affected area at the time. Several such instruments have since been installed. Some witnesses timed the quake by wrist or pocket watch, and their timings ranged from 1½ to 7 minutes or more. Most such timings ranged from 3 to 4 minutes, whether measured at Anchorage, Seward, Valdez, or elsewhere. By comparison, the great San Francisco earthquake of 1906 is said to have lasted about 1 minute.

Several factors besides the human element may influence the variation from place to place of the estimated duration of the shock. Shocks are more intense in some geologic settings than in others; the character and amplitude of seismic waves passing through one medium are unlike those passing through another of different elastic properties. Ground motion is more intense and sometimes more prolonged over thick unconsolidated fills as at Anchorage or Valdez than over firm bedrock, as in the Chugach Mountains. Under certain ground conditions the intensity of ground motion may be amplified by resonance. Motions are stronger in high buildings than in low ones, so an observer in a tall building is likely to record a longer duration than an observer in a low building. And under certain conditions, shaking may be prolonged locally after direct seismic motion has stopped: for example, if landslides or avalanches, triggered by the earthquake, are in progress in the vicinity. At any rate, even the shortest estimates indicated an earthquake of unusual duration, a duration that had marked effects on the behavior of earth materials and manmade structures and on their susceptibility to damage.

The main shock was reportedly felt throughout most of Alaska, including such remote points as Cape Lisburne, Point Hope, Barrow, and Umiat on the Arctic slope of Alaska and at Unimak Island beyond the tip of the Alaska Peninsula—points 600–800 miles distant from the epicenter. The earthquake was recorded by seismographs throughout the world. It caused significant damage to ground and structures throughout a land area of about 50,000 square miles and it cracked ice on rivers and lakes throughout an area of about 100,000 square miles (Grantz and others, 1964, p. 2). Marked fluctuations of water levels in recording wells were noted at places as far distant as Georgia, Florida, and Puerto Rico (Waller and others, 1965, p. 131).

Effects of so great an earthquake hold the utmost interest of scientists and engineers. Few earthquakes have had such marked effects on the crust of the earth and its mantle of soil. Perhaps the effects of no earthquake have been better documented. Early investigation has provided a clear picture of much that happened, but years will pass before all the effects are understood. In fact, secondary effects are still in progress. In the fjords and along the shores at tectonically disturbed tidal zones, wholesale extermination of sessile organisms has been followed by a slow restoration of the biotic balance. Marine shellfish are now seen attaching themselves to the branches of drowned spruce trees (Hanna, 1964, p. 26). Rivers are regrading their channels to new base levels. Long-term effects on glaciers, shorelines, and the ground-water regimen will bear further watching.

But despite its magnitude and its impressive related tectonic effects, the earthquake ranks far below many other great natural disasters in terms of property damaged and lives lost. Less violent earthquakes have killed many more people. The reasons are many: The damage zone of the Alaskan quake has a very low population density; much of it is uninhabited. In Anchorage, the one really populous area in the damage zone, many modern buildings had been designed and constructed with the danger of earthquakes in mind.

The generative area of the earthquake was also sparsely inhabited, and the long-period seismic vibrations that reached the relatively distant inhabited areas wreaked heavy damage on tall and wide-area buildings but caused mostly light damage to small one-family dwellings of the type prevalent in Alaska (Steinbrugge, 1964, p. 71). According to White (1965, p. 91), attenuation of sinusoidal seismic waves at low frequencies should vary as the square of the frequency. Thus, destructive short-period vibrations presumably were attenuated to feeble amplitudes not far from their points of origin. Most residential buildings, moreover, were cross-braced wood-frame construction, and such buildings usually fare well in earthquakes.

Severe earthquakes during last 1,100 years, and resulting casualties

[After Hill, 1965, p. 50]

Year	Place	Deaths
856	Corinth, Greece	45,000
1038	Shansi, China	23,000
1057	Chihli, China	25,000
1170	Sicily	15,000
1268	Silicia, Asia Minor	60,000
1290	Chihli, China	100,000
1293	Kamakura, Japan	30,000
1456	Naples, Italy	60,000
1531	Lisbon, Portugal	30,000
1556	Shenshi, China	830,000
1667	Shemaka, Caucasia	80,000
1693	Catania, Italy	60,000
1693	Naples, Italy	93,000
1731	Peking, China	100,000
1737	Calcutta, India	300,000
1755	Northern Persia	40,000
1755	Lisbon, Portugal	30,000–60,000
1783	Calabria, Italy	50,000
1797	Quito, Ecuador	41,000
1811–12	New Madrid, Missouri, U.S.A.	-------------
1819	Cutch, India	1,500
1822	Aleppo, Asia Minor	22,000
1828	Echigo (Honshu) Japan	30,000
1847	Zenkoji, Japan	34,000
1868	Peru and Ecuador	25,000
1875	Venezuela and Columbia	16,000
1896	Sanriku, Japan	27,000
1897	Assam, India	1,500
1898	Japan	[1] 22,000
1906	Valparaiso, Chile	1,500
1906	San Francisco, U.S.A	500
1907	Kingston, Jamaica	1,400
1908	Messina, Italy	160,000
1915	Avezzano, Italy	30,000
1920	Kansu, China	180,000
1923	Tokyo, Japan	143,000
1930	Apennine Mountains, Italy.	1,500
1932	Kansu, China	70,000
1935	Quetta, Baluchistan	60,000
1939	Chile	30,000
1939	Erzincan, Turkey	40,000
1946	Alaska-Hawaii, U.S.A	[1] 150
1948	Fukui, Japan	5,000
1949	Ecuador	6,000
1950	Assam, India	1,500
1953	Northwestern Turkey	1,200
1954	Northern Algeria	1,600
1956	Kabul, Afghanistan	2,000
1957	Northern Iran	2,500
1957	Western Iran	1,400
1957	Outer Mongolia	1,200
1960	Southern Chile	5,700
1960	Agadir, Morocco	12,000
1962	Northwestern Iran	12,000
1963	Taiwan, Formosa	100
1963	Skopje, Yugoslavia	1,000
1964	Southern Alaska, U.S.A	[2] 114

[1] Principally from seismic sea wave.
[2] Does not include 12 deaths in California and 4 deaths in Oregon, by drowning.

The timing of the earthquake undoubtedly contributed to the low casualty rate. It was a holiday; many people who would otherwise have been at work or returning from work were at home. Schools were closed for the holiday. In coastal areas the tide was low; had tides been high, inundation and destruction by sea waves would have been much more severe. Nevertheless, sea waves caused more deaths than all other factors combined.

Hill (1965, p. 58) has compiled a chronological list of severe earthquakes dating back more than 1,100 years. Her list, reproduced at left, places the Alaskan earthquake of 1964 in a proper perspective so far as deaths are concerned.

Throughout history, earthquakes have ranked high among the causes of sudden disaster and death, but many other causes have added as much or more to the misfortunes of mankind. Some of these, such as dam failures, for example, man has brought on himself. Others he has not. The great epidemics of the past are not likely to recur, but disease, famine, floods, and landslides all still take huge tolls. Single tornadoes in the American midcontinent have taken more lives than the Alaska earthquake of 1964; so have mine explosions. In East Pakistan, thousands of lives were lost in 1965 to floods and hurricanes ("cyclones"). It would be irrelevant to enlarge here on natural and manmade disasters. Hill, however, has compiled another table that sheds pertinent further light on some of the causes of human misery in the past 600 years, other than earthquakes. Wars have been omitted.

Deaths (rounded) from some of the world's worst man-made accidents and natural disasters

[After Hill, 1965, p. 57]

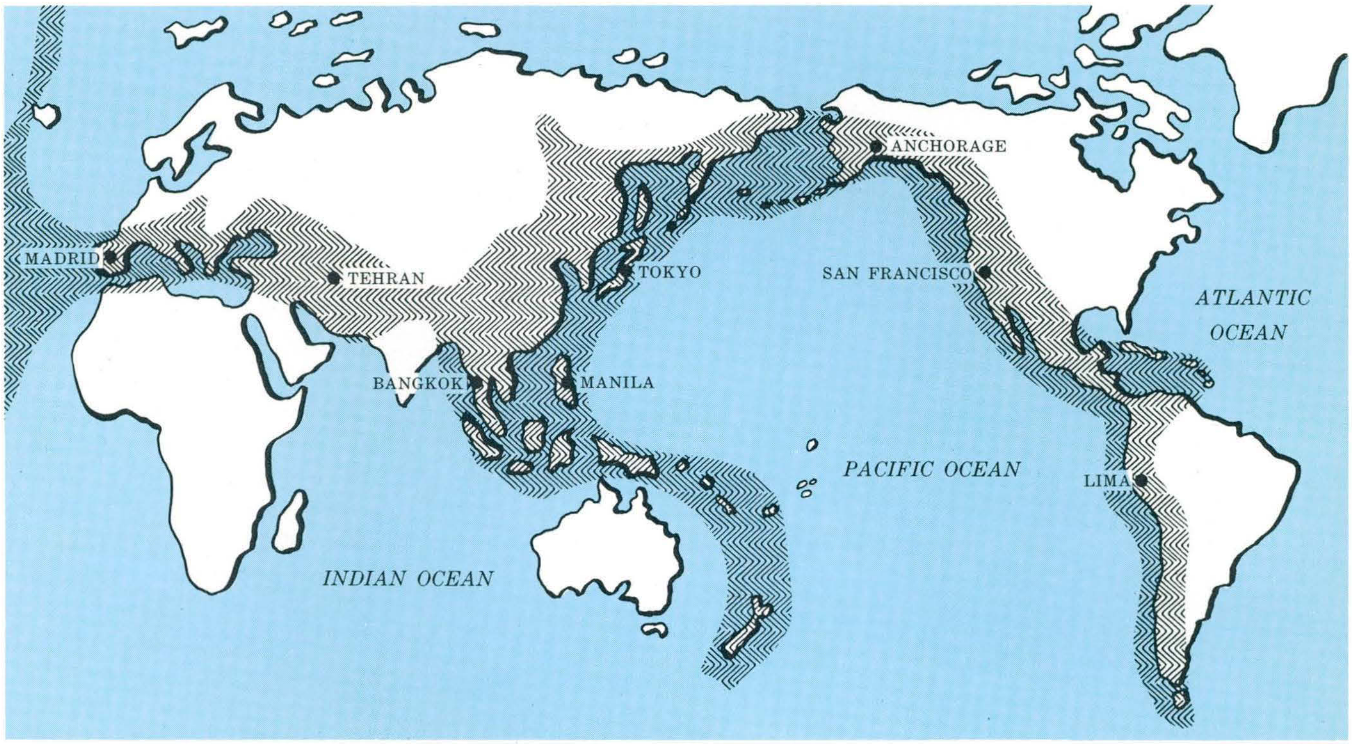
Date	*What and where*	*Deaths*
1347–51	Bubonic plague in Europe and Asia.	75,000,000
1918	Influenza throughout the world.	22,000,000
1878	Famine in China	9,500,000
1887	Flood in China	900,000
1556	Earthquake in China	830,000
1881	Typhoon in Indochina	300,000
1902	Eruption of Mount Pelee, West Indies.	40,000
1883	Eruption of Krakatoa, near Sumatra.	36,000
1941	Snow avalanche in Peru	5,000
1963	Overflow of Vaiont Dam in Italy.	2,000
1942	Mine explosion Manchuria	[1] 1,500
1912	Sinking of the *Titanic*	[2] 1,500
1871	Forest fire, Wisconsin	1,000
1925	Tornado in south-central United States.	700
1944	Train stalled in Italy	[3] 500
1928	Collapse of St. Francis Dam, California.	500
1960	Airliners collided over New York City.	[4] 134

[1] Actual count 1,549.
[2] Known dead 1,513.
[3] Passengers suffocated when the train was caught in a tunnel; actual count 521.
[4] Including casualties on the ground.

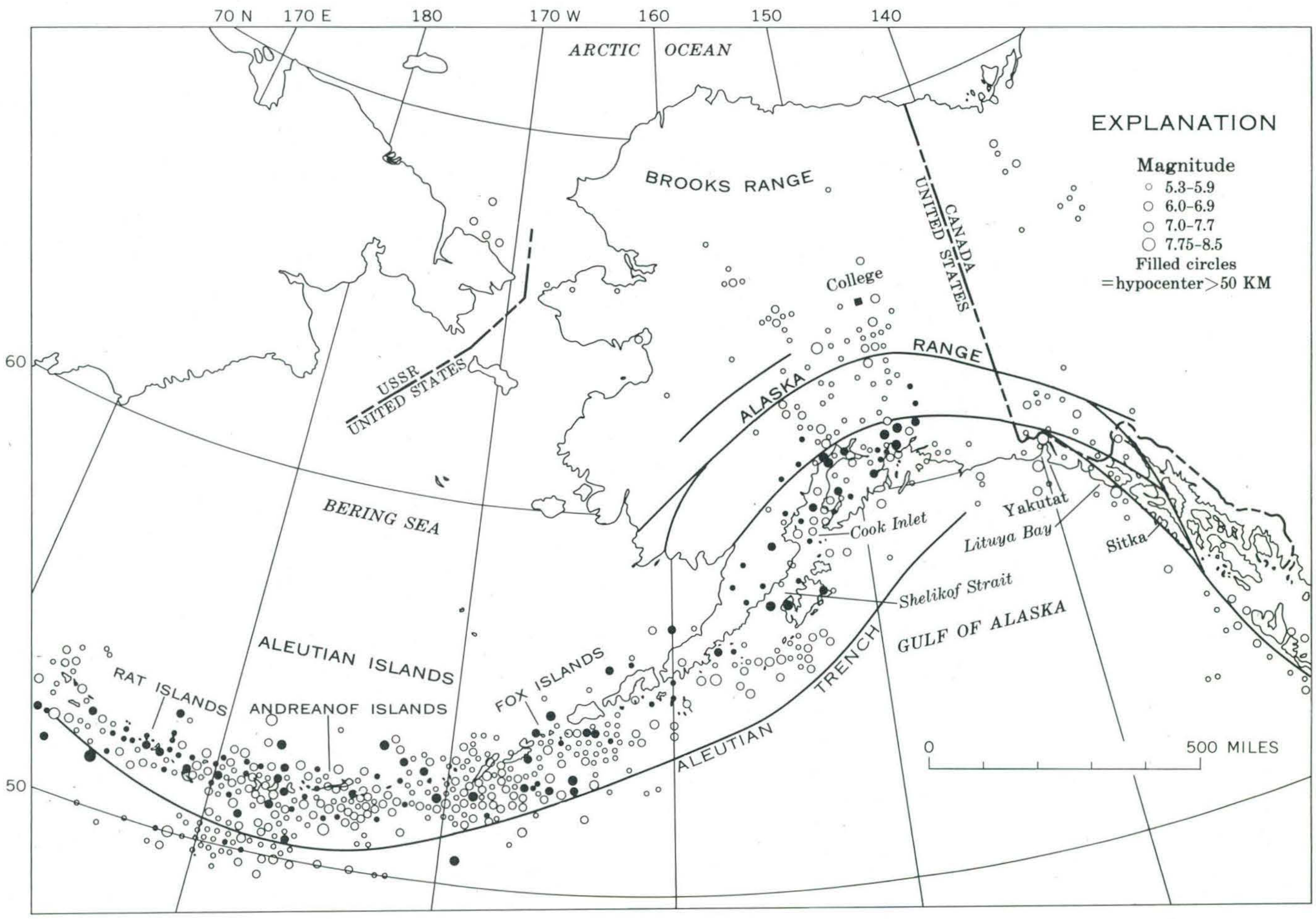
Some of the tolls listed in Hill's tables differ substantially from those reported by other authorities for the same disasters. Perhaps this difference is not surprising in view of the chaos and lack of communication that generally accompany great natural disasters and the varying casualty estimates, therefore, that appear in the subsequent literature. Hill did not cite the sources of her data, and the some of her figures are questionable; she lists 143,000 deaths in the Tokyo earthquake of 1923, for example, whereas Richter (1958, p. 561, citing Imamura) lists 99,331. For the Messina earthquake of 1908 Hill lists 160,000 deaths, whereas other authors list from 82,000 to 100,000. Nevertheless, used with caution, Hill's tables help to equate the magnitudes of past tragedies, and they provide some basis for comparing one disaster with another. Compared with the eruption of Mount Pelee in 1902, for example, or the sinking of the Titanic in 1912, the Alaska earthquake of 1964 took a small toll of lives. In view of the magnitude of the event, the relatively small size of the toll is in some ways remarkable.

AFTERSHOCKS

The long series of aftershocks that followed the main Alaska earthquake gradually diminished in frequency and intensity over a period of several months. Within 24 hours the initial shock was followed by 28 aftershocks, 10 of which exceeded Richter magnitude 6. The epicenters of these shocks were disposed in a zone 50–60 miles wide reaching from Prince William Sound southwest to the Trinity Islands area south of Kodiak (fig. 9). Fifty-five aftershocks with magnitudes greater than 4 were recorded within 48 hours after the main earthquake, including a shock of magnitude 6.7 on March 29 at 4:18 p.m. (March 30, 02:18:05.6 Gmt). Within a week 75 shocks with magnitudes greater than 4 had been recorded by the U.S. Coast and Geodetic Survey (1964, table 2). In the 45 days following the earthquake, 728 aftershocks were recorded (Jordan and others, 1965, p. 1323). According to Press and Jackson (1965) about 12,000 aftershocks with magnitudes equal to or greater than 3.5 probably occurred in the 69-day period after the main shock, and several thousand more were recorded in the next year and a half (U.S. Coast and Geodetic Survey, 1965a, p. 44).



MADRID
TEHRAN
TOKYO
ANCHORAGE
SAN FRANCISCO
ATLANTIC OCEAN
BANGKOK
MANILA
PACIFIC OCEAN
LIMA
INDIAN OCEAN



70 N
170 E
180
170 W
160
150
140
ARCTIC OCEAN
EXPLANATION
Magnitude
5.3-5.9
6.0-6.9
7.0-7.7
7.75-8.5
Filled circles
=hypocenter>50 KM
BROOKS RANGE
CANADA
UNITED STATES
College
60
USSR
UNITED STATES
ALASKA RANGE
BERING SEA
Cook Inlet
Yakutat
Lituya Bay
Sitka
Shelikof Strait
GULF OF ALASKA
ALEUTIAN ISLANDS
RAT ISLANDS
ANDREANOF ISLANDS
FOX ISLANDS
ALEUTIAN TRENCH
0
500 MILES
50

PREVIOUS ALASKAN EARTHQUAKES

Southern Alaska and the adjoining Aleutian Island chain together constitute one of the world's most active seismic zones. Extending from Fairbanks on the north to the Gulf of Alaska on the south, the Alaskan seismic zone is but a part of the vast, near-continuous seismically active belt that circumscribes the entire Pacific Ocean basin (fig. 2). Figure 3 shows the distribution of earthquake epicenters of magnitude 5.3 and greater recorded in Alaska since instrumental measurements began, through 1961. Between 1899 and May 1965, seven Alaska earthquakes have equaled or exceeded Richter magnitude 8, and more than 60 have equaled or exceeded magnitude 7 (Davis and Echols, 1962). According to Gutenberg and Richter (1949, table 7) about 7 percent of the seismic energy released annually on the globe originates in the Alaskan seismic zone.

2 (left).—Earthquake belts of the world. These belts coincide with the earth's orogenic zones and contain most of the earth's active volcanoes.

This highly active zone is circumferential to the Gulf of Alaska and parallel to the Aleutian Trench. It embraces the rugged mountainous region of southern Alaska, Kodiak and the Aleutian Islands, the continental shelf, and the continental slope of the Aleutian Trench. Most of the earthquakes originate at shallow to intermediate depths—mostly less than 50 km—between the Aleutian Trench and the Aleutian Volcanic Arc. Foci are generally deeper away from the trench toward the arc (Gutenberg and Richter, 1949, fig. 7).

3 (left).—Epicenters of major Alaskan earthquakes, 1898–1961. Reproduced from Davis and Echols (1962). More recent earthquakes include the Alaska earthquake of 1964 (magnitude 8.3–8.4) and the Rat Islands earthquake of 1965 (magnitude 7.75).

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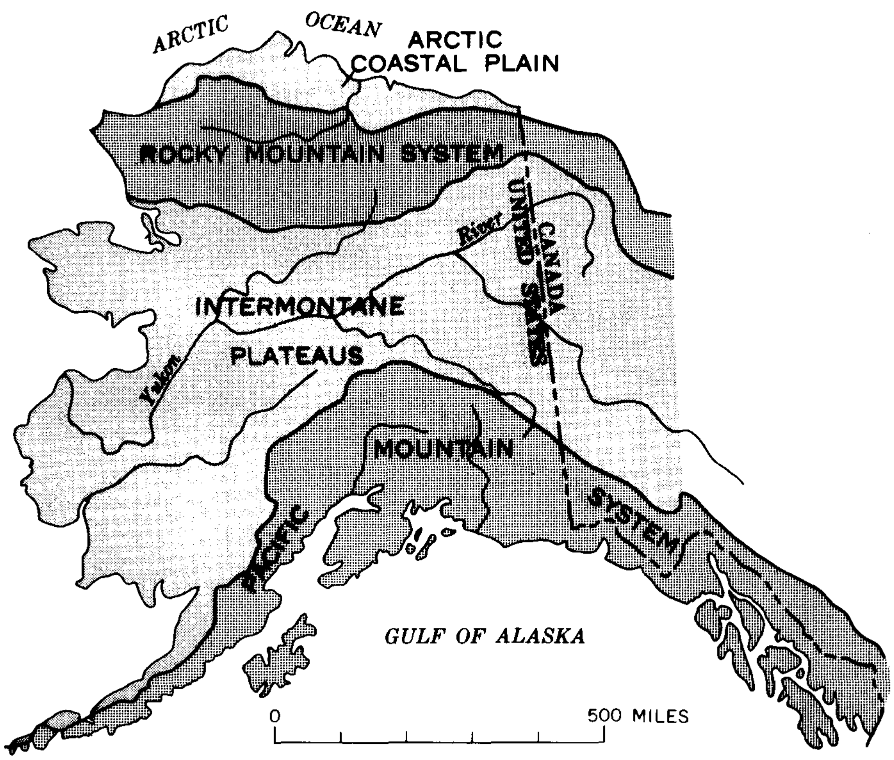
PHYSIOGRAPHIC AND GEOLOGIC SETTING OF THE EARTHQUAKE

It was noted above that the earthquake was felt throughout nearly all of Alaska, although for various reasons it was not felt in certain local areas distant from the epicenter. The level of intensity diminished appreciably northward from mountainous southern Alaska to the intermontane plateaus of the interior. Damage, moreover, was restricted generally to an arcuate area within about 150 miles of Prince William Sound (Grantz and others, 1964, fig. 1). This area coincided approximately with the area of tectonic land-level change. The cardinal geographic setting of the earthquake, therefore, was southern Alaska south of the Alaska Range, west of the "Panhandle," and east of the Alaska Peninsula.

The four major physiographic divisions of Alaska are shown in figure 4. Each division is a northwesterly extension of a major physiographic division of Canada and conterminous United States. Tectonic effects of the earthquake and significant damage were confined largely to the southernmost division of Alaska, the Pacific Mountain System.

Physiographic divisions of Alaska are definitively described and summarized by Wahrhaftig (1966). They are outlined concisely by Wahrhaftig and Gates (1964, p. 27). Those parts of Alaska principally involved in the earthquake have been described by Miller, Black, Barnes, and Wahrhaftig in a summary volume



4.—Major physiographic divisions of Alaska.

"Landscapes of Alaska," edited by Howell Williams (1958). The geotectonic setting and structural history of Alaska have been outlined by Gates and Gryc (1963) and by Gates (1964). Most of the information that follows is abstracted from the several reports noted above. The physiographic nomenclature is that of Wahrhaftig, who followed and elaborated the early nomenclature of Brooks (1906, 1911).

The Pacific Mountain System extends from the southern part of the conterminous United States north through British Columbia and Yukon into Alaska. Not surprisingly, therefore, subdivisions of the system in Alaska have geologic and physiographic counterparts in the conterminous States. In mainland Alaska the Pacific Mountain System forms a broad arc, concave toward the south. Two mountainous belts are separated by a discontinuous belt of lowlands—the Alaska-Aleutian Ranges on the north, the Coastal Trough province in the center, and the Pacific Border Ranges on the south. The Alaska-Aleutian Ranges are analogous to the Cascade-Sierra Nevada Ranges of Washington, Oregon, and California—these provinces contain eugeosynclinal suites of graywacke, argillite, and volcanic rocks that are variably metamorphosed, are intruded by batholithic plutons, and are surmounted in places by Pleistocene and Recent volcanoes. The Coastal Trough province of Alaska is analogous to the Puget Sound-Williamette Valley-Great Valley of California lowland—these provinces contain thick fills of Cretaceous and Tertiary sedimentary rocks. The Pacific Border Ranges of Alaska are analogous to the Olympic Mountains and Coast Ranges. They contain suites of graywacke, slate, and phyllite tightly folded and intruded by silicic to ultramafic plutons.

The Pacific Mountain System in Alaska is a region of dramatic physiographic contrasts—glacier-clad mountains, active volcanoes, lake-dotted lowlands, great rivers, fjords, and waterfalls framed in a setting of primeval forest on the one hand and trackless tundra on the other. Local relief in some places is astonishing: Mount McKinley at 20,269 feet, the highest summit in North America, looms above lowlands only a few hundred to 3,000 feet above sea level. In the nearby Wrangell Mountains, 12,000- to 16,000-foot peaks rise above the floor of the Copper River valley at an altitude of less than 1,000 feet. The abrupt relief of the St. Elias Range to the southeast is legendary—Mount St. Elias, visible from tidewater, is 18,008 feet high; Mount Fairweather, only 15 miles from the Gulf of Alaska, is 15,300 feet high.

ALASKA-ALEUTIAN PROVINCE

The Alaska-Aleutian province, a region of extreme seismic-tectonic activity, includes the Aleutian Island chain, the contiguous Aleutian Range on the Alaska Peninsula, and the Alaska Range (figs. 1 and 4). Together they form a great sigmoid wall concave northward on the west (the Aleutian Arc) and concave southward on the east, altogether totaling about 3,200 miles in length and averaging, on land, about 60 miles across.

ALEUTIAN RANGE

The Aleutian Range and its seaward extension, the Aleutian Islands, surmount a partly submerged ridge 20–60 miles wide extending 1,600 miles from Mount Gerdine west of Anchorage to Attu Island at the west end of the chain. About 80 Quaternary volcanoes, some deeply dissected but many of them historically active (Coats, 1950), stand 2,000 to more than 12,000 feet above sea level. Mount Gerdine, the highest peak (but not a volcano), stands 12,600 feet above sea level at the north end of the arc. The volcanoes themselves rest on a platform made up largely of deeply eroded volcanic rocks of Tertiary age, interbedded with sedimentary rocks of volcanic provenance, all cut by dikes and irregular bodies of gabbro, diorite, and granite (Powers, in Williams, 1958, p. 61). Although the Alaska earthquake of 1964 was felt throughout much of the Aleutian Range, tectonic and geomorphic effects apparently were negligible. Reportedly, there was ground breakage on the flanks of Augustine Island volcano (R. M. Waller, oral commun., 1964). Landslides were triggered along steeper slopes as far south as Mount Iliamna. There was extensive ground cracking in the alluvial flats of most rivers and some lake deltas, and ice cracked in all the larger lakes.

ALASKA RANGE

The Alaska Range forms a great semicircular barrier about 600 miles long that merges imperceptibly with the Aleutian Range on the southwest and with the Wrangell and St. Elias Ranges on the southeast. Its faulted northern slope is one of the most abrupt mountain fronts in the world (Reed, 1961, p. A3). Despite its height and formidable aspect, however, the Alaska Range is breached by several low passes and river valleys utilized for transportation routes. The crestline of the range is mostly 7,000–9,000 feet high. Isolated massifs of great jagged peaks rise much higher, each the center of extensive systems of icecaps and valley glaciers. The two icy summits of Mount McKinley (19,370 and 20,269 ft) and their sister peak, Mount Foraker (17,280 ft), dominate the range. McKinley and Foraker both are visible on clear days from Anchorage, 130 miles to the south. About 140 miles east of Mount McKinley a second group of high peaks culminates in Mount Hayes (13,700 ft).

Internally the Alaska Range consists of a great synclinorium flanked by large longitudinal faults (Brooks, 1911, p. 111). In general, Cretaceous rocks along the center of the fold are bounded by Paleozoic and Precambrian rocks in the limbs. All are intruded by bodies of granitic rock, some batholithic in size. Most of the higher peaks, including the Mount McKinley group, consist of granitic rock. The north peak of Mount McKinley is slate and graywacke (Reed, 1961, fig. 2).

The Alaska Range was mostly outside the area markedly affected by the earthquake. Strong ground motion was felt well north of the range, however, and releveling suggests possible uplift of nearly a foot (U.S. Coast and Geodetic Survey, 1965a, p. 16).

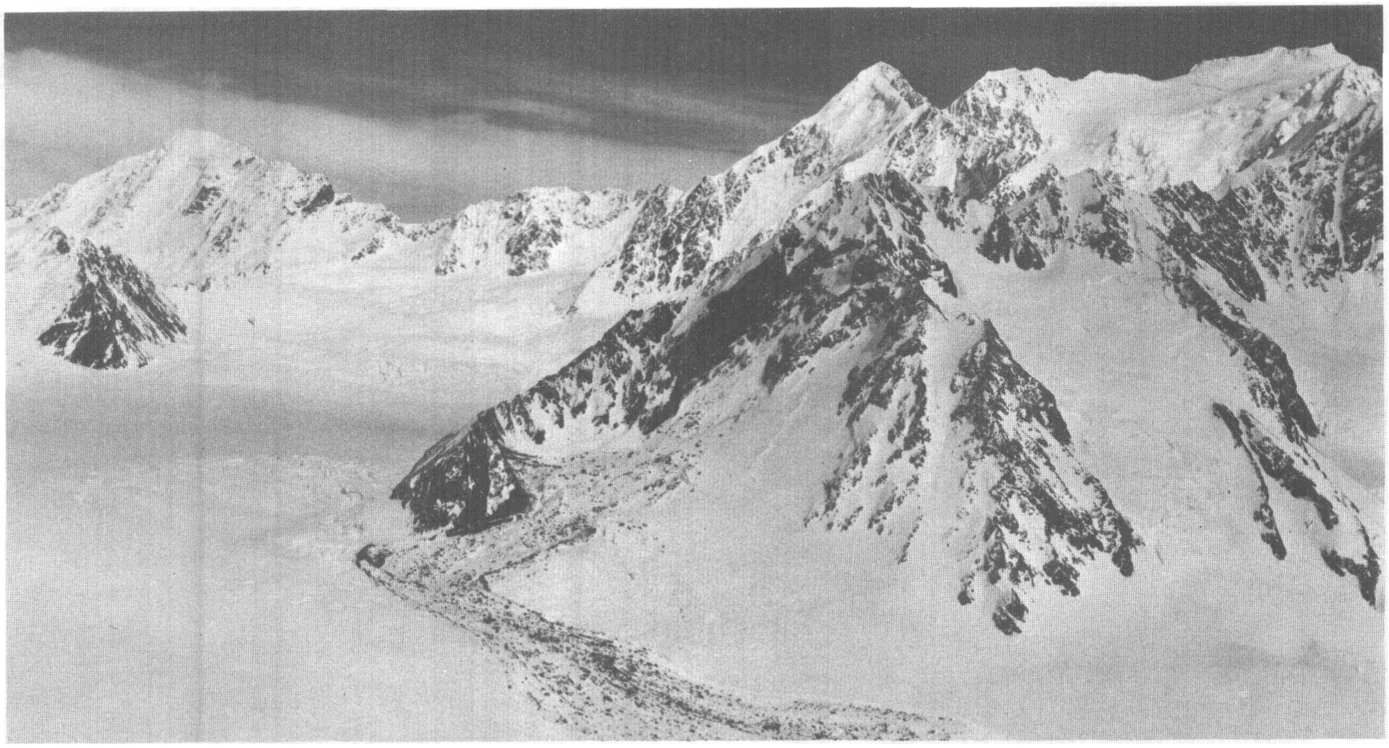
COASTAL TROUGH PROVINCE

The Coastal Trough province sustained severe damage in the March 27 earthquake. Damage to properties and manmade structures was related especially to the relatively high local population density and to the behavior of certain Pleistocene formations that underlay parts of the area. Landslides, ground cracks, subsidence, and vibration were the chief causes of damage. The province consists of two main lowland belts, the Cook Inlet-Susitna Lowland and the Copper River Lowland, separated by the Talkeetna Mountains. On the east, the Wrangell Mountains project deep into the Copper River Lowland. Wahrhaftig has divided the Coastal Trough province into several sections on the basis of geologic and physiographic distinctions.

COOK INLET-SUSITNA LOWLAND

The Cook Inlet-Susitna Lowland is a deep structural basin more than 200 miles long and about 60–70 miles across. It is bounded by the Alaska and Aleutian Ranges on the west and north and by the Kenai, Chugach, and Talkeetna Mountains on the east. Its surface is mostly less than 500 feet above sea level, and much of it is submerged beneath the Cook Inlet. It contains such well-known subdivisions as the populous Anchorage Lowland, the agricultural Matanuska Valley, and the petroleum-rich Kenai Lowland. It is underlain by thick sequences of poorly consolidated coal-bearing rocks of Tertiary age mantled with glacial, glaciofluvial, and glaciomarine deposits, and flanked by hard-rock mountains on the east and west. Parts of the area

5.—A rock avalanche on the Surprise Glacier near Harriman Fjord, about 50 miles east of Anchorage. Photograph taken May 29, 1964.



6.—Debris flow (avalanche) and Upper Miles Glacier, in the Chugach Mountains near mouth of the Copper River. View east from 6,300 feet, April 19, 1964. The flow is approximately 2 kilometers long.

have been described by Capps (1916) and by Martin, Johnson, and Grant (1915). The Quaternary geology has been described in detail by Karlstrom (1964).

TALKEETNA MOUNTAINS

The little known Talkeetna Mountains are a dissected highland of diverse topography and geology, about 100 miles long north to south and 60–70 miles across west to east. Extremely rugged glacier-covered peaks and ridges in the central part, standing 6,000–8,000 feet above sea level, are carved from a large Jurassic batholith that has intruded older Jurassic volcanics and pre-Jurassic rocks. On the south a large fault (Lake Clark-Castle Mountain fault) separates the hard rocks of the mountains from the softer Cretaceous and Tertiary rocks of the Matanuska Valley. The southeast part of the Talkeetna Mountains consists of soft Jurassic and Cretaceous sandstones and shales overlain by thick Tertiary basalt flows (Brooks, 1911, pl. 9; Capps, 1940, pl. 2; Grantz, 1961). During the earthquake the southern part of the range subsided as much as 2 feet (U.S. Coast Guard and Geodetic Survey, 1965a, p. 16). Avalanches and landslides were triggered in the upper Matanuska Valley and doubtless occurred in the mountains also.

COPPER RIVER LOWLAND

The Copper River Lowland as here described includes all the area between the Alaska Range on the north, the Wrangell Mountains on the east, the Chugach Mountains on the south, and the Talkeetna Mountains on the west. As thus limited, it includes marginal areas called the Gulkana Upland in the northwest part of the area and the Lake Louise Plateau in the west (Wahrhaftig, 1966). Thus delineated, it is drained not only by the Copper River itself, but also by the Susitna, which arises in the Alaska Range, flows south into the lowland, then west across the Talkeetna Mountains, and by the Delta River, which heads in the Gulkana upland and flows north across the Alaska Range to the Tanana River. A low pass at the south end of the Talkeetna Mountains connects the Copper River Lowland with the Cook Inlet area by way of the Matanuska Valley. The surface of the lowland ranges in altitude from less than 1,000 feet above sea level where the Copper River enters the Chugach Mountains at Wood Canyon (alt 581 ft at Chitina) to more than 3,500 feet in the Gulkana Upland. Most of the area is underlain by perennially frozen ground, and the surface consequently is dotted with shallow lakes. Several large lakes are of glacial origin. Bedrock in the northern and western parts of the lowland consists chiefly of greenstone and other metavolcanic rocks of late Paleozoic and Triassic age. In the southern part of the lowland, bedrock consists chiefly of sedimentary rock of Mesozoic age. Most of the lowland, however, is mantled with unconsolidated deposits of Pleistocene age. On the east is the volcanic pile of the Wrangell Mountains.

The earthquake caused avalanches, landslides, and ground breakage in the Copper River Lowland. Several buildings were shifted on their foundations. Throughout the lowland, ice was cracked on lakes and rivers.

WRANGELL MOUNTAINS

The Wrangell Mountains, austere and beautiful, dominate the landscape of the Copper River region. They are a cluster of great ice-capped volcanoes crowded into an area about 100 miles long, northwest to southeast, and 60 miles across, northeast to southwest. To the southeast they merge with the St. Elias Range. Several volcanoes exceed 14,000 feet in altitude, including Mount Blackburn (16,523 ft) the highest in the range, and Mount Sanford (16,208 ft). Historically active Mount Wrangell (14,163 ft) still emits steam and vapors. At least a dozen summits exceed 12,000 feet. The volcanoes rest on a base of deformed Paleozoic and Mesozoic sedimentary and volcanic rocks. During the earthquake the apparent subsidence was less than a

7.—Clastic dikes composed of sand and silt were intruded along fissures into near-surface sediments and overlying snow and ice in the delta of Snow River, Kenai Peninsula. The dikes were left in relief when the snow and ice melted.

foot at the southwest front of the range. Extensive ground cracks formed in the alluvial flats of the larger rivers in the McCarthy area.

PACIFIC BORDER RANGES PROVINCE

The Pacific Border Ranges province contains the epicenter of the March 27 earthquake and most of the land areas of major tectonic deformation. It consists of several mountain ranges, most of which merge laterally with one another. Including some of the world's most rugged mountains, the province forms the mountainous and adjacent coastal lowland border of the Gulf of Alaska, an arcuate belt about 1,000 miles long and 20–110 miles across stretching from Kodiak Island on the southwest to Sitka Island on the southeast. Included as subdivisions are the Kodiak Mountains, Kenai-Chugach Mountains, Gulf of Alaska coastal section, St. Elias Mountains, Fairweather Range, and the mountains of the western part of the Alexander Archipelago (Wahrhaftig and Gates, 1964, p. 27). Only the Kodiak Mountains, Kenai-Chugach Mountains, and the Gulf of Alaska coastal section, described below, were significantly involved in the earthquake, although a large clay-silt mudflow was triggered on Admiralty Island in the Alexander Archipelago near Juneau, 480 miles from the epicenter (oral commun., Keith Hart, Alaska Department of Highways, to Robert D. Miller, U.S. Geological Survey, 1965).

KODIAK MOUNTAINS

The Kodiak Mountains (Wahrhaftig, 1966) are a structural-topographic continuation of the Kenai-Chugach Mountains. They form a rugged northeast-trending divide 2,000–4,000 feet high along the crestline of Kodiak Island and slope abruptly to the southeast and more gradually to the northwest to an irregular coastline modified by many fjords and islands. The mountains consists mostly of argillite and graywacke of Mesozoic age intruded along the main divide by an elongate granitic batholith of Tertiary age (Dutro and Payne, 1957). Eocene sedimentary rocks along the southeast border of Kodiak Island and in the Trinity Islands to the south are downfaulted against the older rocks. Most of Kodiak Island subsided during the earthquake, but a narrow zone along the southeast coast had no displacement, and the outermost headlands on the southeast coast were elevated. Other effects of the earthquake included landslides and avalanches on the steeper slopes, local subsidence and cracking of many unconsolidated deposits, and the cracking of lake ice (Reuben Kachadoorian and George Plafker, written commun., 1966).

KENAI-CHUGACH MOUNTAINS

The Kenai-Chugach Mountains form the landward closure of Prince William Sound. The greater part of this region subsided during the earthquake, although part of it was elevated. Landslides, avalanches, and ground cracks were abundant (Hackman, 1965, p. 608; Ragle and others, 1965; Post, 1965; Tuthill and Laird, 1966). Wahrhaftig's description (1966, p. 40) of the general topography and geology is quoted as follows:

> The Kenai-Chugach Mountains form a rugged barrier along the north coast of the Gulf of Alaska. High segments of the mountains are dominated by extremely rugged east-trending ridges 7,000 to 13,000 feet high. Low segments consist of discrete massive mountains 5 to 10 miles on a side and 3,000 to 6,000 feet high, separated by a reticulate system of through valleys and passes ½ to 1 mile wide that are eroded along joints and cleavage. The entire range has been heavily glaciated and the topography is characterized by horns, aretes, cirques, U-shaped valleys and passes, rock-basin lakes, and grooved and mammilated topography. The south coast is deeply indented by fiords and sounds, and ridges extend southward as chains of islands. The north front is an abrupt mountain wall.
>
> The Kenai-Chugach Mountains are composed chiefly of dark-gray argillite and graywacke of Mesozoic age [some of these rocks are now known to be of Tertiary age (George Plafker, written commun., 1965)], mildly metamorphosed and with a pronounced vertical cleavage that strikes parallel to the trend of the range. In the Prince William Sound area large bodies of greenstone are associated with the argillite and graywacke. A belt of Mesozoic and Paleozoic schist, greenstone, chert, and limestone lies along the north edge of the Kenai and Chugach Mountains. All these rocks are cut by granitoid masses.
>
> All the higher parts of the range are buried in great icefields, from which valley and piedmont glaciers radiate. Many glaciers on the south side of the mountains are tidal.

Although the earthquake caused many snow and rock- slides that avalanched onto glaciers in the Kenai-Chugach Mountains, there were relatively few slides that seemed to be large enough to materially alter the regimens of the glaciers in the manner proposed by Tarr and Martin (1912; Ragle and others, 1965, p. 31, 42). Tarr and Martin attributed rapid advances of glaciers in southeastern Alaska in the first decade of the 20th century to avalanching caused by the great Yakutat earthquakes of 1899, a view disputed recently by Post (1965). The long-term effect of the snow added to the surfaces of the glaciers in the Chugach Mountains, however, will require years to evaluate.

8.—The Hanning Bay fault scarp, Montague Island, looking northeast. Vertical displacement in the foreground, in rock, is about 12 feet; the maximum measured displacement of 15 feet is at the beach ridge near trees in background.

Rock avalanches were more numerous in the Chugach Mountains than in the Kenai Mountains (Ragle and others, 1965, p. 31). A notably large one fell onto the Sherman glacier near Cordova (Post, 1965; George Plafker, oral commun., 1965).

From a study of aerial photographs, Hackman (1965, p. 609) identified 1,958 avalanches and snow slides, 58 combined snow and rock slides, and 20 rock slides in the mountainous areas adjoining Prince William Sound after the March 27 earthquake. It is not known what the normal incidence of spring avalanching is in the Chugach Mountains adjacent to Prince William Sound, or how many of the avalanches were caused by the earthquake, but Hackman suspected that most of them were caused by the earthquake.

