THE ALASKA RAILROAD BETWEEN ANCHORAGE AND FAIRBANKS

Guidebook to Permafrost and Engineering Problems

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STATE OF ALASKA

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Reuben Kachadoorian
March 30, 1921 - June 30, 1983

This guidebook is dedicated to the memory of Reuben Kachadoorian, who worked as a geologist for the U.S. Geological Survey. During his long association with the Alaska Railroad, Reuben earned the respect of the Alaska Railroad engineers and their acceptance as a true railroader.

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GUIDEBOOK TO PERMAFROST AND ENGINEERING PROBLEMS ALONG THE ALASKA RAILROAD BETWEEN ANCHORAGE AND FAIRBANKS

By T.C. Fuglestad[1]

INTRODUCTION

The Alaska Railroad extends from Seward, a year-round ice-free seaport, to Fairbanks in interior Alaska (sheet 1), a distance of 470 mi (756 km). The railroad crosses two major mountain ranges and traverses various terrains. This guidebook focuses on the route between Anchorage, the largest city in Alaska, and Fairbanks, the second largest city and transportation hub of interior Alaska. Over half of this segment of the railroad is within the discontinuous permafrost zone (fig. 1).

The Alaska Railroad was constructed by the same methods used to build the transcontinental railroads in the western United States. Men dug their way through hillsides with picks and shovels; solid rock was drilled and shot with primitive tools and powder; wheelbarrows were used to build the fills; and teams of horses pulled small dump carts and plows to widen shoulders and shape the subgrade.

Excavated material was never wasted; it was placed in an adjoining fill section along a center line selected to balance the cut-and-fill sections. When the centerline crossed a level valley, fill material for an embankment section was usually borrowed from adjacent ground, with little regard to the type of material present or its susceptibility to frost. This indiscriminate use and placement of unclassified materials resulted in a track subgrade that required constant maintenance because it heaved in winter and settled in summer. The roadbed has been substantially improved, but operating and maintenance costs continue to be influenced by these early construction techniques.

Although it is easy to criticize the original railroad construction techniques, limitations were imposed on the locating engineer by the primitive construction equipment and the uncharted Alaskan wilderness. That many of the bridges erected during construction are still used is a tribute to the capability of these engineers.

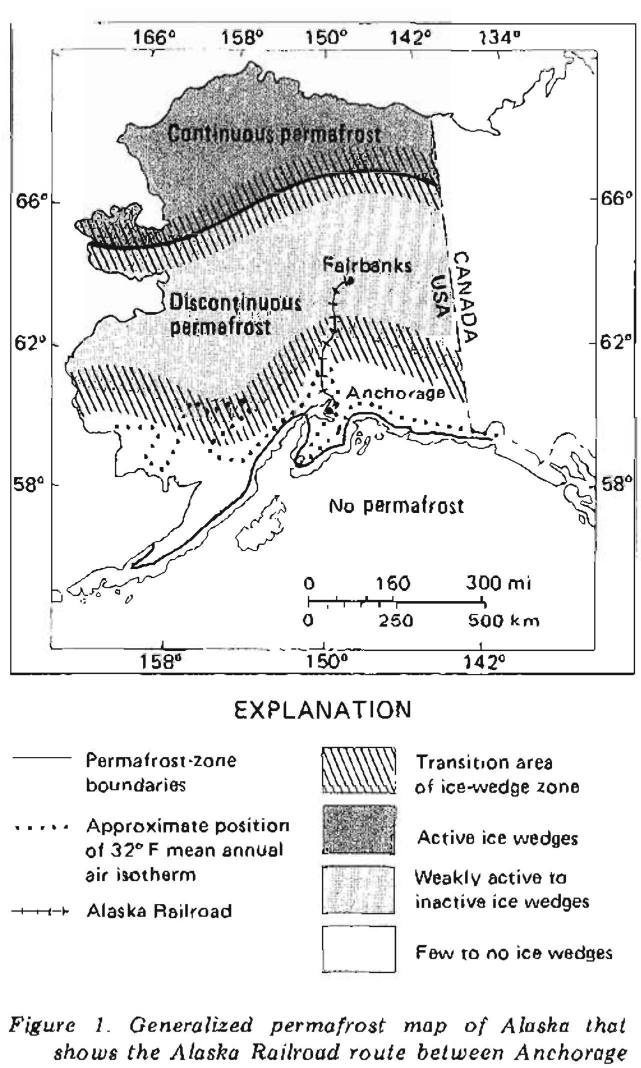

Figure 1. Generalized permafrost map of Alaska that shows the Alaska Railroad route between Anchorage and Fairbanks.

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HISTORY OF THE ALASKA RAILROAD

Construction of the Alaska Railroad began in 1904 as a private venture founded by John E. Ballaine. Ballaine envisioned the Alaska Central as a utilitarian railroad that would aid the general development of central Alaska, help develop agriculture and timber, and give Fairbanks year-round access to the 'Outside.' Additionally, the extensive Matanuska Valley coal deposits could easily be transported to tidewater for the U.S. Navy and export to world markets.

Ice-free Resurrection Bay was selected as the terminus of the railroad, and the city of Seward and a port facility (sheet 1, Mile 0.0) were developed. Reconnaissance surveys extended as far north as the Tanana River in interior Alaska, and by 1909, track was laid across the Kenai Peninsula to Kern Creek (Mile 70.5). The 2.2-percent grade from Mile 49 to 54 past the foot of Bartlett Glacier required the construction of seven tunnels, a horseshoe trestle that curved 235°, and roadbed and trestles that looped through 394° of total curvature.

The heavy construction costs severely strained the limited financial resources of the Alaska Central, which was already subject to a federal levy of $100/mi of track/yr. The railroad also faced a completion deadline of 6 yr from filing for a complete right-of-way to the Tanana River. Bickering and speculation among the stockholders did not help. Any hope for the tonnages required for a financially successful railroad vanished in 1906 when the federal government withdrew all Alaska coalfields from private entry. By this decree, even the coal that fueled the locomotives had to be imported! Bankruptcy for the Alaska Central occurred in 1909. After reorganization, railroad construction (as the Alaska Northern) continued before shutting down completely in 1912.

An engineering report published in 1916 commented favorably on the location of the 71 mi (114 km) of track constructed by the Alaska Central. However, the quality of construction was heavily criticized: "The roadbed is in very bad physical condition - the rail is too light - embankments along the rivers are too low and too narrow and many of the bridges were not carefully constructed, spikes instead of bolts being used and the former having shaken out, the trestles are now unsafe" (Alaska Engineering Commission, 1916).

The conservation policies of President Theodore Roosevelt, particularly the withdrawal of public lands from private use, made it apparent that private capital could not build adequate transportation facilities to interior Alaska. If interior Alaska was to be developed, the government would need to construct and operate the necessary transportation facilities. In 1912, a presidential commission visited Alaska and reported to President Taft that they were in favor of such construction.