GULF OF ALASKA COASTAL SECTION

Wahrhaftig (1966) describes the Gulf of Alaska coastal section as an area of diverse topography carved in Tertiary rocks. It extends about 340 miles along the coast in a strip 2–40 miles wide from the vicinity of Cordova on the west to Icy Point on the east, between the Gulf of Alaska to the south and the high Chugach and St. Elias Mountains to the north. It is basically a coastal plain marked by beach and dune ridges, belts of morainal topography, outwash plains, marine terraces, and enormous piedmont glaciers. It is deeply indented locally by large fjords and by the valley of the Copper River but, for the most part, its coastline is less irregular than that of the rest of southern Alaska. The largest of the piedmont glaciers, the Malaspina, covers an area the size of Rhode Island. The Bering Glacier is almost as large.

Large thrust faults separate the Tertiary rocks of the coast from the older rocks in the mountains. During the earthquake the western part of the section was tectonically elevated; the eastern part was little affected. Uplift died out between the Bering Glacier and Yakataga (Plafker, 1965, p. 1679). Other great earthquakes have centered in this area in the past, including the great Yakutat earthquake of 1899 (Richter magnitude 8.6) and the Lituya Bay earthquake of 1958 (magnitude 8), the latter remembered for the giant waves generated by avalanching of rock into Lituya Bay (Miller, 1960). As a result of the March 27, 1964, earthquake, slides and slumps occurred as far east as Yakataga; unconsolidated deposits cracked and slumped eastward to Yakutat Bay and lake ice cracked as far east as Lituya Bay.

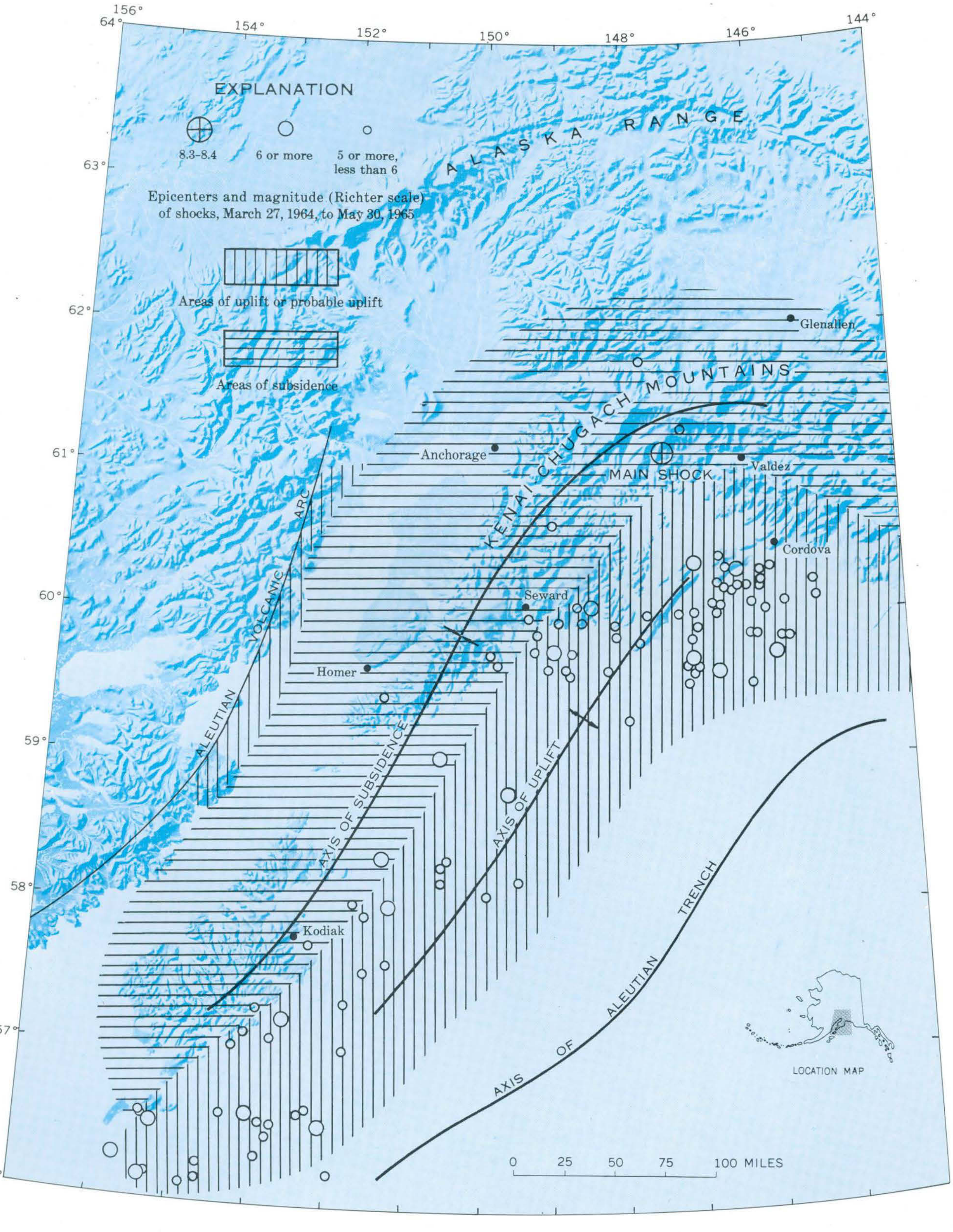
ST. ELIAS MOUNTAINS AND FAIRWEATHER RANGE

The colossal St. Elias Mountains and Fairweather Range are largely peripheral to the region affected markedly by the earthquake but they have had a long history of seismic activity. Iceclad and drained by glaciers, they are the highest coastal mountains in the world. Among them also are some of the highest and most impressive peaks in North America, including Mount Logan (19,850 ft) entirely in Canada, Mount St. Elias (18,008 ft), Mount Vancouver (15,700 ft), Mount Hubbard (14,950 ft), and Mount Fairweather (15,300 ft), all along the international boundary and all visible from tidewater (Bostock, 1948, p. 92). Many other peaks range in height from 12,000 to 17,000 feet. Little is known of the geology. The Alaska part of the mountains is topographically continuous with the Chugach Mountains and is geologically similar. The St. Elias Mountains also merge with the Wrangell Mountains and also contain volcanic rocks. Reconnaissance in the Fairweather-Yakutat Bay area indicates bedded sedimentary and volcanic rocks of Paleozoic and Mesozoic age intensely folded and faulted. Many of the higher peaks are carved from granitic intrusive rocks (Miller, in Williams, 1958, p. 21).

TECTONIC EFFECTS

Tectonic effects of the Alaska earthquake of 1964 have been studied and described in detail by Plafker (1965). Crustal deformation associated with the earthquake was more extensive than any known deformation related to any known previous earthquake. From the Wrangell Mountains at the northeast to the Trinity Islands south of Kodiak, the zone of land-level changes extended southwest through the epicenter a distance of more than 500 miles (Plafker, 1965, fig. 5). From northwest to southeast it extended at least from the west shore of Cook Inlet to Middleton Island in the Gulf of Alaska, a distance of about 200 miles. Crustal warping may have extended inland as far as the Alaska Range and seaward out onto the continental slope of the Aleutian Trench (U.S. Coast and Geodetic Survey, 1965a, p. 15–16). East along the Alaska coast, deformation died out somewhere between the Bering Glacier and Yakataga (Grantz and others, 1964, p. 5). An area of at least 70,000 square miles and possibly 110,000 square miles or more was tectonically elevated or depressed during the earthquake (fig. 9).

Areas of uplift and subsidence are separated by a zero line or axis of tectonic tilting that trends southwestward from the vicinity



9.—Map of south-central Alaska, showing epicenter of March 27, 1964, earthquake, major aftershocks, and areas of tectonic land-level changes. Most aftershocks centered in the area of uplift along the continental margin of the Aleutian Trench between the Trinity Islands and the epicenter of the main shock. Data chiefly from reports by the U.S. Coast and Geodetic Survey (1964, 1965a), Grantz, Plafker, and Kachadoorian (1964), and Plafker (1965).


of the epicenter to the seaward side of Kodiak and the Trinity Islands (fig. 9). East from the epicenter the zero line passes approximately through Port Valdez fjord, trends along Heiden Canyon east of Valdez (H. W. Coulter, written commun., 1965), and crosses the Copper River Valley about 50 miles above the mouth (Plafker, 1965, fig. 5; Coulter and Migliaccio, 1966). Areas north and northwest of the hingeline subsided; areas south and southeast arose. A line of maximum subsidence about coincided with the mountain axes of the Kenai Peninsula and Kodiak Island, where downwarping exceeded 6 feet; uplift over wide areas of Prince William Sound exceeded 6 feet and, in an area of surface rupture on Montague Island, locally exceeded 30 feet (Plafker, 1965). This uplift deleteriously affected shipping lanes and harbor facilities in parts of Prince William Sound; docks at Cordova and elsewhere were left high and dry during times of low tide.

10 (left).—Reddish-brown spruce trees in foreground were drowned when gravel spit in Resurrection Bay area subsided about 3 feet.

Southwest from Montague Island, where bottom soundings show seaward continuations of new fault scraps along old fault lines on the island, the sea bottom was uplifted locally more than 50 feet (Malloy, 1964, p. 1048). Inferred large-scale uplift of the continental shelf and slope southeast of Montague Island probably generated the seismic sea waves that spread across the Pacific Ocean (Van Dorn, 1964, p. 186; Plafker, 1965, p. 1680). Much, if not all, of the uplift probably accompanied the few minutes of most violent ground shaking during the earthquake (Plafker, 1965, p. 1680).

11 (left).—Uplifted sea floor at Cape Clear, Montague Island, in the area of greatest recorded uplift on land (33 feet). The white coating, about a quarter of a mile wide, consists of the remains of calcareous marine organisms that were killed by dessication when their sea-floor home was lifted above high tide.

Tectonic changes, both up and down, caused extensive damage to the biota in such areas as coastal forests, migratory-bird nesting grounds, salmon spawning waters, and shellfish habitats. These effects are described further in subsequent paragraphs. Land-level changes at Alaskan coastal communities are shown in table 1 (p. 19).

EFFECTS ON COMMUNITIES

Earthquake damage to the cities, towns, and villages of southern Alaska was caused by direct seismic vibration, ground breakage, mud or sand emission from cracks, ground lurching, subaerial and submarine landslides, fires, sea waves, and land-level changes (Grantz and others, 1964). Not all these factors caused damage in every community. Some communities were devastated by only one; the village of Chenega, for example, was destroyed by a sea wave. Overall, landslides probably caused the most damage to manmade structures and property, but sea waves took the most lives.

Effects of one factor cannot always be separated from effects of another. Thus, at Seward (Grantz and others, 1964, p. 15; Lemke, 1966) the waterfront was racked by vibration, slides, sea waves, fires, subsidence, and ground cracks. All these factors contributed significantly to the havoc, and all in combination wiped out the economic base of the town. Comparable damage at Valdez, plus the threat of recurrent damage in the future, forced relocation of the village and abandonment of the present townsite (Coulter and Migliaccio, 1966).

Most of the small coastal villages in the earthquake zone were damaged chiefly by sea waves, subsidence, or both (Kachadoorian, 1965). Among the larger towns, only Cordova was significantly damaged by uplift, but the native village of Tatitlek and several canneries and residences at Sawmill Bay on Evans Island were also adversely affected by uplift.

Direct vibratory damage was significant chiefly in Anchorage and Whittier, although minor vibratory damage was widespread through the area of intense shaking. At Anchorage several buildings were destroyed by vibration, and nearly all multistory buildings were damaged (Berg and Stratta, 1964; McMinn, 1964; National Board of Fire Underwriters and Pacific Fire Rating Bureau, 1964; Hansen, 1965). At Seward, Valdez, and Whittier, ground vibrations ruptured oil storage tanks, and the spilled petroleum quickly caught fire.

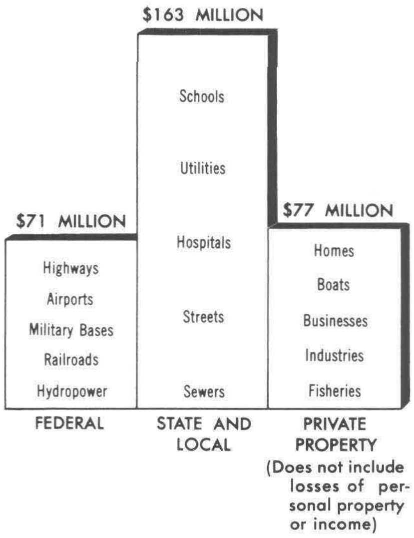
Ground breakage caused extensive damage in Anchorage, Seward, Whittier, and Valdez, not only to buildings but also to buried utilities such as water, sewer, gas, electric, and telephone lines. Cracked ground resulted from the passage of sinusoidal seismic waves through the soil, from lurching, from lateral spreading of soils under gravity, especially near the heads of landslides, and from differential settlement of alluvial and artificial fills.

Mud and sand were pumped from ground cracks throughout the damage zone where water tables were shallow in saturated granular soil. At Valdez, and to a lesser extent at Seward (Forest Acres), large volumes of sediment were ejected from cracks into cellars and crawl spaces (Coulter and Migliaccio, 1966; R. W. Lemke, oral commun., 1965).

Submarine and subaerial landslides triggered by the earthquake caused spectacular damage in Anchorage, Seward, Valdez, Whittier, and Homer (Engineering Geology Evaluation Group, 1964; Grantz and others, 1964; Shannon and Wilson, Inc., 1964; Hansen, 1965; Lemke, 1966; Coulter and Migliaccio, 1966; Kachadoorian, 1965; Waller, 1966). Four large slides in built-up parts of Anchorage were caused by failures along bluff lines in soft, sensitive silty clay whose water content at critical depths exceeded its liquid limit. Failure at Anchorage was mostly subaerial, although the large Turnagain Heights slide failed partly below sea level and slipped part way down the mudflat into Knik Arm of Cook Inlet. At Valdez and Seward, violent shaking spontaneously liquified granular deltaic materials; slumping which initiated well below sea level carried away the waterfronts of both towns. The seaward slopes of the deltas, moreover, were left less stable after the earthquake than they were before.

Estimates by the Federal Reconstruction and Development Planning Commission for Alaska, as of August 12, 1964, indicated that total property damage to Alaska by the earthquake exceeded $311 million (fig. 13). This figure does not include loss of personal property or in-

12 (above).—Transverse fissure in Valdez at corner of McKinley St. and Keystone Ave. Note damage to cinderblock building where the main fissure, foreground, intersects it. Similar ground fractures, with or without sand and mud spouts caused much damage to streets, utilities, and buildings in many parts of the earthquake-affected area.



13 (left).—Earthquake damages in Alaska. From estimates by the Office of Emergency Planning (1964a).

come. Not only was the economic base of entire communities destroyed, but the resultant loss of income severely crippled the economy of the whole State and deprived Alaska of a major share of its tax base at the time when funds were most needed to aid in restoration.

As also pointed out by the Federal Reconstruction and Development Planning Commission, the disaster struck at the heart of the State's economy, inasmuch as nearly half the people of the State reside in the stricken area. About 100,000 of the State's estimated 265,000 people live in the greater Anchorage area alone. Anchorage, because of its size, bore the brunt of property damage, but the per capita damage and the actual death toll were much greater in many smaller towns. Although the combined population of Chenega, Kodiak, Seward, Valdez, and Whittier is less than 9,000 people, each of these communities lost more lives than Anchorage.

Despite the extensive damage at Anchorage to residence and business properties, utilities, and transportation, a large segment of the economy was intact, and recovery was relatively rapid. But at many small towns and villages, where virtually entire populations were dependent on one or two industrial enterprises—fisheries, for example—the effects of the earthquake were staggering. Whole fishing fleets, harbor facilities, and canneries were destroyed.

The native villages of Chenega, Kaguyak, Old Harbor, and Afognak, all remote waterfront fishing villages, were nearly or completely destroyed by waves, especially Chenega, population 80 before the earthquake. There, 23 lives were lost, and only the schoolhouse remained of the village's buildings. Six homes were left standing at Old Harbor, where there had been about 35. There were nine homes in Kaguyak and a Russian Orthodox Church; all were carried away or destroyed. At Afognak, four homes, the community hall, and the grocery store were carried away by waves; several other homes were moved partly off their foundations (Alaska Depart. Health and Welfare, 1964b); and subsidence made the townsite uninhabitable. The sites of Chenega, Kaguyak, and Afognak have been abandoned in favor of new townsites.

Earthquake damages to communities of Alaska are summarized in table 1.

TABLE 1.—*Summary of earthquake damages to Alaskan communities*

Place	Population [1] 1960	Deaths (total, 114)	Principal causes of damage								Townsite acreage (estimated)			Premises (estimated)		Type of structures damaged							
			Subsidence	Uplift	Landslides: Land	Landslides: Submarine	Ground cracks	Vibration	Waves	Fire	Total	Damaged	Percent	Total	Damaged	Homes	Business and public	Military	Harbor	Water supply	Other utilities	Highways	Airports
Afognak	190	0	X						X		20	2	10	38	23	X	X		X	X	0	X	
Anchorage	[2] 44,237	9			X		X	X			4,500	700	14	15,000	750	X	X	X	X	X	X	X	X
Cape St. Elias	4	1			X				X														
Chenega	80	23		X					X		20	20	100	20	20	X							
Chugiak	51	0												0	0					X			
Cordova	1,128	0		X			X		X		200	20	10	400	40	X	X		X	X	X		
Cordova FAA airport	40	0					X	X								X	X			X	X	X	X
Eagle River	130	0									20	1	5	0	0					X			
Ellemar	1	0		X													X						
Girdwood	63	0	X				X									X	X						
Homer	1,247	0	X			X		X									X		X			X	
Hope	44	0	X								10	3	30		10	X				X			
Kadiak Fisheries Cannery	2		X					X	X					15	15	X	X		X	X	X		
Kaguyak	36	3							X		15			15	15	X	X						
Kodiak	[3] 2,628	15	X						X		285	31	11	1,100	130	X	X	X	X	X	X	X	X
McCord	8							X	X							X	X						
Old Harbor	193	0							X		30			38	35	X	X		X	X	0		
Ouzinkie	214	0	X						X		50		10	38	6	X	X		X				
Point Nowell	1	1							X					1	1	X							
Point Whitshed		1		X					X						10	X							
Portage	71	0	X				X						20			X	X			0		X	
Port Ashton		1							X						0								
Port Nellie Juan	3	3							X						0			X	X				
Seldovia	460	0	X													X	X		X				X
Seward	1,891	13	X			X	X		X	X	400	400	100	700	200	X	X	X	X	X	X	X	X
Tatitlek				X															X				
Valdez	1,000	31	X			X	X		X	X	300	300	100	200	40	X	X		X	X	X	X	X
Whittier	70	13	X			X		X	X	X	30	10	35	10	8	X	X	X	X	X	X	X	X

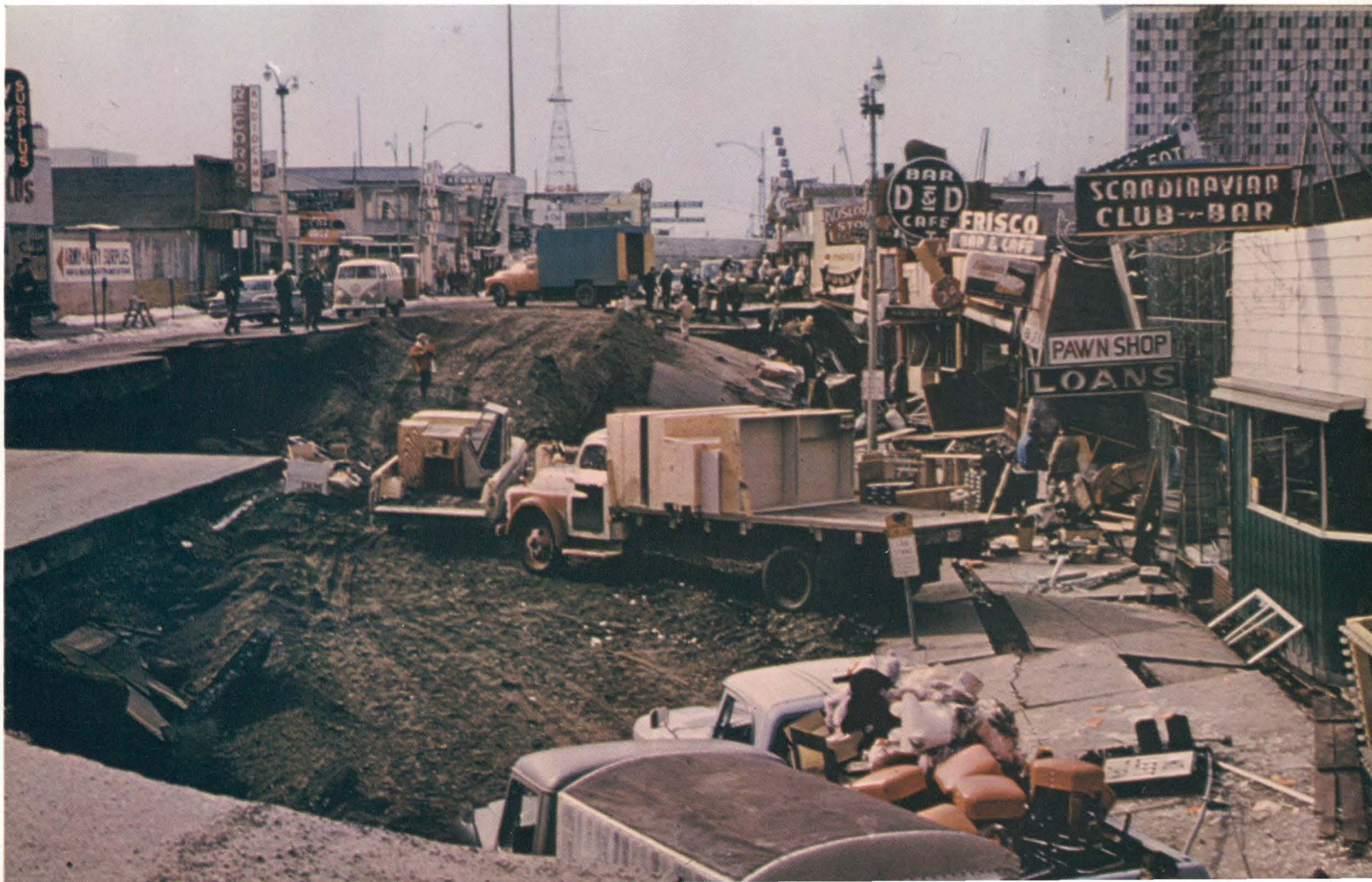
[1] Alaska Depart. Health and Welfare (1964).
[2] 82,833 including military personnel.
[3] 4,788 including personnel at Kodiak Naval Station.

14 (left).—Remains of the Native village of Chenega, Prince William Sound, after devastation by waves.

16 (upper right).—Hinchinbrook Coast Guard dock, raised above all but the highest tides by regional uplift in Prince William Sound. Docks at Cordova and elsewhere were also made useless by the same uplift.

15 (below).—Damage to railroad yard and petroleum tank farm at Seward, looking northwest. The extensive damage at Seward, as at Whittier and some other towns, was caused by a combination of submarine slides, waves and fire.

17 (below).—Scrap at the subsidence trough or graben of the Fourth Avenue slide, Anchorage. The graben dropped 11 feet in response to 14 feet of horizontal movement of the slide block.



18.—The 1200 L Street apartment building in Anchorage that was severely damaged by shaking during the earthquake. Note X-shaped fractures caused by vertical shear.

19.—The Alaska Sales and Service building in Anchorage, which was under construction, partially collapsed during the earthquake. The building was constructed of prestressed concrete roof T's which rested on precast reinforced concrete T-columns; it had precast reinforced concrete walls.

20.—Store building in Anchorage wrecked by seismic shaking.

21.—Toe of Turnagain Heights landslide exposed at low tide as viewed from new bluff line, looking northeast toward Anchorage waterfront. Trees that formerly stood 70 feet above sea level were swept downward and outward into Knik Arm by mass movement of landslide.

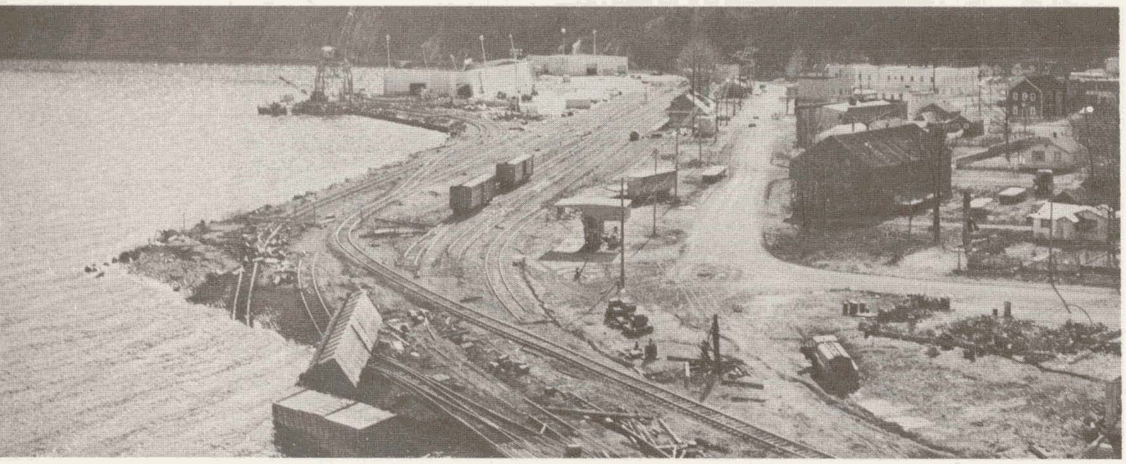
22.—A wooden fence which lay athwart the toe of the L Street landslide, Anchorage, was buckled and shortened by compression.

DAMAGE TO TRANSPORTATION FACILITIES

THE ALASKA RAILROAD

Damage to The Alaska Railroad, totaling about $27 million (Office of Emergency Planning, 1964a), has been described briefly by Grantz, Plafker, and Kachadoorian (1964, p. 24). It has been investigated more fully by McCulloch and Bonilla. Most of the damage was along the 150 miles of trackage between the terminal at Seward and Anchorage (fig. 24). Damage to the terminal and marshaling yards at Seward (described by Lemke, 1966), was caused by submarine slumping and waves. Two railroad docks valued at $4 million were completely destroyed, together with $2 million of freight and 50 freight cars. Between Seward and Anchorage, damage was caused by direct seismic shaking, landslides, subsidence, ground cracks and lurching, and inundation by high tides. Seventeen bridges were damaged or destroyed. Ground slumping along the right-of-way was severe at Kenai Lake and at Potter. Inundation and current scour were severe near Portage. Snow avalanches covered trackage along Turnagain Arm. At Anchorage,

23.—Rail and highway net of south-central Alaska. Damage to these routes was heaviest between Anchorage and Seward. Heavy damage was sustained also along the Copper River Highway east of Cordova.



24 (above).—The rails in this approach to a bridge near the head of Turnagain Arm were torn from their ties and buckled laterally by streamward movement of the riverbanks.

25 (left).—Railroad yard and warehouse damage at Seward caused by submarine slides, waves and fire. Looking west toward railroad warehouses and docks.

26 (left).—Potter Hill slide on The Alaska Railway near Anchorage.

shops and rolling stock were damaged by vibration and landslides. North of Anchorage light damage was reported as far as Hurricane. Trackage just south of Matanuska was inundated by high tides.

The spur line from Portage to Whittier was also severely damaged. The port facility at Whittier was destroyed (Kachadoorian, 1965).

HIGHWAYS

Most of the following information is abstracted from Grantz, Plafker, and Kachadoorian (1964). Subsequent, more detailed studies have been made by Kachadoorian. Highway damage resulted chiefly from destruction of bridges and cracking, collapse, or differential compaction of fills that rested on unconsolidated deposits. Estimates for repairs alone came to about $21 million (Alaska Construction Consultants Committee, 1964). Repairs plus upgrading to higher standards may come to $55–$65 million. The Seward Highway was severely damaged between Ingram Creek and Potter, where 22 bridges were destroyed. Between Potter and Anchorage there were many pavement breaks caused by differential subsidence of fills. Damage was light on the Richardson Highway between Glennallen and Valdez. Lurching displaced the alinement laterally at mile 69, and just outside Valdez there were many pavement breaks where large ground cracks crossed the highway (Coulter and Migliaccio, 1966).

27 (right).—Fissures in Seward Highway near The Alaska Railroad station at Portage, at head of Turnagain Arm. Many bridges were also damaged and at some places tectonic subsidence and consolidation of alluvial materials dropped both highway and railroad below high-tide levels.

28 (right).—Richardson Highway near mile 69, showing offsets of center line stripe caused by lurching. Road embankment shifted to right without appreciable vertical offset. Chugach Mountains in background.

29.—One span of the Million Dollar truss bridge of the former Copper River and Northwestern Railroad was dropped into the Copper River by the earthquake, and the other truss spans were shifted on their piers.

30.—Twentymile River Bridge near Turnagain Arm of Cook Inlet. The bridge fell into the river and some of the wood piles were driven through the reinforced concrete deck. The adjacent steel railroad bridge (upper right) survived with only minor damage. Both bridges were founded on thick deposits of soft alluvium and tidal flat mud and were subjected to severe seismic vibration.

The partly completed Copper River Highway was severely damaged from Allen glacier to Cordova. Nearly every bridge along the route was seriously damaged or destroyed, including the famous Million Dollar Bridge.

North from Anchorage the Glenn Highway received mostly minor damage. Part of the highway, however, was inundated by high tides near Eklutna, and the piers of the Knik River Bridge were damaged. Damage was light on the Sterling Highway between Moose Pass and Homer, except that a bridge was destroyed across the outlet of Kenai Lake (McCulloch, 1966). At Homer, about 4½ miles of road along Homer Spit was inundated by high tides and damaged by waves and currents. Homer Spit subsided 4–6 feet during the earthquake (Waller, 1966; Stanley in Waller, 1966).

Near Kodiak, highways were severely damaged by sea waves and by tectonic subsidence.

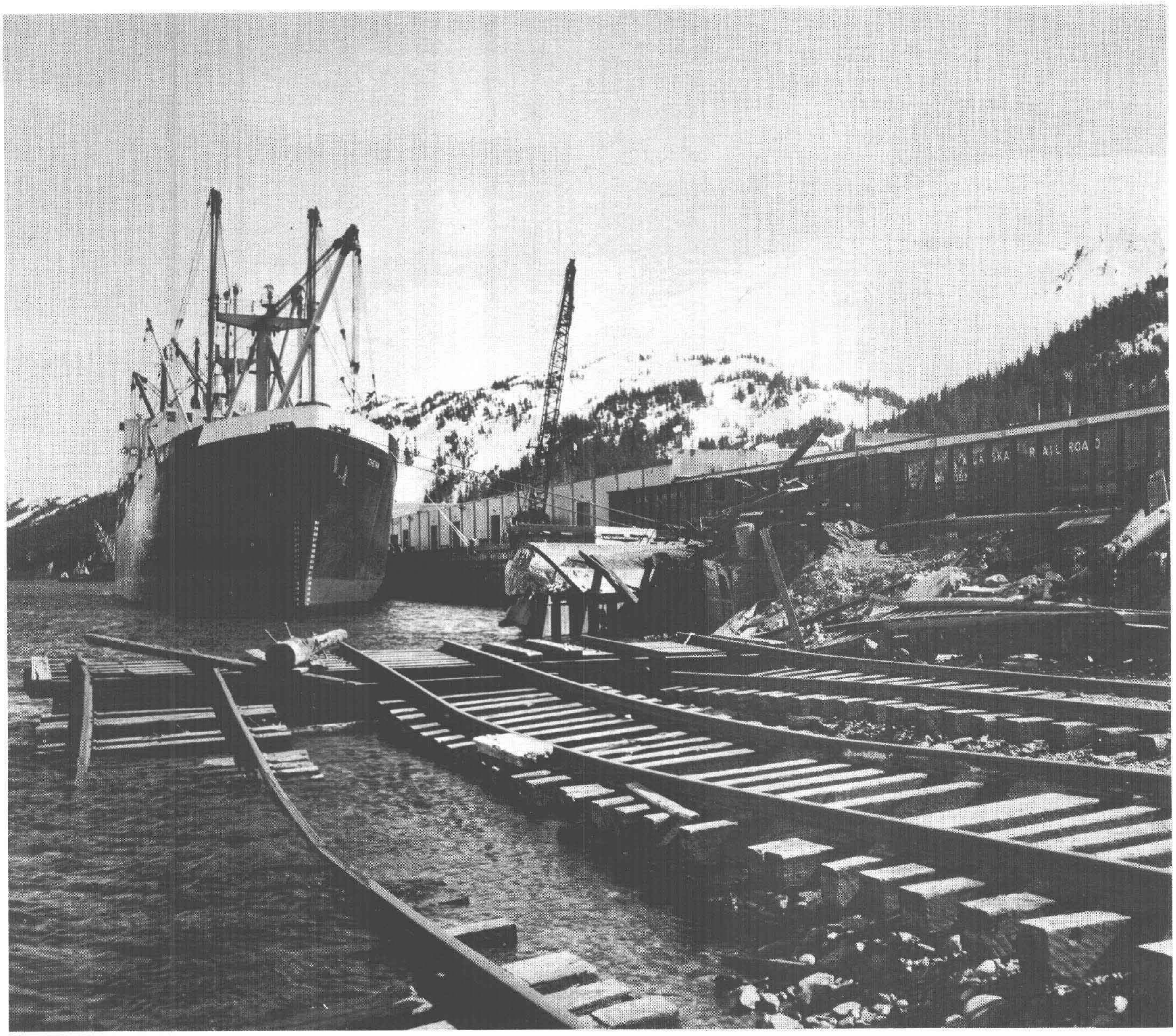
AIRPORTS

Damage to airports was relatively minor, although loss estimates totaled about $3.3 million (Alaska Construction Consultants Committee, 1964). Greatest damage was at Anchorage International Airport, where a life was lost when the control tower collapsed under sustained seismic vibration and where minor damage was sustained by other buildings. Also, 20,000 barrels of aviation fuel was lost from a ruptured storage tank. Runways and taxi strips were only slightly damaged.

At Elmendorf Air Force Base just north of Anchorage, the control tower was damaged by cracks from its base to a height of about 15 feet. In Cordova, Homer, Kodiak Naval Station, Seldovia, Seward, and Valdez, damage to runways and taxi strips was mostly light.

31 (right).—An indication of the violence of the surge-waves that struck Whittier.

32 (below).—Ground cracks damaged runway at Cordova Airport. Similar cracks formed on the taxiways.



33.—Fire, wave, and submarine slide damage to railroad and port facilities at Whittier.

PORTS AND HARBORS

Water transportation is one of Alaska's vital links with the outside world and is the base for one of her major industries, commercial fishing. Many Alaska communities can be reached only by water or air. The severe damage to port and harbor facilities, therefore, was a staggering blow to the State's economy and health. Moreover, destruction of The Alaska Railroad terminal and port facilities at Seward and Whittier, coupled with the destruction of the highway port at Valdez, deprived Alaska of any ice-free, all-weather ship terminals.

Ports and harbors sustained heavy damage from several different causes. Damage by direct seismic vibration generally was subordinate to other secondary causes. Submarine slides, sea waves, ground cracks, fires, subsidence, and uplift all took large tolls. Hardest hit in terms of port and harbor facilities damaged or destroyed were Seward, Valdez, Kodiak, Whittier, Cordova, and Homer. Listed below are estimated major damage losses to ports and harbors; these figures have been gathered from several sources, but mainly from estimates by the

Alaska Construction Consultant Committee (1964).

Community	*Damage*
Seward	$15, 375, 000
Valdez	3, 585, 000
Kodiak (excluding Naval facilities)	2, 165, 000
Whittier	[1] 5, 000, 000
Cordova	1, 645, 000
Homer	[2] 460, 000
Woody Island FAA Station	158, 000
Seldovia	[3] 25, 000
Kodiak Naval Station	11, 000, 000

[1] Total damage—port facilities not itemized separately.
[2] Excludes $1,250,000 estimate for new small-boat harbor.
[3] Estimated cost of raising canneries, commercial buildings, and boardwalk is additional $1,750,000.

Submarine sliding at Seward, Valdez, and Whittier generated large local waves that added to the destruction already caused by the slides and shaking (Kachadoorian, 1965; Coulter and Migliaccio, 1966; Lemke, 1966). Except at Whittier, subsequent damage was then caused by seismic sea waves generated in the Gulf of Alaska or possibly by seiches (standing waves: Van Dorn, 1964, p. 166; Plafker, 1965; Plafker and Mayo, 1965). When seismic vibration sundered petroleum storage tanks in Seward, Valdez, and Whittier, the contents quickly caught fire and added to the devastation. At Seward and Valdez, burning oil that was swept into the bay by submarine sliding was carried back across the waterfront by the returning surge of water; docks, piers, and small-boat harbors were thus destroyed by water and fire. At Seward, tugs, fishing boats, and a tanker were washed ashore. At Valdez, more than 40 boats were smashed. At Whittier, the railroad port facilities were swept away.

At Kodiak, damage was caused mostly by a succession of huge seismic sea waves, intensified by tectonic subsidence of 5–6 feet. Forty percent of the business district and many homes were destroyed, as well as 30 percent of the fishing industry facilities and most of the fishing fleet (Tudor, 1964, table 1 and p. 41). Some vessels were washed several city blocks inland where they collided with buildings and houses like great battering rams. At Kodiak Naval Station more than $11 million damage was inflicted on buildings, materials, and equipment by 30-foot sea waves and by subsidence (Tudor, 1964, fig. 3). Piers were covered by 10 feet of water, and the buoyed-up superstructure of the cargo pier shifted off its pilings. Boat-repair shops, gear-storage buildings, and warehouses were damaged or swept out to sea (Stroh, 1964, p. 254).

Port and harbor facilities at Cordova were damaged chiefly by tectonic uplift of about 6 feet and subordinately by sea waves. Although the immediate effect of uplift was to minimize wave

34.—Fire and wave damage to Seward port facilities.

damage, it placed docks and piers beyond reach of shipping during low tides. Boats were grounded in the small boat harbor, Orca Inlet shoaled, and passages through the adjacent islands became unnavigable.

Facilities at Homer were damaged by subsidence and submarine landsliding. Wave damage was minimal (Waller, 1966). The small-boat harbor disappeared into a "funnel-shaped" pool, and a lighthouse that had been on the harbor breakwater subsided into 40–50 feet of water (Grantz and others, 1964, p. 24). Homer Spit, a gravel bar that extends 5 miles into Kachemak Bay and on which various commercial buildings and storage tanks were placed, subsided 4–6 feet, partly by local compaction and lateral spreading and partly by regional tectonic lowering (Grantz and others, 1964). During subsequent high tides, facilities on the bar were inundated.

Facilities at Seldovia sustained damage chiefly from subsidence. At Woody Island FAA facility outside Kodiak, docks and storage tanks were damaged by seismic sea waves and subsidence. A cannery at Shearwater Bay was thrown off its foundations by the earthquake and later destroyed by waves. At Cape St. Elias lighthouse, about 135 miles southeast of the epicenter, a coastguardsman was injured by a rockslide and later drowned by seismic waves (Grantz and others, 1964, p. 6).

The Port of Anchorage was damaged by ground displacements along fractures and by direct seismic shaking. The main pier lurched laterally 5–19 inches. It sustained large longitudinal and transverse cracks, and several buildings were cracked. Gantry

35.—Tsunamis washed many vessels into the heart of Kodiak. A section of the harbor and partly submerged breakwater can be seen in upper left.

cranes on the pier were damaged when they jumped their tracks. Approach roads settled as much as 18 inches. Cement-storage tanks were toppled. Bulk petroleum tanks were ruptured, and large quantities of fuel were lost (Berg and Stratta, 1964, p. 44).

Throughout coastal areas of the damage zone many fishing vessels and other small craft were destroyed by direct wave action or by being battered against docks or the shore. Boats in harbors or tied to docks were hit hardest; vessels underway in deep water were generally undamaged; one fishing boat was sunk with all hands while underway in shallow waters near Kodiak.

ATMOSPHERIC EFFECTS

Widespread atmospheric effects are sometimes associated with large earthquakes; some have been documented (Richter, 1958, p. 128; Benioff and Gutenberg, 1939, p. 421; Van Dorn, 1964, p. 174). An atmospheric pressure wave attributed to the Alaskan earthquake was recorded by microbarographs at Scripps Institute of Oceanography at La Jolla, Calif., more than 2,000 miles from the epicenter, and at the University of California at Berkeley (Van Dorn, 1964, p. 174; Christensen and Bolt, 1964, p. 1208). This wave must have passed unnoticed at many other stations. It resembled air waves previously recorded from the detonation of large nuclear explosions. The wave traveled at acoustical velocity, reaching La Jolla 3 hours and 19 minutes after the onset of the earthquake (at 06:55 Gmt, March 28, 1965); it was, therefore, the atmospheric counterpart of the seismic sea waves generated in the Gulf of Alaska. Like the seismic sea waves, the air wave must have been caused by the tectonic uplift of the sea floor and the overlying water column. To displace the atmosphere in the form of a pressure wave, uplift must have been very rapid over a very large area, and must have coincided with the time of the most violent earth tremors (Van Dorn, 1964, p. 173–174; Plafker, 1965, p. 1680).

The earthquake also generated ordinary sound waves of very low subaudible frequencies in the atmosphere.[1] These sound waves were recorded by the National Bureau of Standards at microphone stations in Washington, D.C., Boulder, Colo., and Boston, Mass. Sound waves were radiated by the earthquake at the epicenter and by seismic waves passing through the earth remote from the epicenter, exciting the atmosphere with their passage. Thus, the Rocky Mountains and the Mississippi delta were local sources of sound as they vibrated with the passage of the shock. In addition, Rayleigh waves (surface seismic waves) crossing the continent displaced the ground surface about 2 inches in the conterminous United States and produced strong subaudible sound waves that traveled vertically upward to the ionosphere, amplifying greatly as they ascended. The ionosphere, in turn, oscillated up and down at a rate of several hundred yards per second in motions that were detected by means of reflected radio waves broadcast from one ground station to another.

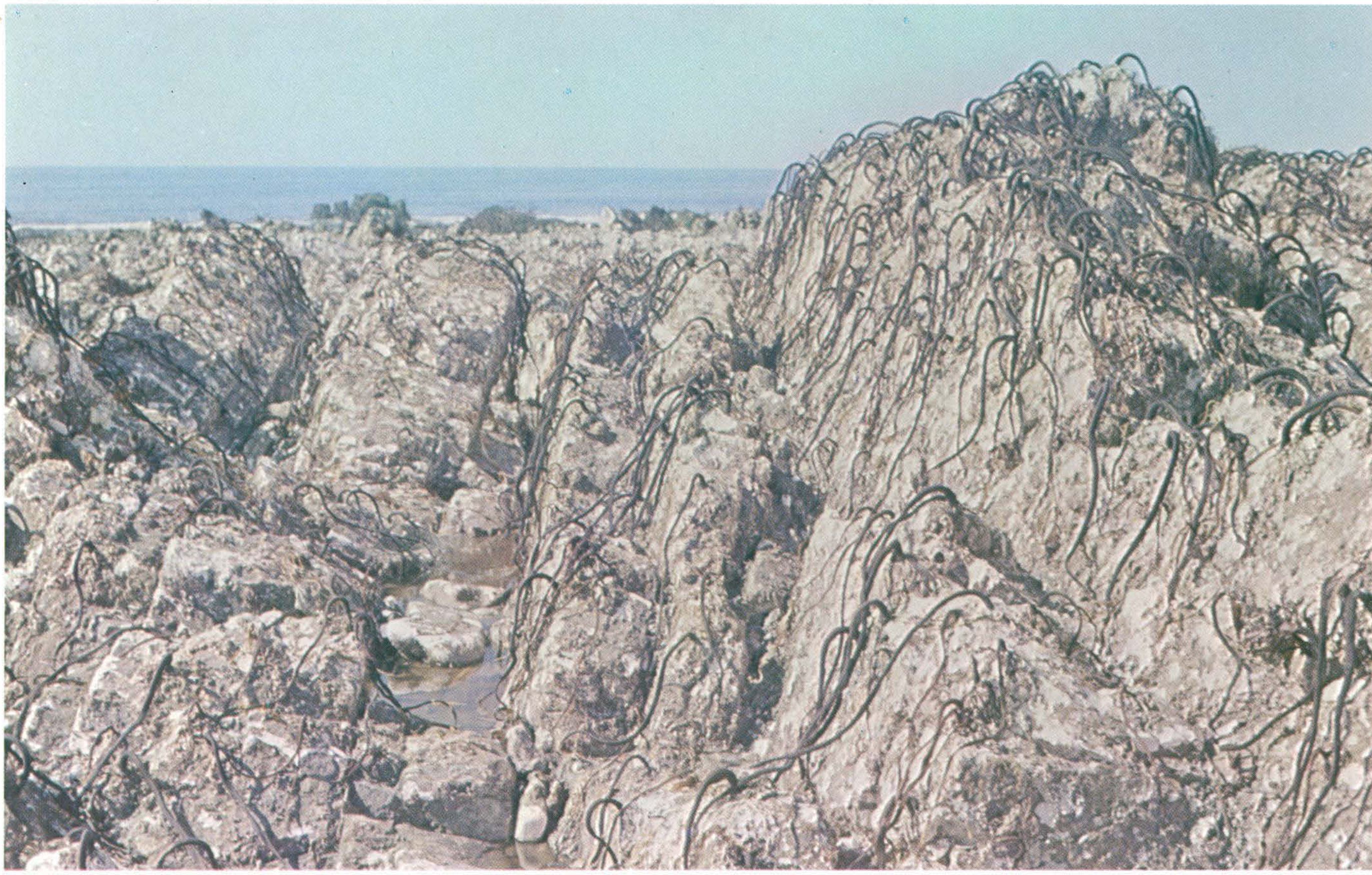
Atmospheric waves coupled to surface seismic waves were also recorded by a barograph at Berkeley. These waves started at Berkeley about 14 minutes after the onset of the quake and lasted about 4 hours (Christensen and Bolt, 1964, p. 1208).

Localized atmospheric effects in Alaska were related to avalanches triggered by the earthquake in the Chugach Mountains (Tuthill and Laird, 1966). Around the peripheries of large snow avalanches, trees were toppled by pressure blasts as the snow plummeted downward. Air blasts commonly accompany large fast-moving avalanches, whether such avalanches are triggered by earthquakes or not. The chief prerequisite is a large cross section of dense swiftly traveling snow (or rock), and the accompanying blast may be caused both by the frontal thrust of the snow and the vacuum created by its passage (Church, 1942, p. 135). Another local effect was a distribution of dust as thin coatings on glaciers adjacent to rock avalanches throughout the Prince William Sound region.

POSSIBLE MAGNETIC EFFECTS

Magnetic disturbances that began 1 hour 4 minutes before the earthquake momentarily increased the magnetic field at Kodiak by as much as 100 gammas (Moore, 1964, p. 508). Moore has inferred a possible causal relationship between the magnetic disturbances and the earthquake, and a possible means, therefore, of predicting major earthquakes by magnetic monitoring. Why abrupt magnetic disturbances should precede an earthquake is unknown, but "one possibility is that the magnetic events which preceded the Alaska earthquake resulted from piezomagnetic effects of rocks undergoing a change in stress" (Moore, 1964, p. 509).

[1] Reported by J. M. Young and R. K. Cook in papers presented at the meeting of the Acoustical Society of America in Washington, D.C., June 2–5, 1965.



36.—Uplifted wave-cut sea floor at Cape Clear, Montague Island. Shows white coating of dessicated calcareous marine organisms and brown stripes or "stalks" of kelp. The stalks are about 2 feet long.

BIOLOGIC EFFECTS

Probably few earthquakes have so strongly affected the fauna and flora of a region as did the Alaska earthquake of 1964. Moreover, because of the complex interrelations of one organism to another, the total biologic effects will not be known for a long time. In the littoral zones of the Prince William Sound region, of the Kenai Peninsula, Kodiak and elsewhere, large communities of organisms were adversely affected when pronounced crustal changes completely altered the ecologic setting of the shore. Broad expanses of shore and sea bottom were elevated above tide water in Prince William Sound, and innumerable marine organisms were exterminated. Effects were equally marked in the subsided upper end of Turnagain Arm near Girdwood and Portage, where coastal marshlands and forest were inundated by salt water—areas that formerly had provided winter forage for moose and nesting grounds for migratory birds. Extensive forested and grassland areas on Kodiak and Afognak Islands were drowned, also.

Hanna (1964, p. 24) has summarized the biologic effects of the earthquake in the littoral zone of Prince William Sound, and he portrays the extent of the depopulation in the following passage:

The exposed areas spread out before the observer are many hundreds of square miles, once densely populated by a varied fauna and flora, now completely desolated. Many of the great array of marine animals that you read about when you study zoology are dead. There is now no littoral zone anywhere that the land went up 10 feet or more. Most of the soft-bodied creatures had decomposed or had become food for birds by the time of our visit, 2 months after the earthquake, so the odor was not overpowering. The great array of living marine plants, so conspicuous along most coastlines, was gone. The *Fucus* had turned black from thirst; the calcareous algae were bleached white and so were the many species of green algae. The great fields of big brown kelp were gone, but the individual stalks left their stems and holdfasts, black and bent over, a menace to the unwary footman.

In many places there were great accumulations of dried starfish; and in one, the dried necks of clams formed a solid mass covering about a square yard. We left to speculation the manner in which these objects came to congregate. In some places a shovel could have been used to collect almost pure concentrations of small shells. Bleached remains of Bryozoa and calcareous algae were so white that the rocky beaches rivalled the snow covvered adjacent mountains in brightness.

During studies that are still in progress, G. D. Hanna and George Plafker jointly examined the distribution of tectonically disturbed zones of sessile organisms. Some of these organisms, such as barnacles and various algae, grow in response to rigorous water-depth controls, and their postearthquake vertical distribution above or below mean high-tide level provides a reliable measure of land displacement where geodetic control is unavailable (Tarr and Martin, 1912, p. 29; Plafker, 1965).

Other deleterious effects on organisms were caused by sea waves. In addition to the enormous direct destruction caused by the waves themselves, salt water invaded many coastal lakes and destroyed, at least temporarily, the freshwater habitat. Spawning beds for salmon in some instances were destroyed by siltation in river deltas. Direct kills of eggs and fry were caused by disturbance of the gravel beds of streams (Alaska Dept. Fish and Game, 1965).

Fish populations were also destroyed when streams and lakes temporarily lost water into ground cracks, or when streams were dammed by landslides (Alaska Dept. Fish and Game, 1965). On the other hand, subsidence in some areas opened miles of new spawning habitat by inundating previously impassable falls and velocity barriers in coastal streams.

The salmon fishery is one of Alaska's foremost resources, and the full impact of the quake on this fishery will not be realized until the matured 1964 hatch returns from the sea to spawn. Spawning areas for pink and chum salmon, which are intertidal spawners, received major damage in nearly all coastal sections affected by sea waves, uplift, or subsidence (Thorsteinson, 1965a). On Kodiak and Afognak Islands, moreover, the waves struck at a critical time when pink salmon fry were just moving from the spawning beds into the stream estuaries. Spawning areas for red

37.—Tectonically elevated shoreline, Latouche Island, Prince William Sound. Heavy white encrustation of barnacles, topped by reddish-brown fucus, marks former mean high-water line. Uplift was about 10 feet.

and silver salmon were little affected by the earthquake (Alaska Dept. Fish and Game, 1965).

Sport fisheries, including salmon, trout, char, and smelt, all were damaged by environmental disturbances, chiefly by subsidence, emergence, and salt-water pollution, especially in spawning areas.

Vast numbers of red snapper (red rock cod) were exterminated in Port Valdez, Port Wells, and in the area between Knight Island, Chenega Island, and Evans Island, possibly by turbulence or sudden upwelling associated with submarine slumping, or perhaps by sudden pressure changes caused by the passage of high-amplitude surface waves (H. W. Coulter, written commun., 1965). Countless thousands of these fish, which normally are bottom dwellers in deep water, were left floating dead at the surface (Grantz and others, 1964, p. 13; Hanna, 1965, p. 25; Coulter and Migliaccio, 1966).

Mortalities of dungeness crab were noted in the Copper River delta area after the earthquake, but the commercial catch appears to have been unaffected. King Crab, a deeper water species, apparently was not significantly affected by the earthquake.

Although the total crab population itself was not markedly affected by the earthquake, the crab industry was severely damaged by the loss of boats, gear, harbor facilities, and canneries. The loss of fishing vessels amounted to about $7 million and of related facilities to about $13 million. To some extent the loss was offset on the market by unusually heavy catches of crab during the 1964 season, so that the crab harvest was actually larger than usual (Office of Emergency Planning, 1964a, p. 23).

Much of the commercial clam habitat in Prince William Sound and in the Copper River delta was damaged or destroyed (Alaska Dept. Fish and Game, 1965, p. 52). The estimated total loss of clam habitat in the sound was 43 percent, and the reduction in the amount of commercially accessible clam habitat was 31 percent. (More recent observations by G. D. Hanna, oral commun., 1965, led him to believe that the clam mortality was closer to 90 percent.) In the Copper River delta and vicinity there was a high mortality of razor clams, duck clams, and cockles. At the Cordova small-boat harbor, for example, the loss of commercial size cockles was about 3.6 per square foot. Razor clams were exterminated on the higher bars of the Copper River delta. The mortality of duck clams was as high as 324 per square foot in the Martin River Slough on the east side of the Copper River delta. Duck clams are an important food for sea ducks, divers, and other birds, as well as for the starry flounder. Recovery of clams as a commercial resource is expected to be slow. Many of the new beach areas are now unsuited for clam habitat. In suitable areas, moreover, reseeded clams will require 8 to 12 years of growth before reaching commercial size (Alaska Dept. Fish and Game, 1965, p. 52).

The effects of the earthquake on terrestrial wildlife are mixed, and some short-term effects have even been beneficial. Again, only time will disclose the long-term effects. In the mountains, some mountain goats are reported to have been killed by avalanches, and there probably was some mortality among mountain sheep, deer, and moose. Although uplift adversely affected shellfish habitats, it favorably altered nesting habitats of ducks, geese, and trumpeter swans by eliminating flood dangers. The long-term ecology may be less favorable—a new balance will be established as brush gradually invades upland areas and emergent vegetation spreads over former mudflats; nesting places will shift accordingly (Olson, 1964; J. W. Brooks, Director, Div. Game, Alaska Dept. Fish and Game, written commun. to U.S. Bureau Commercial Fisheries, Jan. 12, 1965). In tectonically subsided areas where extensive fresh-water marshlands and meadows have been invaded by salt water, populations of moose and other grazing animals will have to readjust downward to the new restricted food supply.

DAMAGE OUTSIDE ALASKA

Secondary damage effects of the earthquake reached far beyond Alaska as seismic sea waves generated on the continental shelf in the Gulf of Alaska spread rapidly across the Pacific Ocean to Hawaii, Japan, and Antarctica. The source mechanism of the waves has been investigated by Van Dorn (1964), who concluded that the waves were caused by the sudden displacement of water in the Gulf of Alaska, accompanying the uplift of thousands of square miles of sea floor. A maximum wave height of 4 feet was reported in the Antarctic Peninsula (Palmer Peninsula), but heights in Japan were only a foot or so (Van Dorn, 1964, p. 187). Hilo, Hawaii, had a 7-foot wave, but received only minor damage. Apparently the source was directional, the waves radiating preferentially southeastward. Wave heights thus were greater along the North American coast than they were in the Aleutian Islands at comparable distances from the source.

As the train of sea waves advanced southward it spread damage in British Columbia, Washington, Oregon, and California. Heavy damage was localized in Alberni and Port Alberni, B.C., in Hot Springs Cove, B.C., and in Crescent City, Calif. (U.S. Coast and Geodetic Survey, 1964a, p. 40). At Alberni and Port Alberni, damage to houses and a forest-industries complex totaled several million dollars; 260 houses were damaged, 60 heavily. Of the 17 homes at Hot Springs Cove, 5 were washed away and 10 were heavily damaged.

The coast of Washington was damaged lightly. In Grays Harbor County, the waves destroyed a bridge across the Copalis River and overturned several trailer houses (Tudor, 1964, p. 4).

The Oregon coast was struck by 10- to 14-foot waves. Damage was concentrated in estuaries; a family of four was drowned at De Poe Bay. At Seaside, where a trailer park was flooded as water backed up the Necanicum River, damaged totalled about $250,000. At Cannon Beach, damages totalled $250,000; power and telephone services were cut off and several houses were toppled off their foundations. At Gold Coast, docks and small boats were smashed in the Rogue River (Tudor, 1964, p. 4). At Coos Bay, an initial wave 10 feet above mean high water was attenuated by crossing wide tidal flats before it reached Pony Point 7 miles up the channel, but at Florence an 8-foot wave traveling up a narrow channel was negligibly dissipated (Schatz and others, 1964, p. 231).

In California, minor harbor damage was sustained as far south as San Diego where small craft were destroyed and dock installations were damaged. In San Francisco Bay, water surging through the Golden Gate set adrift a ferry boat and a house boat, and caused about $1 million damage to small boats and berthing facilities at San Rafael. At Santa Cruz, a 35-foot floating dredge was set adrift and a 38-foot power cruiser was crushed (Tudor, 1964, p. 4).

At Crescent City, which bore the brunt of wave damage in California, 12 lives were lost despite a 1-hour tsunami warning. Eight boats were sunk, 3 are unaccounted for, and 15 capsized. Docks, harbor facilities, and the seawall were heavily damaged. Fifty-four homes were destroyed, 13 were heavily damaged, and 24 were slightly damaged. Forty-two small business buildings were destroyed, 118 were heavily damaged, and 29 were slightly damaged. Fires were started by the rupture and explosion of 5 bulk-storage oil tanks (Tudor, 1964, p. 61–64).

The fifth seismic sea wave to arrive at Crescent City caused most of the damage and took all 12 lives. After the first wave crested at 14.5 feet above mean low low water (MLLW), a second wave slacked off to 12 feet, followed by two much smaller waves. The townspeople, thinking that the tsunami was over, had begun to return to the flooded area when the fifth wave—coming in on a high tide—crested at 20.5 feet above MLLW.

Seiches were generated in various places remote from Alaska by amplification of direct seismic vibrations (Donn, 1964, p. 261). In the Gulf of Mexico off Texas—completely separated physically from any possible effects of tsunamis—waves as much as 6 feet high damaged small craft. In addition, water was agitated in many swimming pools in Texas and Louisiana (U.S. Coast and Geodetic Survey, 1964, p. 41). Surface-water gages recorded fluctuations in Texas, Louisiana, Arkansas, Missouri, Kentucky, Tennessee, Alabama, Georgia, and Pennsylvania (Waller and others, 1965, p. 130).

The ground-water regimen was affected throughout much of North America. Water-level fluctuations were noted in wells throughout the conterminous United States and at points as distant as Puerto Rico, the Virgin Islands, and Denmark. Fluctuations of as much as 6 cm were recorded in wells in Denmark (R. C. Vorhis, written commun., 1965). The maximum reported fluctuation was 23 feet in a well at Belle Fourche, S. D. Fluctuations apparently were greatest in a broad belt extending southeast from South Dakota and Wisconsin, through Missouri and Illinois, and on through Georgia and Florida to Puerto Rico (Waller and others, 1965, p. 131). Most level changes in wells were temporary, but some were permanent. The water in some wells was temporarily muddied.

INVESTIGATIONS BY THE GEOLOGICAL SURVEY

By Wallace R. Hansen

Within hours after the March 27 Alaska earthquake, the Geological Survey had begun to assemble a force of scientists at the scenes of the disaster in south-central Alaska. To cope with the many problems produced by a disaster of such magnitude, a wide spectrum of capability was needed, and the energies of many agencies—public and private—were called into play. A sizable need could be filled only by geologists, whose background and training equipped them to solve problems outside the competence of other professional groups. In addition to the massive purely scientific effort called for, geologists were able to assist the stricken Alaskans not only during the emergency of the immediate aftermath of the earthquake, but also during the more time-consuming tasks of restoring long-term economic health. Specialized knowledge was needed to help evaluate damage in terms of geologic environments and to assure adequate remedial measures when restoring damaged properties. Areas of enduring geologic hazard or potential future hazard had to be outlined so that, within the limits of human judgment, recurrences of the March 27 disaster could be avoided.

Quick answers were needed to questions whose diversity spanned the width and breadth of the geological sciences. Much reconstruction work hinged on proper solutions to many geologic problems and proper answers to such geologic questions as: What was the pattern of sea-level changes throughout coastal southern Alaska, and how would it affect, for example, the restoration of harbor facilities? What was the outlook for fisheries? What were the short-term and long-term effects on water supply, both surface and underground? How was devastation related to ground conditions, and how could past mistakes be avoided in the future? What soil environments were susceptible to landsliding, could existing slides be stabilized, and could future slides be avoided? What areas could be considered safe for restoration or repair? In slide areas? Along waterfronts? What safeguards were needed to protect the Federal Government in granting emergency repair loans? What steps were needed to restore damaged railroad facilities? Highways and bridges? Where could suitable supplies of embankment material and riprap be obtained? These and countless other questions pressed on the minds of geologists and laymen alike.

For Geological Survey personnel headquartered in Alaska or already assigned to Alaskan research, the earthquake investigation was in some ways a logical extension of their program. But in other ways, and to other participants, the earthquake meant postponing important but less pressing duties.

George O. Gates, former Chief of the Alaskan Branch of the Survey, was early named coordinator at the Washington level of all Geological Survey studies on the earthquake. He shuttled between Washington, Alaska, and his headquarters in Menlo Park, Calif., until the fall of 1964, coordinating intra-Survey groups, keeping in touch with other Federal agencies, and, in particular, planning the activities of far-flung field parties in Alaska. When the Survey's activities had progressed to the stage of report preparation, his coordination duties were transferred to Edwin B. Eckel.

As described in "The Work of the Scientific and Engineering Task Force: Earth Science Applied to Policy Decisions in Early Relief and Reconstruction," (p. 46), the Geological Survey played an important part in the Federal Reconstruction and Development Planning Commission for Alaska, from its inception until October 1964. G. Donald Eberlein and Ernest Dobrovolny served as Geological Survey representatives on the Commission's Scientific and Engineering Task Force in Washington, and Dobrovolny and Eckel served on the Task Force's Field Team in Alaska, with Eckel as chairman of that group. Though paid and supported by the Geological Survey, these men were directly responsible to the chairman of the Commission. With their colleagues from the U.S. Army Corps of Engineers and the U.S. Coast and Geodetic Survey, they played significant roles in advising all Federal agencies involved in the problem as to where Federal funds should or should not be spent on reconstruction or on land stabilization.

Survey personnel headquartered within the damage zone of Alaska, after seeing to the safety and welfare of their families, faced the tasks of cleaning house and picking up after the earthquake; at the same time they attempted to meet the formidable challenges of the earthquake itself and the increased level of operations necessitated by the earthquake. For some personnel this meant finding new office space to replace quarters destroyed by the quake.

By Monday morning following the earthquake, the administrative staff of T. B. Ball, management officer at Anchorage, had contacted all local units of the Geological Survey, had obtained estimates of the situation from each, and had provided Washington with an evaluation of damage to property and facilities. A local base of operations was established in one of the undamaged offices, temporary space was obtained as needed, and salvage operations were begun. Throughout the succeeding months, Ball and his staff and the staff of the local Ground Water Branch provided administrative support for all Geological Survey visitors and assignees, plus the Field Team of the Scientific and Engineering Task Force of the Federal Reconstruction and Planning Commission for Alaska.

Even while cleanup work was in progress, technical investigations were underway. On Monday following the earthquake, a start was made on a continuing program of water-well monitoring throughout the damage zone. J. L. Morgan visited and reset all automatic water-level recorders in the Anchorage area. Three of seven recorders were out of operation. Marked drops in artesian pressure levels were noted. On Tuesday, daily water-level measurements were started in Anchorage, Chugiak, and the Matanuska Valley. Surface Water Branch personnel stationed in Palmer verified streamflow losses at Anchorage, and on Wednesday, reconnoitered streams and lakes in the Chugach Mountains for possible earthquake effects.

Less than 24 hours after the earthquake, Arthur Grantz, George Plafker, and Reuben Kachadoorian arrived at Anchorage to begin a reconnaissance study of the whole stricken area. These geologists had many years of experience in southern Alaska and a detailed knowledge of much of the affected area. Their investigations took them by plane, helicopter, car, and boat to virtually all parts of the affected area. Their study was directed toward outlining the entire problem in such a way that a preliminary view of the effects of the earthquake would be readily available on which to base later and more detailed investigations. Their reconnaissance thus provided first-hand information for subsequent workers, and their preliminary report, "Alaska's Good Friday Earthquake, March 27, 1964" (U.S. Geol. Survey Circ. 491), published one month after the earthquake, was immediately in great demand. The first printing was quickly exhausted and several subsequent printings were necessary.

Grantz, Plafker, and Kachadoorian were the vanguard of a staff of geologists who soon began to arrive. Roger M. Waller assumed the duties of Field Coordinator of Geological Survey activities at Anchorage. Harold E. Thomas and Charles H. Hembree reconnoitered the hydrologic effects. Ernest Dobrovolny and Robert D. Miller made an extended stay at Anchorage. Henry W. Coulter went to Valdez and Richard W. Lemke went to Seward. A very brief reconnaissance of Valdez had already been made by Robert M. Chapman of Fairbanks. George W. Moore arrived at Kodiak to begin a study of earthquake effects on Kodiak Island.

Roger Waller, as Field Coordinator, had gained through previous administrative experience in Alaska extensive knowledge of Alaska geology, hydrology, and geography. While in charge of the Ground Water Branch office in Anchorage, Waller had prepared, or shared authorship on, several reports on the geology and ground-water conditions in the greater Anchorage area. During and after his tour of duty as Field Coordinator, Waller made hydrologic studies of the stricken area and studied the overall effects of the earthquake on the community of Homer on the Kenai Peninsula, where slides and subsidence had curtailed the sea- and tourist-based economy.

Robert Miller and Ernest Dobrovolny had written a Geological Survey bulletin on the surficial geology of the Anchorage area, published in 1959, in which earthquake warnings were sounded and potentially unstable areas were noted. Dobrovolny also had previous experience in the Chilean earthquake. While in Anchorage, Miller and Dobrovolny attended many open meetings with local groups and officials, issuing reassurances or words of caution, as appropriate. They served as informal consultants to many groups and agencies, including homeowner groups, urban planners, structural engineers, the Bureau of Land Management, the Bureau of Reclamation, and the Air Force. Meanwhile, they

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began their own study of landslides and the relationships between ground conditions and property damage in the devastated parts of Anchorage.

Richard Lemke, who had made earthquake evaluation studies in south-central Chile, began comprehensive studies in Seward where slides, sea waves, fires, and ground cracks had practically wiped out the town's economy. Very little geologic work had been done in the Seward area, and in order to evaluate earthquake effects at Seward, Lemke first had to reconnoiter the general geologic setting of Seward before he could map in detail the geology of the city itself. During his stay at Seward, Lemke was an informal consultant to the city, the Alaska Department of Highways, and the Corps of Engineers. He also served as an advisor to urban planning and renewal groups and to the contractors of the Corps of Engineers.

Henry Coulter, having recently finished mapping the geology of the Valdez quadrangle, evaluated the earthquake damage at Valdez and made recommendations to the local authorities for reconstruction and redevelopment. The damage at Valdez was very similar to that at Seward, and the problems were much the same. Coulter's recommendations led to plans to relocate Valdez in a more suitable geologic setting on the north shore of Port Valdez fiord, about 4 miles west of the present townsite. These plans are now being carried out. Coulter also studied the causes and effects of sea waves in Port Valdez. One giant wave destroyed buildings on shore and left high-water lines 170 feet above the fiord 10 miles west of Valdez at the Cliff mine.

Manuel G. Bonilla and David S. McCulloch arrived at Anchorage to begin studies of earthquake effects along the heavily damaged Alaska Railroad. Bonilla had studied earthquake effects in California and McCulloch had previously done geologic mapping in Alaska. Their findings were made immediately available to The Alaska Railroad agency. They examined nearly all the railroad bridges between Anchorage and Seward, studied several landslides along the route, and mapped ground cracks in the area between Portage and Seward. Their work also included surveys of materials for riprap and roadbed fill, studies of compaction along the right-of-way, and various independent studies unrelated to the railroad at such places as Campbell Bluff line south of Anchorage, the Seward Highway at Moose Pass, the Eklutna Power Station, and Kenai Lake. They made measurements at Kenai Lake to determine the extent of slumping into the lake, the extent and character of high waves generated by landslides, and the extent and character of seiching.

Immediate heavy demands were placed on the Public Inquiries and Map Sales Offices of the Geological Survey in Alaska. For weeks after the earthquake these demands were met entirely by the Alaska Distribution Section in Fairbanks. Sales offices and agencies in Anchorage, Kodiak, Seward, and Valdez were put out of operation by the earthquake, and all their orders had to be filled at Fairbanks. Map sales at Anchorage had been made from the Public Inquiries Office in the Cordova Building—a building so damaged structurally that it had to be evacuated. A temporary sales office was set up by Margaret

I. Erwin in a vacant grocery store. Even at Fairbanks, maps and supplies were scattered all over the floor when racks and shelving were overturned by the earthquake. Demands were particularly heavy for maps and reports that would be helpful in assessing land and coastal changes, in evaluating damage, and in planning rehabilitation of stricken areas.

Reuben Kachadoorian in the meantime started a regional study of earthquake effects on land. With a background of 12 years experience in the engineering geology of Alaska, he made detailed studies of virtually all major highways in south-central Alaska, including part of the Denali Highway and the Seward, Glenn, Richardson, Edgerton, and Sterling Highways. He and George Plafker examined the Copper River Highway and the Copper River delta. He studied the highway net on Kodiak Island, the Matanuska flats, the Robe River flats, the Portage area, part of the Kenai Lowland, Whittier, and Kodiak. Kachadoorian and Plafker also examined the Cape Hinchinbrook Lighthouse Station. Kachadoorian gathered information on geology, damage to bridges and roadbeds, the water regimen, subsidence, fractures, areas of ejected sand, eyewitness accounts, and the direction, duration, and type of seismic motion. He did reconnaissance in the Chugach, Kenai, and Talkeetna Mountains, and in the mountains near Katalla.

The U.S. Geological Survey research vessel *Don J. Miller*, which was wintering in Seattle, was hurried to Alaskan waters for geological, geophysical, and submarine studies in Prince William Sound and Resurrection Bay. A party headed by George Plafker undertook a systematic study of all earthquake effects along the shorelines of the sound and of Resurrection Bay. The *Miller* served as the base of operations from mid-May to early July. The party included J. E. Case, L. R. Mayo, S. L. Robbins, and William Bastian, all of the Geological Survey. Studies were made of vertical displacements along the shorelines resulting from crustal warping, ground breakage (surface rupture) by faults, submarine slides, the effects of destructive waves along the shorelines, distribution and nature of ground cracks, landslides and avalanches, and seismic shock damage sustained at the smaller communities and habitations throughout the sound area. Plafker later extended these studies on a reconnaissance basis to the outer coast of the Gulf of Alaska between Yakutat and Seldovia and to the coast of the Kodiak Islands group, using a helicopter

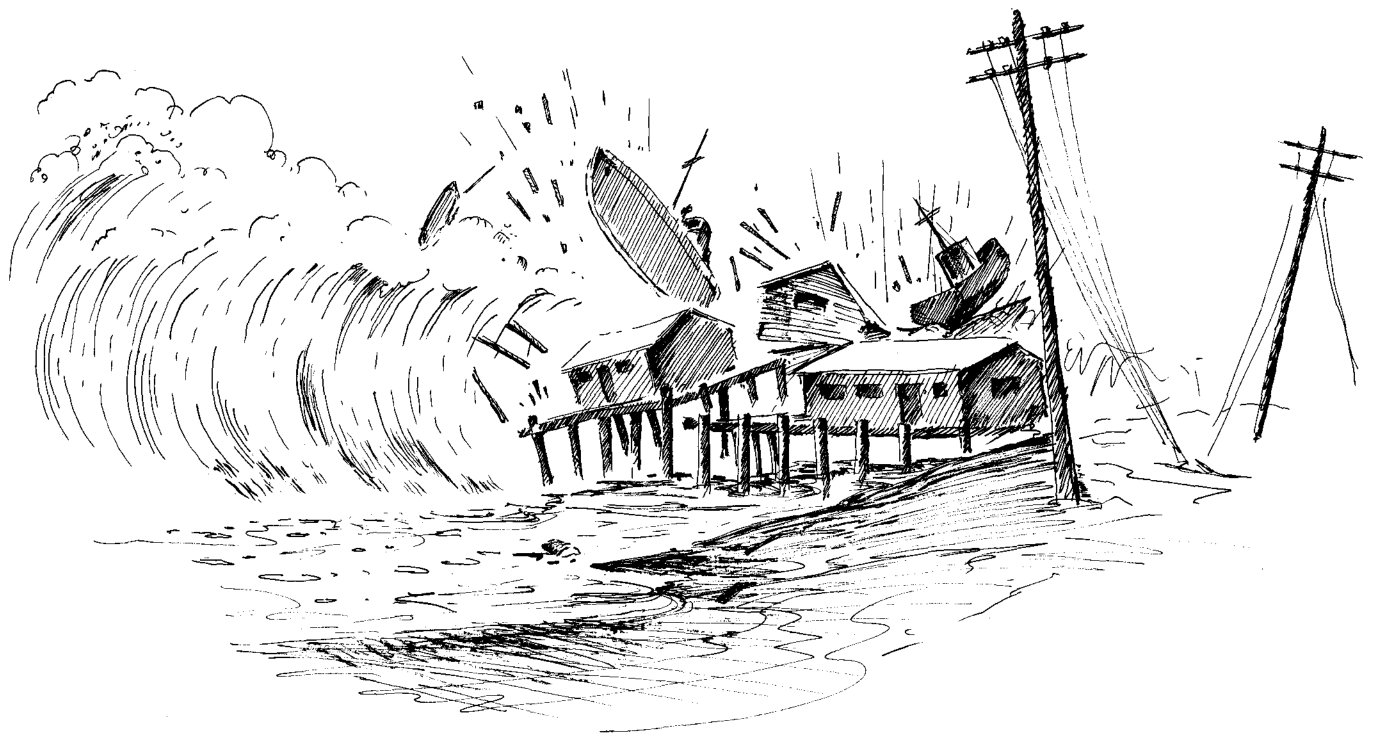
38.—Immediately after the earthquake, the U.S. Geological Survey's research vessel, the *Don J. Miller*, sailed to Prince William Sound.

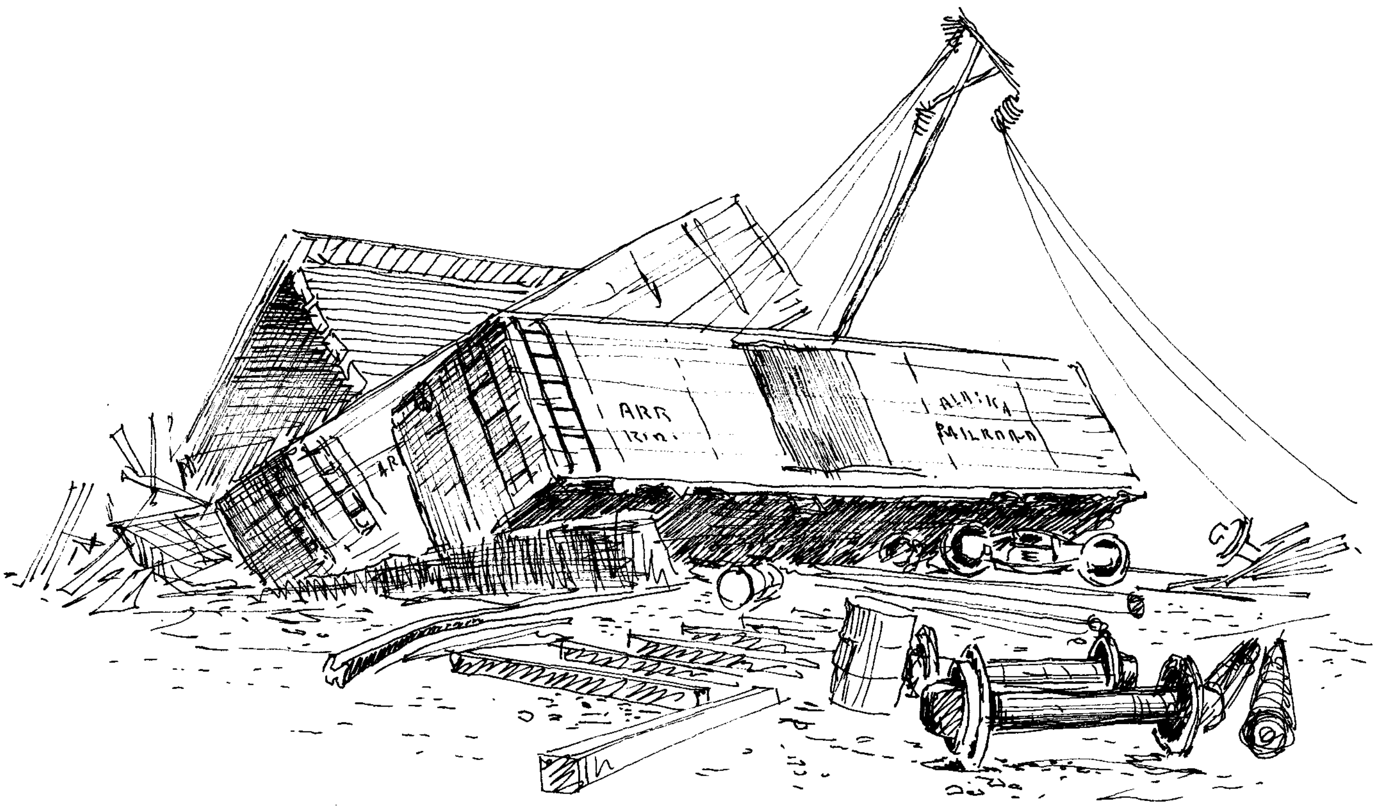
and seaplane for logistic support. Concurrently with the work in Prince William Sound, Case and Robbins made a reconnaissance gravity survey of the entire area. G. Dallas Hanna, marine biologist of the California Academy of Science, spent 3 weeks with the party in Prince William Sound studying the effects of the earthquake on the ecology of intertidal fauna and flora. Changes in distribution of the fauna and flora were related in turn to tectonic changes in level of the land.

Investigations of the tectonic deformation by the Geological Survey resulted in locating the only known surface faults that accompanied the earthquake, and in delineating a zone of crustal warping that for 500 miles extends parallel to the coast of the Gulf of Alaska. Within this zone, uplifts of as much as 33 feet and subsidence of as much as 7½ feet were noted. These investigations, supplemented by the U.S. Coast and Geodetic Survey's releveling inland from the coast and measurement of land-level changes at tide-gage stations, showed that crustal warping extends over an area of at least 70,000 square miles. Information on the changes in land level was made immediately available to the U.S. Bureau of Commercial Fisheries and the Alaska Department of Fish and Game in order to aid in an appraisal of the long-range effects of the deformation on salmon spawning grounds and commercial clam beds. It also provided a basis for planning remedial measures by The Alaska Railroad, the Alaska Department of Highways, and private groups that would be required to protect or restore the usefulness of shoreline structures and installations. The data on the permanent crustal warping and surface faulting are of vital scientific interest to geologists and seismologists who are concerned with the cause and mechanism of the earthquake and the destructive seismic sea waves it generated. The findings were promptly made available in a press release and in oral reports to scientific groups.

James E. Case, who boarded the *Don J. Miller* to record gravity variations, found a large positive anomaly nearly parallel to the zero isobase and probably associated with outcrops of lower Tertiary greenstone. In late June, Captain Fair Bryant of the U.S. Coast and Geodetic Survey ship *Surveyor* invited David F. Barnes aboard the *Surveyor* while the Coast and Geodetic Survey was investigating the seaward end of the Montague Island fault. During the month of July, Barnes thus had an opportunity to study the seaward extension of the Knight Island anomaly. (During early 1965 he assisted Richard Malloy of the Coast and Geodetic Survey in preparing the reports on the project.) Barnes reoccupied several preearthquake gravity stations later in the summer of 1964 and found that the earthquake had caused measurable gravity changes.

Widespread damage to the coastal parts of southern Alaska was caused by submarine landslides and locally generated waves. Damage initiated by sliding was compounded by the backwash of the resulting waves, commonly while the earthquake was still in progress. Much property was thus destroyed and many lives were lost. The effects of the





sliding at the port cities of Seward, Valdez, and Homer were recognized in the initial reconnaissance phase of the investigation. More detailed studies of shoreline damage carried out aboard the *Miller* indicated that submarine landslides and their accompanying destructive waves were widespread phenomena. The 13 deaths and the damage at the port of Whittier also were caused by local waves generated by submarine landslides. The effects of comparable local waves, some of which reached altitudes of 170 feet along the shoreline, were noted throughout the sparsely settled Prince William Sound area and the south coast of the Kenai Peninsula.

In early July, Gene A. Rusnak, a marine geologist of the Geological Survey, equipped the *Miller* with precision electronic sounding gear, bottom-sampling apparatus, and seismic equipment (sonoprobe) and began a program of submarine geological and geophysical study of the slide areas and their resulting deposits on the sea floor. He was assisted in the investigations, which were carried out in July and August, by D. S. McCulloch, L. R. Mayo, and L. L. Benton, Jr.

Clifford A. Kaye and Wallace R. Hansen joined the field team at Anchorage. As a consultant to the Scientific and Engineering Task Force of the Federal Reconstruction and Planning Commission for Alaska, Kaye contributed his special knowledge of soil mechanics and clay properties. He also collaborated with Hansen and Miller in landslide studies. Edwin B. Eckel followed shortly to take over the leadership of the field team of the Task Force, a position which Dobrovolny had held on an interim basis. Dobrovolny and Eckel now devoted full time to their fast-increasing duties on Task Force Nine.

To obtain quantitative evaluations of landslides and ground displacements, Arthur Gervais, Jack R. Helm, and Alfred B. Dodd, topographic engineers, spent 3 weeks at Anchorage working closely with Hansen and Miller; they surveyed precision profiles across landslides, prepared planetable maps, and established ground control for photogrammetric mapping. Large-scale topographic maps of the Turnagain Heights, Government Hill, and Native Hospital landslides were subsequently prepared in Denver, Colo., by photogrammetric methods.

Regional effects of the earthquake in the Cook Inlet area were analyzed by Thor N. V. Karlstrom, assisted by Helen L. Foster. Karlstrom had a detailed knowledge of this area, having spent many seasons of study along Cook Inlet in connection with his Alaskan terrain and permafrost studies. His earthquake evaluations covered all phases of the problem as related to that area. He made detailed studies of ground breakage in the Kenai Lowland and did widespread reconnaissance elsewhere in the inlet, noting different types of behavior in different types of materials. He related the regional pattern of fracturing to inferred and mapped tectonic elements, and he studied ground failures in sea bluffs and associated changes in shoreline geomorphology. Miss Foster collaborated mainly in the Kenai Lowland. Previously, she had investigated and reported on the Fukui, Japan, earthquake of 1948.

The sparsely settled Copper River basin, northeast of Prince William Sound, sustained relatively light, but nevertheless significant, earthquake damage. This area was examined by Oscar J. Ferrians, Jr., by aerial, ground, and aerial-photograph reconnaissance. Buildings, highways, and bridges in the lowland areas were damaged by vibrations, subsidence, and ground cracks. Landslides were triggered along slopes and bluff lines, avalanches and rockslides in the mountains. Ephemeral cracking was widespread on frozen lakes, rivers, muskegs, and flood plains.

Effects of the earthquake on glaciers in southern Alaska have been studied by Austin S. Post, as part of a continuing glaciological investigation that began in 1960. In 1960, 1961, 1963, and 1964 Post examined nearly all the glaciers in Alaska and western Canada by visual aerial inspection and on aerial photographs. He found that the earthquake produced some rockfalls but no significant snow and ice avalanches on glaciers. Recent evidence, according to Post, fails to support the widely accepted earthquake-advance theory of Tarr and Martin that earthquake-triggered avalanches have caused rapid short-lived surges in Alaskan glaciers in the past.

Other photogeologic studies were made by Robert J. Hackman, who reviewed all available postearthquake aerial photographs and prepared reconnaissance maps showing slides and avalanches.

The earthquake had widespread remote hydrologic effects at places as far distant from the source as the southeastern conterminous United States, Puerto Rico, and even Denmark; both surface and underground water supplies were affected. Marked level changes were recorded in many wells and in surface-water bodies. Robert C. Vorhis undertook a study of such effects and found that many ground-water instruments faithfully recorded the earthquake, in detail comparable to that recorded by highly sophisticated strain seismographs. Vorhis also noted two types of "permanent" groundwater level changes—instantaneous and gradual.