In 1914, passage of the Enabling Act empowered newly elected President Woodrow Wilson to locate and construct a railroad (or railroads) that would connect at least one Pacific Ocean port with a navigable river in interior Alaska and with one or more coalfields [aggregate mileage not to exceed 1,000 mi (1,609 km)]. To accomplish this, the three-member Alaska Engineering Commission was created. Wilson appointed William C. Edes as chairman. Edes was unfamiliar with Alaska, but had an excellent reputation as a locating engineer with several western railroads. The second member of the Commission was Lt. Frederick Mears of the U.S. Army Corps of Engineers. Mears had considerable experience with the Great Northern Railroad and the Panama Canal Railroad, but no experience in Alaska. The third member was Thomas Riggs, who had considerable experience in Alaska as a mining engineer and surveyor on the International Boundary Commission.

Under the direction of these men, preliminary location surveys were conducted in 1914 to select potential corridors for the construction of a railroad to interior Alaska. Results were formally presented to Wilson on February 11, 1915. The gentle terrain of the Goldstream valley was selected for the corridor between Nenana and Fairbanks rather than a route along the north side of the Tanana River. Today, with our knowledge of permafrost, we would probably opt for hillside construction on a south-facing slope rather than construction on the ice-rich soils of Goldstream valley.

An evaluation of existing railroads was also included in the report to Wilson. One such railroad was the 44.7-mi-long (72 km) narrow-gauge (3 ft; 92 cm) Tanana Valley Railroad built by private capital in 1905 to connect various gold-mining camps in the Fairbanks area with the community of Chena on the Tanana River. During construction, grading was minimized, and valleys were crossed on wooden trestles because of insufficient suitable embankment material and the presence of permafrost. Despite heavy maintenance costs, the

Tanana Valley Railroad was a success until 1916, when the grade of the rich placer deposits began to decline. The Tanana Valley roadbed from Fairbanks to Happy (Mile 460 to 463) became part of the Alaska Railroad standard-gauge main line. The remainder, designated as the Chatanika Branch, continued to operate as a narrow-gauge branch line until 1930, when it was abandoned.

After President Wilson selected and approved the Susitna route, which included purchase of the Alaska Northern and the Tanana Valley Railroads, the Commission quickly surveyed the final route and began construction in 1915. Edes established headquarters in Seward and oversaw construction of the Alaska Railroad. Mears moved to Ship Creek and laid out the townsite of Anchorage, prepared facilities for receiving construction materials and supplies, and began constructing the line to the Matanuska coalfields. Riggs, the surveying member of the Commission, traveled to Fairbanks to walk every foot of the location surveys before he proposed a final right-of-way between Broad Pass and Fairbanks. The first rolling stock and construction equipment came from the Panama Canal Railroad as surplus.

The roadbed was constructed by station contract in which "a number of men associate themselves together as partners, taking short pieces of work at a certain price per cubic yard for grading, or per acre for clearing and grubbing. Each man signs the contract for doing the work and becomes equally interested in it as a co-partner or small contractor. Scarcely any capital is necessary to make a station contract, as the Commission furnishes the necessary equipment at a moderate rental" (Alaska Engineering Commission, 1916). Such an arrangement effectively limited the type of embankment material to that at hand. Commission forces handled all bridge work and any trestle work required for high fills and laid the track.

Specifications for construction contracts predictably stated, "All materials taken from cuts shall be deposited in the embankment within the distance prescribed by the Engineer." Only three classifications for excavated materials were listed: loose rock, solid rock, and common excavation. Although no classification was originally listed for excavation of frozen material, its presence in the upper Chulitna - Broad Pass area was acknowledged in the 1915 report. Native timber was used for ties and timber trestles. In laying the main line with 70-lb (32 kg) rail, only the curves had tie plates.

The construction years (1915 to 1923) saw an outstanding engineering achievement marred by labor unrest, inflationary costs caused by participation of the United States in World War I, the failure of Congress to appropriate construction funds in a timely manner to meet limited construction seasons, and intense personal and political bickering. The initial $35 million appropriated for railroad construction was $22.9 million short of actual construction costs.

Commissioner Riggs resigned in 1918 to become Governor of the Territory of Alaska after admitting that expediency sometimes governed construction on the north end of the line. Chairman Edes resigned in 1919 because of ill health. Mears returned from France to become Chairman, but was relieved of that post on March 26, 1923, just 3 mo before the railroad was completed.

Erection of the 702-ft-long (214 m) truss span across the Tanana River at Nenana marked completion of construction of the Alaska Railroad. On July 15, 1923, President Warren G. Harding drove the golden spike at the north end of the bridge, officially marking the opening of the Alaska Railroad.

Although the completed railroad offered such immediate benefits as bringing coal from the Suntrana fields near Healy (Mile 358) to the fuel-starved gold-mining industry at Fairbanks, the expected resource development in central Alaska did not materialize. Until 1940, the total population of Alaska was less than 65,000. From 1923 to 1940, revenues for the railroad fell below operating expenses in all but 1 yr. Maintenance was either deferred or severely modified; this included improvements slated for miles of substandard roadbed and bridges constructed by the Commission under the constraints of fixed federal appropriations and inflationary costs. Funds that remained after meeting operating expenses were used to replace large timber bridges with permanent steel structures.

With the onset of World War II, the military arrived in Alaska in strength. Supplying the military increased yearly tonnages dramatically, with a corresponding effect on track and bridges. Increased revenues provided funding for desperately needed maintenance, but a war-time manpower shortage made it impossible to stop further deterioration of railroad property.

Once again Congress was asked to consider the fate of the railroad, which either had to be completely rebuilt or abandoned because it could no longer function as a transportation system in its '1946' condition. Fairbanks was totally dependent on Suntrana coal for its power and heat, and no other energy alternatives were in sight. Anchorage, with its two military bases, relied almost as heavily on coal from the Matanuska fields. There were slightly more than a thousand miles of roads in the entire territory, mostly substandard. The Alaska Railroad had to be rebuilt.

Under an ambitious rehabilitation program, the main line from Portage (Mile 64.2) to Fairbanks (Mile 470.3) was to be rebuilt to modern standards. (A decision to rehabilitate the line from Portage to Seward was made in 1954.) Heavy (115 lb; 52 kg) rail would replace the worn 70-lb (32 kg) rail, and treated-fir crossties would replace untreated native-spruce ties. Sags would be eliminated by raising the track as much as 5 ft (1.5 m), and shoulders would be widened to a standard 20 ft (6 m). The new track structure was placed on 12 in. (30 cm) of select pit-run gravel to permit speeds as

Figure 2. Car-barge slip at Whittier. Much freight destined for Alaska arrives by rail at Seattle, where freight cars are loaded directly onto huge rail barges that hold up to 64 cars each. A tandem tow of two barges usually makes the 1,590 nautical-mile (2,945 km) trip up the Inside Passage and across the Gulf of Alaska to Whittier, where the cars are unloaded at the car-barge slip and hauled to their destinations along the railroad route. This service has been offered since 1963. Photograph by Bill Coghill, 1980.

high as 60 mph (96 kmph). Surplus war material would be used to build new steel bridges and shops and supply new rolling stock and heavy construction equipment.

This effort outspent the money available, but not before many improvements were made. However, the raises were reduced and the shoulder-widening program cut back. The tie-replacement program was stretched out because the railroad was mandated to maintain and rebuild with revenues rather than with Congressional appropriations. Later, as new track-maintenance equipment became available, manpower was reduced.