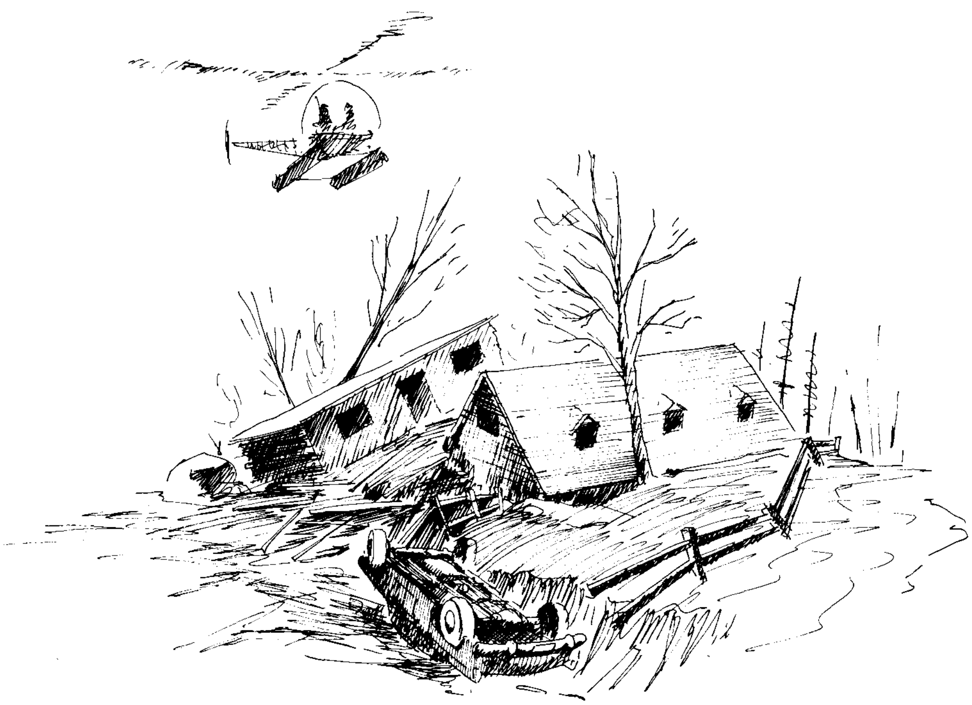
An outcome of early postearthquake reconnaissance was a decision to document on 16-mm color motion-picture film all geologic phases of the earthquake. Hal G. Stephens photographed geologic evidence of subsidence, emergence, compressive and tensive forces, vibration, and wave action. He recorded types and amounts of damage to buildings, docks, and various other structures, and related the damage to such causes as vibration, landslides, seismic and locally generated sea waves, and submarine slides. All significant parts of the damage zone were photographed from the ground or from the air. This zone included Anchorage and vicinity, the highway between Anchorage and Valdez, Valdez and vicinity, the Copper River valley, Cordova, Homer, the Kenai Peninsula, Kodiak, Portage, Prince William Sound (where the evidence of emergence was most striking), Seward and vicinity, and Whittier. An edited, narrated film has been prepared.

As the start of a long-term project to monitor crustal changes in southern Alaska, Robert C. Foley and Arthur Gervais established a network of permanent bench marks on the shores of 17 large lakes within about a 500-mile radius of Anchorage. These bench marks were referenced to the water levels of the lakes, so that the direction and amount of any tilting can be obtained from periodic monitoring. Thus each lake surface is analogous to a giant spirit level. Bench marks were set at the following lakes: Ugashik, Becharof, Naknek, Iliamna, Kontrashibuna, and Clark on the Alaska Peninsula; Karluk on Kodiak Island; Crescent, Chakachamna, and Beluga at the north end of Cook Inlet; Kenai, Skilak, and Tustumena on the Kenai Peninsula; and Eklutna, George, Tazlina, and Klutina in the Chugach Mountains.

One of the Geological Survey's functions, under its Branch of Waterpower Classification, is to appraise potential hydroelectric powersites on the public lands. Several such sites on the Kenai Peninsula and in the Talkeetna Mountains had been studied by

Russell G. Wayland and David L. Gaskill some years prior to the 1964 earthquake. After the earthquake, these sites were reexamined by Wayland and Harold L. Pumphrey to determine if the earthquake had caused any obvious ground changes, such as landslides, that might alter their classification status. The more accessible sites were visited on the ground, but others were reexamined only from the air, it being recognized that, in any event, detailed ground studies would be needed before any site could be developed. Wayland concluded that none of the sites was so modified by the earthquake as to invalidate the earlier preliminary examinations.

Geological Survey investigations of the great Alaska earthquake of 1964 are still in progress and will continue for several years. New data are still being collected and processed, and new concepts are being tested and evaluated. Many level lines and bench marks must yet be resurveyed by the U.S. Coast and Geodetic Survey, and several years, therefore, may pass before a really synoptic view of regional crustal change can be obtained. Many geophysical data must yet be interpreted and related to geologic cause and response. Hydrologic changes are still in progress. Some time must pass before the permanent effects of the earthquake on ground-water aquifers can be screened out from the transient effects. Long-term effects on glaciers—minimal on most glaciers, perhaps, but great on some—will be watched with great interest. Along the rivers and on the deltas, in the bays and inlets, and along the shorelines, geomorphic changes will continue; studies of effects in these areas have only started. A clear picture of ecologic effects is coming into focus, but many years will pass before all ramifications of new plant and animal relationships are clearly apparent. Finally, corollary studies are underway in Anchorage, Juneau, and in all coastal towns of southern Alaska to underline possible hazards—of the kinds generated by past earthquakes—to the future security of these communities. Aided by experience gained from the 1964 earthquake, these studies will help to establish a better relationship between local geologic settings and urban planning, zoning, and industrial development in the State.



THE WORK OF THE SCIENTIFIC AND ENGINEERING TASK FORCE—EARTH SCIENCE APPLIED TO POLICY DECISIONS IN EARLY RELIEF AND RECONSTRUCTION

By EDWIN B. ECKEL and WILLIAM E. SCHAEM [2]

INTRODUCTION

The prompt and direct application by the Federal Government of knowledge drawn from earth scientists and engineers to the problems of reconstruction that resulted from the Alaska earthquake of March 27, 1964, was unique in the history of disasters. Consequently, the story of how this knowledge was applied deserves to be put on record, if only for study by those involved in future problems of the same sort.

The Scientific and Engineering Task Force, an arm of the Federal Reconstruction and Development Planning Commission for Alaska, was the vehicle for gathering engineering and earth-science information from all available sources, for interpreting it, and for making recommendations to Federal agencies on matters that involved the stability of buildings or their foundations.

The Federal Government's part in the reconstruction effort must be described briefly in order to put the work of the Task Force in proper perspective, for the part played by the Federal Government in aiding Alaskans, beginning with the first throes of disaster and continuing throughout the reconstruction period, was very great.

The full story of government participation would require several volumes, but the following summary of the immediate response by military and civilian agencies and of the work accomplished through a novel commission established by the President to coordinate the work of all Federal agencies will serve to give the necessary background here. Much of the material in the following paragraphs is based on, or quoted from, a highly significant report entitled "Response to Disaster," prepared by the Federal Reconstruction and Development Planning Commission for Alaska (1964).

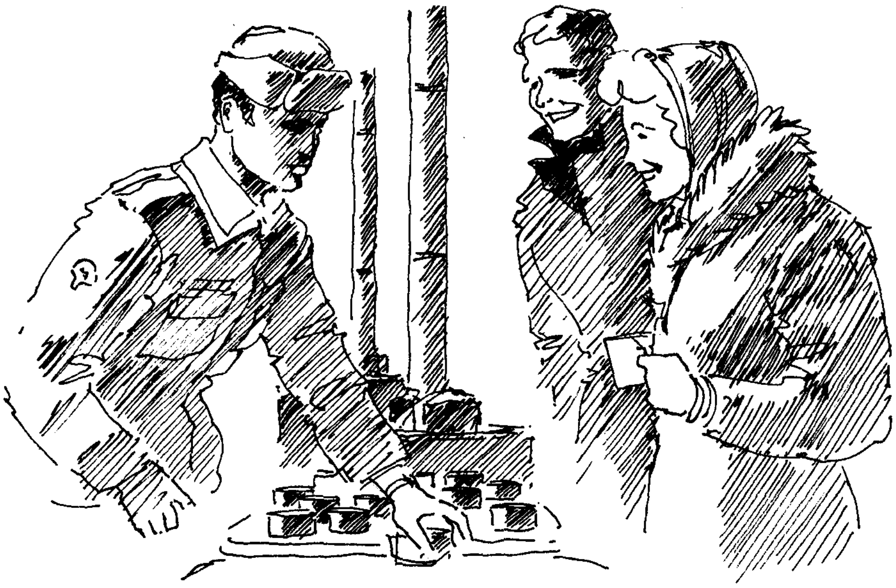
IMMEDIATE RESPONSE OF THE FEDERAL GOVERNMENT

While the Federal Government was organizing its relief effort, the military gave immediate aid to the civilian community and supplemented the help given by State and local groups and by individuals. Most communications systems had, of course, been disrupted. The first word from outlying areas, and to the rest of the United States, was sent out through a patchwork system of radio stations belonging to ham operators, fishing vessels, oil companies, and various State and Federal agencies. Within minutes after the earthquake, the U.S. Army Alaskan Command and the Elmendorf Air Force Base at Anchorage started the task of restoring regular telephone and radio communications among the stricken towns and between them and the rest of the United States. Within 3 hours, military water tanks began supplying water in Anchorage, and less than 48 hours later water-purification units had been flown in to Anchorage; other relief supplies were airlifted to isolated communities. Fort Richardson and Elmendorf Air Force Base provided guard troops, served thousands of meals, and offered emergency housing.

At Kodiak the Navy provided meals, blankets, and many tons of supplies, plus the services of more than 1,000 men for emergency work. Similar military aid went to nearly every inhabited place that had been hit by the earthquake or by its aftermath of fire and flood.

The day after the earthquake, in response to a request from the Governor, the President declared Alaska to be a major disaster area. This declaration meant different things to different people—ranging from apprehension to wild hopes of immediate and complete relief—depending on their prior experiences and the degree of shock that they had already experienced. Actually it merely vide the immediate financial and meant that governmental machinery could be set in motion to promaterial help that was needed. Thus began a series of unprecedented emergency measures executed or financed by the Office of Emergency Planning (OEP). Under Public Law 81–875, OEP had the major responsibility for assisting State or local units in disaster-

[2] Structural engineer, Office of Chief of Engineers, Department of the Army, Washington, D.C.



stricken areas to make emergency repairs and to restore public facilities. The authority provided by the law and substantial funds available from the President's Disaster Relief Fund were used speedily and effectively by OEP. The philosophy adopted was to provide assistance as broadly and flexibly as possible within the spirit and intent of Public Law 81–875.

A wide range of relief and reconstruction work began at once, much of it at the request of, and eventually repaid by, the Office of Emergency Planning, and some by other Federal agencies using their regular authorities and funds or special ones made available by the President's designation of a disaster area.

The Army Corps of Engineers contracted for debris clearance, restoration of public utilities, and repair of docks and other community facilities in Anchorage, Seward, Valdez, Whittier, and elsewhere. The Navy's Bureau of Yards and Docks aided Kodiak in the same way. The Alaska Railroad of the Department of the Interior assessed its damages and began repairs. The Bureau of Public Roads of the Department of Commerce worked with the Alaska Department of Highways to restore the highway system. The Departments of Health, Education and Welfare, Labor, Agriculture, and Commerce, the Coast Guard of the Treasury Department, and several independent agencies also took part in the early recovery effort.

These government actions, both State and Federal, were essential, but much of the success of the early work was due to fraternal, social service, religious, civic, and private business organizations and to individuals. These groups worked effectively, unselfishly, and in complete cooperation with governmental units, yet with the heartwarming spirit of independence and self help so characteristic of the people of Alaska.

FEDERAL RECONSTRUCTION AND DEVELOPMENT PLANNING COMMISSION FOR ALASKA

MAKEUP AND FUNCTIONS

Some means had to be found to coordinate and streamline the efforts of the many Federal agencies that had parts to play in the relief and rebuilding of stricken Alaska. On April 2, 1964, less than a week after the earthquake, President Johnson issued Executive Order 11150 (Federal Register Doc. 64–3378), establishing the Federal Reconstruction and Development Planning Commission for Alaska. This group, hereafter called the Reconstruction Commission, or more simply the Commission, was directly responsible to the President. It was composed of the heads of all Departments and independent agencies that had any direct financial or technical parts to play in the reconstruction effort. Members were:

- Senator Clinton P. Anderson, Chairman
- Secretary of Defense
- Secretary of the Interior
- Secretary of Agriculture
- Secretary of Commerce
- Secretary of Labor
- Secretary of Health, Education, and Welfare
- Director, Office of Emergency Planning
- Administrator, Federal Aviation Agency
- Chairman, Federal Power Commission
- Administrator, Housing and Home Finance Agency
- Administrator, Small Business Administration

Dwight A. Ink was lent to the Commission by the Atomic Energy Commission to serve as Executive Director, Frank C. DiLuzio of Senator Anderson's staff was named as assistant to the Chairman, and Wilmot L. Averill of the Office of Emergency Planning was made Deputy Executive Director. The remainder of the small staff, which never numbered more than 25 people, was recruited for full or part time from the staffs of Senator Anderson's Senate Committees or from some of the Commission's constituent agencies.

The Reconstruction Commission established the Alaska Field Committee, composed of representatives of those agencies on the Commission which had offices in Alaska. Burke Riley, Regional Coordinator, Department of the Interior, was chairman of the Field Committee. This group provided effective coordination at field level for problems which cut across agency lines. The Alaska Field Committee also worked closely and to advantage with the parallel State group established by the Governor—the Alaska Reconstruction and Development Planning Commission, headed by Joseph H. Fitzgerald, Coordinator.

The Commission was unique in several significant respects. First, it was the first Federal commission of this kind that combined the legislative and executive arms of government. Second, by its very composition as well as by the wording of the Executive order, decisions reached by the Commission had the effect of Presidential orders on all constituent agencies. Lastly, the Commission probably set a record by terminating its existence as soon as its major tasks were accomplished. Established on April 2, 1964, it was completely dissolved 6 months later by Executive Order 11182 on October 6, 1964.

The functions of the Commission, as defined by the Executive order were as follows:

Sec. 2. *Functions of the Commission.* (a) The Commission shall develop coordinated plans for Federal programs which contribute to reconstruction and to economic and resources development in Alaska and shall recommend appropriate action by the Federal Government to carry out such plans.

(b) When the Governor of Alaska has designated representatives of the State of Alaska for purposes related to this order, the Commission shall cooperate with such representatives in accomplishing the following:

(1) Making or arranging for surveys and studies to provide data for the development of plans and programs for reconstruction and for economic and resources development in Alaska.

(2) Preparing coordinated plans for reconstruction and economic and resources development in Alaska deemed appropriate to carry out existing statutory responsibilities of Federal, State, and local agencies. Such plans shall be designed to promote optimum benefits from the expenditure of Federal, State, and local funds for consistent objectives and purposes.

(3) Preparing recommendations to the President and to the Governor of Alaska with respect to both short-range and long-range programs and projects to be carried out by Federal, State, or local agencies, including recommendations for such additional Federal or State legislation as may be deemed necessary and appropriate to meet reconstruction and development needs.

DUTIES AND ACCOMPLISHMENTS

The Reconstruction Commission's varied duties and accomplishments can be grouped under four general headings: (1) estimates of damage and the work required for reconstruction, (2) drafting of special legislation, (3) initiation, scheduling, and coordination of reconstruction and financial relief, and (4) long-range economic planning and recommendations.

ESTIMATES OF DAMAGE

First estimates of the amount and nature of damages sustained by Alaska were made by many State, Federal, and local agencies within a few hours or days after the earthquake. These estimates were soon followed by more comprehensive ones. In addition to analyses of their own installations made by such agencies as the Department of Defense, the Alaska Department of Highways, and The Alaska Railroad, a broad study was made by the Alaskan Construction Consultants Committee—a group appointed by the chairman of the Commission. This committee, whose members were drawn from the Associated General Contractors of America and the International Union of Operating Engineers, inspected the damage to private and public property, reviewed the manpower situation, and reported its estimates of damage to the Commission (Alaskan Construction Consultant Comm., 1964). The Alaska State Housing Authority cooperated with the Federal Housing and Home Finance Agency in estimating damages to private real property. Under sponsorship of the Commission, the American Institute of Architects and the Engineers Joint Council also established a team to advise the Commission and the Governor both as to reconstruction plans and the long-range development program (Am. Inst. Architects and Engineers Joint Council Comm., 1964).

Based on these and other sources, the Commission's estimate of damages, as of August 12, 1964, is shown in table 2.

In addition to estimates of the dollar values of damaged properties, it was essential to the planning of a rebuilding program that the nature of the landslides and submarine slides that had caused much of the damage be understood in detail. To this end the Office of Emergency Planning financed and greatly expedited an intensive program of soils investigations. The program was conducted by the Corps of Engineers in Anchorage, Seward, Valdez, and Homer. The results of these studies, plus the results of the

TABLE 2.—*Summary of estimated damages, August 12, 1964*

[Condensed from Federal Reconstruction and Devel. Plan. Comm. Alaska, 1964, p. 11]

Public Property:		
Federal:		
Military	$35, 610, 000	
Nonmilitary	35, 641, 000	
Non-Federal:		
State and local	107, 373, 000	
Highways	[1] 55, 568, 000	
		$234, 192, 000
Private property:		
Real	77, 000, 000	
Personal	No estimate.	
		77, 000, 000
Total damage, excluding personal property and loss of income		311, 192, 000

[1] Includes all highways on Federal-aid system; highways to be restored to preearthquake condition. Estimated cost of highway construction to 1964 design standards is $65,088,000.

seismic engineering and geologic investigations that were carried on by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey, respectively, formed the basis for the recommendations made to the Commission by the Scientific and Engineering Task Force, whose activities are described below.

SPECIAL LEGISLATION

It was apparent that Alaska would require even more aid than could be provided under existing programs or legislative authorities. The Commission, therefore, took a leading part in working with the Bureau of the Budget, with its own constituent agencies and those of the State, and with the Congress in preparing needed legislation.

Two principal legislative accomplishments resulted. The first accomplishment was a request from the President for extension of his authorization to provide transitional grants to Alaska. When Alaska became a State in 1959, Congress provided transitional grants of $28.5 million to help the State assume the responsibilities for public services that had earlier been provided to the Territory by the Federal Government. It was obvious that earthquake damages would lead directly to cuts in tax bases and other sources of revenue. The Congress agreed with the need for continuance of the transitional-grants policy and appropriated about $41 million, for the period ending June 30, 1966, to be used to carry on essential State and local services.

The Commission's second large accomplishment in the legislative field was the drafting of the Alaska Omnibus Bill (S. 2881 and H. R. 11438, 88th Cong., 2d Sess.), which was transmitted to the Congress on May 27, 1964, was later passed with several significant amendments, and became law on August 19, 1964.

The Omnibus Bill provided for many changes in existing laws so that a maximum of disaster aid could be provided in a minimum of time. Among the more significant items were the following:

1. The Federal share of Federal-aid highway costs was increased from 50 percent to 94.9 percent.
2. The Corps of Engineers was authorized to modify civil works projects, such as expansion of small-boat harbors, to meet prospective future requirements.
3. Certain lending agencies were authorized to adjust the indebtedness of borrowers.
4. The Housing and Home Finance Administration was authorized to contract for as much as $25 million for urban renewal projects; the Federal share of the participation was increased from 75 percent to 90 percent.
5. The Federal Government was authorized to purchase as much as $25 million of State of Alaska bonds.
6. The President was authorized to grant a total of $5.5 million to the State, on a 50–50 matching basis, to adjust or retire mortgage obligations on family dwellings.

RECONSTRUCTION PLANS AND SCHEDULING

The Commission also played a leading part in drawing up plans and schedules for reconstruction, in coordinating the work of Federal, State, and local agencies, and in expediting actual work schedules. The plans had to take cognizance of the fact that the normal construction season in Alaska is very short and that there were immediate needs that must be met. On the other hand, it was considered undesirable to put all reconstruction work on a crash basis, for this would have tended toward price inflation and importation of non-Alaskan labor, both of which would have weakened the Alaskan economy. For these reasons, efforts were made to compromise between the needs for immediate high-priority work and the desire to stretch out the reconstruction on projects of lower priority. Despite these compromises, however, the Commission emphasized speed throughout its work, both in releasing a flow of funds to bolster the economy and in the physical reconstruction of facilities.

Emergency repairs to utilities and highways were of course given first priority. The extensive geologic and soils investigations that were needed as a basis for reconstruction plans at Anchorage, Seward, Valdez, and elsewhere were next in priority. Engineering design of reconstruction projects followed closely; preliminary designs, indeed, paralleled basic soils investigations in some places. Finally, bids were examined and contracts awarded.

In addition to aiding in the reconstruction of utilities and other public properties, it was essential that the Federal Government help strengthen the State's economy by providing all possible aid and encouragement to private individuals and business groups—from the individual homeowner to the lending institutions. In this work the Commission again played an important part. Normal disaster-aid policies were liberalized and expedited; longer term loans at lower interest rates were permitted, and owners who had lost their properties or suffered extensive damages were released from all or part of their debts to the Federal National Mortgage Association, the Veterans Administration, and the Small Business Administration. Further relief was provided by income-tax deductions and rebates based on property losses. Rebates were expedited by the Internal Revenue Service by the use of the risk maps prepared by the Scientific and Engineering Task Force, described below, that is, properties within the "high-risk" areas, as designated by the Task Force, were automatically assumed to have suffered losses; hence rebates could be made immediately and without further investigation.

LONG-RANGE ECONOMIC PLANNING

Even though the Commission was preoccupied with immediate problems of reconstruction, it could not lose sight of the long-term needs of Alaska. To this end, and to the extent possible under applicable law, it gave its backing to construction of facilities that were more modern, larger, or safer than would have been called for by reconstruction of facilities merely to their pre-earthquake condition. For example, it recommended the reconstruction of rail facilities at Seward, the rebuilding of highways to modern design standards, the complete relocation of the town of Valdez, and the enlargement of several small-boat harbors.

The Commission also made a series of strong recommendations for more research on scientific and engineering subjects, designed to aid in the prediction and understanding of earthquakes and their effects, hence to provide better safeguards to the public in the event of future earthquakes, whether in Alaska or elsewhere.

FEDERAL FINANCIAL ASSISTANCE

The Federal financial assistance that was made available by the Alaska Omnibus Bill and by existing legislation is shown in table 3.

TABLE 3.—*Estimated Federal assistance to Alaska after March 27, 1964, earthquake*

[Slightly condensed from Federal Reconstruction and Devel. Plan. Comm. Alaska, 1964, p. 20]

	Millions of dollars
Federal aid to State and local governments:	
Disaster relief	60– 70
Transitional grants	17– 23.5
Highways	43– 63
Urban renewal grants	25– 40
Purchase of Alaska bonds	10– 25
Planning advances	.3– 0.5
	155.3–222.0
Federal aid to private individuals and groups:	
Loans by Small Business Administration, Depts. of Interior, Agriculture	60 – 70
Forgiveness and other adjustments on outstanding loans	7 – 10
Tax refunds and offsets	20 – 30
	87 –110
Restoration of Federal facilities and direct Federal operations:	
Defense facilities	35.6
The Akaska Railroad	27.0
All other Federal agencies	19.6
	82.2
Total (rounded)	325–414

The fact that the estimated funds made available for reconstruction by the Federal Government exceed the estimates of damage caused by the earthquake is in part due to the provisions to upgrade some facilities—such as highways and small-boat basins—to better than preearthquake condition. In part it also means that the damage estimates do not include losses of personal property and income, whereas these were covered in various ways in authorizations for assistance. Whatever the specific reasons, however, it is generally recognized that the Federal Government must continue to aid in Alaska's economic development for some years to come. The earthquake of 1964, disastrous though it was, can thus be thought of as actually having given impetus to government policies and philosophies that were already in being.

TERMINATION OF THE COMMISSION

The Reconstruction Commission was dissolved by Executive Order 11182 (Federal Register Doc. 64–10178) on October 6, 1964. In its place the President established a Federal Field Committee for Development Planning in Alaska, to be headquartered in Alaska, and a President's Review Committee for Development Planning in Alaska, with the Secretary of Commerce designated as Chairman. The same Executive Order transferred to the Director of the Office of Emergency Planning the residual functions of the Reconstruction Commission with respect to earthquake reconstruction. So long as the President's declaration of a major earthquake disaster remained in effect, the Office of Emergency Planning was given responsibility of "developing coordinated plans for Federal programs which contribute to reconstruction in Alaska and recommending appropriate action by the Federal Government to carry out such plans."

SCIENTIFIC AND ENGINEERING TASK FORCE AND ITS FIELD TEAM

HISTORY AND OBJECTIVES

From the standpoint of the earth sciences and their application to the reconstruction problems of Alaska, one of the most significant of the Commission's actions was the establishment of the Scientific and Engineering Task Force. On April 7, 1964, shortly after the Federal Reconstruction and Development Planning Commission for Alaska was established, it appointed eight special task forces; later it added a ninth one, which is the subject of this section. Each task force was composed of representatives from selected Federal agencies and each was to assist the Commission in developing coordinated plans in a single area of study. The original task forces were:

1. Community facilities
2. Economic stabilization
3. Financial institutions
4. Housing
5. Industrial development
6. Natural resources
7. Ports and fishing
8. Transportation

It became evident that a ninth task force was needed to advise the Commission on those aspects of geology, soils, and related engineering knowledge that had a bearing on reconstruction plans. On April 25, 1964, the Commission's chairman, Senator Anderson, established the Scientific and Engineering Task Force. This group, which became better and more simply known in Alaska and Washington as Task Force 9, was one of the more active among the Commission's task forces. Its recommendations played a significant part in guiding reconstruction decisions in Anchorage, Seward, Homer, Valdez, and Kodiak. Its basic charter follows:

The first objective of the Scientific and Engineering Task Force is to advise the Commission immediately as to the physical parameters in Alaska which should be considered in connection with reconstruction, on the basis of information available now. These recommendations will be submitted to the Commission in a form applicable to reasonable, practical and economical reconstruction.

The second objective for the Scientific and Engineering Task Force is to participate in the conduct of a scientific study. While it is recognized that a decision has not been made as to the manner in which the long-range scientific study of Alaska will be made, this task force fully endorses the need of such a study for the following reasons:

This earthquake, one of the major ones of history, provides a unique opportunity to obtain and make widely known reliable scientific and technical data concerning the cause and effect of seismic disturbances. Concerted effort in the scientific and engineering investigation of the Alaska earthquake and its related phenomena should be executed. The study should include such things as methods to predict the initial shock and after shocks of future earthquakes, a better understanding of the geologic and geomorphic factors affecting earthquake damage, the development of more efficient seismological equipment, better understanding of the generation and propagation of seismic seawaves, better understanding of the engineering aspects of earthquakes, improvement and application of structural engineering criteria for earthquake-resistant structures, and the improvement and application of techniques for minimizing destruction and loss of life in the future.

In practice, the urgencies of the situation were such that the Task Force had to devote nearly all of its energies to the first of the two objectives described above. It did, however, make definite recommendations to the Commission concerning the need for long-range scientific studies (Federal Reconstruction and Devel. Plan. Comm. Alaska, 1964, p. 54–58), and many of the ideas of its members have borne fruit in the plans for further scientific studies by the U.S. Coast and Geodetic Survey, the U.S. Geological Survey, and other public and private agencies.

The Scientific and Engineering Task Force saw the need for a field element, stationed in Alaska, to meet its immediate requirements for geological, earth mechanics, and engineering information relative to zoning and reconstruction problems. On April 30, 1964, it established a Field Team and assigned it two primary duties. The first was to develop and coordinate the execution of specific plans for field studies pertinent to reconstruction. The second duty was to recommend to the Task Force, and through it to the Commission, those areas suitable for reconstruction and to establish interim zoning and design criteria to guide construction in this earthquake-prone region.

The Task Force was authorized to draw on the talents of Federal agencies and their consultants as required to augment memberships in both Task Force and Field Team. Also, in compliance with Executive Order 11150, the Field Team was required to work very closely with State, local, and Federal representatives in the field.

All members of Task Force and Field Team were paid and supported by their parent organizations. The U.S. Geological Survey in Anchorage provided a secretary and office facilities and services, and the Alaska District Engineer's office, Corps of Engineers, was extremely generous in providing facilities for press conferences, reproduction facilities, and many other aids to the Field Team's work.

By courtesy of Senator Ernest Gruening, the Field Team was stationed in his office in the Federal Building, Anchorage. This address was not widely known, but the door was always open to officials or private citizens.

Personnel of the Task Force and Field Team are listed below:

Scientific and Engineering Task Force

S. Theodor Algermissen, Data Analysis and Research Branch, Coast and Geodetic Survey, Commerce

Ernest Dobrovolny, Engineering Geology Branch, Geological Survey, Interior

G. Donald Eberlein, Alaskan Geology Branch, Geological Survey, Interior

Robert H. Nesbitt, Civil Works, Office of Chief of Engineers, Department of Army, Defense

William E. Schaem, Military Construction, Office of Chief of Engineers, Department of Army, Defense (Chairman)

Charles A. Whitten, Office of Physical Sciences, Coast and Geodetic Survey, Commerce

(Note: Because he was also assigned to Anchorage with the Field Team, Dobrovolny played only a small part in direct Task Force work.)

Field Team

Ove Carstensen, North Pacific Division, Corps of Engineers, Department of Army, Defense

William K. Cloud, Seismological Field Survey, Coast and Geodetic Survey, Commerce

Ernest Dobrovolny, Engineering Geology Branch, Geological Survey, Interior

Edwin B. Eckel, Special Projects Branch, Geological Survey, Interior (Chairman)

W. Harold Stuart, North Pacific Division, Corps of Engineers, Department of Army, Defense

In addition to these members, Karl V. Steinbrugge, a consultant to the Coast and Geodetic Survey, worked effectively with the Field Team and added greatly to its strength. On occasion, other members of the Coast and Geodetic Survey, the Geological

Survey, and the Corps of Engineers took part in some of the Field Team's conferences and meetings. They also supplied it with needed facts and opinions based on their own field observations. Dwight A. Ink, executive director of the Commission, kept in close personal touch with both Task Force and Field Team, and gave them constant strong support, as did members of his staff. In particular, Colonels Harry N. Tufts and William J. Penly, who alternated between Alaska and Washington, provided direct liaison between Task Force, Field Team, and various governmental agencies. These men were helpful in many ways and added greatly to morale during some trying moments.

The degree of detachment from their parent organizations varied widely among the participants of both Task Force and Field Team. Some were completely detached, and were thus able to give full attention to their duties for the Commission, whereas others were expected to perform these duties in addition to full-time regular duties for their parent organizations. The responsibilities of the Task Force and its Field Team were so demanding that those members who were nearly or quite relieved of regular duties provided most of the continuity and performed, perhaps, a disproportionate share of the work.

Credit for the choice of such a group of experts and specialists and for their release from other duties must go to the foresight of the heads of their parent agencies. However, the fact that members, despite great differences in technical backgrounds and personalities, could work together as a well-balanced team must be ascribed to chance. Whatever the causes, the results were good.

The Task Force was dissolved on October 6, 1964, at the same time as its parent Commission. The Field Team had already ceased to function as a unit at the conclusion of its final reports on Anchorage and Homer, dated September 8, 1964. Individual members of both Task Force and Field Team continued to carry some responsibilities intermittently for a few months, chiefly by responding to queries from various citizens or agencies as to the application of the Task Force recommendations. Even though there was no longer any effective enforcement mechanism, all recommendations with respect to land classification and use were still being followed by Federal agencies at the time this report was sent to the printer.

ACTIVITIES AND METHODS

As it evolved, the principal responsibility of the Task Force and its Field Team was to make firm recommendations to the Commission and its constituent agencies as to where Federal funds should or should not be spent for ground stabilization, for repair of damage, or for complete reconstruction or relocation of structures and facilities. Despite this seeming preoccupation with financial matters, all members of the Task Force and Field Team kept constantly in mind that their primary responsibility was for the public safety. This fact doubtless led to recommendations that were more conservative than they otherwise might have been.

By the time the Task Force was organized, the Alaska District, Corps of Engineers, had already been designated by the Office of Emergency Planning as the responsible agency for developing most of the basic information that was essential for final recommendations. This situation called for the closest possible cooperation between the users and gatherers of basic data—that is, between the Task Force and Field Team on the one hand and the Corps of Engineers and its consultants and contractors on the other. Much of the credit for the cordial and friendly cooperation that ensued belongs to Col. Kenneth T. Sawyer, Alaska District Engineer, and to Warren R. George, Chief, Engineering Division, Alaska District Office.

The Field Team participated in thorough discussions of the soils-exploration program of the Corps of Engineers when it was being formulated and scheduled with the contractor firm of Shannon and Wilson, Inc. All suggestions and requests made by the Field Team were accepted by the District Engineer, and the responsibility for carrying them out was added to the contractor's job. These suggestions included the drilling of several additional holes and testing of samples therefrom, the electric logging of some exploratory holes and geologic examination of samples, and the completion and equipment of a few holes as observation wells for future studies of the groundwater regime.

Members of the Task Force and the Field Team and scientific colleagues from their parent organizations were welcome at all times to follow the progress of the exploratory work, to examine records or samples, to view laboratory or field tests, or to discuss mutual problems with members of the Corps or its contractors and consultants. Except for thorough reviews of the formal interim reports, however, such contacts were deliberately kept to a minimum in order to avoid interference with the progress of the soil-exploration program.

In all its series of recommendations on parts of Anchorage, the Field Team adhered to a rigid schedule that paralleled a similarly rigid schedule of reports on its soils investigations by the Corps of Engineers and its contractor, Shannon and Wilson, Inc. By joint decision of the Commission, the Alaska District Engineer, and the contractor, the results of the soil program were reported in segments and on specified dates. It is to the credit of the Shannon and Wilson firm and the Corps of Engineers that each of the deadlines was met, despite the fact that the entire schedule called for the telescoping into a very few weeks of work that would have ordinarily required many months.

For each segment of the report-and-recommendation process, the Shannon and Wilson firm presented both written and oral reports to the Alaska District Engineer and his staff. Consultants retained by both the contractor firm and its sponsor took part in the discussions either in person or by telephone. The Scientific and Engineering Task Force Field Team shared in all the presentations and therefore had an opportunity to make suggestions, ask questions, and understand fully the basic facts that had been gathered and the meaning of the recommendations made by Shannon and Wilson, Inc., to the Corps of Engineers.

After each initial presentation, the Field Team commonly met with Corps of Engineers personnel, and generally with one or more of the Corps consultants, to discuss the matter more fully and to translate the findings from the soil-exploration program, first into a set of official engineering decisions by the Corps of Engineers and finally into a map that divided the area under study into various categories of risk from the standpoint of reconstruction. At this point the Field Team drew on the specialized knowledge of its own members or on the knowledge of their colleagues who were engaged in field studies sponsored by the parent organizations.

The final recommendations and risk maps thus represented the combined judgment of a large group of scientists and engineers, each of whom was a specialist in one or more facets of the immediate problem. The Task Force, which presented the recommendations to the Commission for approval, and the Field Team, which reported the final decisions to city officials and the public, necessarily assumed primary responsibility for their validity.

In conference with the Alaska District Engineer, his staff, and consultants to the Corps of Engineers, the Field Team commonly drafted a press notice. The text was dictated to the Task Force chairman in Washington by telephone, and accompanying maps were either sent by airmail or were described in detail by telephone. The Task Force in Washington studied each proposed release, revised it as necessary, and obtained approval of the Federal Reconstruction Commission. This approval, whether given by its executive officers or by the full Commission, constituted a firm policy decision by the Federal Government that applied to all agencies involved in financing the reconstruction efforts.

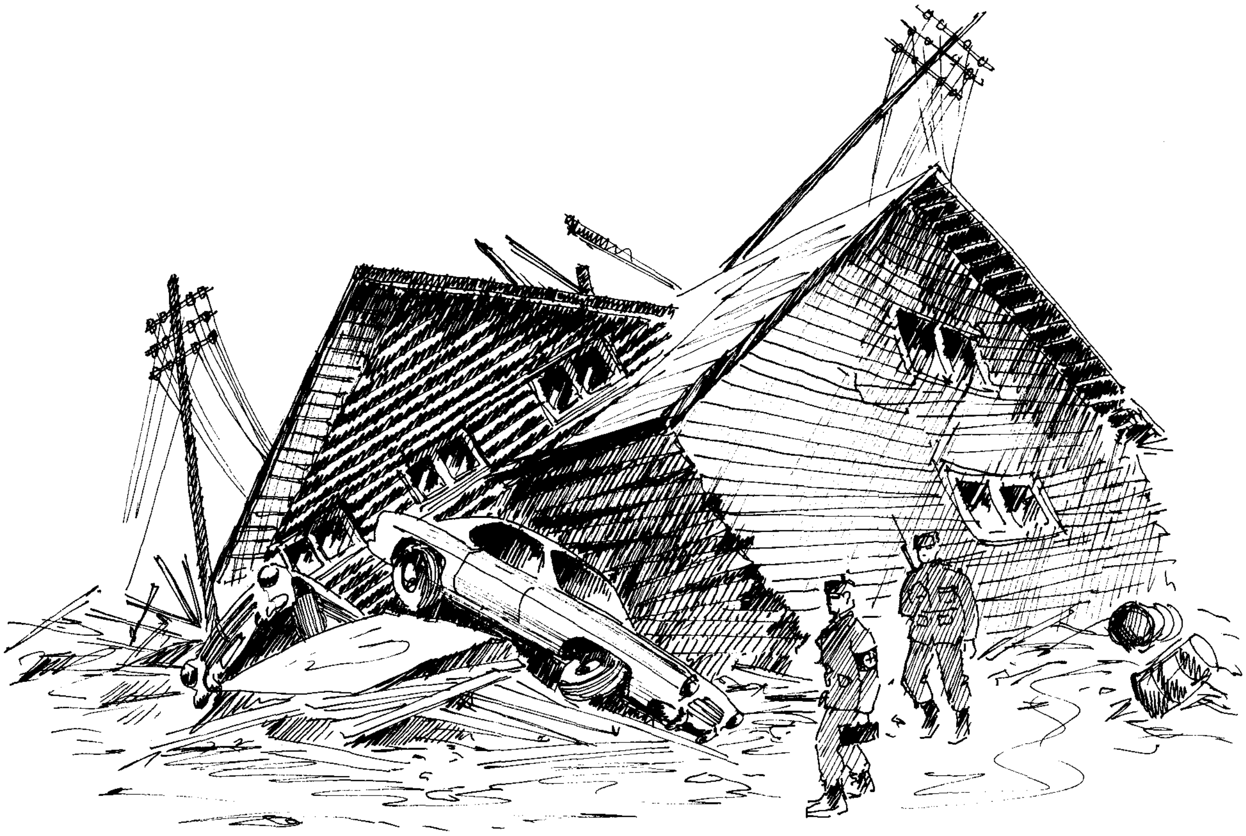
When word of Commission approval of a given set of recommendations reached Anchorage, the Alaska District Engineer's office and the Field Team met with the mayor and other city and State officials; representatives of all local news media were invited. The District Engineer and his staff and consultants explained the recent fiindings of the soil-exploration program, and the chairman of the Field Team announced and explained the Task Force recommendations that had been adopted by the Commission. Copies of the press notices and maps, issued jointly by the Task Force and the Corps of Engineers, were distributed, and the availability of extra copies for interested individuals or groups was announced. The conferences commonly lasted several hours, providing ample opportunity for questions, discussion, explanation of details, and expressions of opinion. As a general rule, the Anchorage City Council met shortly after the close of the press conference and made its own decisions concerning the impact of the Task Force recommendations on the City's activities.

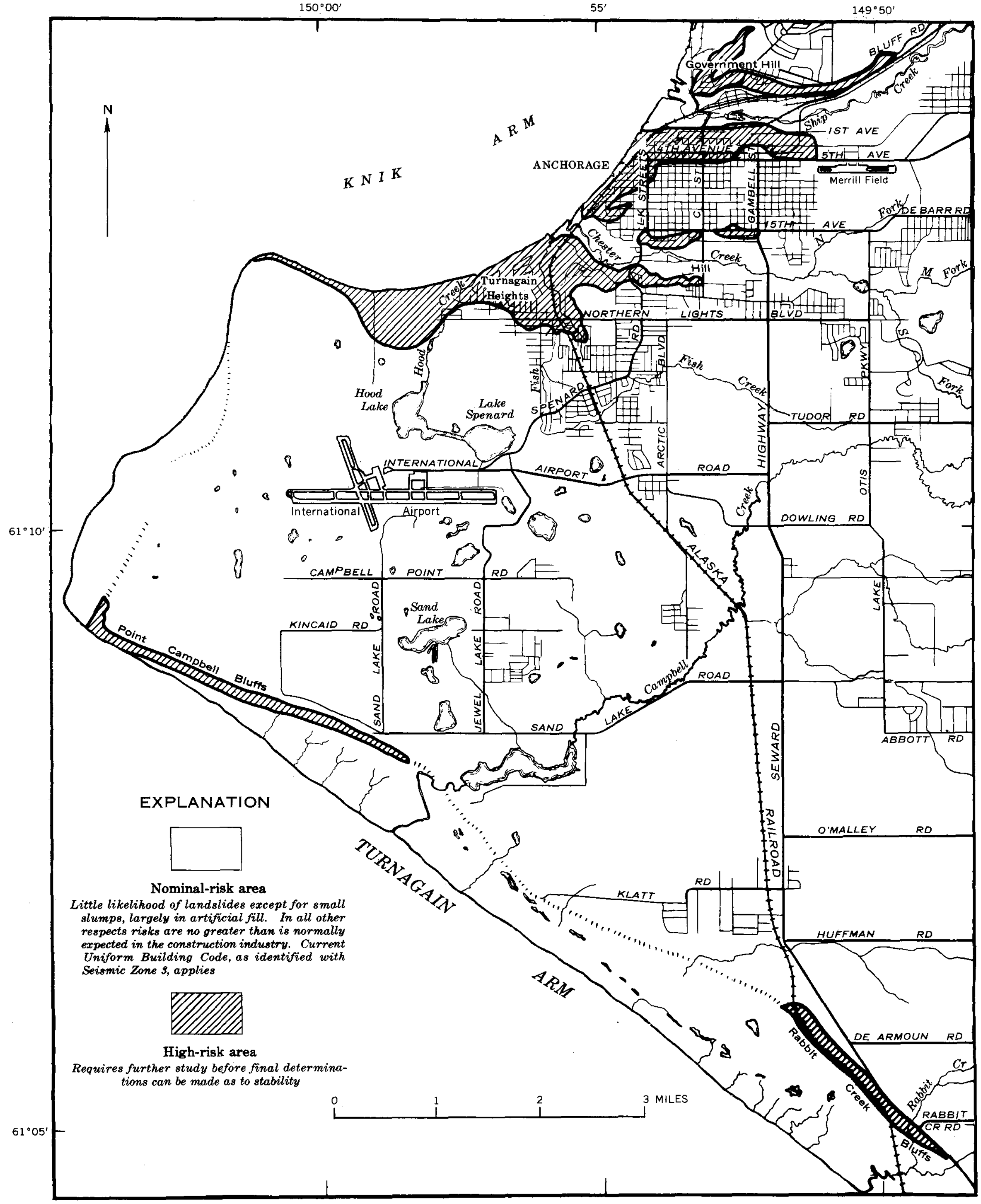
BOUNDARIES OF ACTIVITIES

The Task Force was concerned almost exclusively with the land stability and reconstruction problems of Anchorage, Seward, Valdez, Homer, and, to a lesser degree, of Kodiak. Many other towns and cities had also suffered severe damage, but it was not of a nature that called for the special skills or knowledge of Task Force members in assessing damage or in planning reconstruction. Damage by waves or fire, for instance, was due to transitory causes; there was little that the Task Force could contribute other than to encourage long-range studies aimed at better prediction of earthquakes or their effects, such as tsunamis. Cordova, which had been affected by tectonic uplift and consequent withdrawal of the sea, suffered great losses. So also did towns like Kodiak, where tectonic downdrop and sea waves drowned port facilities or the entire town. Because of our present inability to predict earthquakes and their tectonic effects, such changes in land and sea level can only be considered as permanent or semipermanent in terms of human time. Reconstruction had to be planned and conducted on this basis with little or no interpretation of local geologic or seismic conditions.