The Great Alaska Earthquake on March 27, 1964, caused heavy damage, but subsequent repair work improved the line. Today's railroad, particularly its equipment (figs. 2 and 3), is modern in many respects. High-production surfacing equipment is used during the short construction season to offset the legacy of poor subgrade conditions and prepare the track for the long winter.

The 140 to 160 mi (225 to 290 km) of track that are raised, lined, and dressed each summer equal a 3-yr ballasting cycle; the average figure for other railroads in the United States is 5 yr.

Fifteen years ago, three track gangs of 10 men each were required to augment the 25 section crews of two or three men each that maintained the track through the winter. Today, only the regular section crews, each patrolling an average of 20 mi (32 km) of track, are needed for necessary winter maintenance.

PHYSIOGRAPHIC SETTING OF THE RAILBELT[2]

The area traversed by the Alaska Railroad is a north-south strip (sheet 1) that crosses several distinct physiographic divisions of southcentral Alaska. The Pacific coast margin of North America is bordered by a broad belt of mountainous country that comprises many closely connected ranges known as the Pacific

[2]Modified from Capps, 1940.

Figure 3. Extra 3009 northbound along Turnagain Arm toward Anchorage. A four-engine 'consist' totaling 12,000 h.p. heads this 80-car train, which has a gross tonnage of 5,600 tons (5,080 t). Photograph by Bill Coghill, 1980.

mountain system. Where this northwest-trending mountain system crosses the eastern boundary of Alaska at the 141st meridian, its trend becomes nearly east-west, and the mountain system divides into two rather distinct ranges: the Chugach Mountains, along the coast, and the Alaska Range, inland. Swinging farther to the west, both ranges merge into and join the intermediate mass of the Wrangell Mountains. West of the Wrangell Mountains, the two ranges are sharply separated by the Copper River basin, but at the 148th meridian, the intervening space is occupied by the Talkeetna Mountains and their northern extension. The western axis of each range is deflected in a great crescentic arc to the southwest; the Kenai Mountains and the mountains of Kodiak Island extend from the Chugach Range; and the Alaska Range curves southwest past Mount McKinley and merges into the Aleutian Range. The Kenai, Chugach, and Talkeetna Mountains are separated on the west from the Aleutian and Alaska Ranges by the Cook Inlet depression and the Susitna and Chulitna River basins. North of the Alaska Range, the broad lowland of the Tanana basin intervenes between that range and the Yukon-Tanana Upland. Geographically, the region traversed by the railroad comprises six natural subdivisions that are described below (Wahrhaftig, 1965).

CHUGACH-KENAI MOUNTAINS

The north shore of the Pacific Ocean from the 151st meridian to Cook Inlet is bordered by a broad belt of rugged mountains that rises abruptly or is separated from the shore by a narrow coastal plain. From Mount St. Elias west to Turnagain Arm, this range is called the Chugach Mountains. South of the depression formed by Turnagain Arm and Passage Canal, the term 'Kenai Mountains' is used. The two ranges are geologically and structurally alike; they are named separately because of their erosional history. Two glacial fiords and a relatively low pass have formed a depression across the mountain range. East of the Copper River, the Chugach Mountains trend slightly northwest and are about 100 mi (160 km) wide. The western portion of Prince William Sound and its long fiords cut deeply into the mountains, so that the head of College Fiord is only 40 mi (64 km) across the range from the Matanuska River. The mountainous islands that form the outer border of the Sound belong to the Chugach Mountains. Prince William Sound lies in the convex area formed by the range as its trend changes in a crescent-shaped curve from northwest to west to southwest. The Kenai Mountains that trend southwest and across the mouth of Cook Inlet are connected by the mountains of Afognak and Kodiak Islands.

The Chugach-Kenai Mountains consist of rugged peaks that rise to elevations of 4,000 to 7,000 ft (1,200 to 2,300 m) above sea level; at the head of College Fiord, several peaks rise above 10,000 ft (3,100 m), and the highest, Mount Marcus Baker, reaches 13,250 ft (4,000 m). These mountains are composed dominantly of folded, deformed sedimentary rocks. Their surface has been conspicuously modified by glacial erosion. Higher parts of these mountains nourish glaciers, many of which are large. Distributary valley glaciers radiate from several large centers of ice accumulation, notably on the south and east sides of the Kenai Peninsula and in the area north of Prince William Sound. In Prince William Sound and along the south coast of the Kenai Peninsula, the region's scenic beauty is enhanced by glaciers that reach the sea in fiords whose steep walls and bordering ridges rise abruptly from the water. The mountains are peculiar in that they have few large, systematically developed rivers. The coast line is deeply embayed and sinuous, and Prince William Sound is dotted with scattered mountainous islands whose topography resembles that of the mainland. The railroad route from Seward starts at the head of Resurrection Bay, a beautiful fiord, and runs north through mountain valleys that follow the trend of the Kenai Mountains. At Turnagain Arm, another great fiord, the route turns west along the flank of the Chugach Mountains, which it follows to the Matanuska River. The Eska branch of the railroad lies along the boundary between the Chugach and Talkeetna Mountains.

TALKEETNA MOUNTAINS

The Talkeetna Mountains form a large, crudely circular mountain mass that is bordered on the west by the lower Susitna valley, on the south by the Matanuska River, and on the east by the Copper River basin. The Talkeetna Mountains differ markedly in topography, structure, and rock type from the Chugach Range to the south and the Alaska Range to the north. The Talkeetna Mountains are dominantly composed of igneous rocks, including granitic materials and lava flows of several ages. The eastern half of the mountains are composed primarily of sediments of Mesozoic age. The present relief of the range is the result of a large domal uplift; many formations are only slightly deformed. A radial drainage pattern is common, and most streams are tributary to the Susitna River. A small area drains east to the Copper River, and most water from the south slope finds its way to the Matanuska River. The mountain mass is divided almost in half along a north-south line by the north-facing headwaters of the Talkeetna River and the Chickaloon River, a tributary of the Matanuska River. These stream valleys form the first available route across the range east of the Susitna valley.

The Talkeetna Mountains are rugged and consist of sharp, saw-toothed ridges and peaks. Streams and glaciers have dissected the range and produced deep valleys and high interstream ridges. Only a few larger stream valleys offer feasible approach routes to the center of the range, and passes across the ridges are few. Mountain crests generally average between 5,000 and 7,000 ft (1,500 and 2,300 m) in elevation. Near the heads of the Sheep and Talkeetna Rivers, many peaks exceed 8,000 ft (2,450 m), and one approaches 9,000 ft (2,750 m). These high parts of the range nourish many valley glaciers. Most streams are glacier-fed, and their silty waters flow over wide gravel bars of glacial outwash. The glacier at the head of the Sheep River is about 12 mi (19 km) long.

COOK INLET - SUSITNA LOWLAND

Cook Inlet is a long, narrow embayment that is bordered on the east by the Kenai Peninsula and on the west by the south end of the Alaska Range. Near its mouth, high mountains rise from the water's edge. North of Kachemak Bay, the Inlet is bordered by cliffs several hundred feet high; these cliffs form the wave-cut edge of a rolling lowland that extends 30 to 40 mi (50 to 60 km) east to the base of the Kenai Mountains. This lowland is partially underlain by coalbearing Tertiary beds that form conspicuous exposures along the shore. The surface is covered by glacial deposits and stream and terrace gravel. Across Cook Inlet, similar lowlands extend west to the base of the Alaska Range and to the north; they also occur east and north of Point Campbell (between Turnagain and Knik Arms), north of Knik Arm, and at the head of Cook Inlet, where they merge into the Susitna lowland.

These lowlands have a common origin. They are partially floored by Tertiary sedimentary rocks and have been overridden by large glaciers from the Susitna valley and Cook Inlet. The lowland topography is due to the erosive action of glaciers that also deposited till, sand, and gravel. Upper Cook Inlet is shallow, and deltas of the Susitna, Matanuska, and Knik Rivers and the head of Turnagain Arm are rapidly encroaching on the tidewater area. The wide expanses of mud flats that are visible at low tide in upper Cook Inlet testify to the volume of detritus deposited by glacial streams in Cook Inlet.

The broad Susitna lowland, which is the landward extension of the Cook Inlet depression, is a structural basin that comprises the lowland basins of the Susitna River, its tributaries, and several other rivers that flow directly into the head of Cook Inlet. The basin is bordered on the south by Cook Inlet, on the east by the Chugach and Talkeetna Mountains, and on the northwest and north by the Alaska Range. The main basin is about 100 mi (160 km) long; it is more than 50 mi (80 km) wide near the Kashwitna River and narrows to the north. The entire Cook Inlet - Susitna Lowland, which extends from the mouth of Kachemak Bay into the Chulitna Valley, is over 200 mi (320 km) long and averages about 60 mi (100 km) wide. Branching arms of the lowland project up the larger tributary valleys into the surrounding mountains. The Susitna River lies about 8 mi (13 km) west of the Talkeetna Mountains and occupies a 1- to 8-mi-wide (2 to 13 km) flood plain. The surface of the bordering lowland is covered with a veneer of glacial deposits and stream gravel and dotted with numerous lakes. From the river to the bordering mountains, the tributary streams are more deeply entrenched, and the rolling lowlands give way to the steeper slopes of the foothills and mountains.

ALASKA RANGE

The Alaska Range comprises a great crescentic belt of rugged mountains that sweeps north from the base of the Alaska Peninsula to Mount McKinley, extends northeast and east to the Delta River, and continues southeast to the Nutzotin Mountains. As thus defined, the range is nearly 600 mi (970 km) long and averages 50 to 80 mi (80 to 130 km) wide. Its southwestern end partially merges with the Aleutian Range to form a continuous mountain belt that reaches east and southeast to the Canada-Alaska border. This range forms the divide between streams that flow south into the Susitna and Copper Rivers and the tributaries of several north-flowing streams. Near the south end of the range at the head of the Skwentna River, the peaks of the divide range from 5,000 to 9,000 ft (1,500 to 2,800 m) high; the crest is broken by several passes that average about 3,000 ft (900 m) in elevation. To the north, the mountain range is higher, more rugged, and culminates in two great peaks, Mount McKinley and Mount Foraker, 20,320 and 17,400 ft (6,194 and 5,304 m) high, respectively. East of these mountains, peaks generally reach elevations of 7,000 to 9,000 ft (2,300 and 2,800 m). This portion of the range contains North America's highest mountain; only two other peaks, Mount Foraker and Mount Hunter, exceed 14,500 ft (4,420 m) in elevation, and few others reach 12,000 ft (3,700 m).

From passes at the head of the Skwentna River to Mount McKinley, the inland front of the range rises abruptly from the piedmont plain. East of Mount McKinley, the main range is separated from the lowland by one or two minor chains of mountains or foothills as far east as the Delta River. The Kantishna Hills are the most conspicuous and massive of these minor ranges. The foothill belts are separated from the summit ridges of the range and from one another by a series of depressions or broad basins floored with Tertiary sedimentary rocks and recent gravel that represent remnants of an ancient drainage system. Currently, these low basins and passes are occupied by minor streams; the trunk streams flow north from the crest of the range and cross the basins to plunge into deep rock canyons that cross the foothills. For example, the Teklanika River, the first north-flowing stream west of the Nenana River, leaves the high range and crosses three broad basins that are separated from one another by ridges through which the stream has cut canyons from 1,200 to 2,000 ft (330 to 600 m) deep. The present courses of these north-flowing streams were established before the transverse ridges were uplifted or, more likely, when the streams eroded the Tertiary deposits without displacing the drainage.

The Nenana River crosses the range north of Broad Pass through the first low pass across the mountains north of the Yentna basin. East of Broad Pass, the mountains are rugged, with elevations that reach 5,000 to 9,000 ft (1,500 to 2,800 m) and increase to nearly 14,000 ft (4,300 m) at Mount Hayes. Beyond Mount Hayes, the Delta River flows through a low pass beyond which the range terminates in the Nutzotin Mountains.

Between the head of the Skwentna River and Mount McKinley, most of the mountain range lies on the Susitna River side of the divide. The asymmetric position of the divide has substantially affected the development of the large glaciers that fill the mountain valleys on the southeast slope. Moist Pacific winds are chilled when they pass over the surrounding mountains and drop their moisture as snow in the Cook Inlet - Susitna depression. Glaciers in this area are generally much larger than those on the northwest slope, where the basins are smaller and the snowfall lighter. East of Broad Pass in the high mountains that surround Mount Hayes, the glaciers on the coastal side of the mountains are larger than those on the north because the coastal side receives more snow.

TANANA-KUSKOKWIM LOWLAND

The Alaska Range is bordered on the west and north by a broad structural basin that extends from the Bering Sea across the Kuskokwim valley northeast to the Tanana Valley and east across the Alaska-Canada border to the upper Yukon basin. This lowland ranges from 30 to 60 mi (48 to 97 km) wide, gently slopes away from the range, and has only a few isolated hills that rise above its general level. The lowland is floored by unconsolidated materials, mostly gravel, eroded from the Alaska Range. Extensive Tertiary deposits underlie the gravel.

In the upper Kuskokwim basin, the edge of the lowland rises in a piedmont plateau to elevations of 2,500 ft to 3,000 ft (670 to 930 m), where it abuts the steep mountain front. This plateau slopes toward the Kuskokwim basin at a grade that locally exceeds 100 ft/mi (19 m/km). In the Tanana basin, the piedmont plateau is less evident. Here, the gravel plain slopes north from the base of the foothills at an elevation of about 1,000 ft (310 m) to the Tanana River. Only the larger streams maintain well-defined channels across the lowland; water from smaller tributaries percolates into the gravel and emerges at a lower elevation to form meandering creeks that drain the basin.

Open marshes, lakes, and patches of timber occur on the lowland surface and make the area difficult to cross in summer. In this area, the Tanana River flows along the northern border of the lowland. The north-flowing streams, many of which are glacier-fed, carry large quantities of gravel and silt that they deposit in the lowland. The less vigorous streams that flow south from the Yukon-Tanana Upland are generally clear.