Structural engineers, including those on the Task Force and Field Team, recognized very early after the earthquake that, except in the areas of ground failure, those structures designed in accordance with sound design criteria for seismic areas and constructed in accordance with sound construction practices generally withstood the temblor without major damage. The Task Force, therefore, tended to ignore seismic damage to specific structures. Instead, it directed most of its efforts toward problems of land stability—that is, to determining which parts of the several cities were unstable or might be made so by another great earthquake. It was the belief of the Task Force, supported by the Commission, that decisions to rebuild or to raze specific damaged structures—so long as they stood on stable ground—were the responsibility of city officials and private engineers and architects. The responsibilities of the Task Force were more general than this, and were in part discharged by its continual stress on the recommendation that the construction of all new buildings or the reconstruction of earthquake-damaged structures must be in strict conformity with the requirements of the latest edition of the Uniform Building Code for Seismic Zone 3 (Internat. Conf. Bldg. Officials, 1964).

Similarly, but for other reasons, the Task Force played only a small part in reconstruction plans for airports, railroads, or highways. These three kinds of facilities were separately funded, largely by the Federal Government, so there was little need for recommendations from the Task Force to guide the Reconstruction Commission or its constituent agencies. Only at Seward and Anchorage, where The Alaska Railroad's reconstruction problems were linked inextricably with those of the cities, did the Task Force and Field Team act as advisors to railroad officials.





39.—Map showing high- and nominal-risk portions of Anchorage and vicinity, generally excluding military lands. This map and an accompanying press notice were issued May 19, 1964, by the Scientific and Engineering Task Force as the first of a series of interim recommendations to the Federal Reconstruction and Development Planning Commission for Alaska.

TASK FORCE RECOMMENDATIONS

ANCHORAGE

The first set of Task Force recommendations on Anchorage was made by the Field Team to city officials and the public on May 19, 1964. Figure 39 is a simplified and greatly reduced version of the map that accompanied the press announcement. The base for this map and those which accompanied later releases on Anchorage consisted of parts or all of the U.S. Geological Survey topographic map of Anchorage and vicinity at a scale of 1:24,000, with a 20-foot contour interval. Later determinations of "risk" lines were also plotted on a much larger scale for office use so that the relations of risk lines to individual properties could be determined where needed.

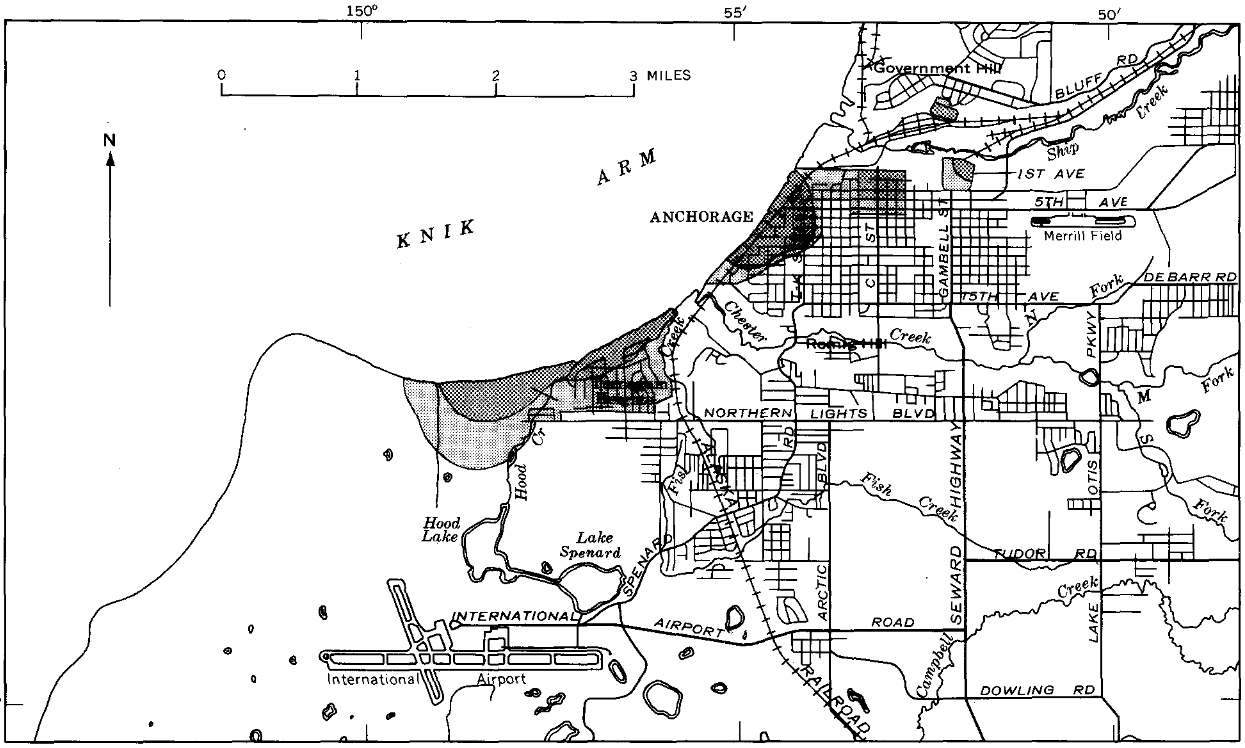
The May 19 map, from which military lands were generally excluded, divided Anchorage into two categories—areas where risks were considered "nominal," and those where risks were considered "high" and were to be studied further before final determinations could be made as to stability. The intent of this first map was to "release" as much of Anchorage and its surroundings as possible so that reconstruction and repair, financed wholly or in part by Federal agencies, could go ahead. The boundaries of the high-risk areas were drawn conservatively, in the hope that they would not have to be enlarged later with consequent damage to public faith and morale or to changes in the Federal lending agencies' plans. With one or two minor exceptions, where new information from the soils-exploration program made it necessary to expand the high-risk areas slightly to protect the public safety, this hope was realized.

Delineation of the areas to be classed as high risk was based on the Field Team's knowledge of the underlying geology as drawn from an earlier report by Miller and Dobrovolny (1959), on personal observations by Field Team members and their professional colleagues, and on the maps prepared by the Engineering Geology Evaluation Group (1964). In the first, as in all later recommendations, the Task Force made it clear that any new building or repair work, regardless of the risk classification of specific properties, should be in strict conformity with the requirements of the Uniform Building Code for Seismic Zone 3 (Internat. Conf. Bldg. Officials, 1964).

After the first report of May 19, four other interim Task Force reports successively reduced the Anchorage areas classified as "high risk, subject to further studies." These reports were based primarily on the Shannon and Wilson explorations, and the resultant recommendations, hence, followed closely the reporting schedule that had been established for the soils studies. The Task Force recommendations of June 26, 1964, dealt entirely with the Fourth Avenue slide area, that of July 8 with the L–K Street slide area and the relatively undamaged downtown part of Anchorage that lies between the Fourth Avenue and the L–K Street slides. The Turnagain Heights slide area was treated in the Task Force report of July 14, 1964, and a miscellaneous group of smaller but significant slides were covered in the report of July 27. This latter group included the Romig Hill, Government Hill, First Avenue (including the Alaska Native Hospital), and Chester Creek areas. The general location of all these areas is indicated on figure 39.

In all the interim reports just mentioned, additional intermediate categories, other than "nominal risk" and "high risk" were introduced. Generally these were aimed at identifying areas where the land was considered unsafe for building unless certain stabilization procedures recommended by the consultants to the Corps of Engineers were put into effect. The term "provisional nominal risk" was used for such areas with or without subcategories to define land on which special restrictions should be applied even where stabilization was effected. This detailed land classification had its value in formulating plans for stabilization and in the search for legal and financial means of doing so, but in practice the Federal lending agencies adopted only two classifications to guide their decisions. That is, land classified as "nominal risk" by the Task Force was open to Federal aid; all other lands, regardless of the qualifying adjectives used by the Task Force, were classed as "high risk" for loan purposes.

The final report of the Task Force was made to city and State officials and to the public on September 8, 1964. It was based on the final comprehensive report to the Corps of Engineers by Shannon and Wilson, Inc., and on thorough discussions in Anchorage by Corps of Engineers staff and consultants, several members of the Commission staff, and most members of both the Task Force and its Field Team. The joint release announcing the final recommendations is reproduced below, and the map that accompanied it is shown in figure 40, next page.



EXPLANATION

Nominal-risk area

Little likelihood of landslides except for small slumps, largely in artificial fill. In all other respects risks are no greater than is normally expected in the construction industry where structures are built on a thick sequence of unconsolidated sediments. Current Uniform Building Code for Seismic Zone 3 applies both to new buildings and to plans for rehabilitation of earthquake-damaged structures. Special engineering consideration should be given to construction near the top, at the base, and on steep slopes, especially wherever the Bootlegger Cove Clay is present. No filling, cutting, or construction should be permitted that will steepen or increase the load on or above these slopes

Provisional-nominal-risk area

Reclassification to "nominal-risk" in these areas is contingent on stabilization of adjacent slide areas or stabilization within the areas themselves. If stabilization is not effected, land will be "high-risk" classification

Unstable area

Land considered unstable in the event of future earthquakes unless stabilization is attained. No new construction and only limited rehabilitation is recommended unless stabilization is attained. It is recommended that after stabilization new buildings on Fourth Avenue, L-K Streets, and Government Hill slides be limited to light structures not over two stories high. No buildings are recommended on the Turnagain Heights slide between the bluff and tidewater, nor on the First Avenue slides, even after stabilization. If stabilization is not effected, land will be "high-risk" classification

40.—Map showing classification of earthquake risk areas, Anchorage and vicinity. This map and a press notice released September 8, 1964, represent the final recommendations in risk classification of Anchorage by the Scientific and Engineering Task Force.

Joint Release—U.S. Army Engineer District, Alaska Task Force 9, Alaska Reconstruction Commission

Final Recommendations on Risk Classifications, Anchorage and Vicinity

For Release September 8, 1964

Task Force 9 made its final recommendations on earthquake-risk classifications to the Alaska Reconstruction Commission.

All parts of Anchorage and vicinity are now classified as "Nominal Risk" or "Provisional Nominal Risk"—subject to successful stabilization of adjacent slide areas. Even if stabilization is effected certain restrictions on construction or rehabilitation in these areas are considered necessary. Federal, State, and City officials are investigating technical means of stabilization and exploring the possibility of financing the needed work for stabilization.

At joint meetings held in Anchorage over the past several days, members of the Task Force from Washington and its Alaskan counterpart field team studied the final comprehensive report to the Corps of Engineers on soil studies by the firm of Shannon and Wilson, Inc. Findings of these investigations were discussed in detail with experts of the Corps, Shannon and Wilson, Inc., and outstanding consultants to both organizations. Based as they are on the best professional judgements of all concerned, these recommendations represent joint concurrence by Task Force 9 and the Corps of Engineers.

For those parts of the 4th Avenue, 1st Avenue, L-K Streets, Turnagain Heights and Government Hill areas that actually slid during the Good Friday earthquake, certain stabilization measures are considered necessary to assure the future safety of these and adjacent areas. It is believed that even though these areas are reasonably safe under normal static conditions, dynamic stresses from future similar earthquakes would cause renewed disastrous movements either in the disturbed areas or in adjacent land. In general, stabilization will probably take the form of regrading of the surface, drainage, some form of buttressing, or some combination of these. It is not within the responsibilities of the Task Force to make specific recommendations as to the methods of stabilization to be applied. These technical and economic questions are under study by Federal, State, and City officials and decisions are expected in the near future.

Fourth Avenue. Specific designs for stabilization of the Fourth Avenue area between Barrow Street on the east and I Street on the west are now being completed under the supervision of the Corps of Engineers. When the stabilization work is completed, all of that area will be returned to Nominal Risk. In the slide area below Fourth Avenue and between Barrow and E Streets, however, construction should be limited to parks, parking areas, and light occupancy structures not over two stories in height. Even for such structures, certain restrictions must be imposed on depths of excavations or fills and on weights of buildings to prevent an unbalance of the buttress which could impair or destroy its effectiveness.

In all of the Fourth Avenue slide area between Barrow and I Streets and bounded on the south by a line running from Barrow Street to F Street midway between Fifth and Sixth Avenues and along Fourth Avenue between F Street and I Street, it is anticipated that normal consolidation of the underlying soils will result in some vertical and horizontal movement. Because this condition can be expected to result in localized differential movement, both horizontal and vertical, particular attention must be given to the design of structures and their foundations so that such movements may be accommodated without undue damage to the building.

L-K Slide Area. Additional studies in the L-K Slide Area have resulted in the conclusion that a significant portion of the area may be returned to Nominal Risk classification if certain stabilization action is taken. These measures may be a combination of slope flattening, drainage, and buttressing. Stabilization would permit the area landward of the graben to be returned to Nominal Risk. In the remaining area toward Knik Arm (seaward), it is anticipated that stabilization, if undertaken, may require removal of some existing buildings. The extent of such removal cannot be forecast until detailed designs for stabilization are completed.

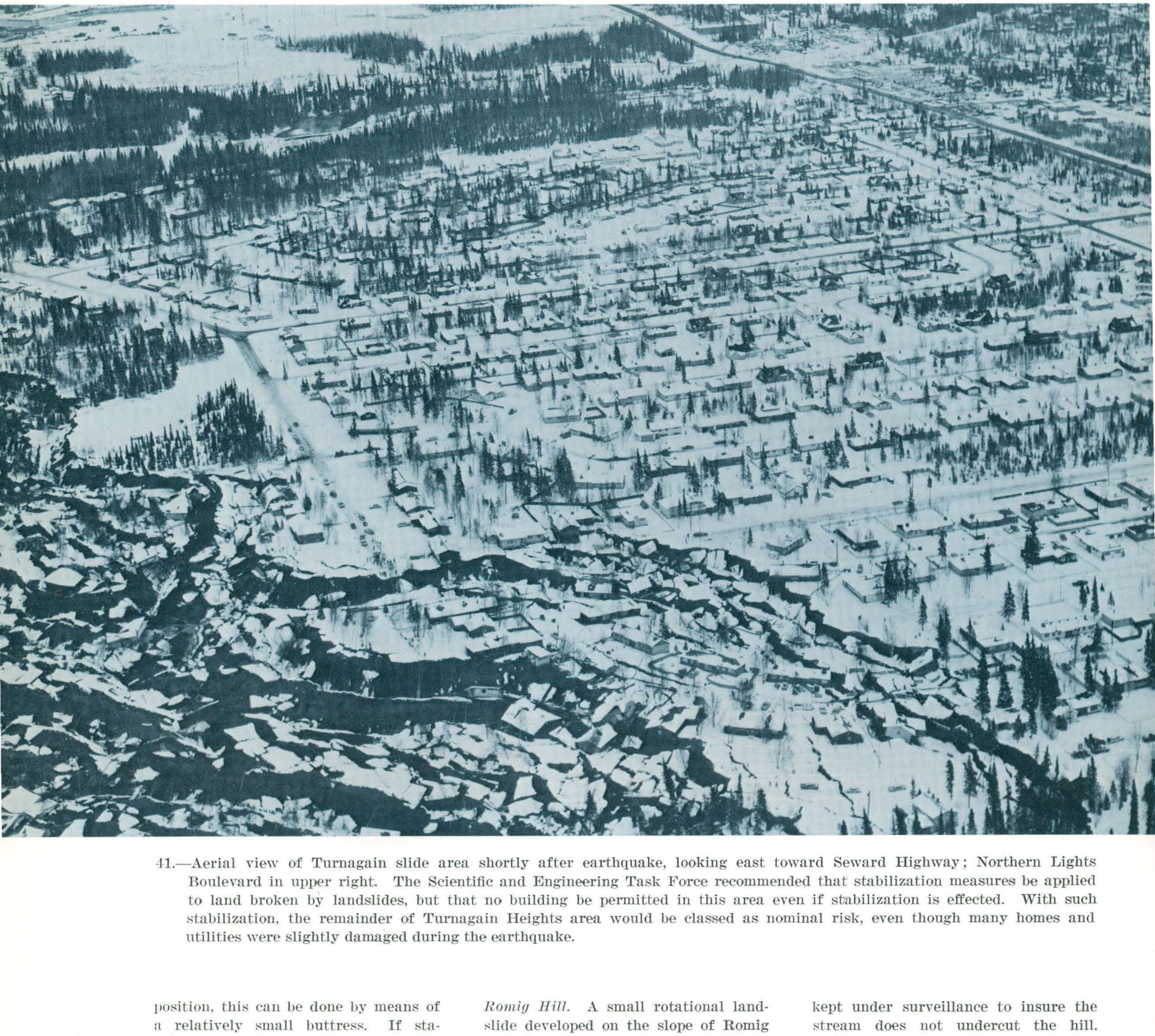
The same design precautions should be applied in the area above the graben line as are outlined for the Fourth Avenue Slide area. In the area below the graben line and toward Knik Arm construction should be limited to light occupancy structures not over two stories in height.

Turnagain Slide. The Turnagain Area has been classified as "Provisional Nominal Risk Area." The area above the present bluff is recommended for unrestricted residential construction after its stability is assured by strengthening of the slide. Because of the complex nature of the slide, no construction other than drives or walks should be permitted on the slide area. The area west of Turnagain Heights shown as "High Risk Final Classification" on the 27 July risk classification map has been included in the Provisional Nominal Risk Area. Among the methods being considered for stabilization are a series of underground charges and sand drains to disturb and cause consolidation of weak clays to provide a buttress, or freezing of a belt of clays for the same purpose. The buttress provided by either of these methods, or a combination of the two, would be located in the slide area below the present scarp (bluff). A test section will be required to determine the most effective method and establish technical criteria for the final design.

First Avenue-Native Hospital. The First Avenue slide, close to the Native Hospital, occurred on a hillside that had probably been oversteepened by excavation at the toe in past years. Recommended remedial measures, all of them comparatively minor, include slope flattening, buttressing and improved surface drainage. If this work is done, the area occupied by the Native Hospital, as well as nearby land, would be classed as Nominal Risk. No buildings are recommended in this actual slide area even if stabilization is accomplished.

No stabilization measures are considered necessary for the area between Barrow Street and the Native Hospital but similar restraints on the use of steep slopes are applicable there.

Government Hill. It is believed that the slide at Government Hill School can be stabilized in its present extent by means of simple grading and drainage. If it is desirable to restore the toe of the slide to its pre-earthquake



41.—Aerial view of Turnagain slide area shortly after earthquake, looking east toward Seward Highway; Northern Lights Boulevard in upper right. The Scientific and Engineering Task Force recommended that stabilization measures be applied to land broken by landslides, but that no building be permitted in this area even if stabilization is effected. With such stabilization, the remainder of Turnagain Heights area would be classed as nominal risk, even though many homes and utilities were slightly damaged during the earthquake.

position, this can be done by means of a relatively small buttress. If stabilization is effected, the land near and above the slide would be classed as Nominal Risk. Construction on the regraded or buttressed slope should be restricted to light buildings not more than two stories in height, and special attention given to their design because of the danger of settlement that can be expected.

Romig Hill. A small rotational landslide developed on the slope of Romig Hill just north of West Anchorage High School. Minor regrading is recommended to stabilize the slope. While no other slopes on either side of Chester Creek failed during the earthquake and no remedial measures are necessary, it is recommended that no fill be placed on the top of the slopes and that meandering of Chester Creek be kept under surveillance to insure the stream does not undercut the hill.

Other than the areas discussed above, all other parts of Anchorage and vicinity are classified as "Nominal Risk." This means that the Task Force considers there is little likelihood of landslides except for small slumps, largely in artificial fill. In all other respects, risks are considered to be no greater than is normally expected in the construction industry in seismic areas where structures are built on a thick sequence of unconsolidated sediments. Special engineering consideration should be given to design and construction on any steep slope or near the top or base of such slope. Examples of such slopes, some of which were earlier classed as "High Risk," are the Point Campbell and Rabbit Creek bluffs along Turnagain Arm, the Point Woronzof bluffs, Romig Hill, the steep slopes on both sides of Ship Creek, and the steep slopes between the City Docks and the top of Government Hill. No filling, cutting or construction should be permitted on these or similar slopes that will steepen them or increase the loads on or above them.

In all areas, design and construction for both reconstruction and new structures should be in strict accordance with the provisions of current edition of the Uniform Building Code for Seismic Zone 3. Particular attention should be given to the foundation conditions existing at each specific site and due recognition taken of design requirements that are imposed by such conditions.

The Task Force 9 Field Team was formed to rate areas of Anchorage and other quake-damaged cities for the Alaska Reconstruction Commission as a guide in developing insurance and loan policies of Federal lending agencies. Its findings are to be considered as advisory but by no means mandatory to City officials. Throughout its work, protection of human life, as well as of property, has been paramount in the Field Team's considerations. Based on the history of earthquakes in Alaska the possibility of another major earth shock cannot be overlooked. With the present state of knowledge, the year, the month, the day, the hour or the location cannot be predicted. Prudence, however, dictates that the public should be protected against another disastrous earthquake, should one occur at any time. For these reasons the field team firmly believes that stabilization and strict adherence to the requirements of good design and construction practice for active seismic zones represent minimal safeguards for the public.

Future Observations. The Task Force strongly endorses recommendations by the Shannon and Wilson firm that a continuing program of technical observations be carried on by local and other authorities. Such observations might provide knowledge of natural stabilization of underlying clay strata and might ultimately serve as a basis for gradual relaxation of building restrictions. These recommendations include the following. Many piezometers (to measure level and pressures of water in the clays beneath the City) were installed during the soils studies. These should be observed on a continuing basis in order to detect changes due to future earthquakes, large or small. Similarly, slope indicators that have been installed to measure even slight land movements should be observed regularly. When regrading and stabilization for the various slide areas is put into effect, a system of accurate horizontal and vertical surveys should be instituted in order to determine changes due to settlement of artificial ground or to movements caused by future earth shocks. Enlargement of the strong-motion seismograph recording net in the Anchorage area, particularly to study the effects of earthquakes on the soft clays that underlie the city, is already being undertaken by the Federal Government.

With these final recommendations to the Alaska Reconstruction Commission, Task Force 9 and its field team have completed their responsibilities in the Anchorage area. Final reports on Seward, Valdez, Kodiak, and Homer have been made to the Commission.

The Task Force 9 Field Team includes Edwin B. Eckel, Chairman, and Ernest Dobrovolny, both of the U.S. Geological Survey, Denver; Harold Stuart, Division geologist, and Ove Carstensen, structural engineer, both of U.S. Army Engineer Division, North Pacific, Portland; William K. Cloud, seismologist, U.S. Coast and Geodetic Survey, San Francisco. William E. Schaem, Office of the Chief of Engineers, Washington, D.C., is Chairman of Task Force 9, which, like the Field Team, is made up of professionals loaned by the Corps of Engineers, the Geological Survey, and the Coast and Geodetic Survey.

Consultants to the Alaska District, Corps of Engineers, are: Dr. Ralph B. Peck, Professor of Foundation Engineering, University of Illinois; Mr. Thomas F. Thompson, consulting engineering geologist, Burlingame, California; Dr. Laurits Bjerrum, Director Norwegian Geotechnical Institute, Oslo, Norway.

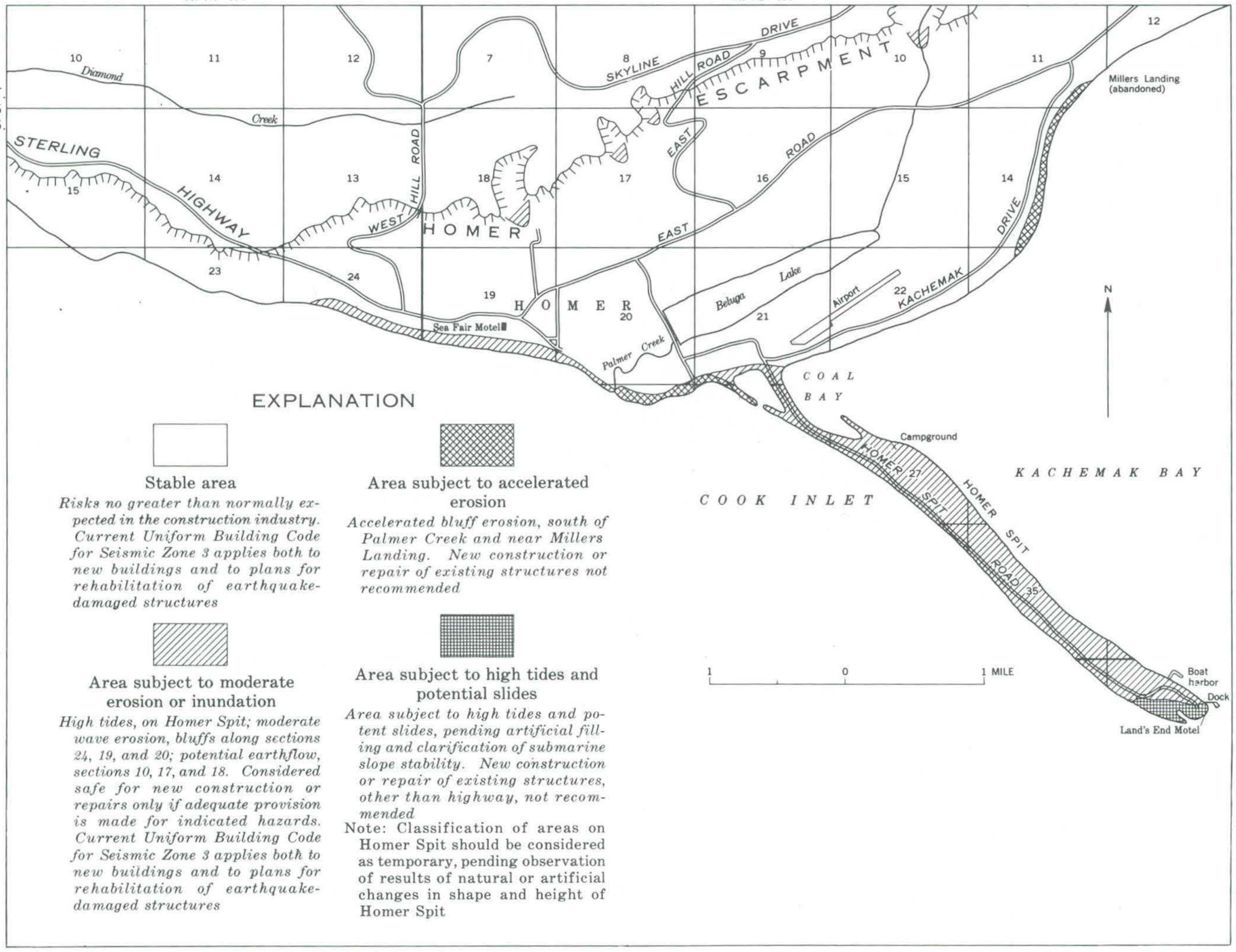
Consultants assisting Shannon and Wilson, Inc., are: Dr. Harry B. Seed, Professor of Civil Engineering, University of California; Dr. Neil Twelker, consulting engineer, Seattle; Dr. Richard Meese, University of Washington; Mr. Robert Spence, consultant, Vancouver.

The Corps of Engineers studies have been under the direction of Colonel Kenneth T. Sawyer, until recently District Engineer, U.S. Army Engineer District, Alaska, and his successor Colonel Clare F. Farley, and Mr. Warren George, Chief, Engineering Division, Alaska District.

Copies of the comprehensive final Shannon and Wilson, Inc., report on the soil studies in the Anchorage area, dated 28 August 1964, have been deposited with City officials by the Alaska District Corps of Engineers. Copies are also available for public inspection at the Office of the District Engineer, Elmendorf Air Force Base. Copies of the final report will be available to the public upon further printing at cost.

HOMER

Task Force recommendations on Homer were released to the town's Mayor on September 8, 1964, and to Anchorage news media the following day. Although the Corps of Engineers was deeply involved in plans for restoring damaged harbor facilities, it had not had to schedule subsurface soil explorations as at Anchorage, Seward, and Valdez. For this reason, the announcement was not made jointly with the Corps, although the Field Team had discussed its findings with the District Engineer. Aside from several brief visits by members of the Field Team, the recommendations were based almost entirely on reports by Roger M. Waller, a member of the U.S. Geological Survey who had been assigned to follow up his earlier studies of the area's ground-water resources with a study of earthquake damages. Waller's com-



42.—Map showing land classification, Homer and vicinity; released to Homer officials on September 9, 1964, by the Scientific and Engineering Task Force.

43.—Homer Spit.

plete report appears as a chapter in USGS Professional Paper 542.

As shown in figure 42, the Task Force report adopted different risk classifications for Homer than had been applied in Anchorage and other cities. Instead of such terms as "nominal," "provisional nominal," and "high risk," it classified areas of Homer as "stable," "subject to moderate erosion or inundation," "subject to accelerated erosion," and "subject to high tides and potential slides." Only for the last two categories did the Task Force recommend against new construction or repair of existing structures.

The difference in treatment of the risk categories at Homer was due to the fact that most of the danger of renewed earth movements there was related to earthquake-induced subsidence of the area and consequent increased erosion by wave action, or to danger of further submarine landslides off the tip of Homer Spit. Moreover, it was realized that any risk classifications at Homer might well be less permanently valid than those at Anchorage, Valdez, and elsewhere. There was not enough offshore information available to permit firm judgements as to the stability of the end of Homer Spit. Also, further uncertainty existed because the future shape and character of the spit cannot be determined until a new pattern of erosion and deposition of spit materials is established. The first of these uncertainties was resolved within a few months as a result of intensive studies off the end of the spit by the Corps of Engineers. These studies produced sufficient evidence that there is little danger of disastrous submarine slides even in the event of another earthquake. Accordingly, late in 1965 the District Engineer recommended that the restrictions be removed. Former members of the Task Force and Field Team were asked to review these recommendations and concurred in them informally. A long-term study of beach-erosion processes was begun in 1964 by the Corps of Engineers. When its results become available it may be possible for the town of Homer to relax even further the restrictions recommended by the Task Force in 1964.

SEWARD

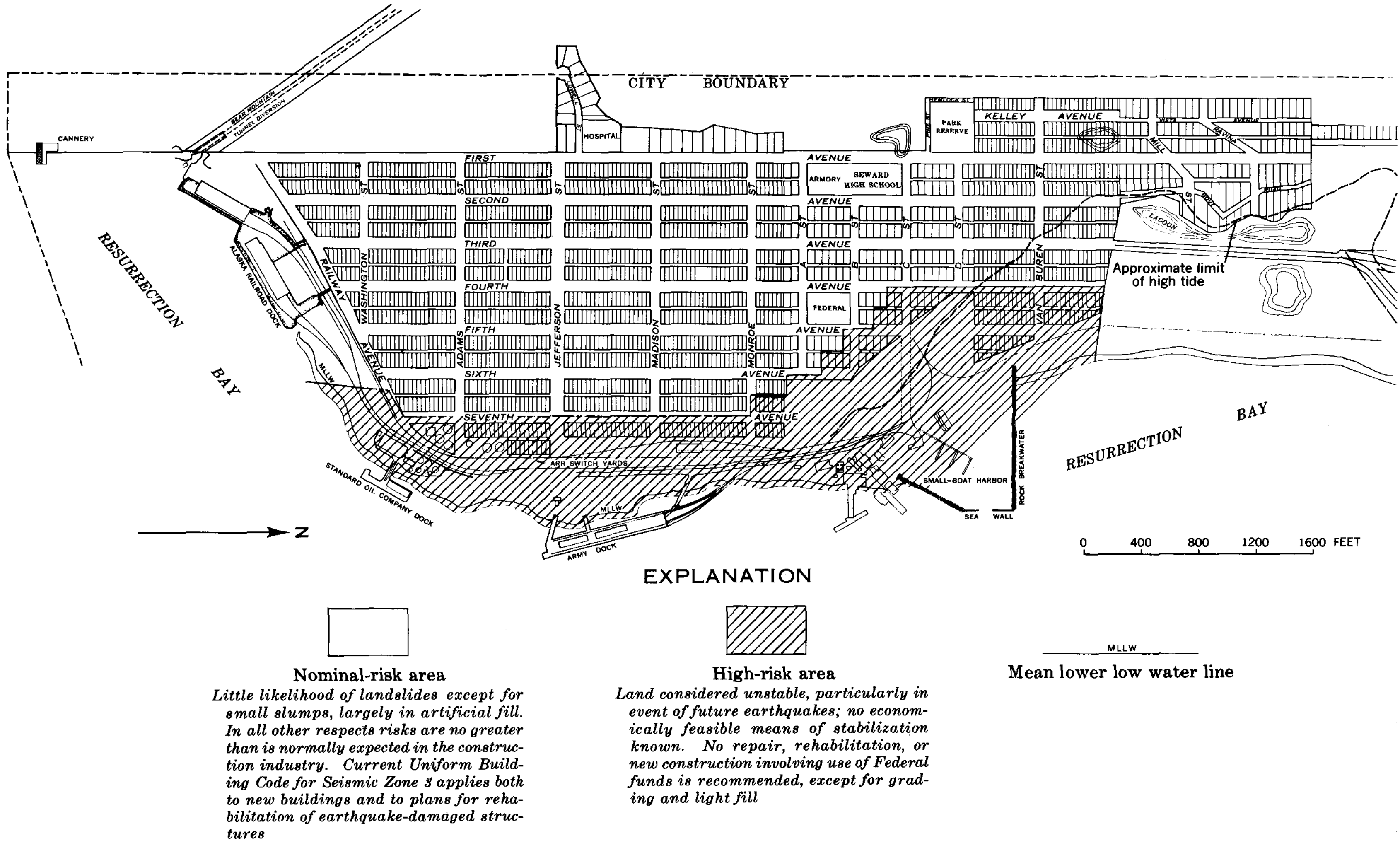
The Task Force made two sets of recommendations to the Commission on Seward; these recommendations were based on visits to the town by Field Team members, on detailed geologic reports by Richard W. Lemke of the U.S. Geological Survey, and on a soils report to the Corps of Engineers by Shannon and Wilson, Inc.

The first report, released to the Mayor of Seward on July 17, 1964, and to Anchorage news media the following day, had to do with the suburban subdivisions of Clearview and Forest Acres and the Eads site at Lowell Point. Inasmuch as the Corps of Engineers was not involved in exploration in these areas, the recommendations were made solely by the Field Team and Task Force, with only informal consultation with Corps of Engineers officials.

The Clearview and Forest Acres subdivisions were classified in two categories — "nominal risk," in which the hazards from another earthquake were considered no greater than are normally expected in the construction industry, and "limited risk." This latter classification included the land that had been strongly fractured by the earthquake. Within such areas, it was recommended that all new foundations be of reinforced concrete and that all concrete or masonry work be reinforced and interconnected. On the basis of Richard W. Lemke's findings that Lowell Point had incurred damage from waves only, none from ground fractures or submarine slides, that area, on which it was desired to build a marine way, was placed in the nominal-risk category. These suburban areas are the more fully described by Lemke in a chapter in USGS Professional Paper 542 of this series.

Recommendations on Seward proper were made in a joint Corps of Engineers and Task Force report, released to the Mayor of Seward on July 24, 1964, and to news media in Anchorage on July 25. These recommendations were based on the findings of Shannon and Wilson (1964b), on the opinions of consultants to the Corps of Engineers, and on the geologic investigations of Lemke, who was considered for this purpose to be a member of the Field Team.

The greater part of Seward was classified as "nominal risk," with consequent eligibility for Federal aid, providing that the current Uniform Building Code for Seismic Zone 3 was followed in all design and construction work (fig. 44, next page). The waterfront area, carefully defined in detail on the map was classed as "high risk," and the firm recommendation was made that it be reserved for parks or other uses that do not involve large congregations of people. The waterfront land within the high-risk line is fractured and weakened as a result of the submarine landslides that destroyed the Seward dock facilities, and the Field Team and Corps of Engineers believed that another large earthquake might cause further submarine sliding within the area designated as



44.—Map showing high- and nominal-risk areas of a part of Seward; released to Seward city officials on July 25, 1964, by the Scientific and Engineering Task Force.

high risk. The line between high- and nominal-risk areas was based in part on the distribution of visible earth fractures, but in greater part on differences in the underlying geologic materials.

KODIAK AND VALDEZ

Recommendations on both Kodiak and Valdez were made to the Commission, but because they were merely endorsements of reconstruction plans that were already adopted and had been publicized, no public announcements were made by the Task Force.

Kodiak was visited on May 20, 1964, by members of the Field Team, who conferred with city and U.S. Navy officials and inspected most of the damaged areas from the air or on the ground. A brief report by George W. Moore of the U.S. Geological Survey was also studied.

Damage at and near Kodiak was caused by tectonic subsidence and flooding by nonbreaking sea surges, plus a small amount of subsidence due to compaction of sediments. Except for harbor facilities, most Navy and civilian buildings were founded on bedrock. Short of another major earthquake which could cause tectonic uplift, renewed subsidence, or seismic sea waves, there are no apparent reasons to expect further trouble. The Field Team, therefore, endorsed plans that were already under way for reconstruction and relocation of town and harbor facilities, subject to its usual requirements that all design and construction be in strict accordance with the Uniform Building Code for Seismic Zone 3. The Task Force agreed with these recommendations and transmitted them to the Commission on May 28, 1964.

The Field Team visited Valdez on May 17, 1964, inspected the existing devastated town and the proposed relocation site, and conferred with city and Corps of Engineers officials. The Field Team also had access to thorough geologic information, both on and off shore, that was being assembled by Henry W. Coulter, U.S. Geological Survey, and Ralph R. Migliaccio, Alaska Department of Highways. Their detailed report on Valdez and its environs appears as a chapter in USGS Professional Paper 542.

The destruction of nearly all of Valdez, the long history of floods from the Valdez glacial stream, and the obvious instability of the shoreline, all argued strongly for abandonment of the townsite. Accordingly, Coulter and Migliaccio had early recommended to city and Federal officials that it would be safer to rebuild town and dock facilities at the "old" townsite, 4 miles northwest of Valdez. The geologic and topographic conditions there were considered to be far superior to those of the present town, an opinion that was subsequently reaffirmed by the soils explorations of Shannon and Wilson, Inc. The Task Force agreed with these recommendations, which had already been adopted by the city, and transmitted them to the Commission. As usual, the endorsement was made subject to the requirement that design and construction conform to the current edition of the Uniform Building Code for Seismic Zone 3.

REACTIONS OF FEDERAL AGENCIES AND LOCAL OFFICIALS

Reactions of the principal Federal agencies to recommendations by the Task Force were uniformly favorable. All its recommendations were adopted as policy with but little debate and without essential change. There was some tendency to soften the policies, such as by permitting loans for repair of buildings within zones designated as "high risk—no Federal funds recommended." This softening was not unexpected. The prime mission of the Reconstruction Commission, hence of the Task Force, was to put Federal dollars and skills to work in helping rebuild Alaska quickly and safely.

Local offices of the main agencies were given policy guidance quickly and firmly by their parent agencies and bureaus. Nearly all fell into line at once and welcomed the guidance provided them. A few local officials at first seemed reluctant to depart from long-established routine procedures of letting contracts, authorizing loans, reviewing reports, and similar activities. Such instances were rare, and none resulted in delays of more than a day or two in adopting the new policies, for the Commission was alert and issued unmistakable orders for compliance from the highest levels of the agencies involved.

As was true of the Federal agencies, the mayors and other city officials of all the towns involved were uniformly cooperative and receptive toward the Task Force and its work. Such cooperation might have been expected because all the towns were necessarily dependent on the Federal Government for funds and for much of the actual reconstruction work, but cordial cooperation went far beyond the necessities that were so imposed. The city officials gave freely of their time and services and they gracefully accepted Task Force decisions—even those that were disappointing.

At all times the Task Force took care to make it clear that its responsibility was only to the Commission and that it had neither right nor desire to dictate to local communities or individuals. The Task Force's firm recommendations as approved by the Commission became binding on its constituent Federal agencies. These same recommendations, however, were in effect only advisory to local officials with respect to zoning, applications of building codes, issuance of building permits, or even to requests for Federal financial aid in initiating ground stabilization measures.

PUBLIC RELATIONS

Coverage of announcements by the Task Force and Field Team by Alaskan news media—newspaper, radio, and television—was uniformly superb. This reaction was particularly welcome because it was so contrary to widely held beliefs among technical people to the effect that "reporters garble everything and seek only for sensationalism." It also fostered a receptiveness on the part of the public that would have been lacking had the news media, inadvertently or otherwise, created a less favorable climate for the work of the Field Team.

Not the least of the departures from normal governmental practice was the fact that all formal decisions made by the Task Force were transmitted to the Commission in the form of proposed press notices. When approved, these were ready for distribution as policy guides to the Federal agencies, and were also ready for release to the public. News media representatives were present at all report conferences between city and State officials, the Corps of Engineers, and the Field Team. At each such meeting, the latest set of recommendations was explained and press notices and accompanying risk maps were distributed.

The Task Force findings were immediately and fully reported to the public by all news media, often by means of extra editions of the newspapers or by special broadcasts. In addition to complete news stories, plus occasional editorial comment, each of the texts and accompanying maps was reproduced in full by local newspapers, and the maps were exhibited on television.

This prompt, complete, straightforward, and sympathetic reporting of the Task Force recommendations by all news media had much to do with a calm and generally favorable acceptance by the public. There were dissidents, of course, for each set of decisions perforce contained bad news for some property owners, investors, or others. But nearly all the public accepted the bad medicine with the good, gracefully if not happily.