YUKON-TANANA UPLAND

That part of the Yukon-Tanana Upland that lies within the study area consists of rounded, northeast-trending ridges that rise above the surrounding upland. The Tanana River and its surrounding upland are at elevations that range from 300 to 600 ft (90 and 180 m). Ridges with crests 1,000 to 3,000 ft (300 to 1,000 m) high project as islands or peninsulas above the uplands. Farther north, a few peaks and domes rise above the upland surface to elevations of nearly 5,000 ft (1,500 m); this northern area is part of the Yukon plateau. The Yukon-Tanana Upland is comprised of highly folded, metamorphosed rocks. The topography of the upland north of the Tanana River contrasts sharply to that south of the Tanana River, where extensive glaciers have modified the topography. North of the Tanana River, fluvial erosion has developed maturely dissected ridges and broad valleys that parallel the prevailing trend of the bedrock. The surface is generally mantled by a thick layer of muck, soil, humus, and detrital rock material; rock outcrops below the ridge crests are uncommon. Major stream valleys have wide floors and gentle gradients; thick alluvial fill is common.

GENERAL PROPERTIES OF PERMAFROST[3]

Permafrost is any soil, subsoil, or other surficial deposit that has a temperature lower than 32°F (0°C) for at least 2 yr. This definition is based exclusively on temperature. Part or all of the deposit's moisture may be unfrozen, depending on the chemical composition of the water and capillary action. However, most permafrost is cemented by ice; permafrost without ice is called dry permafrost. The upper limit of permafrost is called the permafrost table.

When the mean annual air temperature drops below 32°F (0°C), ground frozen during the winter may not completely thaw in summer, and a layer of permafrost may form. This layer may continue to thicken below ground that thaws seasonally. The thickness of the permafrost layer is controlled by the balance between the mean annual air temperature and heat from the earth's interior. The temperature of permafrost at the depth of minimum annual seasonal change, usually 30 to 60 ft (9 to 18 m) below the surface, varies from 32°F (0°C) at the southern limit of permafrost to 12°F (-11°C) in northern Alaska (fig. 1) and 8°F (-13°C) in northeastern Siberia. Where permafrost is widespread, its temperature is colder than 23°F (-5°C). Although some permafrost is the result of the present climate, many permafrost areas are not in equilibrium with the present climate because they are the product of a colder past climate.

Permafrost is essentially a phenomenon of polar, subpolar, and alpine regions. About 20 percent of the world's land is underlain by permafrost. Perennially frozen ground is most widespread and thickest in northern regions of the northern hemisphere. Fifty percent of the Soviet Union and Canada, 20 percent of China (mainly the high-plateau country), 82 percent of Alaska, and probably all of Antarctica are underlain by permafrost. Perennially frozen ground is 2,000 ft (610 m) thick in northern Alaska and thins progressively to the south.

In the northern hemisphere, perennially frozen ground is differentiated into two broad zones: 1) the continuous-permafrost zone in which permafrost is present in all surficial deposits except under lakes and rivers that do not freeze to the bottom; and 2) the discontinuous-permafrost zone, which includes many permafrost-free areas that increase progressively in size and number from north to south. Permafrost also occurs on the submerged continental shelves in polar areas.

In the Goldstream valley near Fairbanks, permafrost occurs nearly everywhere except beneath hilltops and moderate to steep south-facing slopes. The permafrost table in the silty lowlands is 1 to 3 ft (0.3 m to 1 m) below the ground surface.

[3]Abstracted from Péwé, 1982.

Permafrost in fans, slopes, and lowlands contains large horizontal or vertical sheets, wedges, lenses, and irregular masses of ice. These ice masses are up to 15 ft (4.6 m) thick by 50 ft (15 m) long. Water often freezes in ice-wedge polygons up to 40 ft (3 to 12 m) diam. Although the polygons are covered by silt and vegetation, they produce a polygonal surface pattern that is visible from the air.

If undisturbed, permafrost can form a stable foundation for a railroad embankment and other engineering structures. Unfortunately, when the Alaska Railroad was constructed, the protective vegetation cover was removed, which disturbed much of the near-surface permafrost. Also, over the years, thousands of cubic yards of gravel have been used along the railroad to fill sags and replenish shoulders. Dry gravel generally conducts heat better than silt or vegetation. Consequently, during summer, the added gravel conducts heat to the permafrost, and thawing occurs. Thawing of the relatively cold permafrost in northern Alaska can be minimized by placing a gravel pad on roadbeds. However, to prevent thawing of the relatively warm permafrost in the Fairbanks-Goldstream area would require a very thick protective pad of gravel that would be prohibitively expensive. Thus, other means must be used to protect the permafrost along the Alaska Railroad in these areas.

Although permafrost is the predominant and most serious cause of engineering problems that affect the Alaska Railroad in interior Alaska, many problems described in this guidebook are associated with seasonal frost, even within the discontinuous-permafrost zone. These seasonal problems, such as icings or the heaving and settlement of the subgrade, are shared to a lesser extent by railroads that operate under severe winter conditions in Canada and the 'lower 48.'

GLACIAL HISTORY OF THE UPPER COOK INLET REGION[4]

The upper Cook Inlet region has been repeatedly glaciated. Lowland areas are all underlain by thick glacial deposits and are generally characterized by an irregular, hummocky topography typical of glaciated areas. The chronology of the late Quaternary glaciations is shown in table 1 and figure 4.

Of the five recognized Pleistocene glaciations that occurred in the area (sheet 2), the two oldest, the Mount Susitna and (later) Caribou Hills, filled the upper Cook Inlet depression with ice at least to elevations of more than 3,000 ft (900 m). Most valleys in the bordering mountains contained tributary glaciers that joined the major glaciers. For example, the Susitna and Matanuska Glaciers formed a continuous ice field that extended down Cook Inlet, beyond Shekilof Strait and Kodiak Island, and generated an ice shelf that fronted along the north Pacific Coast.

The third glaciation, the Eklutna, again buried the upper Cook Inlet area under a massive ice field. After each glaciation, the tributary glaciers retreated, and the entire Cook Inlet - Susitna Lowland was probably ice free for extensive periods of time.

During the Knik Glaciation, which included one or possibly two readvances, ice apparently covered the floor of the Cook Inlet - Susitna Lowland for the last time. Broad lobes of tributary glaciers merged in the Anchorage area to elevations that ranged from 700 to 2,400 ft (212 m to 727 m).

The final major glaciation, the Naptowne, included several advances and was responsible for the complex deposits that now cover most of the Matanuska Valley floor and the upper Cook Inlet region. Glacial moraines, such as the Elmendorf Moraine that was built by a late resurgence of the Knik lobe, are conspicuous and well preserved. Kettle lakes, kames, eskers, and well-defined northeast-trending drumlins are visible along the Alaska Railroad from Mile 167 to 171.

The absence of a terminal moraine of early Naptowne age in south Anchorage suggests that the trunk glaciers may have terminated in an ice shelf that floated in moderately deep water. Clays of the Bootlegger Cove Formation, which underlies most of Anchorage, were deposited under predominantly glaciomarine conditions. Glaciomarine waters inundated the southern Susitna lowland as far north as Caswell, Mile 202.3 on the railroad.

In the Anchorage area (under static conditions), most of the Bootlegger Cove Formation forms moderately reliable foundation material comprised of seven distinctive facies that range from finely laminated silt and clay to thin-bedded, fine- to medium-grained sand to massive clayey silt with random gravel. However, several facies are highly sensitive to dynamic loading; if enough moisture is present at appropriate depths, these sensitive layers are potential liquefaction hazards. Most major failures that occurred in Anchorage during the 1964 earthquake, including the landslide at Government Hill School, were directly caused by seismic loading, oversteepened slopes, undercutting of the toe of slopes, ground-water piping, induced loading at the heads of former slides, and lateral spreading due to removal of support.