Such reliance on the part of the public could not have been achieved without the kind of treatment that was accorded by the news media. This treatment, in turn, was apparently based on a firm conviction on the part of the news media representatives that they were getting the complete truth, good and bad, from the Task Force and its Field Team, and that the decisions were based on their best judgments of real facts, scientifically and objectively evaluated.

In Anchorage there was one long and undesirable hiatus in public information. This extended from the release of the initial Task Force report of May 19, 1964, to the report of June 26, 1964, on the Fourth Avenue slide area. This period of silence, which lasted more than a month, covered the time that it took the Corps of Engineers to mobilize its soils-exploration program, to test the samples recovered by drilling, and to interpret the results. The public, however, wanted and needed more information and reassurance than it received during this period. The situation was possibly even worse at Seward. After the initial cleanup operations there, when funds were spent freely and employment was at a peak, there followed a long period of apparent governmental inaction when local business and employment fell toward the vanishing point. As at Anchorage, the reason for this hiatus in activity and in public information was the necessity of waiting for adequate scientific and technical information on which to base reconstruction plans.

For Homer and Seward, the Field Team first conferred with the mayor of each town, discussing the recommendations and their possible impact and giving him copies of the pertinent press notices and maps. First announcements were made by the mayors through local radio and newspaper media. On the day following such releases, press notices were given to Anchorage news media for broader distribution, and impromptu conferences were held with individual reporters who requested further information.

Recommendations on Valdez and Kodiak were made by the Task Force to the Commission, but inasmuch as they were merely corroborations of decisions that had already been made by the town officials, and had been widely publicized, there was no need to make news announcements to the public.

The favorable reaction of press and public was quite different from that accorded the early reports and recommendations of the Anchorage Engineering Geology Evaluation Group. As suggested in an understatement by Schmidt (1964), the initial reactions of both news media and public to the Group's work were marked by strong tones of dismay and cries that might be aptly paraphrased as "Geologists and other scientists, go home!" The entirely different public reactions to work of the Task Force and its Field Team can perhaps be attributed to four factors: (1) passage of time that had allayed some of the earlier panic, (2) a conviction reached by the news media and transmitted to the public that the Task Force decisions were honest and objective, (3) the local group, competent and objective as it was, was at a disadvantage simply because "a prophet is without honor in his own country," and—perhaps most important—(4) the fact that the Task Force progressively reduced the areas classified as high risk, whereas the Evaluation Group had recommended complete evacuation of all unstable areas.

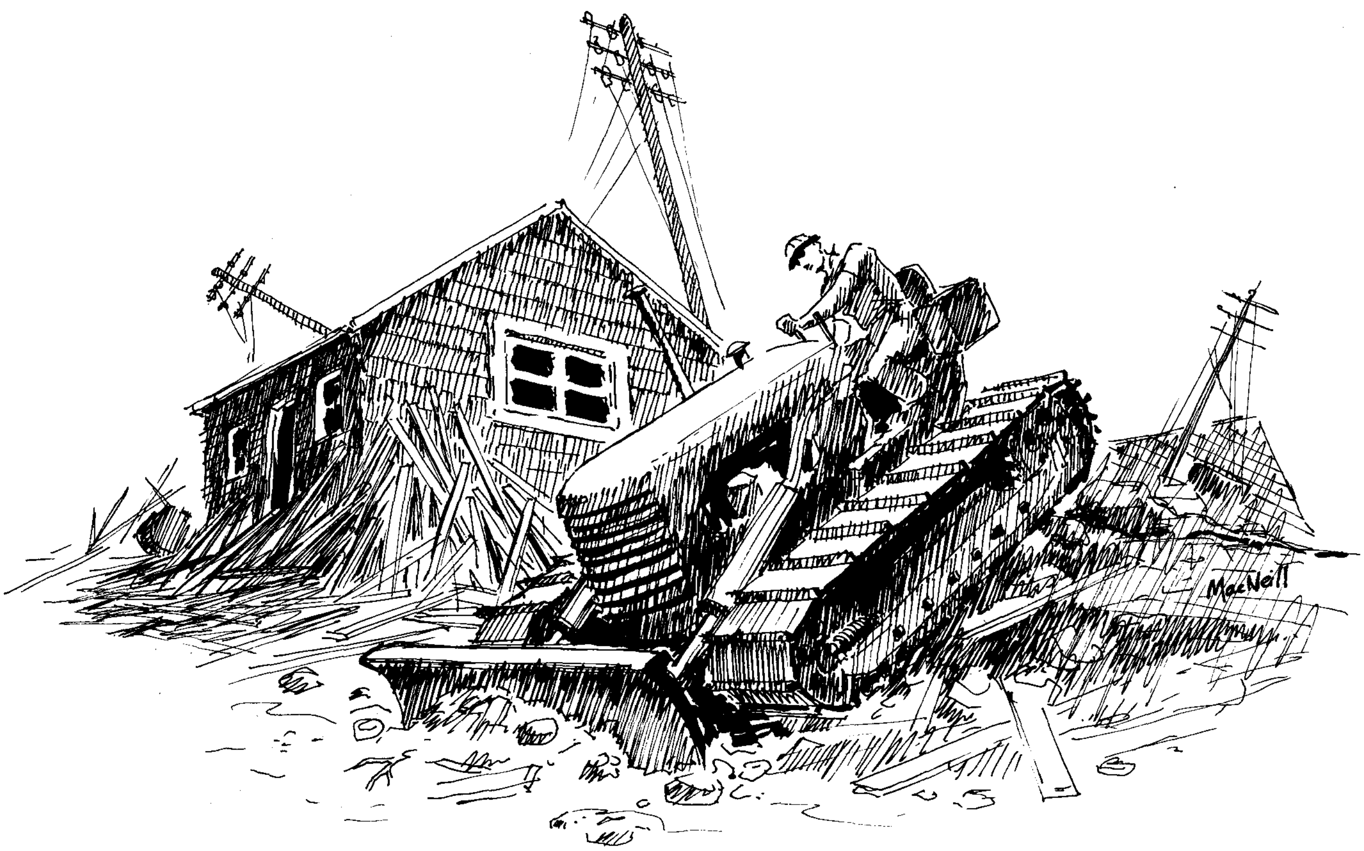
Successful public relations were not attained as easily as the foregoing paragraphs would make it appear. In fact, there were factors working against the Task Force of which its members were not even aware until long after it had disbanded. For an understanding of these factors, we cannot do better than to quote directly from a discerning member of the press. Genie Chance, an editorial reporter for one of the Anchorage radio and television stations, who covered all the activities of the Task Force, was asked to review the manuscript of this paper. Parts of Mrs. Chance's letter to one of the writers are quoted below, with her permission:

In your report, you refer to a "long and undesirable hiatus in public information" that lasted from May 19, 1964, to the report of June 26, 1964. You give good reasons for this hiatus and for the one at Seward. Actually, however, the lack of understanding of Federal Government activities prior to your first report of May 19 had already created difficulties with respect to public acceptance of the Task Force and its findings.

The problem was this: On March 28, 1964, President Johnson declared this a disaster area. The initial reaction of the people was shock. Everyone knew we had been hit hard, but they had no conception of what it was to be declared a disaster area. This is something you read about happening other places, not at home. Apprehension gave way to hope—the first real hope that there would truly be a tomorrow—with the explanations that the declaration merely set the machinery into motion for the Federal Government to move swiftly to give help. This meant that red tape could be cut and the affected communities would be back on their feet in short order.

Of course, people who are already in a state of shock when they are promised immediate help have an entirely different concept of the term "immediate help" than those who are giving the assistance. Consequently, when each day brought news about the arrival of a different group of Federal officials or specialists, the hope for quick action blossomed. But each group soon left Alaska after making a quick tour of damaged areas and after making glowing promises to the public as to the aid that would be forthcoming quickly. After their departure, the fulfillment of their promises appeared to bog down in red tape—the very thing that we had been told would not happen. In retrospect, we realize that the Federal agencies were moving more rapidly and were streamlining their procedures more than ever before. But their speed had to be properly balanced with caution lest precedents be set that could be abused in the future. But to the victims who were adrift in a sea of uncertainty, the slightest delay seemed like an eternity. Initial cleanup and rescue operations had been done expeditiously and effectively, and basic utilities had been restored, but the public wanted to know what the future had in store for them—whether they could rebuild their damaged homes and stores, or whether, indeed, large parts of their towns and cities would be abandoned and rebuilt elsewhere. Employers worried about meeting payrolls and feared that each day of indecision pushed them closer to the brink of bankruptcy. Disillusionment and bitterness took root.

And then, Task Force Nine slipped silently into town. The word was around that you were here—but nobody cared. Everybody had already learned about these groups of specialists from Outside. But they soon found out that this group was different. After a long and continuous diet of platitudes it was rather hard to swallow the bitter truth. And yet, Task Force Nine, unlike the others



who had preceded them, was prescribing just this. Of course, there was an outcry. And it became even worse when there were no progress reports for another five weeks. The silence made the Task Force activities suspect. This created an attitude among the citizens that had to be corrected. You must have public confidence before you can get public cooperation.

This need to get the public on your side was strange to scientists who are unaccustomed to conducting investigations and studies under constant public scrutiny. It was against all your training as scientists and engineers to say anything to the public until the final decision had been reached. It seemed logical to you to assume that unfounded rumors would spread if anything were said in the interim.

However, rumors did spread during the periods of official silence. They were the kind of speculations that undercut public confidence in the studies. A people who are emotionally and economically distraught and frustrated quite often will believe anything—even those who are quite reasonable under normal circumstances. And since there was official silence, unfounded rumors had a fertile field.

During this period, background information could have been periodically released that would have kept the people informed on the project without giving any reason to speculate on the results.

For example, the members of Task Force Nine could have been presented to the public as individual human beings. Their previous experiences could be highlighted to give prestige and importance to the project at hand. This would have built up public confidence in the individuals so that their findings would be more readily accepted.

These "human-interest" stories on the scientists and engineers could be interspersed with stories on each type of study being made in the overall project—how the procedure was developed, where it has been used before, why it is necessary or desirable, how its results will be used in relation to other tests. In the Task Force press conferences, these techniques were explained simultaneously with the release of the results. It was too much to absorb at one time. If the procedures and techniques are understood in advance, the results are a little less startling. Some of the descriptions of Anchorage landslides and what caused them, as described by Shannon and Wilson would have made good full-page picture stories in the newspapers or could have been used on TV stations with explanatory commentary. This could be done in advance of the announcement of the test results and recommendations. And this could be used to occupy the minds of the public while the scientists and engineers are performing their studies. This would also release them from much public pressure.

We of the news media were probably greatly at fault in this area. We could have dribbled this information out during the periods of lull. But it was a new experience for us, too. And you will very seldom go into a disaster area and find yourself dealing with local people experienced in dealing with such matters. When everything was released at once, the most important part was the result and recommendation of the Task Force. Naturally, we went into this thoroughly. But, by so doing, we minimized the story of how the results were obtained. Hereafter, I recommend that the horse be put before the cart—create interest in the personnel and the procedures first. Then the findings of the scientists and engineers and the procedures will bear more credence. And, too, this method would leave little time for the public to wonder what's going on and to start rumors.

My suggestions are not an indictment of Task Force Nine, the Field Team, or any other agency. But, perhaps, this review of some of the obstacles your group faced and conquered will help forestall similar problems in any such assignment in the future.

There was a job of great magnitude and unprecedented difficulty to perform, and it was handled admirably. Although the work was begun in a climate of resentment, the Task Force and Field Team very successfully overcame public suspicion and bitterness. And this was no easy task.

EVALUATION OF TASK FORCE EFFORT

In the certain knowledge that the Federal Government will one day be called on for massive assistance in similar disasters somewhere in the United States, it seems well to record our thoughts, positive and negative, as to the concept and accomplishments of the Scientific and Engineering Task Force.

We feel that the Task Force was a very worthwhile component of the Government's reconstruction effort, both in concept and accomplishment. This view is perhaps prejudiced, based as it is on the opinions of two writers who were intimately associated with the venture from its inception. But the validity of our personal opinions gains substance from the favorable reactions of the Commission and its chairman, and those of the Federal agencies, local officials, and the public. The greatest single factor in the success of the Task Force concept was the unfailing support that was accorded it by the Reconstruction Commission and its constituent agencies.

Some of the shortcomings that marked the Task Force operations were unavoidable, in that they resulted from the hurry and confusion that would characterize the early recovery period after any great natural disaster. Thus, there were many times when the Field Team and Task Force wished for more basic data, for more time to study the data that were available, or for more opportunity to make their own independent field observations. Time schedules simply did not permit the realization of these wishes, so that final judgments represented the best possible compromises between available knowledge and available time.

As described above, the Task Force early adopted a guiding policy of basing all its decisions and recommendations on scientific and engineering grounds—and of avoiding economic, political, or emotional ones so far as possible.

This general policy is to be recommended to any similar future organization, together with a warning as to the pitfalls that may develop if the policy is ignored.

Good and continuous relations with the press, and through it with the public, are considered essential to the success of any future Task Force effort of the sort described here. The experience of the Scientific and Engineering Task Force was excellent in this regard. Even so, there were some shortcomings in public relations, and future groups might do well to heed the lessons learned in Alaska. These are described in the section "Public Relations" (p. 65).

The direct assignment of Task Force and Field Team members to the Reconstruction Commission, with freedom from administrative or technical control by their parent agencies, was largely beneficial. It permitted much faster actions than would have been possible had decisions required coordination and transmittal through the several parent agencies. The fact that the Task Force was free to call on services and knowledge from its parent organizations also gave it strength and breadth that it would not have had otherwise. The availability of this help was well known to the Task Force, and was drawn on freely. Field personnel of the parent agencies, however, were possibly too poorly informed as to the responsibilities and restrictions imposed on the Task Force and Field Team. All such personnel were happy to contribute freely of their knowledge or services. Some of them, however, did not fully realize that the Task Force was only advisory to the Commission, hence were disappointed that it took less than positive action at times. This kind of minor misunderstanding might have been avoided by improved lines of communication.

The desirability of an advisory group of scientific and engineering specialists, separate from the group charged with gathering the requisite basic information, may be open to some debate. There is much to be said in favor of providing for independent objective judgments, which would be difficult to obtain from those involved in the pressures of day to day operations. But such pyramiding of advisory and research groups, aside from its overtones of bureaucracy, adds one or more delaying steps in reaching decisions, and it could conceivably have led to confusion, contention, or jealousies. None of these eventualities occurred during the Alaska earthquake studies, largely because of the good will of all those involved.

Both Task Force and Field Team were of about optimum size and composition for efficiency and responsiveness to needs. In view of the emphasis on soils engineering that characterized the exploratory program, it might be argued that soils-engineering talent should have replaced some of the geologic skills directly represented on the Task Force and Field Team. This argument, however, would lead to fruitless discussion as to the overlapping fields of soil mechanics and engineering geology; such a discussion is not appropriate here. The fact is that the best knowledge available in both fields was brought to bear on all problems, through the Corps of Engineers, its contractor and consultants, and the Task Force Team and its own advisors.

The abrupt early termination of the Reconstruction Commission and its Task Forces had both good and bad effects. It served to relax or remove the pressures of Federal dictation and control as soon as practicable, freeing the people of Alaska to shoulder most of their own burdens in their own way. On the other hand, it left dangling a series of firm Task Force recommendations with no very clear plans for enforcement. Moreover, there were no procedures set up for adjusting the recommendations or of relaxing restrictions after ground stabilization measures are effected.

ACTIVITIES OF THE CORPS OF ENGINEERS—CLEANUP AND EARLY RECONSTRUCTION

By ROBERT E. LYLE[3] and WARREN GEORGE[4]

INTRODUCTION

The Alaska earthquake, which occurred at 5:36 p.m. on Good Friday, March 27, 1964, was the greatest single disaster in the State's history. The joint military-civilian effort in cleaning up the debris, providing emergency facilities, and going on to rebuild permanent replacement facilities was one for which all participants may be justly proud.

This paper concerns the activities of the U.S. Army Engineer District, Alaska, of the Corps of Engineers (referred to hereinafter as the "Alaska District") in connection with their assigned responsibilities in solving the complex problems resulting from the catastrophe. The responsibilities of the Alaska District in reconstruction activities were directed by Colonel Kenneth T. Sawyer, District Engineer until August 22, 1964, at which time he was relieved by Colonel Clare F. Farley, the succeeding District Engineer. Colonel Byron M. Kirkpatrick was Deputy District Engineer until June 1965, and Mr. Warren George was Chief of the Engineering Division during the full restoration period.

The Corps of Engineers was formally requested to assume the responsibility for repair and restorative work in the disaster area within the purview of Public Law 875 by letter dated March 31, 1964, from the Director, Office of Emergency Planning, Executive Office of the President, Washington, D. C. The Corps of Engineers proceeded with the repair and restorative work through its own personnel and by contract, where necessary, immediately upon receipt of individual requests from Office of Emergency Planning. The requests were initiated as a result of appeals for aid from public entities and were relayed to the Alaska District for action through the North Pacific Division of the Corps of Engineers, U.S. Army. The Office of Emergency Planning received requests for aid from the State of Alaska; the cities of Anchorage, Seward, Valdez, Homer, Cordova, Seldovia, Kenai, Girdwood, and Whittier; the Palmer and Anchorage school districts; and the Spenard Public Utility District. The requests were transmitted to the Alaska District for necessary action. The Federal Reconstruction and Development Planning Commission was extremely active during the reconstruction phase, and it was for Task Force Nine of this commission that the Alaska District undertook the extensive soils investigation in the Anchorage, Seward, and Valdez areas. Similar requests were received from the Department of Interior's Alaska Railroad, the Alaska State Housing Authority acting for the Urban Renewal Administration, the Alaskan Air Command, and the U.S. Army, Alaska.

The scope of the work accomplished under the provisions of PL 875 generally falls in the following categories: (1) performing protective and other work essential for the preservation of life and property on both public and private lands; (2) debris and wreckage clearance; (3) temporary repair to and temporary replacement of public facilities, except as reserved to other Federal agencies; and (4) furnishing technical assistance, execution of surveys, and submission of recommendations and reports to Office of Emergency Planning relative to PL 875 activities.

The District operations in connection with PL 875 were conducted primarily as civil-works activities. Administrative and professional judgments are required in determining the eligibility of projects under this law, particularly as it relates to emergency repairs and temporary replacement. PL 875 was interpreted as intending to provide Federal assistance to alleviate damage, hardship, and suffering occasioned by disaster, but not to provide for improvement or betterment.

The work specifically assigned the Corps of Engineers consisted of demolition and debris clearance; emergency restoration of public utilities; and the rebuilding of docks, schools, hospitals, and other essential facilities in most of the damaged areas of the State.

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The Corps of Engineers participates in restoration of channels, breakwaters, and harbors through funds appropriated annually under the "rehabilitation" category. This was the source of funds utilized in restoration or rehabilitation of the Kodiak and Seldovia harbors as well as dredging of the original Cordova harbor. These three harbors were still intact after the earthquake and thus qualified for rehabilitation funds.

At Homer, Seward, and Valdez, complete new harbors were required; consequently reconstruction of new harbors equivalent to the previous installations was accomplished under PL 875. Expansion was also desired and economically justified; therefore, the Corps of Engineers, with funds appropriated by Congress in the supplemental Alaska Omnibus Bill, financed the expansion part of these three harbors and also the expansion work at Cordova harbor.

In addition to the work listed above, PL 87–99 funds were utilized by the Corps in furnishing the engineering support requested by the Office of Emergency Planning for that phase of the program. This large item included supervision and administration costs for construction contracts and support for all other types of PL 875 work.

The Alaska District organized three new Resident Engineer Offices, at Anchorage, Valdez, and Seward, and a number of project offices at the smaller towns to maintain close contact with the communities in developing projects. Contracts were awarded for debris clearance, demolitions, and such emergency repairs to sewers, water supplies, communications, and power-distribution systems as were necessary for minimum standards of health, safety, and the conduct of business. Concur-

45.—Collapse of Fourth Avenue near C Street, Anchorage, due to landslide caused by the earthquake.

rently, some 65 engineers in emergency disaster teams were sent to Alaska from the Walla Walla, Seattle, and Portland Districts of the North Pacific Division, to develop the scope of specific projects and make cost estimates for work requiring more deliberate design.

The Alaska District negotiated many contracts with architect-engineer firms to design projects defined by the survey teams. A sizeable cost-plus-fixed-fee contract was negotiated with a master architect-engineer firm to augment the engineering staff of the Alaska District to insure that the designs conformed to standards and met community needs. All contracts with specific architect-engineers were negotiated by the Alaska District engineering staff. To as large an extent as possible, local and Alaska architect-engineer firms were used to accomplish the design in order to utilize local resources as much as possible in helping the damaged economy, to effect closer control of the work, and to speed up the construction effort. This architect-engineer effort required a great deal of criteria assembly, definition of scope, and close contract control to insure appropriate end results.

One of the major problems in every community, and particularly in the smaller ones, was the serious disruption of the local economy. Destruction of established businesses reduced employment drastically and threw people out of work when they could least afford it. To provide urgently needed employment and to channel as much of the restoration work as possible to the hard-hit local residents, construction contracts were sized to allow the maximum participation by local bidders. Utility contracts were put out in successive increments. This approach had an added advantage in allowing the architect-engineers to produce bidding documents earlier than if large segments of the utility system were included in one contract; it was also effective in shoring up the local economies and at the same time accomplishing the assigned mission quickly.

DAMAGE SURVEYS

The immediate problem posed by the earthquake was to determine the extent of damages to civilian communities, to military installations, and to transportation facilities, including rivers and harbors. Engineer disaster teams were organized on a crash basis to survey the damages and furnish guidance for emergency restoration to insure public safety, maintain health, and to restore communications and economic intercourse. Within a few days all areas had had reconnaissance coverage by these groups. Survey teams used light aircraft and wheeled surface vehicles in their checkup. Particular emphasis was placed on damage assessment of the affected schools and hospitals in all the communities. Many schools suffered severe structural damage and were declared unsafe in part or whole. Undamaged or lightly damaged schools were reoccupied only after a very close verification of the structural adequacy by the Alaska District. Actually, owing to the seriousness of follow-on shocks, each building was checked at least twice and some were checked three times.

A vital and most important part of the program was the assembling of adequate technical information to serve as a basis for engineering decision making. As stated, engineering firms were employed by contract to help in this work. Several of the contracts were for inspection of water and sewer systems and underground and overhead electrical distribution systems, to obtain data on which to base the design for restoration and reconstruction. Obviously, detection of all damage could not be done quickly with assurance of complete coverage, without special equipment. It was, therefore, necessary to depend upon visual inspection for accomplishment of the more urgent repairs on an emergency basis. Provisions for testing certain water mains were included in the contracts for inspection, and test requirements were established on the same basis as would be used for new construction. Acceptance of lines tested on this basis gave the communities assurance that the repaired system would be as trouble-free as possible.

In the interim before temporary water lines could be laid, or emergency repairs made to the permanent water systems, the furnishing of potable water to the inhabitants was a major consideration. The U.S. Army, Alaska, set up water points in all the areas of waterline damage. This procedure assured a safe chlorinated supply of drinking water until surface lines were laid or permanent lines repaired.

The determination of the location of damage and the delineation of repair methods for sewer restoration were more complex than for the water-distribution system. Damage to sewers was not confined to slide areas, nor was it obvious at the ground surface as breaks in the water mains often were. Photographic and direct visual inspection of the sewers was employed to determine the location and nature of individual line breaks. Manholes were inspected at the same time that camera crews were using them for access to the sewer. Photographs were made at 3-foot intervals along the pipe in all storm and sanitary sewers less than 24 inches in diameter where damage was suspected to exist, and direct visual inspection was undertaken in all such sewers 24 inches and larger.

Approximately 700,000 linear feet of storm and sanitary sewers was inspected by contract in the Anchorage area alone during the summer of 1964. Photography was of two types, one being the "inspectoline" process, in which a 16-mm single-frame automatic camera with stroboscopic flash equipment was used. This equipment is suitable for pipelines 8 inches and larger, and it was found that color film gave better results than black and white film. The other method utilized a 30-mm double-frame stereoscopic automatic camera, equipped with stroboscopic flash equipment and a heating device to prevent lens fogging; this method produced black and white stereo-paired photographs of excellent quality.

CLEANUP AND RESTORATION

ANCHORAGE

Anchorage, the largest city in Alaska, has a metropolitan population of approximately 100,000. It is on a bluff overlooking Knik Arm, a part of Cook Inlet.

Principal damage to the Anchorage area was caused by landslides, ground subsidence, and fissures resulting from the earthquake. The city was not affected by tidal waves. The major destruction occurred in the main business district along Fourth Avenue, in the K–L Street area west of the business district, in the Government Hill area adjoining Elmendorf Air Force Base on the north side of the city, and in the Turnagain Heights residential area overlooking Cook Inlet south of the city.

Priority attention was given to debris clearance and utility repair. The emergency design was characterized by on-the-spot development, initiation of work by letter contract, and control by a field force into which a design and cost capability was integrated. Emergency repairs were made to the utilities on a temporary basis until more definite information could be gathered on which to base the final remedial solution.

The USAF Hospital at Elmendorf Air Force Base, which was evacuated immediately after the earthquake, was reoccupied in a week. The Presbyterian Hospital also was evacuated to permit cleanup but was reoccupied in a shorter time period. The Providence Hospital, located in an area less affected by the quake, continued in operation. These last two hospitals are privately managed facilities. The public psychiatric hospital, in the same area as the Providence Hospital, continued in operation.

Emergency work was completed on the municipal dock, on the backup storage area, and on other damaged port facilities including construction of a temporary petroleum offloading facility in the Anchorage harbor.

SEWARD

Seward, on the Kenai Peninsula about 80 miles south of Anchorage, has a population of only 3,000 in the city and surrounding district, but occupies an important place in the economy of the State. It has an ice-free harbor and is the southern terminus of The Alaska Railroad and the Anchorage-Seward Highway.

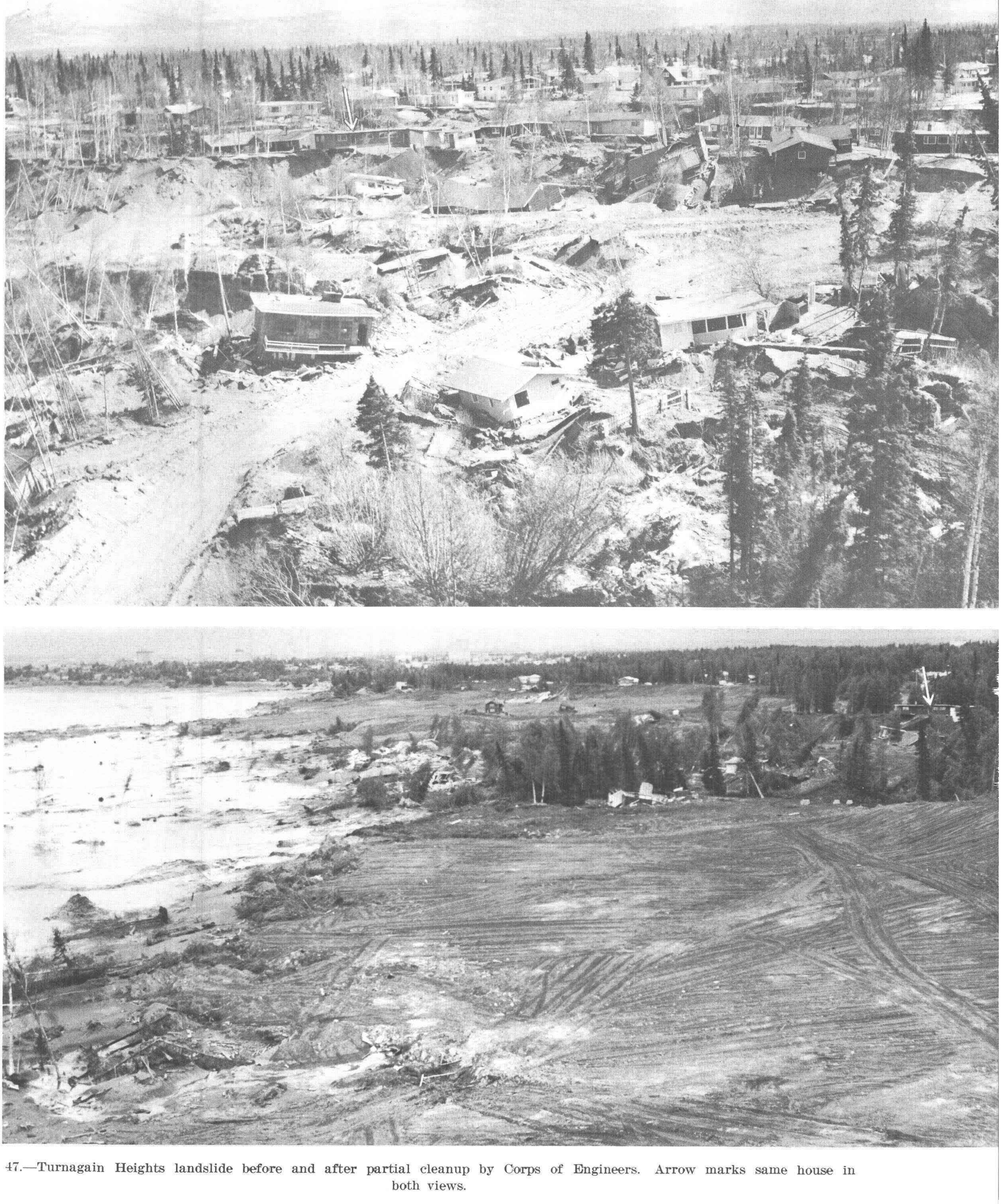
The city's preearthquake economy was to a considerable extent dependent on its transportation industry which included extensive railroad yards and freight staging areas. Fish-processing plants and storage facilities for petroleum products were also a part of the economy. All were located in the waterfront area.

Massive destruction of facilities along the waterfront was inflicted by submarine slides and tidal waves. An immediate result of the seismic shocks was the rupture of fuel storage tanks. The fuel quickly caught fire and flames spread over half a mile of waterfront. Submarine landslides caused the subsidence of about 4,000 feet of the waterfront into Resurrection Bay, and took with them storage tanks and other waterfront facilities including the municipal dock.

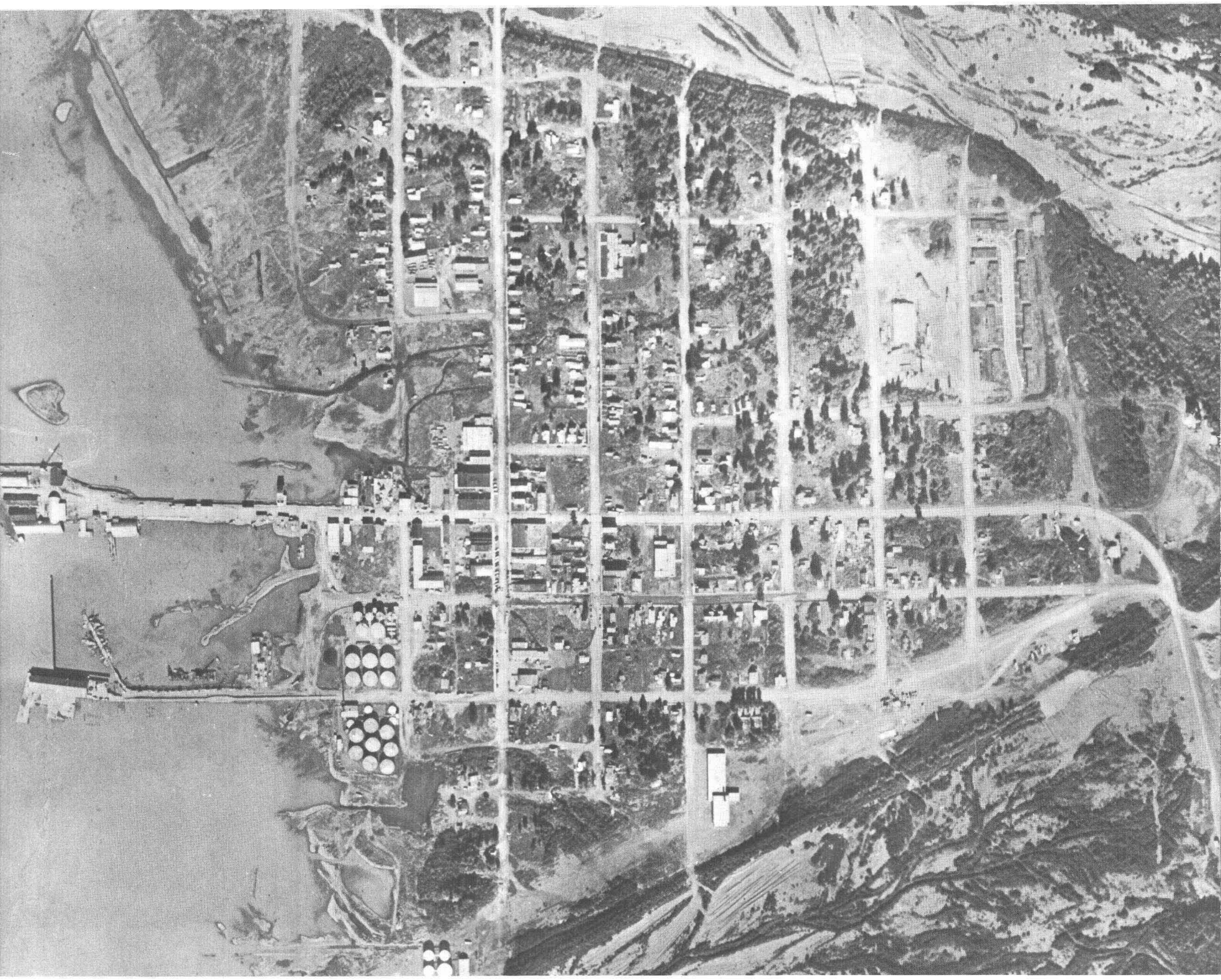
Tidal waves generated by the earthquake to a height of 30 feet destroyed the railroad docks and leveled the remaining facilities along the waterfront. Buildings, boats, and railroad cars were added to the debris already deposited by ground shocks and slides. The industrial area along the waterfront was completely destroyed and the petroleum offloading facilities, canneries, and docks were swept away. The standby powerplant was destroyed and the small-boat harbor was rendered useless.

Emergency repairs to utilities were initiated by letter contracts and were so programmed that they were progressively operational in a very short time. An initial contract for emergency debris cleanup was issued early in April 1964, and additional contracts have been issued periodically.

46.—Aerial view of Fourth Avenue slide area, Anchorage, after initial cleanup of debris, looking northwest; Westward Hotel in top center.



47.—Turnagain Heights landslide before and after partial cleanup by Corps of Engineers. Arrow marks same house in both views.

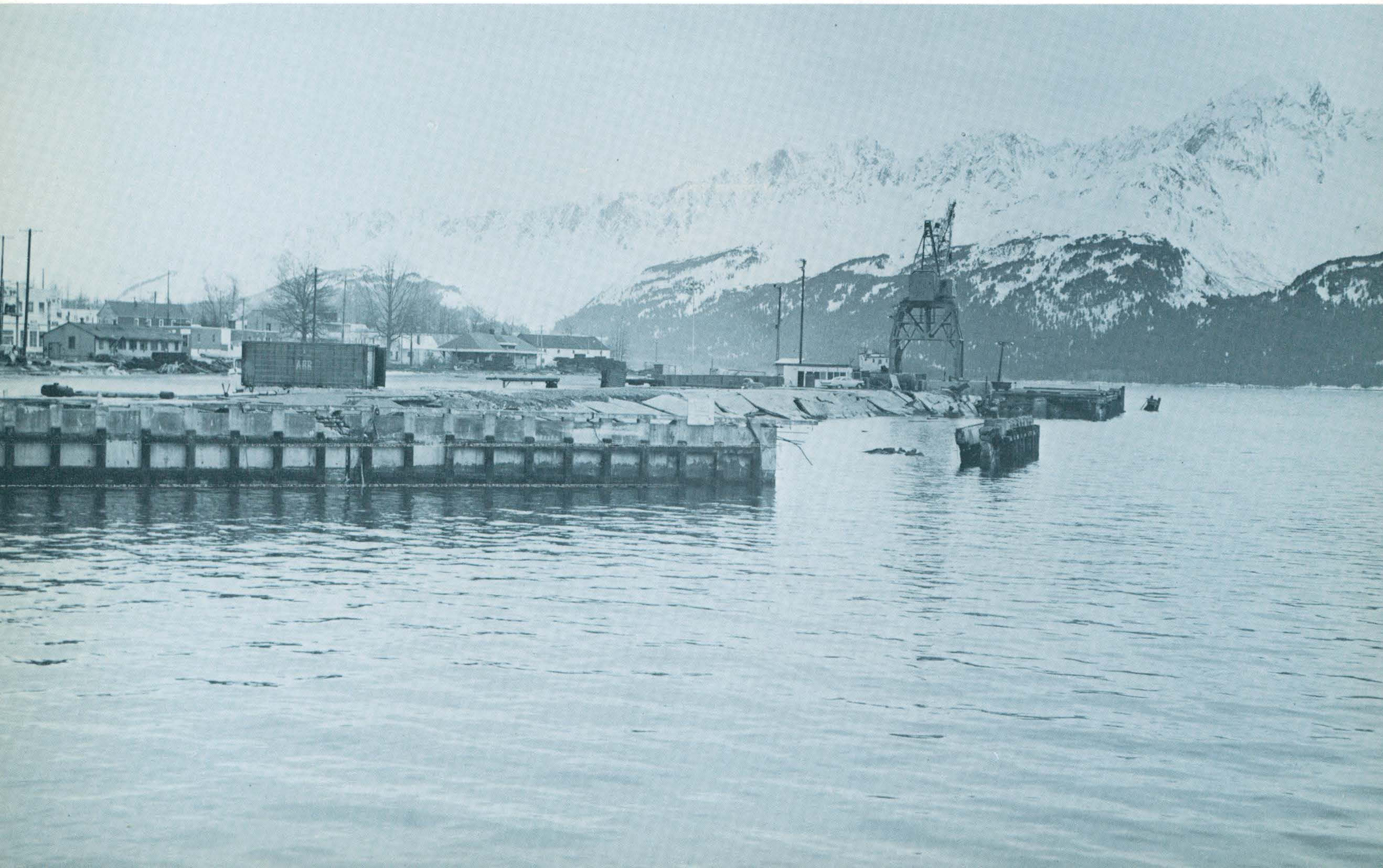


48.—Aerial view of Valdez showing waterfront and city *before* the earthquake, looking northwest. Note the dike built around the town to protect it from floods of the Valdez glacial stream.

49.—Aerial view of Valdez showing waterfront and city after the earthquake, submarine slides, and waves, looking northwest. Note complete removal of docks and recession of shoreline. Temporary dock (lower right) was built after the earthquake.

50.—Partial cleanup of petroleum tank farm area, Seward, looking northwest.

51.—The Alaska Railroad dock, Seward, after initial cleanup of damaged warehouse and debris, looking north.



By the spring of 1965, the waterfront was cleared of all unsalvageable material. The salavageable material was stockpiled or transported away from the waterfront. At Seward, debris clearance alone was a major task, costing more than $2.5 million.

VALDEZ

Valdez, a small fishing port with a population of about 600, is 120 miles east of Anchorage and is the southern terminus of the Richardson Highway which extends northward to Fairbanks.

Damage to Valdez was the result of both tremors and tidal waves. Ground shocks cracked buildings, opened fissures in the streets, and ruptured waterlines and sewerlines. Waves generated by the slide were followed by a series of tidal waves, the fourth and highest completing the devastation of the harbor, the waterfront area, and half of the downtown business area. The small-boat harbor, fuel storage terminal, and piers were destroyed, as well as the entire fishing fleet except for two boats that were out at sea.

The location of Valdez after the earthquake was considered a high-risk area, subject to future waterfront slides and tidal flooding. It was declared unsuitable for rehabilitation and a new site was selected in a safer location about 4 miles west of the old site.

A minimum amount of repair work was performed at the old site to provide emergency services for the inhabitants until accommodations could be provided at the new site.

Debris was removed from the old town and emergency repairs to the city, hospital, school, and utilities completed. A temporary barge terminal to serve the immediate needs of the city was constructed and has been in use since June 1964.

52.—Main business "street" of Seldovia. Regional subsidence due to earthquake caused flooding by high tides; sandbags were placed along boardwalk to prevent it from floating.

53.—Petroleum tank farm at Whittier after wave and fire damage, looking west.

CORDOVA

Cordova is a fishing port of about 1,100 inhabitants and is about 45 miles southeast of Valdez. Damage resulted from an earthquake-induced uplift of about 6 feet, local fracturing of the ground, and a tidal wave which floated away houses and boats along the waterfront and damaged canneries and pier and dock facilities. Emergency work by the Alaska District consisted of removal of debris and wreckage attributable directly to the earthquake, and restoration of essential public utilities.

HOMER

The fishing community of Homer has about 1,200 inhabitants and is on Kachemak Bay at the southwest end of Kenai Peninsula. It is the terminus of the Sterling Highway, which runs northward to connect with the Anchorage-Seward Highway. Its deep-water ice-free port accommodates cargo freighters and barges. The earthquake caused some damage to downtown Homer, principally to the hospital and a new elementary school. A combination of general land subsidence and high water inflicted severe damage to port facilities and made the docks and canneries unusable. The small-boat-harbor protection works in part were severely damaged. Emergency work by the Alaska District consisted of cleaning up, in the interest of safety, health, and sanitation, the debris and refuse caused by the earthquake.

SELDOVIA

Seldovia, a fishing community of about 550 inhabitants, is 20 miles across Kachemak Bay from Homer. Land subsidence, a result of the earthquake, lowered the waterfront about 3 feet and exposed structures along the boardwalk to flooding during the higher tides. Emergency work consisted of (1) furnishing and placing sandbags on the boardwalk to keep it in place during high tides and (2) miscellaneous work in connection with repairs to streets, utilities, and airfield.

WHITTIER

Whittier is an ice-free seaport and a terminus of The Alaska Railroad located on Prince William Sound approximately 60 miles southeast of Anchorage. Emergency work consisted of the removal of debris caused by the earthquake. Much of the commercial petroleum industry at the port was severely damaged and burned, as were the railroad-car-unloading facilities of The Alaska Railroad.

OTHER COMMUNITIES

The Alaska District personnel accomplished inspections, emergency repairs, and miscellaneous work pertaining to earthquake-incurred damages at Chugiak, Dillingham, Fire Island, Girdwood, Glennallen, Hope, Kenai, King Salmon, Klawock, Kodiak Island, Larson Bay Village, Moose Pass, Nikishka, Ninilchik, Orca Inlet, Soldatna, Spenard, and Tatitlek. Reconnaissance and reports were also made concerning damage to the Seward and Sterling Highways, the Cooper Lake transmission line, and the intake section of the Eklutna Power Project.