[4]Modified from Péwé and Reger, 1983.

COOK INLET GLACIAL CHRONOLOGY	ASSOCIATED EVENTS IN COOK INLET	DATED MARINE TRANSGRESSIONS	CORRELATIONS WITH CONTINENTAL CHRONOLOGIES: N. AMERICA	N. EUROPE	SIBERIA
ALASKAN GLAC.: TUNNEL ADVS. A.D. 500; TUSTUMENA ADVS. 3500 B.C.	Minor sea level fluctuations	KRUZENSTERNIAN: GIRDWOODIAN	CLASSICAL WISCONSIN RECENT: "Little Ice Age"	Sub-Atlantic* Sub-Boreal*	Postglacial*
	High Sea Level Stand	KASILOFIAN 5,000-6,000	ALTITHERMAL*	ATLANTIC*	
TANYA ADVS. 7000 B.C.; NAPTOWNE GLACIATION: SKILAK ADVS. 10,500 B.C.; KILLEY ADVS. 13,500 B.C.; MOOSEHORN ADV. 17,000 B.C.; Pre-MOOSEHORN ADVS. 45,000 B.C.	Glacial Lake Cook: final drainage; 275' high lake drainage; 500-600' high lake drainage; 750' high lake drainage?; Advance lake phases		COCHRANE*; MANKATO OR VALDERS*; CARY*; TAZEWELL*; Morton, Farmdale, Roxana Loesses*	Boreal*; Pre-Boreal*; O & Y Dryas*; Bolling*; OLDER WURM II DEPOSITS	NORILSK (SARTAN) GLACIATION*
	High Sea Level Stand	WORONZOFIAN 38,000-48,000	PORT TALBOT*	GOTTWEIG*	KARGINIAN* TRANSGRES.
KNIK GLACIATION	Proglacial Lake		PRE-CLASSICAL WISCONSIN	WURM I	ZYRYANKA
85,000 B.C.	Deep Weathering	PELUKIAN 78,000-100,000	SANGAMON	R/W	KAZANTSEVIAN TRANSGRES.
EKLUTNA GLACIATION	Cook Inlet Icefilled		ILLINOIAN	RISS	YENESEY
	Major Weathering	KOTZEBUAN 170,000-175,000	YARMOUTH	M/R	OPLYUNY-SAMBURG BEDS
CARIBOU HILLS GL.	Cook Inlet Icefilled		KANSAN	MINDEL	BAKHTA
210,000 B.C.	Deep Weathering	MIDDLETONIAN 210,000-224,000	AFTONIAN	G/M	PANTELEYEV BEDS
MOUNT SUSITNA GL.	Cook Inlet icefilled		NEBRASKAN	GUNZ	BAIKHA
Beginning of Quaternary uncertain		Isotope dates in years B.P.	*Isotope-dated deposits		

Table 1. Glacial record, chronology, and continental correlations for Cook Inlet, southcentral Alaska. From Péwé, 1965.

RAILROAD LOG AND LOCALITY DESCRIPTIONS, ANCHORAGE TO SUMMIT STATION

MILE 114.3. ANCHORAGE STATION.

The Anchorage station is the headquarters for the Alaska Railroad and includes shops and a classification yard. In 1914, when the first survey crews landed at the creek mouth that lies just north of the passenger depot, only three families lived along lower Ship Creek. By the end of the construction season, a railroad route was selected that passed east of Anchorage (then called Ship Creek landing). Anchorage was supposed to connect to the main line at Whitney Station by a 4.2-mi-long (6.7 km) branch line that would also receive coal from the Matanuska Valley. When the decision was made to move the railroad headquarters and shops from Seward to Anchorage, the main line was relocated to its present location. The elaborate dock facilities that were planned for Knik Arm never materialized.

Ship Creek valley is incised 60 to 80 ft (18 to 24 m) in the Anchorage outwash plain. The plain was deposited by meltwater streams that originated from a glacial front associated with the Elmendorf end moraine. Most railroad facilities in the valley were constructed on low terraces covered by a veneer of glacial outwash and younger deposits of the meandering Ship Creek. The largest building, the heavy equipment shop, is constructed on outwash gravel that is underlain by clay of the Bootlegger Cove Formation.

Most shops and offices in the Anchorage railroad yard were built when the railroad was rehabilitated (1947-55). Many structures were damaged by seismic shaking, compaction, and displacement of underlying materials during the 1964 earthquake (app. A). Some buildings were displaced, and one railroad structure was overrun and buried by debris from the landslide at Government Hill School.

Few structures received foundation damage during the earthquake because pile-supported, poured-in-place concrete footings were generally used. Most damage caused by the shaking motion occurred in buildings that had heavy masses supported above the ground floor, such as concrete second floors or large overhead cranes.