RECONSTRUCTION BY THE CORPS OF ENGINEERS—METHODS AND ACCOMPLISHMENTS

By Warren George[5] and Robert E. Lyle[6]

INTRODUCTION

Because of the short construction season and the severity of Alaska winters, careful attention had to be given to coordination of the project planning for permanent restoration or for reconstruction of facilities damaged or destroyed by the Alaska earthquake. A studied pattern was followed during reconstruction planning to insure a sound rehabilitation and reconstruction program. First, emergency repairs to the essential facilities such as utilities and transportation were made. Second, extensive geologic and soils studies were made to determine where facilities should be permanently reconstructed. Third, the projects were designed, sometimes concurrently with the soil-study program. Finally, the projects were advertised and contracts were awarded for construction.

Urban-renewal project planning, which became an influence in some of the reconstruction effort, was incorporated with the restoration of facilities at Anchorage, Cordova, Seldovia, Seward, and Valdez. The Urban Renewal Administration, the Alaska Housing Authority, the several communities, and the U.S. Army Engineer District, Alaska, of the Corps of Engineers (hereafter referred to as the "Alaska District") cooperated very closely in order to coordinate and satisfy long-range urban development needs. The ultimate objectives of the urban-renewal projects, which are to provide earthquake-damaged communities with better land utilization, to rehabilitate blighted areas, and to provide more effective traffic patterns, had consideration in this effort. Urban-renewal application and planning procedures were expedited in order to meet the urgent community needs.

Because of the extensive earthquake-induced slides, it was felt that a major soils, geology, and foundation study of these landslides in over seven areas of Anchorage would be needed. Prime aerial photographs were secured by three flight agencies on March 28 and 29; these have proved to be very valuable.

An investigation of the landslides and other earthquake damage was initiated on March 29, 1964, by the Anchorage Engineering Geology Evaluation Group under authorization of the Alaska Housing Authority and the city of Anchorage. As part of this early effort, Arctic Alaska Testing Laboratories, Anchorage, conducted borings, field measurements, and laboratory tests in the principal slide areas and generally throughout the city.

To meet the need for a major study in the soils, geology, and foundation fields of the landslide-affected areas in Anchorage, an operational organization was selected which consisted of an architect-engineer group to function under supervision of the Alaska District's Engineering Division for the investigation and reports, plus a board of consultants for advice, monitoring, and review. Authority to proceed in this manner, requested early in April from higher authority, was received on April 16.

The soils-mechanics and foundations firm of Shannon and Wilson, Inc., of Seattle was selected and a fixed-price contract covering such work at Anchorage, Seward, and Valdez was negotiated on April 25, 1964. This contract required Shannon and Wilson to provide comprehensive soils- and geological-engineering assistance to the Alaska District, to begin field investigations within 10 days at Anchorage, to cover each of five principal slide areas as a separate entity and adjacent areas in the city of Anchorage as well, and to determine: (1) the mechanics of the slide movements, (2) existing static stability of affected areas, (3) stability of affected areas if subjected to future shocks, (4) static and dynamic stability of areas not affected, and (5) methods for improving the stability of existing or potential landslide areas.

Separate work was also assigned at Valdez and Seward, Alaska. Because of the value of the property affected by the landslides and the need for financing reconstruction, all work at Anchorage was programmed

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for completion in units on a rigorous schedule which dovetailed with the Alaska District's assigned responsibilities and which also took cognizance of the urgent need for reliable engineering and geologic information by other Federal agencies, the city, the State of Alaska, and the private sector.

At the same time, the Alaska District engaged, as a board of consultants group, Ralph Peck of the University of Illinois, Laurits Bjerrum, Director of the Norwegian Geological Institute, and Thomas F. Thompson of Burlingame, Calif. This group of eminent soils and geology experts was constituted to monitor the progress and direction of the soils and geology studies of the Alaska District and its soils, geology, and foundations contractor, Shannon and Wilson, Inc., to recommend needed changes; to review reports and findings; and to advise the District Engineer on his courses of action in participation with Federal, State, and city officials concerned with planning recovery from the disaster and reconstruction of public facilities.

Shannon and Wilson, Inc., commenced work on May 4 1964, and within 48 hours had three soil-sampling (drilling) rigs together with supply and inspection services in operation. On May 11 the firm established its Anchorage field office, at which time seven rigs were in operation nearly around the clock on two slide areas, a bucket auger was digging man-sized-access holes for geologic inspection of critical underground areas, a group was installing piezometers and slope-movement indicator assemblies, and another group was taking seismic measurements in the slide areas. By May 29 most of the geophysical exploration had been completed, Shannon and Wilson's slide-project leaders had each reviewed his slide area or areas, subsurface data collection was proceeding with 15 drilling rigs functioning in the field, two laboratory groups were clarifying and testing samples, and the slope-indicator, vane-shear, and piezometer-installation crews were well along in their work.

Work programs were reviewed on May 28 and 29 by the consultant board. Changes made included: more emphasis on bucket-auger inspection holes, additional piezometer installations and vane shears, improved sampling techniques, more inquiry into the earthquake vibrational spectrum, and acceleration of dynamic triaxial testing.

The work of the investigation was voluminous and of great variety, and it resulted in comprehensive engineering data on each slide and surrounding area. Subsurface profiles were developed from some 150 borings, including undisturbed sample borings, vane-shear borings, and bucket-auger holes. Geophysical and geological explorations were undertaken, piezometers were installed, and observations of earthquake-induced ground movement were made. Comprehensive laboratory investigations were conducted on undisturbed and reconstituted samples, including dynamic-strength tests, mineralogical and paleontological studies, as well as conventional classification, consolidation, and strength tests. Laboratory strength tests showed the weak zone of the Bootlegger Cove Clay (Pleistocene) to have shear strength in the range of 0.35–0.40 ton per square foot and sensitivities in the range of 25–50. Special dynamic strength tests, in which specimens were subjected to pulsating triaxial loads, showed that 50 cycles of stress could result in failure of the clay at a stress level approximately 60–80 percent of the static strength. Similar tests on loose sands from the same stratum indicated that failure would occur at cyclic stress levels of the same order of magnitude.

On June 24, 1964, Shannon and Wilson delivered its first preliminary report on the Fourth Avenue slide area to the Alaska District, its board of consultants, the city of Anchorage, the Office of Emergency Planning, and representatives of the Federal Reconstruction and Development Planning Commission for Alaska, including the Scientific and Engineering Task Force ("Task Force Nine"). This report enabled Task Force Nine, the engineering group of the Planning Commission, to revise risk-area classifications for the Fourth Avenue slide areas and other areas of greater Anchorage.

Shannon and Wilson delivered its remaining preliminary reports in the same manner, to about the same group of officials, on the following dates:

Report of slide at—	Date	
	Oral presentation	Written preliminary report
L Street	June 29, 1964	July 6, 1964
Turnagain	July 6, 1964	July 11, 1964
Government Hill, First Avenue, Romig Hill	July 20, 1964	July 25, 1964

Each of these timely presentations gave factual engineering data concerning the causes and effects of the landslides that had occurred during the earthquake, together with recommendations for remedial measures including design criteria. Task Force Nine immediately assigned suitable risk classifications, which were published in the newspapers along with a semitechnical explanation of the Alaska District's findings concerning stability and restoration of the landslide area. The Office of Emergency Planning and the District Engineer also quickly utilized the reports as background for important engineering decisions as to restoration of public facilities and stabilization in each landslide area.

Early in August, Shannon and Wilson compiled all data into a final written report which on August 10 and 11 was given a thorough review by the board of consultants and by representatives of the Alaska District, of the North Pacific Division, and of the Office of the Chief of Engineers. The report was printed and issued on August 28, 1964. It presents the results of the investigation in detail, gives explanations as to what occurred, and makes final recommendations as to design criteria for remedial measures and land uses. The report concluded that (1) the strong ground-motion waves from the earthquake-generated shear stresses in the upper critical soils of the Bootlegger Cove Clay, which underlie parts of Anchorage, caused failure in these soils and permitted horizontal sliding toward the bluffs in locations where height, declivity, and other physical parameters were most unfavorable to stability; (2) though all slide areas are stable under present static conditions, all may be expected to experience additional movements of varying magnitudes in another great earthquake; (3) all areas which failed can be stabilized against another earthquake of similar magnitude and duration by means of slope flattening, buttressing, improvement of subsurface drainage, and other well-established procedures; (4) settlement of the ground surfaces, in and adjacent to the slide areas, will occur over a period of years due to consolidation of the slide-disturbed clay and sand strata, especially within the graben and pressure-ridge parts; (5) many of the bluff slopes in the vicinity of Anchorage underlain by the Bootlegger Cove Clay are of marginal static and dynamic stability, and oversteepening or overloading of existing slopes by excavations at the base or by construction of fills or heavy structures near the crest or on the slope may result in localized landslides; and (6) ground motions during earthquakes will likely be greater near the crest of such slopes than elsewhere.

ANCHORAGE

Restoration of schools that were not in slide areas was initiated immediately after the spring semester. All the schools that had light to moderate damage were carefully investigated by architect-engineer firms and repaired by construction contract in time for the beginning of the fall semester in 1964. Repair of two of the more seriously damaged schools, Denali Elementary and West High School, took much longer. Denali was made available for use at the beginning of the second semester. Government Hill Elementary was destroyed and could not be rebuilt in the same location because of unstable soil conditions. A new school was designed and was ready for occupancy in August 1965 on land made available to the school district by the U.S. Air Force. After determination that the important West Anchorage High School, which was very heavily damaged, was in a nominal-risk area, studies were made to evaluate its restoration. Design and construction proceeded in three separate phases. In phase 1 the moderately damaged auditorium wing was restored, in time to allow use by the school district for the first semester of 1964. Phase 2 consisted of the restoration of the severely damaged classroom wing, which was turned over to the school district for use at the beginning of the second semester. In phase 3, a new one-story classroom wing to replace the original second story will be constructed; this project was scheduled for completion by the beginning of the fall term, September 1, 1965. In order to accomplish these schedules, school-repair contracts required double shifting of work by the contractor and specified high liquidated damages. These measures were effective in procuring completely usable structures in time for the start of school. School-repair contracts alone totaled $5.6 million. All considered, the school program was carried on quite well, but some double shifting of students was necessary.

Repair of underground utilities, as well as the restoration of schools, had priority. Surface waterlines were laid immediately after the earthquake to provide service in the major slide areas where underground lines were seriously damaged. Water pipe for the permanent restoration was purchased while designs were still being developed, and the procurement lead time was thus cut to an absolute minimum. Essential permanent restoration of water service in all areas was completed well before freezeup, and the surface lines were then dismantled. The 24-inch wood-stave supply main from the treatment plant to the city was extensively damaged along part of its route. A mile and a half of this line was bypassed by laying a new cast-iron main. This line and the new wells drilled to replace those destroyed assure a continued dependable water supply. A detailed pitometer survey of the water system revealed additional points of important leakage outside of the various slide areas; these were repaired. Repair of structural damage at the municipal water-treatment plant completed the permanent restoration of the water-supply system.

After emergency work to restore the sewer system to a reasonably workable condition, a major effort was made to photograph all lines with known or suspected damage. This was done to be sure all breaks were properly identified and repaired. Repair contracts were developed progressively as photography revealed the need. All essential sewer repair was accomplished before freezeup, and less critically needed restoration was deferred until 1965. Work under contract to be finished in 1965 completed the restoration of all Anchorage and Spenard Public Utility District sewers.

The municipal electrical distribution system, both overhead and underground, was damaged extensively. An effective tool for examination of underground ducts was a television camera lent, complete with crew, by the U.S. Bureau of Reclamation. This loan enabled the Alaska

54.—Government Hill slide area, Anchorage, showing damage to elementary school. Photograph taken shortly after earthquake, looking northwest. Undamaged far corner of school was preserved for future use when remainder of school was razed. Alaska Communication Service toll building and microwave tower (right) were undamaged.

District to pinpoint damage in ducts and eliminate the need for a "find-and-fix" type contract. All work essential to restoration of an operable system was completed before the normal heavy winter electrical loads.

Most of the damage to the municipal telephone system was in the slide areas. Necessary repairs were made early by city crews. The television camera was again effective in locating damage to ducts. Repair of the system was completed in the spring of 1965.

Street repairs were deferred until 1965 because utility repair required the removal of pavement in many areas late in the fall. All pavement restoration was completed by August 1965. Many utility and street-repair contracts were required to complete the work.

Public buildings belonging to the city of Anchorage had minor to moderately heavy damage and were repaired before winter. The State Mines and Minerals Building was located in the Fourth Avenue slide area and consequently was completely destroyed. A new facility was scheduled for completion by August 1965.

After completion of the soils investigation and the review by the board of consultants, it was apparent that stabilization of the major slide areas would be essential, not only to restore the areas to use, but also to protect adjacent property. Accordingly, a buttress system was designed for the Fourth Avenue slide area. Funds for this project were made available by the Urban Renewal Administration through the Alaska Housing Authority. The project was expanded to include the construction of a complete new utility system and a street system. Design was completed and construction started in 1965 as soon as real estate became available. This major undertaking will be one of great importance to the downtown business area.

In the Turnagain slide area, testing was initiated in the fall of 1964 to determine the most feasible method of stabilization. Both blasting and mechanical disturbance of the sensitive clay developed drawbacks that made use of these stabilization methods unattractive. Electro-osmosis treatment was also explored. A test model consisting of 22 railroad rails as probes introducing direct current at varying voltages and amperages to the clay has been successful in increasing soil strength.

Although the results of some of these experiments were promising, it became apparent that the slide material had spontaneously regained most of its original strength. Accordingly, the Alaska District decided in mid-1966 that stabilization measures, other than protection of the shoreline, were unnecessary.

SEWARD

The permanent restoration of the utilities and the public schools of the city of Seward was completed in 1964. Additional restoration under way included the State Court and Office Building, the City Maintenance Shop, and replacement of the 3000-kw standby electrical-generation facility. All the facilities are being funded by the Office of Emergency Planning except the powerplant, which is funded jointly by the Office of Emergency Planning and the city.

The publicly owned and operated waterfront facilities, which include a small-boat basin, city dock, and associated facilities are being reconstructed under the authority of the Office of Emergency Planning and the Corps of Engineers. These waterfront facilities represent a most important part of the economy of Seward because of its fishing and recreational activities.

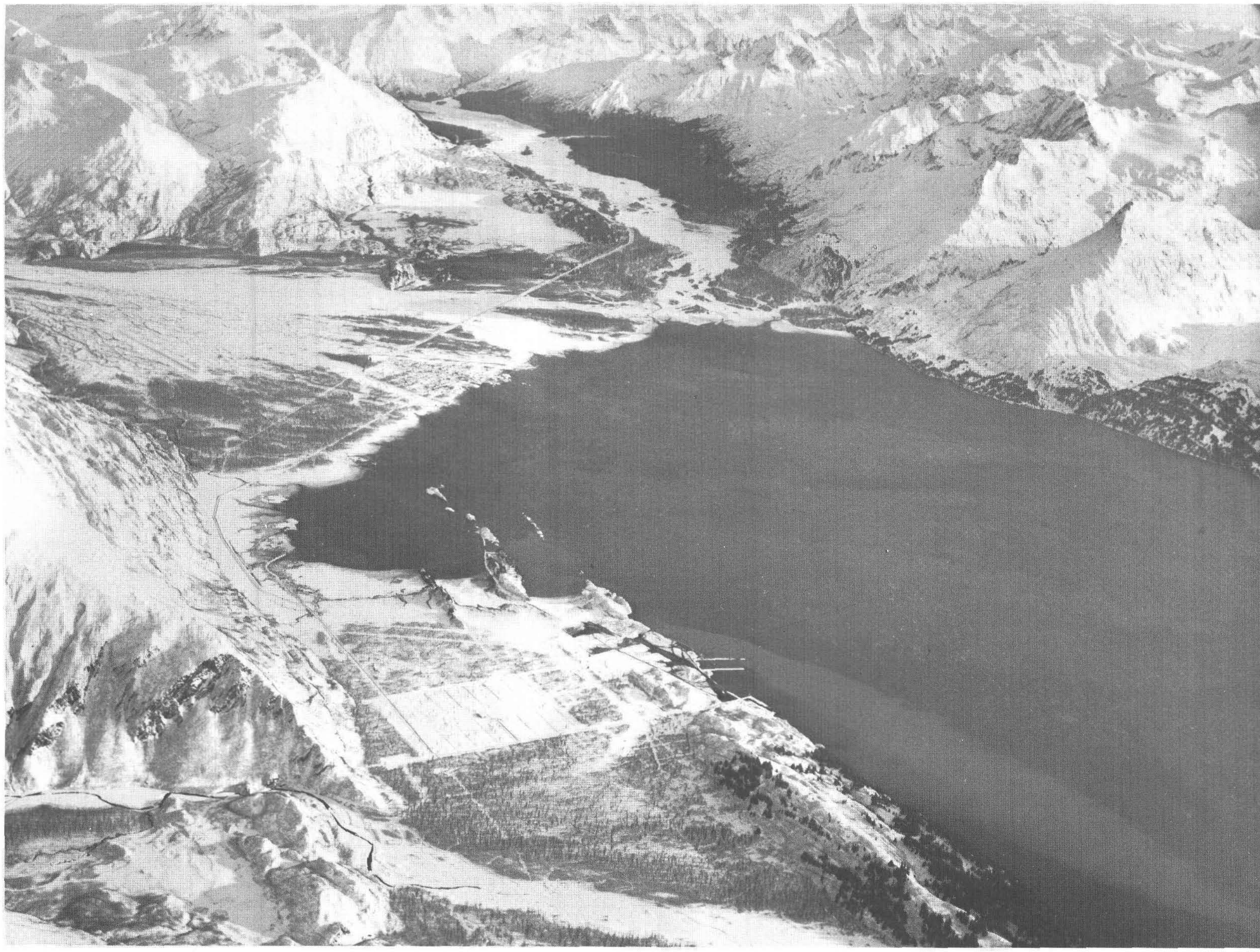
Facilities for The Alaska Railroad, which include a dock suitable for berthing two 600-foot vessels and allied offloading storage facilities and marshaling yard, are being constructed at the northerly end of Resurrection Bay where the shore area is being raised by using material dredged to deepen the harbor in the vicinity of the docks. These facilities also have great economic importance to the town and to the railroad.

VALDEZ

The permanent reconstruction effort in Valdez is unique in that the decision was made to relocate the entire city in an area which is not subject to instability in the event of a future earthquake. The reconstruction project is being undertaken under the joint sponsorship of the Office of Emergency Planning, the Urban Renewal Administration, and the Corps of Engineers. The new city encompasses an area of approximately 200 acres. The general city planning was done by the Alaska Housing Authority under the sponsorship of the Urban Renewal Administration; the design and construction of the streets and utilities, high school, elementary school, and municipal building are being accomplished by the Alaska District under the sponsorship of the Office of Emergency Planning. The utility and street systems in the new townsite represent a sizable investment,

55.—Dock and boat harbor under construction at new site for Valdez, looking east; winter of 1964–65.

56.—Elementary school constructed during the autumn of 1964 at new site for Valdez, looking northeast.



57.—New site of Valdez and dock facilities (foreground). Old Valdez, devastated by the earthquake is at center (left) at head of Port Valdez. Loss of the Valdez waterfront by submarine slides, extensive earthquake damage throughout the town, and the ever-present danger of flooding by Valdez glacial stream (note dikes around town) led to recommendations by U.S. Geological Survey geologists to abandon the town and to rebuild Valdez on the flat near Mineral Creek. The Scientific and Engineering Task Force concurred in this recommendation. Bedrock ridges along shore protect the new townsite and also mean that there is no danger of offshore slides.

funded jointly by the Office of Emergency Planning and the Alaska Housing Authority.

The sea-oriented economy of the city is being reconstructed at the new townsite. The facilities completed or under construction are a city dock and two dry-storage warehouses and a small-boat harbor. Waterfront facilities, funded by the Office of Emergency Planning and the Corps of Engineers also comprise major installations. The two new schools and the city hall replace structures badly damaged.

A complex consisting of a State Highway District Headquarters office building and maintenance depot shops and a state hospital with beds for 150 mentally retarded patients and 15 acute patients is being constructed on a 30-acre tract adjacent to the new city limits. These facilities are important additions to the return of the economic health of the city.

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CORDOVA

At Cordova, the land rose rather than settled, as at most other coastal communities, so the small-boat harbor was rendered useless for anchorage of small craft. Basically, the problem was to deepen the old small-boat harbor and expand it to provide moorage for the boats which, prior to the earthquake, moored in bays and inlets surrounding the Cordova area. In execution the operation became somewhat complicated. It was necessary to provide moorage for small boats within the harbor, to provide a new ferry terminal, and to maintain access to two canneries while dredging was in progress. The total effort represents a major project jointly supported by the Office of Emergency Planning and the Corps of Engineers.

The quake severely damaged the wood-stave water-supply line bringing water to the city from a distant source, and some sewage facilities were wrecked. Total utility repairs represent a sizable investment.

SELDOVIA

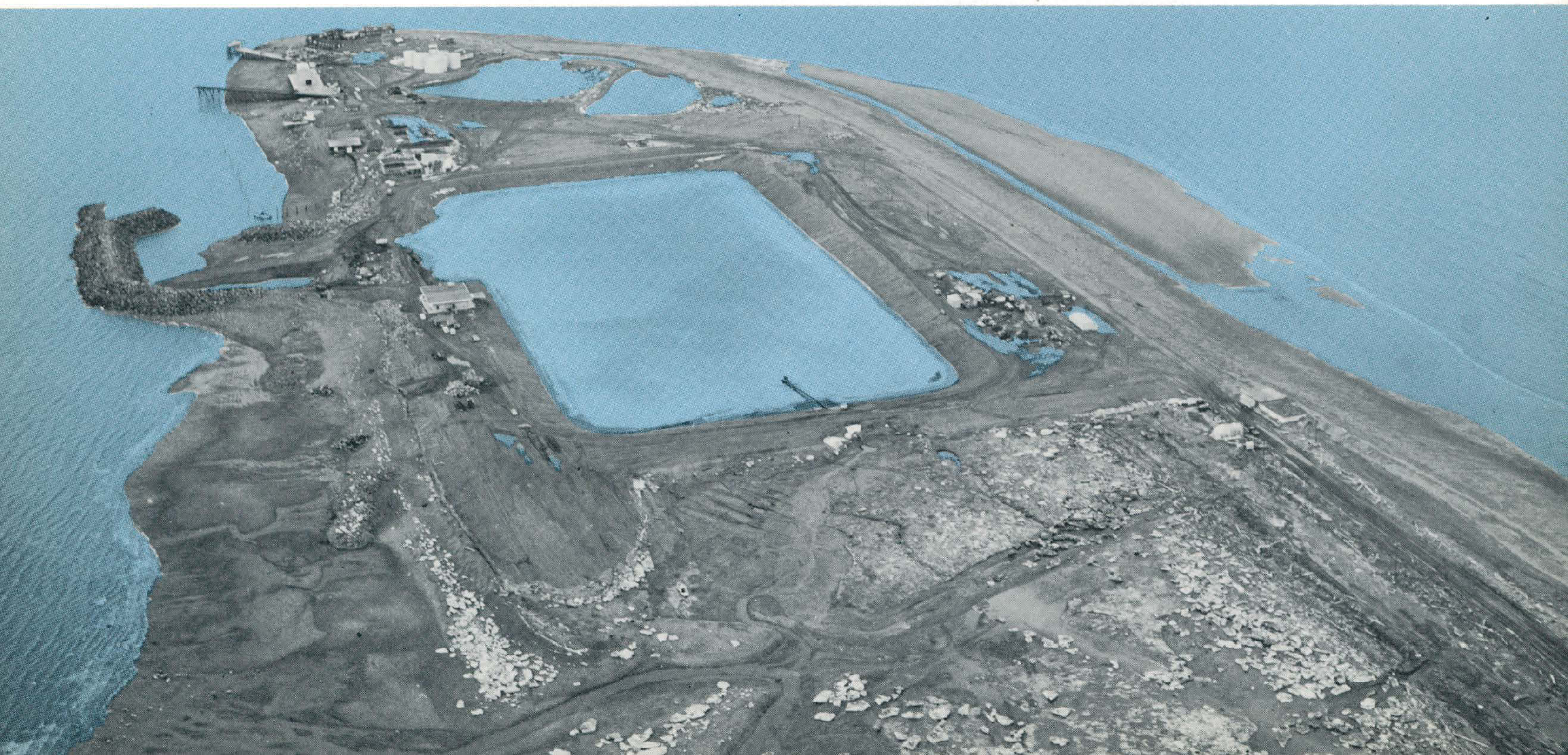
Structural damage to the town of Seldovia was comparatively light. The major problem here was that the whole area settled about 3½ feet, and put in serious jeopardy the business district of the town. The business district is primarily on docks along the boardwalk, which runs the full length of the waterfront. The tsunami broke floats loose from within the small-boat harbor but did very little other damage. The first order of business after the earthquake was to raise the breakwaters for the harbor 4 feet to their original height. Other work consisted of restoration of damaged utilities and reconstruction of the airfield by raising the runway above high tide. A number of contracts to effect this restoration were necessary.

The Alaska Housing Authority developed an urban-renewal project for rebuilding and raising the complete waterfront area. This project consisted of demolition of the boardwalk and other structures along the waterfront, the construction of a breakwater, with fill to form new land upon which property owners could rebuild canneries and other businesses. Work was accomplished in stages in 1965 and 1966 to allow removal of cannery equipment and rebuilding with a minimum of down time. This unusual project required much detailed effort and coordination. It was jointly funded by the Alaska Housing Authority and the Office of Emergency Planning.

HOMER

The town of Homer itself had only light damage, but the Homer Spit, site of the city dock and the small-boat harbor and other commercial facilities, subsided 6 feet; heavy damage resulted. It was impossible to reconstruct the harbor in its original location, so a new harbor has been constructed within the Spit. A new main breakwater was required, and a part of the old breakwater was utilized as an entrance breakwater. Inner harbor facilities and a new city dock completed the waterfront facil-

58.—Partially completed new boat basin on Homer Spit, looking south. Former basin destroyed by subsidence and submarine slides was near new riprapped breakwater on left side of spit. Land's End Hotel is at extreme end of spit.

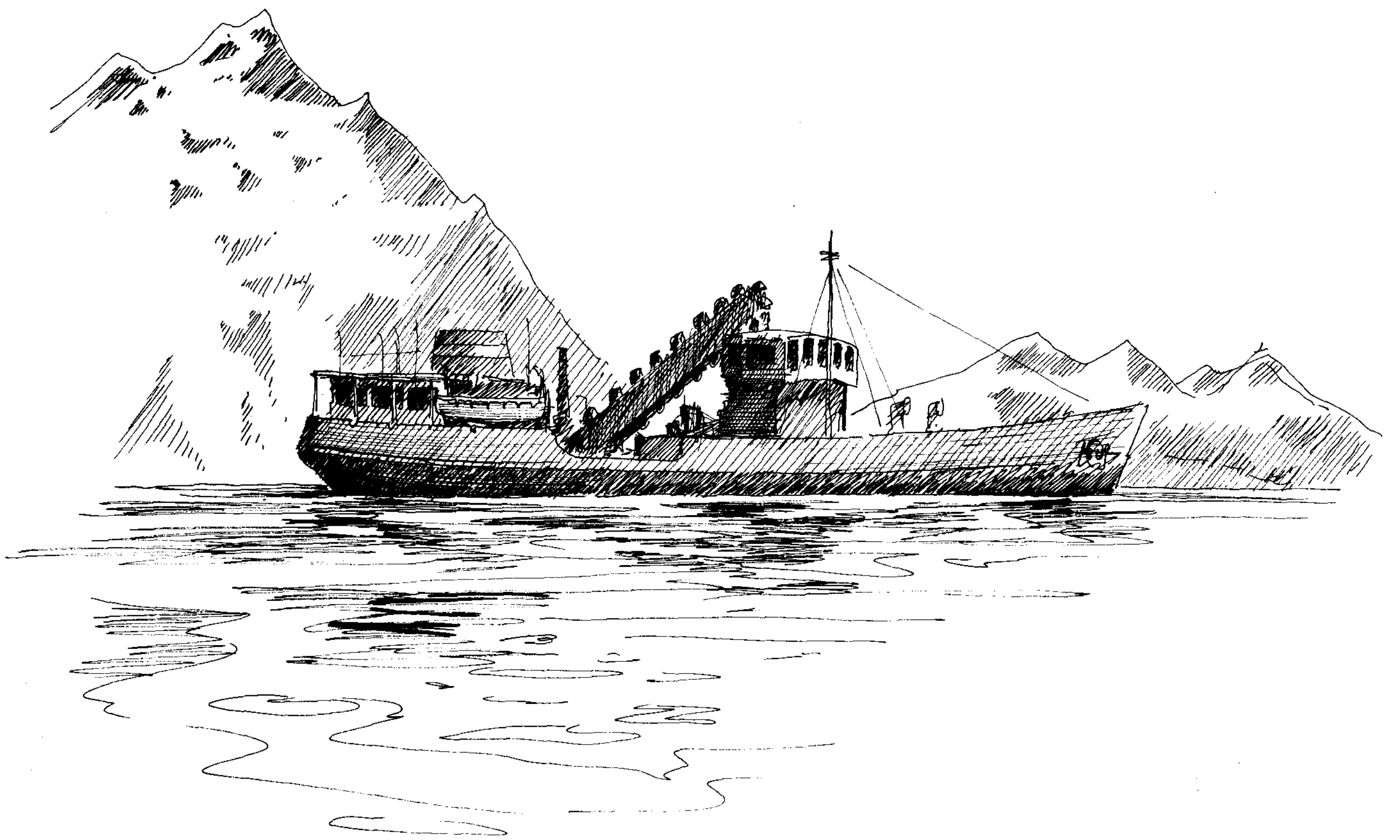


ities for Homer. These were major efforts. The access to these facilities will be provided by a Federal road system which will require extensive reconstruction.

The Alaska District conducted an investigation, funded by the Office of Emergency Planning, to determine the long-term effect of the quake on the Homer Spit. A report was completed in August 1965.

OTHER COMMUNITIES

Restoration and reconstruction of harbor facilities were accomplished at Kodiak and Orca Inlet and the harbor at Tatitlek was dredged. These were major contracts. Other communities in which restoration of public buildings and utilities was accomplished are Moose Pass, Kenai, Chugiak, Palmer, Glennallen, Girdwood, Hope, Whittier, and Klawock. Work was not great in terms of funds spent but restoration effort in each place was of large importance to the community concerned.



THE YEAR OF DECISION AND ACTION

By Genie Chance[7]

INTRODUCTION

During those first dark, cold hours after the Alaska earthquake of March 27, 1964, it was difficult to visualize any good coming out of such tragedy. But a new and better Alaska has risen from the rubble.

Alaska was a young State—barely 5 years old. Newly formed boroughs had been in existence for less than 3 months. (A borough is an intermediate governmental district similar to a county or a parish in other States.) The organization of the boroughs had been slow and cautious. No budgets had been set—no taxes collected. Alaskans were deliberate in setting up another government entity. As one resident said, "They were just trying to set up shop when they had to cope with this emergency—they hadn't even learned how to cope with the ordinary day-to-day stuff yet." The town of Homer was to have been incorporated just 5 days after the earthquake. There could hardly have been a more difficult period for new, inexperienced city officials to take office.

The Federal Government's transitional grants to assist Alaska's move from territorial status to Statehood were almost at an end. At Juneau, the State legislature was trying to trim the proposed $75.9-million budget during the final days of its annual session. So much was needed, and yet the tax base was so limited.

Most State revenues came from south-central Alaska where many coastal towns and villages sustain seafood industries, where metropolitan Anchorage burgeons with 100,000 people, and where the ports of Seward and Whittier handle freight for interior Alaska via The Alaska Railroad. Tax revenues from this area dictated to a large degree the amount that could be spent on State government functions during the next fiscal year.

First with a gentle roll and then a sudden jolt, nature made the proposed budget a worthless piece of paper. The entire State would suffer from the losses sustained in the quake-stricken area. *Miraculously*, few people were killed, but valuable, taxable property lay in worthless heaps of rubble, and the State's economy was crushed.

SEWARD

Seward, a community of about 2,000 people, lies at the foot of 3,200-foot Mount Marathon at the head of Resurrection Bay. It was settled at the turn of the 20th century when a private company attempted to build a railroad into interior Alaska. Although that venture failed, Seward was kept alive when the U.S. Government began to build The Alaska Railroad in 1914. Seward is the ocean terminus of the 540-mile long railroad, and the community's economic mainstay for the past 50 years had been longshoring.

In recent years there had been speculation that Seward was doomed to become a ghost town because of her dependence on a declining water-oriented commerce and the railroad. Since the 1950's, more and more freight was being trucked into the State via the Alaska Highway. The population of Seward slowly dwindled as disenchanted residents sought greener pastures.

However, in 1963 an energetic group of civic leaders determined to put new life into their town. Through their enthusiasm and tenacity, Seward won the coveted "All American City" award. A big celebration was planned for April 4, 1964.

[7] Radio news commentator and public-relations consultant, Anchorage, Alaska.

But—on March 27, earthquake-triggered submarine landslides destroyed most of the waterfront and flames from ruptured petroleum storage tanks were swept into town by tsunamis. Thirteen people lost their lives before the rest of the townspeople fled to the safety of higher ground. Seward was desolate. Some thought Seward was dead.

One year later, the visitor was impressed with Seward's spirited determination to live. Federal funds, of course, were essential to the reconstruction of public facilities in the town, and the decision of the many Federal agencies to "Save Seward" was welcome news. Seward herself valiantly joined in the fight.

With the loss of the docks, the railroad, and the fish canneries, the only immediate source of income was employment on the Federal reconstruction projects.

Mayor Perry Stockton said that, although a few people had to move elsewhere to find work, the city as a whole did not suffer financially in the year following the quake. Realizing that financial support from the "crash" construction program would end by 1966, the city leaders concentrated on attracting industry. The city applied to the State government for title to about 70 acres of reclaimed tidelands that had been filled with materials dredged from the harbor. Using $36,000 from capital improvement funds, the city built a cold-storage plant adjacent to the new city dock. The facility was then leased to a private fishing cooperative under an agreement which would amortize the investment within 5 years. Seward's fishing fleet resumed operations when the plant opened in June 1965.

Before the quake a bond issue had been approved to pave many of the city streets. The work was postponed until 1965 so that underground water and sewer lines could be repaired by the Corps of Engineers.

About one-fourth of Seward was unsafe for the uses to which it had been put before the quake. The Urban Renewal Administration negotiated the acquisition and redevelopment of the unstable land, and by March 1965 an estimated 95 percent of it had been purchased from the private owners. About three-fourths of the displaced families relocated within the town; their relocation was made possible by the cash purchase of their properties by Urban Renewal. The $1.9-million project calls for redevelopment of the 148-acre waterfront area for light industrial and recreational uses.

Several homes were rebuilt with private capital during the first summer after the earthquake. By March 1965, six new homes, a new church, and a parsonage were under construction.

As for the future, Mayor Stockton said, "We are doing everything possible to entice industry. Even if it's one that will only create two jobs, we will do anything we can to assist them." In June 1965, Stockton reported that a second fish-processing plant was negotiating a lease in the newly reclaimed tidelands near the small-boat harbor. Restaurants, recreational facilities, and equipment-repair shops were interested in leasing additional lots on a long-term basis.

In Seward the year of decision had also been a year of action.

HOMER

Homer, Alaska, is a small community on the southwest coast of the Kenai Peninsula. Homer is often called the "Cape Cod of Alaska." The population of about 1,500 people depends primarily on commercial fishing and a seasonal tourist trade for its livelihood. Nestled along a bluff line, Homer faces Cook Inlet on the west and Kachemak Bay on the south. A gravel bar 4½ miles long, extends from the foot of the bluff out to deep water. It was on this natural pier, now known as the Spit, that the town of Homer was first established in 1896. The original colony of 75 people, representing the Alaska Gold Mining Co., was headed by Homer Pennock. The community was named in his honor.

Long before the town was created, the area had been exploited by Russian fur traders and an English coal mining company.

As the town itself moved to the bluff, the Spit was used for recreation and industry. On the extreme tip of the Spit stood Land's End Hotel, a favorite of tourists and commercial fishermen. Next to the hotel was the city dock where fishermen unloaded daily catches of king crab and where freighters and tankers deposited fuel and supplies. A petroleum tank farm sat near the center of the Spit. A small-boat harbor and three seafood-processing plants nearby were focal points of the local economy.

On Friday, March 27, 1964, Glen Sewell and some friends were putting finishing touches on a new restaurant, the Porpoise Room. The grand opening was to be next day, a symbol of triumph over disaster for Sewell and all who knew him. When the original Porpoise Room had burned down a few months earlier, it was only partly covered by insurance. With the assistance of friends and family, Sewell had built the attractive new structure on the Spit. The ground floor, made of concrete blocks, contained storage rooms, refrigeration units, kitchens, and an apartment for the owner. Exterior stairways led patrons to a wide observation platform and unobscured views of Cook Inlet, Kachemak Bay, and the surrounding mountains. The Porpoise Room would be a popular tourist attraction.

As the Porpoise Room began to shake, Sewell ran outside. From across the Spit to the southwest, a huge crack moved toward him and between his feet before he could move. His brother ran from the building and fell into another crack. As the two struggled to their feet, a man's voice shouted, "Look at the boat harbor!" In a great vortex the water suddenly withdrew from the harbor floor. Boats sank into the mud, and the rock jetty surrounding the harbor disappeared. The Porpoise Room staggered and settled as 6 feet of mud filled the ground floor. No one realized then that the whole Spit had subsided several feet. The waters of the bay rushed back in. The city dock shuddered, and erratic tides coursed the main floor of Land's End Hotel.

The town of Homer itself had relatively minor damage, but it was virtually cut off from the rest of the world. Investigators announced that the Spit had sunk as much as 6 feet and it would be inundated regularly by high tides. The canneries, Homer's major industry, stood in the water—their expensive machinery ruined by salt water. But without a harbor and a dock, the fishing fleet could not operate anyway. Homer, moreover, could not receive fuel and freight from marine carriers without a dock and without the Spit's access to a natural deep-water harbor. Supplies could not be trucked in because the highway to Anchorage, 160 miles to the north, had been destroyed. Tourism was curtailed. Because other communities had sustained far more sensational damage, Homer's plight went virtually unnoticed. There were 113 businesses in the Homer area, most of them operating with very limited capital. The 1964 tourist season was out of the question and, with the future of water-oriented industries in grave danger, Homer faced slow economic strangulation.

One year later Homer Thompson, local real estate broker and civic leader, said that the Federal Small Business Administration and the Army Corps of Engineers' projects financed by the Office of Emergency Planning had kept the town's economy from collapse. The Small Business Administration made disaster loans to hard-pressed business men, and the Corps of Engineers began reconstruction of the city dock and small-boat harbor. Thompson estimated that a total of more than $3 million was spent in public and private reconstruction in Homer during the first 12 months following the earthquake.

Material dredged from a new small-boat harbor was used to raise the land around it. With a loan from the Small Business Administration, Glenn Sewell rebuilt the Porpoise Room on the newly filled location. It was open for business in May 1965 in time for the tourist season. The owners of two fish-processing plants also began reconstruction adjacent to the small-boat harbor.

The Alaska Highway Department announced plans for a $1 million project that would reconstruct and raise the road along the Spit to a level 2 feet above the new high tides.

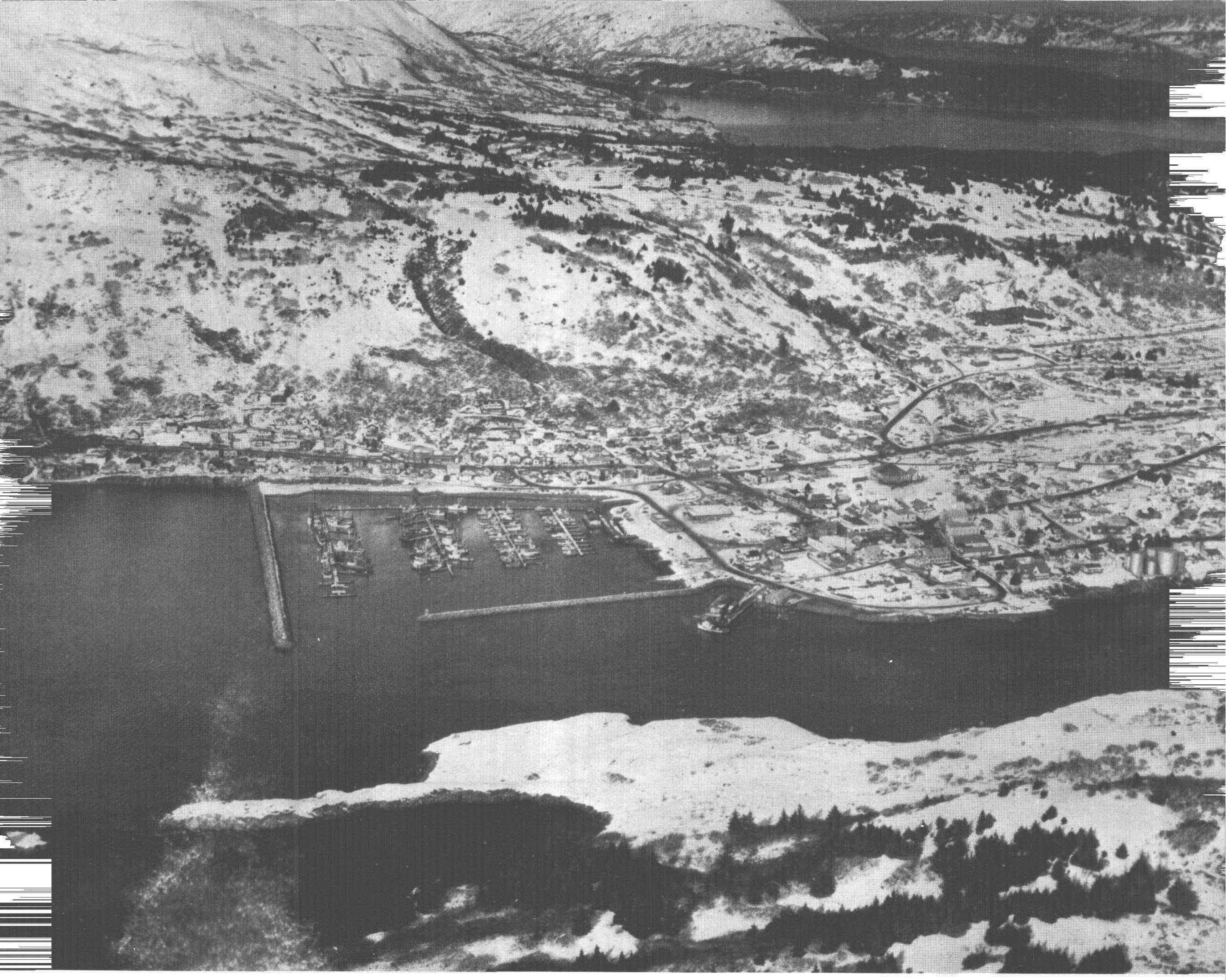
Residents of Homer sought to broaden the economic base of the town. Japanese industrialists interested in establishing a pulpchip plant on the Kenai Peninsula were impressed with the possibilities of Homer. Negotiations were under way for a proposed $3.5-million plant. It would be built on the Spit near the small-boat harbor and would ship 16,000 to 18,000 tons of pulp chips annually from Homer to Japanese paper mills. The operation would utilize timber on the Peninsula and would furnish year-round employment for about 70 persons. Homer officials indicated that an American firm was also interested in such a plant if Japanese plans do not materialize.