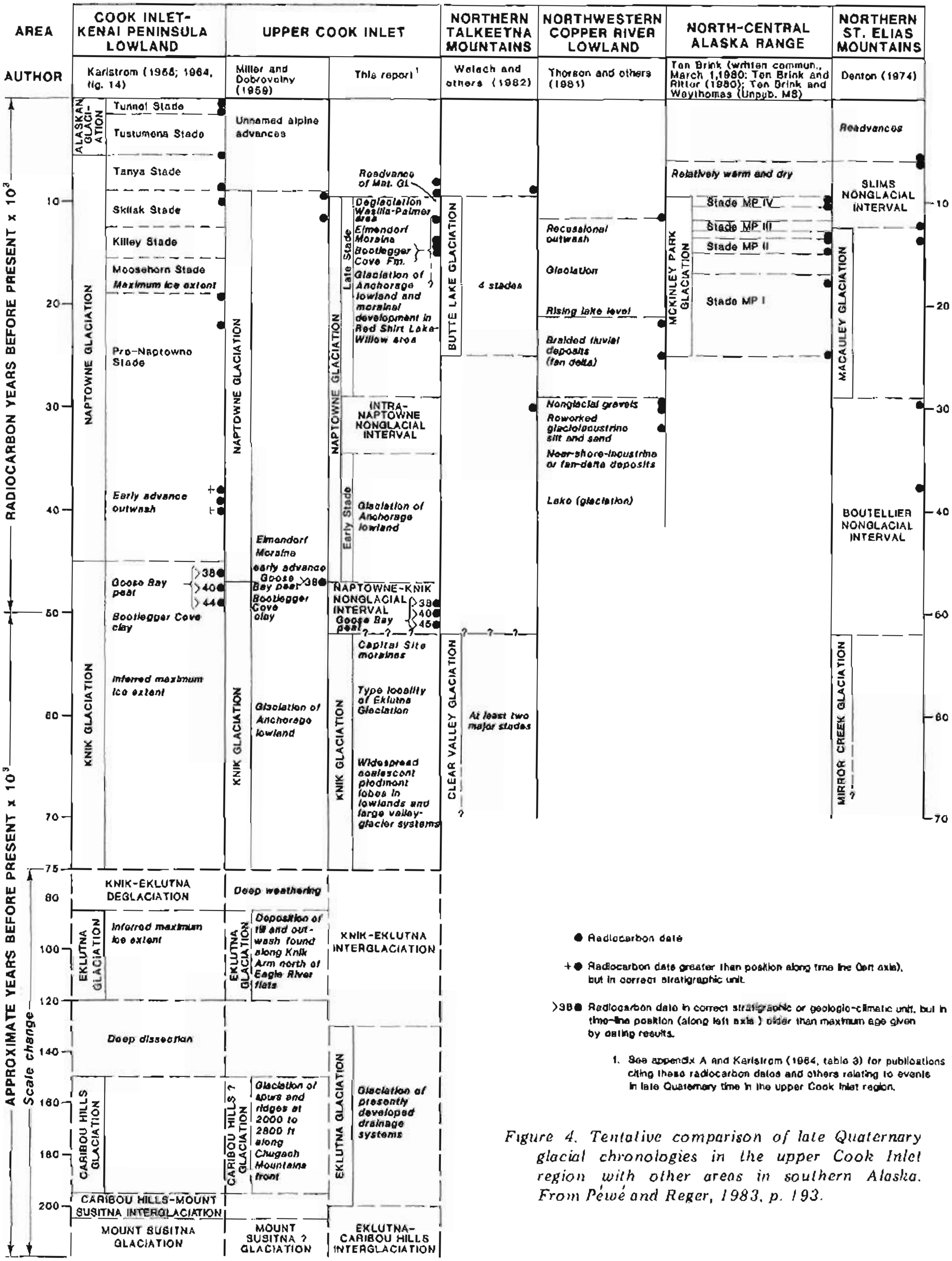


Figure 4. Tentative comparison of late Quaternary glacial chronologies in the upper Cook Inlet region with other areas in southern Alaska. From Péwé and Reger, 1983, p. 193.

Other severe damage was attributed to structural defects, such as lack of adequate connections or sway braces.

MILE 114.3 to 116.5. ANCHORAGE RAILROAD YARD (Anchorage A-8 Quadrangle).

An explanation for track charts is shown in figure 5; figures 6 through 11 are track charts that cover Miles 115 through 145.

MILE 116.8. The train departs from the north end of the Anchorage Railroad Yard and Ship Creek valley and ascends a 1.0-percent 'ruling grade'[5] north. Elmendorf Air Force Base is on the left; the Chugach Mountains are visible to the right.

MILE 119.1. WHITNEY STATION (enter Anchorage B-8 Quadrangle).

The runways at Elmendorf Air Force Base, on the left, are constructed on the Anchorage gravel plain.

MILE 120.5. ELMENDORF END MORAINE.

The winding alignment was selected by the original locating engineer to avoid heavy earthwork. The densely compacted glacial till was difficult to excavate with the old surplus equipment from the Panama Canal Railroad. Several series of sharp curves in the next 45 mi (72 km) restrict the train to 25 mph (40 kmph), resulting in one of the slowest subdistricts on the railroad. The running time from Anchorage (Mile 114.3) to Wasilla (Mile 159.8) is 1 hr 22 min for 46 mi (74 km), compared with 50 min by automobile at 55 mph (88 kmph).

Up to four gravel trains that weigh 8,800 gross tons (8,000 t) each bring pit-run and processed gravel from the Palmer Branch to Anchorage each day. Track maintenance costs are high because of curve wear on rails and 'spike kill' of ties due to repeated spiking when the track is regaged and shimmed on poor subgrade. The track needs to be surfaced and lined frequently.

MILE 126.6. EAGLE RIVER STATION (enter Anchorage B-7 Quadrangle).

MILE 127. GROUND MORAINE.

A restrictive 10° curve was eliminated in a minor line change in 1956.

MILE 127.5. CROSSING OF EAGLE RIVER.

Downstream, to the left, a coal seam is exposed in the Tyonek Formation of Tertiary age.

MILE 128.6. Gravel was dumped by the railroad to widen shoulders and reduce frost heaving in the narrow roadbed.

MILE 131. FIRE CREEK VALLEY.

The railroad gravel pit and powder-storage spur are located here. Coarse gravel next to the main line grades to fine-grained sand east toward the mountains.

MILE 136.3. BIRCHWOOD.

The railroad storage yard and industrial area are built on an alluvial fan that was deposited by Peters Creek. Test holes indicate that the gravel is underlain by clays that may have a glaciomarine origin. The outwash gravel ranges from 10 to 15 ft (3 to 5 m) thick.

[5]The maximum existing grade between two points in a district or subdistrict determines the tonnage rating and therefore the maximum number of cars in a train.

MILE 137.1. Severe icings occasionally occur here in the winter.

MILE 137.5 to 139. The railroad parallels the south shore of Knik Arm (fig. 12), which is a long estuary of Cook Inlet that has a tidal range of more than 39 ft (11 m) (measured at Anchorage).

MILE 138.4. A small creek that drains Mirror Lake has cut a wide reentrant into the edge of the bluff on the right. This area is subject to severe winter icings. The track must be shimmed constantly because excessive ground water combined with poor subgrade materials cause severe frost heaving of the roadbed. In 1958, the track was 'lined over' to a temporary alignment, and the existing subgrade material was removed to a depth of 6 to 8 ft (1.7 to 2.5 m) and replaced with gravel. After the frost-susceptible material was removed, the need for shimming the track was almost eliminated. However, icings continue to be a problem.

A landslide caused by the 1964 earthquake formed a pressure ridge of frozen vegetation 3 to 8 ft (1 to 2.5 km) high by about 500 ft (150 m) long on the west side of the track. The landslide also laterally displaced the track subgrade and lowered it as much as 5 ft (1.5 m). Excessive ground water undoubtedly contributed to the shallow slide.

MILE 139. PANORAMIC VIEW OF UPPER KNIK ARM.

Due west, Mount Susitna rises above the Susitna River lowland to an elevation of 4,379 ft (1,326 m). The rugged Alaska Range is visible in the distance. The old town of Knik is located on the north shore of Knik Arm. Before the Alaska Railroad was constructed, Knik was located at the limit of navigation for shallow-draft vessels on Knik Arm and was the supply center for the Willow Creek mining district. To the north, the long southwest shoulder of the Talkeetna Mountains rises above the lowland and merges with the rounded, glaciated peaks that rise to an elevation of 4,000 ft (1,200 m). The sharp, sawtoothed ridges and peaks visible along the northern boundary of the Matanuska Valley are more typical of the rugged Talkeetna Mountains.

In the foreground to the northeast, an actively eroding face along the south shore of Knik Arm is visible. The face first became noticeable in early 1950, when the shoreline was 0.5 mi (800 m) north of its present location. By 1968, tidal currents were eroding the toe of the railroad embankment at Mile 138 and 138.9, and the railroad was relocated to the south onto a moraine. Excessive ground water from the moraine erodes the exposed fine-grained glaciomarine silts, which makes it difficult to maintain a uniform back slope, and repeated mudflows fill the ditchline and foul the ballast. In summer, continual ditching is required; in winter, icing is a severe problem.