In addition, local development corporations were investigating the possibilities of a 36-unit motel with a large convention hall and dining rooms, three more seafood-processing plants, a freight-handling business, a sawmill, a restaurant, a supermarket, and several equipment-repair shops. Considerable research was being conducted on other diversifications such as agriculture, meat producing and processing, and forest products.

KODIAK

Kodiak was first established by Russian fur traders in 1792 on the southwest coast of Kodiak Island. Eight years later it was relocated on the northeast tip of the island where it stands today. Kodiak has the distinction of being the oldest existing Alaskan community established by white settlers.

In 1964 an expanded influx of tourists was expected with the



59.—New boat basin at Kodiak looking northwest. Former basin was destroyed by tsunami and subsidence.

new service of the State ferryliner that would link Kodiak with the mainland. During and after World War II the United States Navy base near the town of Kodiak contributed to the economy of the area, but the most important industry was fishing and seafood processing. Kodiak had one of the most productive king-crab industries in south-central Alaska, producing some 17 million pounds in 1963.

The crab fleet was working when the earthquake struck. Captains at first thought that lines had become entangled in their propellers. Vessels at dock were helpless as the harbor first overflowed, then drained dry, only to be refilled with a huge, rushing wave. People in town struggled to evacuate buildings along the waterfront. Survivors headed for high ground where they watched as boats, harbor buoys, and drifting dock deckings battered houses, stores, canneries, and garages that just moments before had been blocks from the shoreline.

By 3 a.m., the waves had subsided. At dawn the town began counting its losses. All but one cannery had disappeared. The rock jetty protecting the small-boat harbor was destroyed. The waves had washed into the town, sweeping away everything in their paths and depositing the debris as far as five blocks inland.

One year later, however, Kodiak was a bustling little city. The Office of Emergency Planning financed the reconstruction of publicly owned waterfront facilities. The small-boat harbor, completed by the end of February 1965, was packed with fishing vessels—many of them replacements of those destroyed by the tsunami. The city fathers were planning a big expansion program to accommodate a larger fleet. Although the 1964 season showed a drop to about 12 million pounds of king crab at Kodiak, the processing plants were forging ahead with improvements. Owners of all plants destroyed had either rebuilt or had announced intentions of doing so. Kodiak residents were cheered by the expected arrival of a new floating crab cannery that planned full operations during the entire 1965 season.

Virtually the entire downtown area—34½ acres—was being redeveloped through an $8-million Urban Renewal program. By spring of 1965 most of the land parcels in a planned commercial core facing the boat harbor had been allocated to purchasers. Utilities had been installed, but paving of streets and sidewalks had not yet begun. Construction had begun on the first privately owned structure within the urban renewal area.

Before the earthquake a housing development of about 300 units stood practically empty on the outskirts of the town. One year later all units were filled and would-be residents had to place their names on a 6-months waiting list. At Kodiak Naval Station the construction of 170 housing units was anticipated.

The State ferry was making weekly calls at Kodiak, tourism had increased, and accommodations for visitors were adding rapidly to the skyline. Two new motels, complete with restaurant, coffee shop, and lounges were built with a total investment of about $700,000. The Beachcomber, a former Canadian cruise ship, had been turned into a seaside hotel. The city was weighing the possibility of attracting the convention trade.

During the 12 months following the earthquake, Kodiak also received increased freight service from Alaska Steamship Co.'s freighters and from the vanships of Sea-Land, Inc., which operate also between Anchorage and Seattle. The innovation of vanship service provided aid to Kodiak's canneries and fish-processing plants. Refrigerated vans were parked beside the processing plants, the finished products were moved directly from the plants to the vans, and then aboard ship; thus the expense of rebuilding new warehouse space was eliminated.

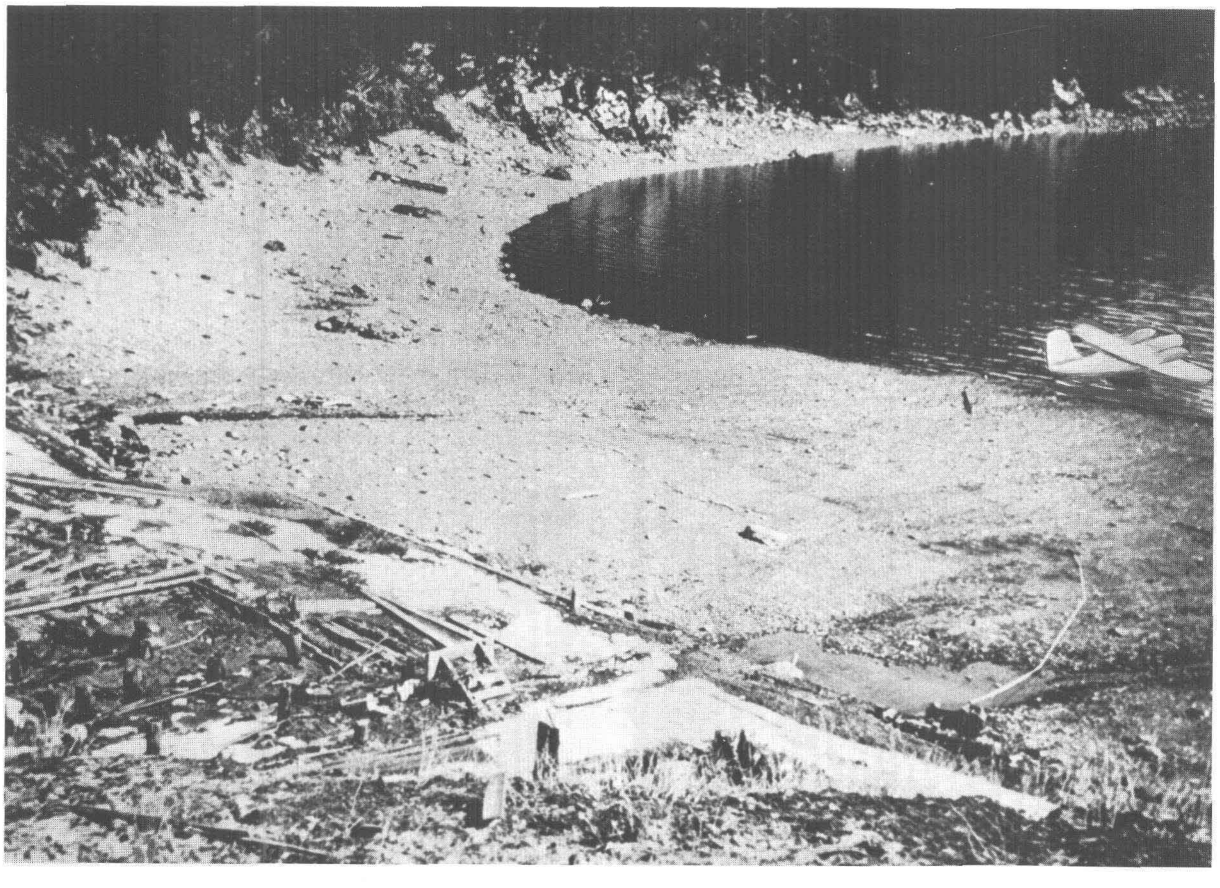
The Kodiak Island Improvement Corp., organized under the Small Business Administration's community development program (commonly called the "502" program), was an economic stimulus to the community. Through this program more commercial and industrial enterprises were anticipated. Some of those proposed are three additional fish-processing plants (which would give the town more production capacity than it had before the earthquake), an electrical supply and contracting firm, a marine supply and equipment company, two recreational resorts, a small-craft repair facility, service stations, garages, a telephone company, and a bus company. Also anticipated in the near future was the private construction of a complete marineways to handle repairs to any size ship working in Alaskan waters. As proposed, it would be comparable to any such facility on the west coast of the United States and would eliminate long voyages to Seattle or San Francisco for repairs.

NATIVE VILLAGES

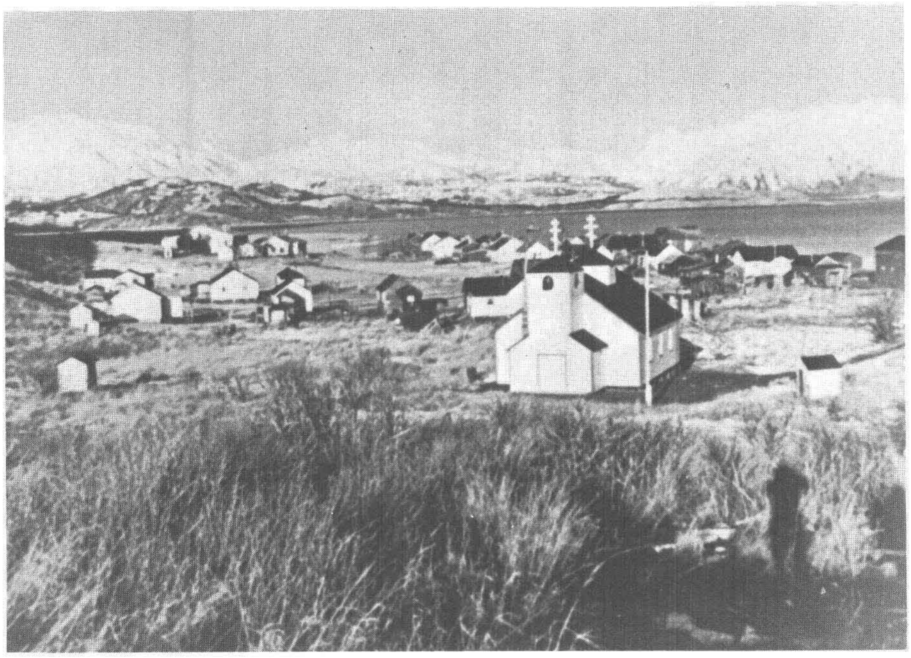
Chenega (fig. 60) was a native fishing village of about 80 persons. Living on a small island in the southwest part of Prince William Sound, the villagers had no tsunami warning. Within minutes after the onset of the earthquake, a wall of water swept across the shoreline, took 23 lives and left hardly a scrap of wood to mark the site. The survivors huddled throughout the cold night on a snow-covered hillside. The next day they were airlifted to Cordova across the sound where the village council held a general meeting in the temporary shelter of a Cordova church and decided unanimously not to return to Chenega. Within a few days the villagers agreed to settle at Tatitlek, another native village where they had relatives and where land was available for homes. Sixteen new homes were built for Chenegans by the Bureau of Indian Affairs (fig. 64). Fishing and hunting equipment purchased with disaster funds enabled the men to resume their occupations as fishermen and seal hunters.

Kaguyak and Old Harbor, two native villages on the east coast of Kodiak Island, also were devastated by waves. Several lives were lost at Kaguyak and all the village's 9 homes were destroyed. Old Harbor was more fortunate—no deaths, but 29 out of 35 homes were lost. No one wanted to return to Kaguyak. Seven families joined relatives at Alitak, a village on the southwest side of Kodiak Island. Five families went with Old Harbor residents to rebuild that village.

60.—Chenega, a small native fishing village on the coast of Prince William Sound.



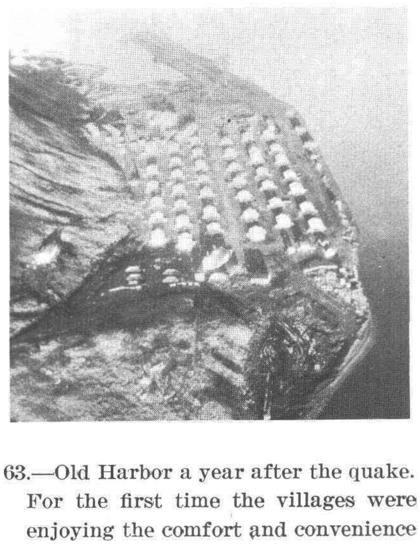
61.—The day after the earthquake, scattered pieces of scrap lumber and an occassional stump were all that remained of several native villages.



62.—Just moments before the earthquake, the school teacher at Old Harbor snapped this picture of the quiet little Aleut village. As villagers ran to the safety of a nearby hilltop, they saw huge waves wash away all their worldly possessions.

Afognak, on an island of the same name, was a village of 38 homes, one store, a 2-story schoolhouse, a community hall, and a sawmill, all lined up single file along three-quarters of a mile of bay. For centuries the Aleuts had made their livelihoods from the sea. When the earth shook, the older people remembered stories told by their grandfathers about walls of water that could swallow whole villages—they headed for the hills, and were saved. But when the waters rushed into their "protected" bay, 23 homes were destroyed or damaged beyond repair. The general store floated inland and stopped against trees almost half a mile from shore. As the water rushed out, fishing boats crunched on the bottom of the harbor. The sawmill and the community hall floated out to sea.

Soon, exceptionally high tides began to flood the townsite; when it became clear that the island of Afognak had subsided, the village council decided that the town must be relocated. Problems and uncertainties immediately arose. Legally, the agencies that work with the native villages could only rebuild the 23 destroyed homes. The 15 families whose homes still stood could expect no assistance in building new homes at the new site. The villagers were afraid to remain at Afognak, but they didn't want to be divided, either.



63.—Old Harbor a year after the quake. For the first time the villages were enjoying the comfort and convenience of community light, water, and sewer systems.

Lions International, 49th District, came to the rescue with needed supplies augmented by lumber donated by firms in Washington and Oregon. In appreciation the villagers voted unanimously to name the new settlement Port Lions. The native men labored beside skilled workers from the Mennonite Disaster Service who volunteered their services for reconstruction. On December 12, 1964, the first bargeload of people and possessions moved into Port Lions.

One year after the disaster, residents of Port Lions could look out into a peaceful cove and smile at the sight of fishing boats bobbing gently in the waves. Each family had a comfortable home, a generator produced electricity for each house, and sewer and water systems were being built. A 3-mile access road led to a 2,600-foot landing strip. The new school scheduled for construction in the summer of 1965 would make the community building (used temporarily for classes) available for village affairs. All this was made possible by the determined hard work of the villagers, Bureau of Indian Affairs, U.S. Public Health Service, Department of Education, Federal Aviation Agency, Alaska Division of Lands, Lions International, Red Cross, Mennonites, Salvation Army, and a host of others.

The story was the same in the other villages. Forty-one new homes sparkled in the sun at Old Harbor, 7 new homes at Alitak

64.—At Tatitlek, new homes were built to modern standards, with villagers furnishing much of the labor. Community utilities were installed to upgrade living conditions in the seven affected native villages.

sheltered the villagers from Kaguyak, and 14 new homes were built at English Bay—all this quite a change to people whose previous experience with running water had been confined to rivers and streams.

CORDOVA

Cordova, a fishing community of about 1,200 year-round residents, was once a busy port on Prince William Sound. It was settled in 1904 as ocean terminus for the Copper River and Northwestern Railway of the Morgan-Guggenheim syndicate. From 1904 to 1938, $48 million in high-grade copper ore was delivered from the Kennecott mine, 193 miles northeast in the Chitina Valley, to Cordova for shipment to the continental United States. Since 1938, when the mine was closed, the town of Cordova has depended wholly on salmon, clam, shrimp, and crab fisheries and processing. During the height of the fishing season each summer, the population would double.

As the only major community in south-central Alaska without a land-link to the rest of the State, Cordova sought continually to have a highway built along the old abandoned railroad bed. Residents felt that this would open the way to a broader economy by creating access to still-rich mineral deposits, timber, and potential agricultural development in the Copper River valley. By 1958 some 39 miles of the needed roadway had been completed.

Fire razed an entire city block in downtown Cordova on May 1, 1963, and completely destroyed business houses and the dwellings of 27 families. Less than 1 year later, earthquake and tsunamis wreaked havoc once again—this time along the waterfront. In the two disasters about 100 family dwellings had been destroyed, and the housing situation was critical.

But the earthquake was even more critical in its impact on the waterfront facilities and fishing industry. Fifteen-foot waves moved the dock off its pilings, and washed away the sawmill, boat landings, and homes. Tectonic forces that uplifted the shoreline left Cordova without deep water during low tides. Even though fish canneries sustained relatively light damage to buildings and equipment, they began to close down or move out because the boats couldn't come in to unload. Sloughs around the town that had yielded rich catches of salmon were high and dry.

One year later Cordova was still struggling. Only one out of nine canneries was operating. It processed crabs on a limited basis. Very little construction was taking place in private housing, but the Corps of Engineers was moving fast ahead with a new harbor and dock.

The city applied to the State for title to 4½ acres of reclaimed tidelands adjacent to the new city dock. The area had been filled by the Corps of Engineers during dredging operations of the harbor. Several small businesses that had been displaced by the expansion of the harbor temporarily relocated in the filled area until details of a proposed Federal Urban Renewal program could be worked out. A spokesman for the city indicated that another 2 to 3 years would pass before the land would be stable enough for heavy industrial and commercial use.

But plans for the future were being made. Through the Small Business Administration's "502" program, a $218,000 loan was granted to Theodore Seafoods, Inc., for a freezer ship. The new firm would employ new concepts in processing and marketing that hopefully would increase the 5-month fishing season to a year-round business.

A proposal was made by the newly organized Cordova Hydroelectric Corp. to build a plant on Power Creek just outside the town. A contract was signed whereby the city would purchase the power to supplement the municipally owned system. The facility would also provide storage for the city's water system. Financing was being sought through the Small Business Administration and the Rural Electrification Association.

Other anticipated projects included a shopping center, two more fish-processing plants, a sawmill, a facility for boat repairs, and a 50-space trailer park.

VALDEZ

Valdez was a quaint little town of about 1,200 people. At the head of long, narrow Valdez Arm off Prince William Sound, it lay beneath towering snowcapped mountains. Large glaciers filled nearby valleys in the Chugach Range. The beauty of the area was renowned.

Valdez came into being in the 1890's as an entry for gold rushers headed for the Klondike. It was the coastal point nearest to the United States and to the interior of Alaska. To eliminate the necessity of crossing Canadian territory, the United States Army built a military trail from the port town to the Yukon. After accommodating military units and adventurous fortuneseekers, the Valdez trail eventually became the Richardson Highway. Valdez thrived as the ocean terminus of the 363-mile land link with Fairbanks deep in the heart of Alaska.

Like most coastal towns in the 49th State, Valdez depended on water-oriented commerce and industry for its existence. In 1958 the community hit an economic low when much of the freight shifted to the port of Seward for delivery by The Alaska Railroad. Since that time it was mainly supported by a State mental hospital, a division of the State highway department, a relatively small fishing industry, and the summer tourist trade.

Good Friday, 1964, had been a joyous reminder at Valdez that spring was near. A festive air greeted the arrival of the steamship *Chena* at the city dock. Merchants, parents, and children looked on with interest as longshoremen and deck hands prepared to unload.

The sudden convulsions of the earthquake turned the pleasant scene into incredible cataclysm. The dock quickly broke to pieces and—with its warehouses and every man, woman, and child on it—disappeared from sight. The steamship *Chena* lurched. Her bow rose 30 feet on an incoming wave, then crashed down where the dock had stood moments before. The waters of Valdez Arm surged furiously through the town as the earth opened in crazy-quilt cracks. Survivors fled up the highway as flames from wrecked oil tanks engulfed the remains of their town's waterfront.

The outside world rushed to the aid of these valiant people as they began to pick up the pieces, but there was one more blow yet to come: geologists announced that the entire townsite had subsided, and that the unstable ground was subject to further slippage toward the sea.

In April 1964—just a few days after the quake—Valdez residents voted to move their townsite. On the advice of geologists, a location was selected on a 125-acre tract 4 miles away, where Mineral Creek empties into Valdez Arm.

In the fall of 1964, the new elementary school was dedicated. It was the only structure in the new townsite, and children were transported by bus 4 miles from their homes to their classrooms. Meanwhile, the Corps of Engineers, with funds from the Office of Emergency Planning, began building the new harbor and dock.

Realizing that the move to the new townsite must be made in stages, the people first patched up their old town. Some homes offered temporary protection with only minimum repairs. Mobile homes were utilized by others, but the critical housing shortage caused the population to dwindle to about 850 people. Businessmen wiped out by the disaster signed on with construction crews.

Work continued on federally financed harbor, dock, and warehouse facilities throughout the winter. Other federally financed construction such as the underground water and sewer systems, the municipal powerplant and distribution system, streets and curbs, and a high school, municipal, and State buildings had to await the spring thaw.

Until public facilities had been restored, the residents could scarcely think of building homes and businesses at the new townsite. At first it was hoped that private construction could be started by the spring of 1965, but such expectations proved unreasonable, and the big move was postponed.

The city planning commission, with the cooperation of the Alaska Housing Authority, had completed a preliminary layout for the new town in September 1964. In the months that followed, details were worked out for city planning, zoning and subdivision ordinances, and building, electrical, plumbing, and housing codes. Advisory bodies to the city council prepared modern regulations. Public hearings were held to assure that the new rules were equitable and just, and would assure orderly growth. By March 27, 1965, the first anniversary of the earthquake, all the new codes, regulations, and ordinances necessary for systematic construction of a new city had been adopted by the voters of Valdez.

During this time, also, negotiations were under way with the Federal Urban Renewal Administration for disposition of property within the old townsite. The proposal for the entire site was to develop it into a recreation area. The capital gained by property owners in the sale of their land to Urban Renewal was to aid them in buying new sites in the Mineral Creek location.

Residents formed the Valdez Development Corp. to assist business and industrial enterprises through the Small Business Administration's "502" program. Through this program, other local residents organized the Valdez Ocean Products, Inc., to build a proposed $750,000 seafood-processing plant in the new townsite. The plant was designed to incorporate the latest techniques in seafood processing, including vacuum sealing in plastic containers, ultracold freezing, and automatic controls. In June 1965, $400,000 of common stock was offered for sale to citizens of the State. The *Valdez Breeze* reported that the remainder of the capital would be sought from the Small Business Administration through the Valdez Development Corp.

Although this project was the only such actually underway by June 1965, 17 other proposals were anticipated. These represented all types of service facilities, including those for fisheries, tourism, and recreation.

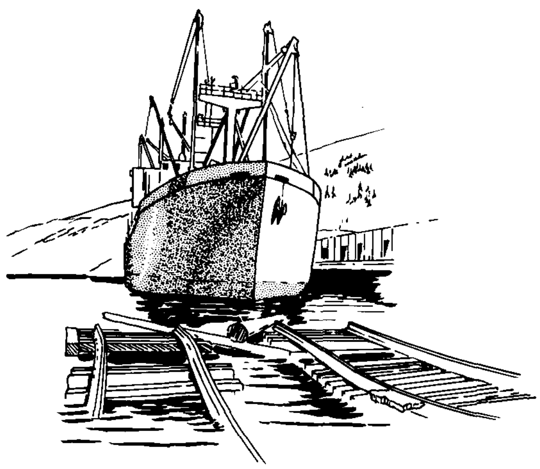
With the completion of the city dock and one of two warehouses by the Corps of Engineers, the Alaska Steamship Lines scheduled a freighter visit on July 8, 1965—the first such ship to visit Valdez since the fateful arrival of the *Chena*.

WHITTIER

The ice-free port of Whittier was built as a military installation during World War II. Lying at the head of the Passage Canal on the west end of Prince William Sound, it had been virtually shut down in recent years. Although it was ravaged by tsunami and fire on March 27, 1964, it was utilized by The Alaska Railroad during the following year as its port of entry for freight bound for other parts of southcentral and central Alaska.

A private corporation purhased and renovated an abandoned apartment complex to develop a recreational resort, the Chenega Inn. Though its operations were limited, the Chenega Inn opened in the summer of 1964. By the middle of May 1965, it was in full-scale operation with accommodations ranging from dormitories and singles to family arrangements. Visitors could enjoy the new cafeteria, a luxurious dining room, and a rustic-style lounge.

Full facilities for small boats were available, as well as rental vessels and other necessities for boating, fishing, and hunting. A 70-passenger yacht offered daily 7-hour cruises through some of the finest scenery in the world, giving a view of 18 glaciers, 8 of which enter tidewater. Via railroad, boats, and small aircraft, tourists traveled to Whittier, a vital community once more.



GIRDWOOD

Girdwood, a hamlet of 80 residents, sat on the shore of Turnagain Arm beside the towering Chugach Mountains. It subsided during the earthquake, and relocation was necessary. Residents preferred to remain near their year-round industry, the Mount Alyeska ski resort. Federal land was selected farther up the valley, available under the statehood land withdrawal program.

Within the next 12 months the new city boasted a school (about half the population are children), a library, a community center, a grocery store, post office building, a small cafe, a new church, and a new community water well. And for the first time in its history, Girdwood had electric lights—three of them. City officials had requested land for development as a municipally operated trailer park. Twenty-six lots had been released for private ownership, and the city was pushing for more so that their community might grow in the future.

ANCHORAGE

Anchorage is Alaska's largest city. Born as a tent town in 1914 at the mouth of Ship Creek on Cook Inlet, it was a supply base for construction of The Alaska Railroad. The following year, a 312-acre tract on the higher area south of the creek was cleared and surveyed. In the original townsite 100 lots were reserved for Federal and municipal purposes, and 887 lots were auctioned for private use. From a population of 2,000 people in 1915, Anchorage had grown to approximately 50,000 within expanded city limits covering 15 square miles in 1964. An estimated 100,000 reside in the greater Anchorage area.

65.—Some homes were repaired on their original sites despite advice to move them. This house, tilted off its foundation in earthquake-triggered landslides along the bluff line, was rehabilitated in place by the owner-occupant.

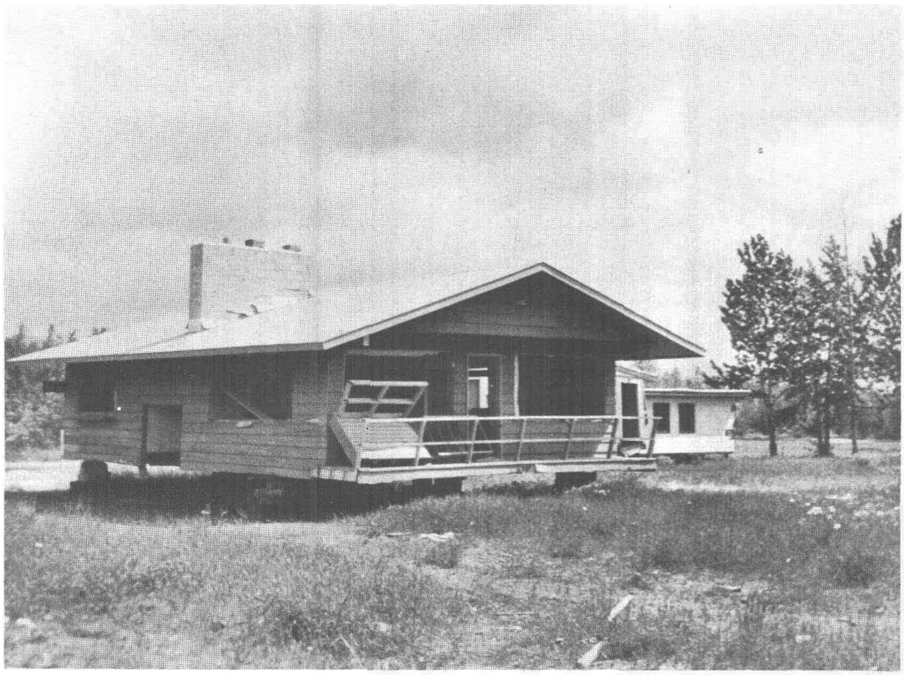
The period of greatest growth was between 1950 (11,200) and 1964. This was also the time of the building boom that added millions of dollars worth of new homes, apartment buildings, hotels, shopping centers, office buildings, hospitals, schools, stores, and bank buildings and a university.

Growth in the private sector was matched by more millions of dollars spent on new public facilities. Multimillion-dollar structures were built by the State to house the State court system and a psychiatric hospital. The city-owned port, an $8-million project commenced in 1959, was dedicated on July 8, 1961. The $1.5-million Public Safety Building, dedicated in August 1961, provided a combined headquarters for the police and fire departments. A $1.8-million water-filtration plant was dedicated on June 30, 1962.

The discovery of oil and gas on the Kenai Peninsula, south of Anchorage, led to optimism of rising prosperity as the city became the service center for one more industry. Anchorage was building toward a greater future when the earthquake struck.

Property owners lost tens of millions of dollars; much of the loss cannot be evaluated in dollars and cents alone. It represented years of planning, personal sacrifice, and labor on the part of the owners and their families. If Anchorage was to rebuild, these very people would have to decide whether to reinvest in an uncertain future. Answers were not easy, but they were made quickly: Rebuild! And the recovery period was almost as dramatic and breathtaking as the earthquake.

The plight of those whose homes were destroyed by landslides was well publicized. But many more people whose homes were not destroyed but were declared unsafe for human occupancy faced critical decisions and financial disaster in the months that followed. Many of these homes had sustained relatively little damage, but because of their location near slide areas, Federal lending agencies could not provide money for repairs. The city



66.—A home moved from a hazardous area to a safe haven.

ordered their removal to safer locations, and the owners, already facing big mortgages, faced additional investments in new lots, repairs, new utilities, and all the other expenses of building a home.

A few could afford to repair their homes and risk remaining on their original sites (fig. 65), but many others accepted the offer by the Corps of Engineers to move their homes to safety without charge. The city provided temporary home sites until the owners could obtain permanent locations. Some houses still stood in the temporary spots a year later.

A typical story is that of a beautiful home in an exclusive neighborhood called Turnagain-by-the-Sea. Before the earthquake, the house was several blocks from the bluff. After the quake, the new bluff line was just a few feet from the door. The preearthquake valuation of the house was $72,000 and the mortgage on it was $21,000. Its postearthquake value was set at $3,000; the lot was valued at $900. Just 3 months before the earthquake, the lot next door had been sold for $15,000. After the owner purchased land south of the city, built a basement, and had the house moved to its new location by the Corps of Engineers, he reported that he had spent more than the original investment to return the house to its preearthquake condition.

Although Federal funds were not available for repairs to properties within the L Street slide zone in downtown Anchorage, private money was used. Owners reasoned that they could not abandon properties that represented their life savings, and, defying the warning that they stood in danger of destruction in the event of another earthquake, they proceeded with repairs even though some of the ground had moved as much as 14 feet laterally.

In the private sector, damaged businesses were rebuilt with speed and imagination—some rebuilt with Federal aid and some without. Many new businesses were launched soon after the earthquake and were carried along by the momentum generated by the reconstruction boom. Spectacular gains were noted in many areas of business. The following are but a few examples.

In the downtown area, a 14-story 450-room hotel that was being enlarged at the time of the earthquake, though significantly damaged, was repaired and reopened for business only a few weeks behind schedule. New facilities include an impressive penthouse restaurant which affords unobstructed views of Cook Inlet and the Chugach Mountains.

Another large hotel, nine stories high, was still on the drawing board at the time of the earthquake. It was started in August 1964 and was completed the following June. Construction proceeded throughout the long Alaskan winter.

Several attractive motels were built in the area between downtown and Anchorage International Airport. Plans were announced in June 1965 for construction of a large hotel near the airport.

Two automobile agencies north of downtown were rebuilt with finanical backing of the Small Business Administration. Lessons learned from the earthquake were applied to the new designs.

A downtown grocery store, destroyed by the quake, reopened at a new location south of town and enjoyed the best business year in its 25-year history.

A five-story downtown department store, which had been damaged beyond repair, was replaced on the same site by a new building three stories high but of twice the ground space, and a new automobile service department was planned for 1966.

A damaged bank building was dismantled down to its steel frame and completely rebuilt. One year later, assets of the bank had increased almost $8.5 million. Another bank, formerly a drive-in bank, was enlarged to nine stories. Two new theater buildings replaced one that was destroyed in the 4th Avenue landslide.

The Anchorage Natural Gas Corp., a private utility that delivers gas from the Kenai Peninsula, sustained about $1 million damage. Repairs were completed before the following winter, and on June 15, 1965, the board of directors voted a capital investment budget of an additional $1 million.

All the activity in the downtown area did not overshadow the fact that the city continued to edge out from the bluff line along Ship Creek and Knik Arm and to reach toward the foot of the Chugach Mountains. New motels, restaurants, a creamery, a medical center, a bank, office buildings, and other services appeared along Northern Lights Boulevard about a mile south of downtown Anchorage. New homes stood in areas that had been the "boondocks" a few months earlier.

Construction of a large shopping center at Northern Lights and Minnesota Drive, just a few blocks from the newly rebuilt West High School, began in May 1965. Just east of that, a housing development was being moved to make room for the growing Northern Lights Shopping Center. Developers planned to triple its size.

Still farther east, at the intersection of Northern Lights Boulevard and Seward Highway, land clearance signaled the beginning of another shopping center covering 20 acres. Plans were announced for another large shopping center a short distance away at the corner of Seward Highway and International Airport Road.

67.—A few homes situated at the toe of the L Street slide remained precariously perched on makeshift foundations 15 months after the earthquake.

These are but a few of the incredible stories of accomplishments in Anchorage, the city that refused to give up, but they are typical of the optimistic attitude found throughout the area. Achievement and expansion were the key words with the city government too. A record-breaking sum of $34,548,678 was spent by the city of Anchorage by December 31, 1964. Only about $6¼ million of this went into earthquake repairs and replacement projects. As new projects in the capital improvement program were completed, design work proceeded on others.

Voters overwhelmingly approved a bond proposition to expand the telephone system which already served 27,098 customers. Approval was also given to issue bonds for $1,750,000 for the construction of a petroleum tanker dock and an extension of the existing dock at the port of Anchorage. The port showed a profit of $218,115 in 1964—the first time in its 4-year history it was out of the red. During the year, 800,000 tons of cargo was handled by the city dock—an increase of 820 percent over the year 1963. And these figures do not include the cargo handled by three private docks nearby.

This growth was due to several factors. When other port facilities in south-central Alaska were wiped out, oil companies moved operations to Anchorage where the port was operational. Many tons of emergency supplies went over the city docks in the early months of recovery. And on

May 10, 1964, the cargo ships of Sea-Land Services, Inc., began a weekly schedule from Seattle to Anchorage. The winter of 1964–65 was the first time that the port of Anchorage had been used year-round.

The Anchorage International Airport, operated by the Alaska Division of Aviation, launched a four-stage multimillion-dollar building program. The Federal Aviation Agency, operator of the control tower at the busy terminal, spent approximately $850,000 for the construction of a new building. The old one had collapsed, killing one man. The new O-design tower—one of the first of its type to be built by the agency—went into operation in February 1965.

A $900,000 two-story building was planned by the State to provide space for agencies directly involved with international flights. Another $300,000 project would provide an enlarged parking area. The present terminal building had been enlarged, and a $750,000 satellite building is scheduled for construction. Five-sided in design, it will provide badly needed parking for five giant jets, which eventually will be refueled through outlets to eliminate fuel-truck traffic.

The Federal Government has granted stopover privileges in Anchorage to four foreign airlines that fly regular routes between Europe and the Orient. This means that the foreign tourist trade can be cultivated.

The year 1965 was a record year for tourism in Alaska. Many people who had planned to visit the 49th State in 1964 had been discouraged by the earthquake, but airlines, travel agencies, and other tourist services reported that 1965 was the biggest money-making year in history.

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This was good news to Alaska. Although her vast natural resources were being slowly and solidly developed for stable economic growth, she could count also on unexcelled natural beauty to attract the tourist dollar.

The petroleum industry had already made a sizable contribution to the economy of south-central Alaska and to the State as a whole. Explorations continued at a rapid pace. In the spring of 1965 it was anticipated that $20 million more would be expended in petroleum activity in the coming year.

THE FEDERAL GOVERNMENT AIDS THE PEOPLE OF ALASKA

Even before March 1964, giant steps had been taken toward the fulfillment of Alaska's promise, but Alaska could not fulfill it alone.

Within a few days after the earthquake, after emergency relief measures had been taken, the President established the Federal Reconstruction and Development Planning Commission for Alaska and appointed Senator Clinton P. Anderson chairman. On the recommendations of the Commission, Congress approved $23.5 million in additional transition grants to supplement the $28.5 appropriated in 1959 to assist the new State in assuming responsibilities carried by the Federal Government when the area was a territory. These funds were needed immediately in Alaska to maintain essential public services and to help State and local governments overcome their loss of revenue.

On the advice of the Commission, many other changes were made to further expedite assistance in the reconstruction and upgrading of highways and harbors. Federal agencies were empowered to adjust mortgages they held or insured. Long-term, low-interest loans were made available to the private sector. Federal participation in urban renewal programs was raised to a limit of $25 million for the entire State. Federal purchase of Alaskan capital-improvement bonds was authorized. The director of the Office of Emergency Planning described the entire legislative package as a "landmark in Federal aid after natural disaster."

The Army Corps of Engineers and the Navy Bureau of Yards and Docks were designated by the Office of Emergency Planning to act as agents for the restoration and reconstruction of public facilities. The Bureau of Yards and Docks concentrated on the city of Kodiak. The Corps of Engineers handled the Office of

Emergency Planning projects in Anchorage, Seward, Homer, Valdez, Seldovia, Cordova, Girdwood, and Whittier. The Federal Bureau of Public Roads assumed responsibility for most of the highway and road projects under its own authorities.

The Alaska Highway Department estimated that projects totaled $84.9 million for the fiscal year ending June 30, 1965. Much of this sum came under the Federal-aid highway program, and more than half of it was spent in the earthquake-affected part of the State.

Most of the projects involving airports were assigned to the Federal Aviation Agency. Close to $1.3 million would be expended when all projects were completed. Additional millions were to be programed by the State for expansion and improvement of State-operated airports.

The Alaska Railroad, operated by the U.S. Department of the Interior, sustained heavy damage to 186 of its 536 miles of tracks and bridges, and about 300 units of rolling stock were total losses. The job of laying new track began the morning after the earthquake, and within a few weeks trains began to operate cautiously over the line. On April 20, 1964, the first sea-train barge was unloaded at Whittier and the cargo was delivered by rail to way points north. On September 14, a triumphant crew brought the first train into Seward since the earthquake.

In the first 12 months following the earthquake, the railroad had spent $20 million in specially appropriated emergency funds for repairs. Another $3 million had been requested of Congress. Bridges were replaced. The roadbed in subsided areas of Turnagain Arm had to be rebuilt above high tides. Some 150 units of rolling stock had been replaced.

The Alaska Railroad had been self-supporting in its operations since 1941, and had been independent as far as capital improvements were concerned since 1955. During the year following the earthquake, its income was down a million dollars from the loss of three petroleum-haul contracts, because two oil companies had moved their operations to Anchorage when their Whittier facilities were wiped out. However, railroad officials instituted economies and announced their intention to remain within the railroad's income.

The Small Business Administration streamlined procedures to make loans available to hard-hit homeowners and businessmen. Required bank participation in loans was reduced from 20 to 10 percent. Disaster loans were made to cover expenses of relocating buildings. Loans to homeowners were made on longer terms and at lower rates of interest than previously. The loan ceiling to businessmen was raised from $100,000 to $250,000.

As of March 31, 1964, the Small Business Administration had accumulated loans in Alaska amounting to $22,249,000. This figure included applications that were later withdrawn, refunded, or paid in full. Little more than a year later, at the close of the business day on April 9, 1965, home and business loans approved in Alaska totaled $74,869,420. These loans covered the State from Barrow on the Arctic Ocean to Unalaska in the Aleutian Islands, and from Nome on the Bering Sea to Ketchikan in southeastern Alaska.

Through the Small Business Administration's Community Development Program, local development corporations were established throughout the State by the middle of June 1965. These organizations could borrow money from the Small Business Administration to finance business, commercial, and industrial ventures of benefit to the communities. Prior to the earthquake only one such corporation was in existence in Alaska, and it had not been active. By the middle of June 1965, the Small Business Administration was doing business with 48 concerns. Not only cities such as Anchorage benefited, but also smaller towns and some 17 native villages. A spokesman for the Small Business Administration anticipated that within the second postearthquake year, the loans approved for the creation, diversification, and improvement of industries would exceed $20 million.

Additional loans of more than $1 million were approved by the Department of the Interior to aid the fisheries.

The Federal Housing Administration held mortgage insurance on 93 homes that were totally destroyed in Anchorage. There were no FHA mortgages in the other communities struck by the earthquake and tsunamis. Aside from homes totally destroyed, 596 FHA-insured homes were suitable for rehabilitation on their original sites; 70 were moved to safer locations. As of May 1, 1965, an estimated 25 homes were still on their originial sites, neither repaired nor occupied. By that date, only 35 homes had been returned to the FHA by the mortgagors.

The "1200 L," a 14-story apartment building with an estimated $1 million damage, and its downtown twin, the Mount McKinley Building, were returned to FHA. Each one had an existing mortgage of about $1.5 million. In

June 1965, the "1200 L" was sold to high bidder for $575,000. The new owners anticipated it would be ready for partial occupancy within 90 days. The Mount McKinley Building had not been put up for bid.

The value of the FHA-insured properties that were lost in the disaster amounted to $6,234,897. Between April 1964, and March 31, 1965, commitments for a total of $25,256,850 had been issued by the FHA for 938 housing units.

To further assist the State's recovery, special congressional legislation authorized Federal purchasers a total of $25 million of State bonds, or a loan in that amount. In addition, the Housing and Home Finance Agency was authorized to purchase $7.2 million in State bonds for completion of Alaskan capital-improvement programs.

When the Federal Government moved to the aid of the 49th State, it was protecting an investment made 100 years earlier. Through the years the $7 million purchase price of Alaska has been repaid manyfold to the nation. By the end of the 19th century, more gold than the original purchase price had been mined in Alaska and sent to the United States. Gold mining was negligible by 1964 but the State boasts of many still-rich mineral deposits, and other natural resources and growing industries promise to make continuing contributions to the national wealth.

During the year of decision and action, resolute Alaskans, with the generous aid of their Nation, worked with quiet determination toward a brighter future.

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The staff of the Alaskan Earthquake Committee of the National Academy of Sciences contributed greatly to this bibliography. This group, led by Earl F. Cook and William L. Petrie, Division of Earth Sciences, made determined efforts to track down all pertinent commentaries on all aspects of the earthquake. Copies of the papers collected, as well as bibliographic references to them, were made available to Geological Survey personnel for use in preparation of their reports.

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