The alluvial delta of the Eklutna River lies 1 mi (1.6 km) to the east and was active until 1929, when a small hydroelectric dam was constructed across the

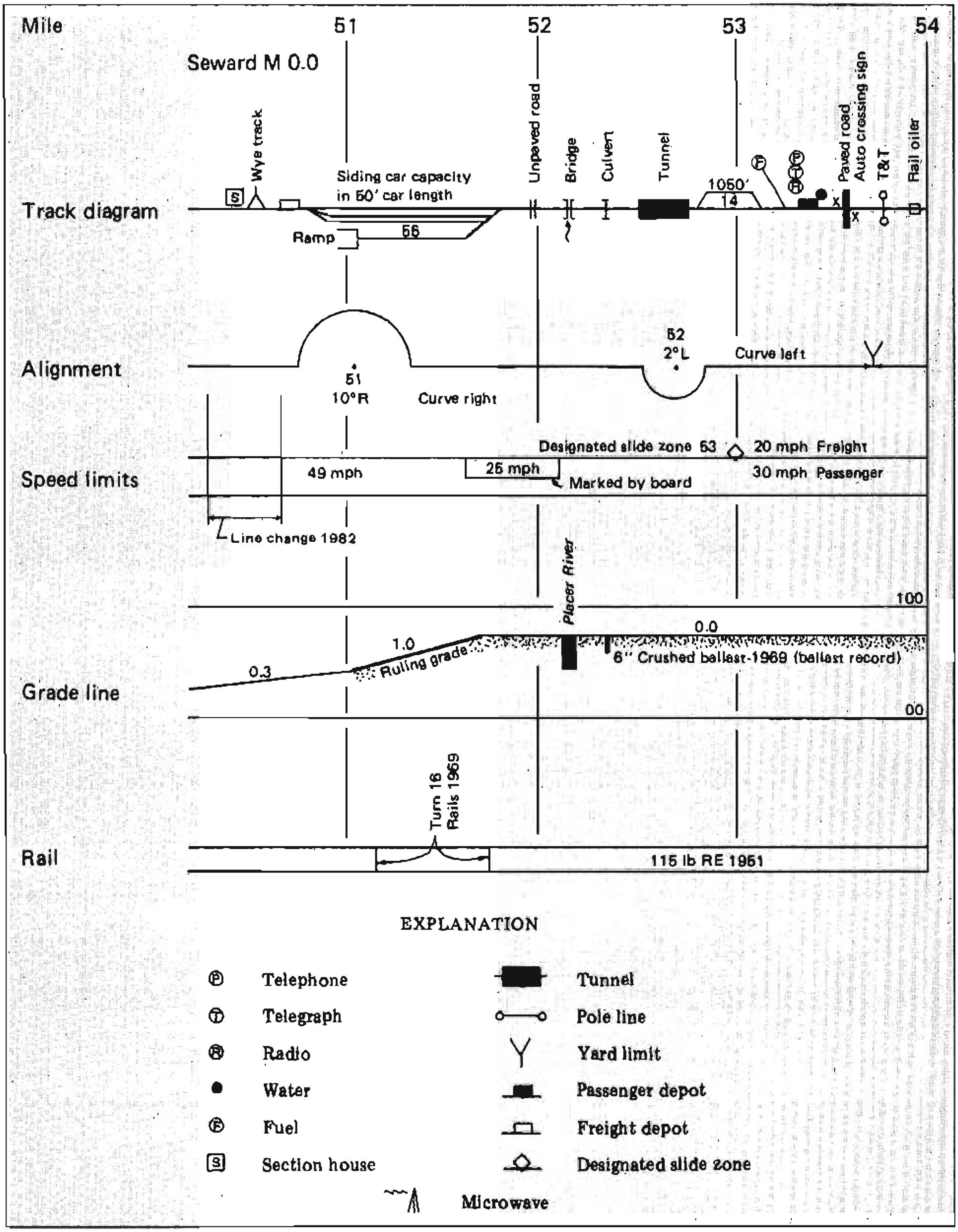


Figure 5. Sample track chart that depicts railroad information, such as alignment, grade, track, and facilities, in a condensed form for easy reference. Figures 6 through 11 are track charts for Mile 115 to 145.

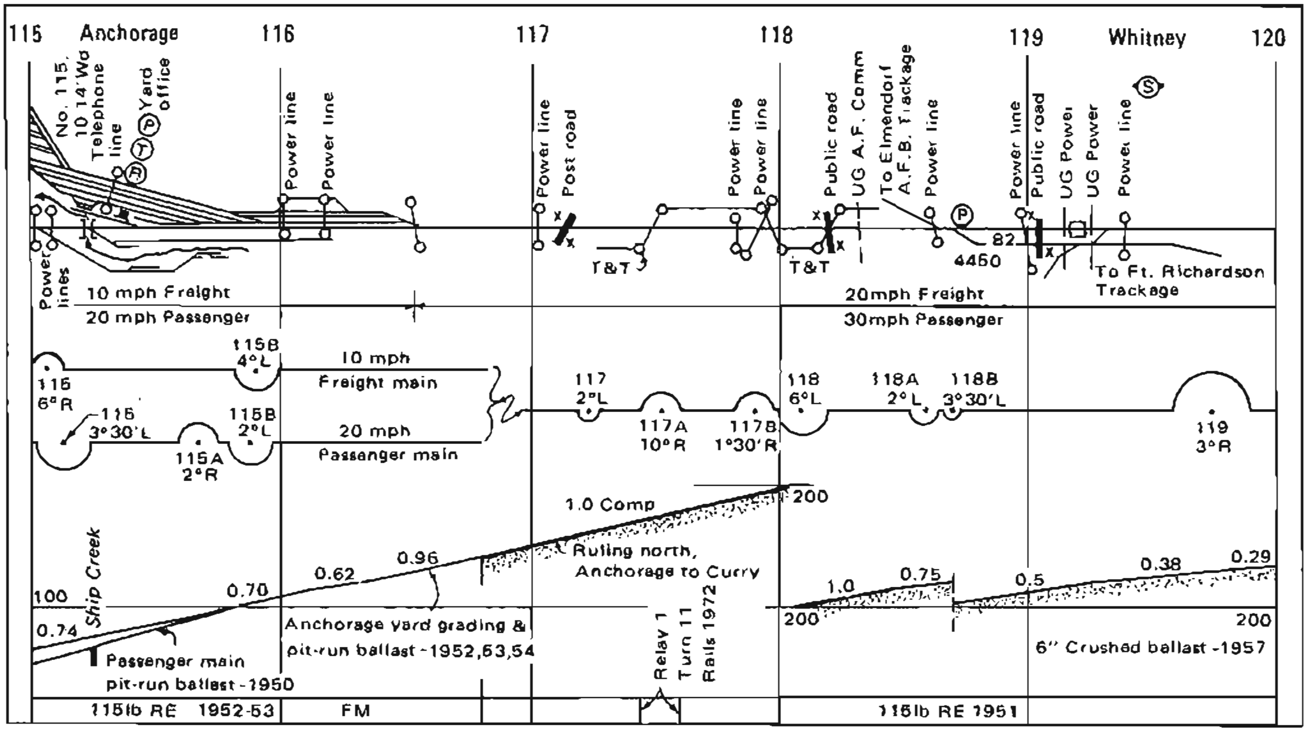


Figure 6. Track chart, Mile 115 (north end of Anchorage Yard) to 120.

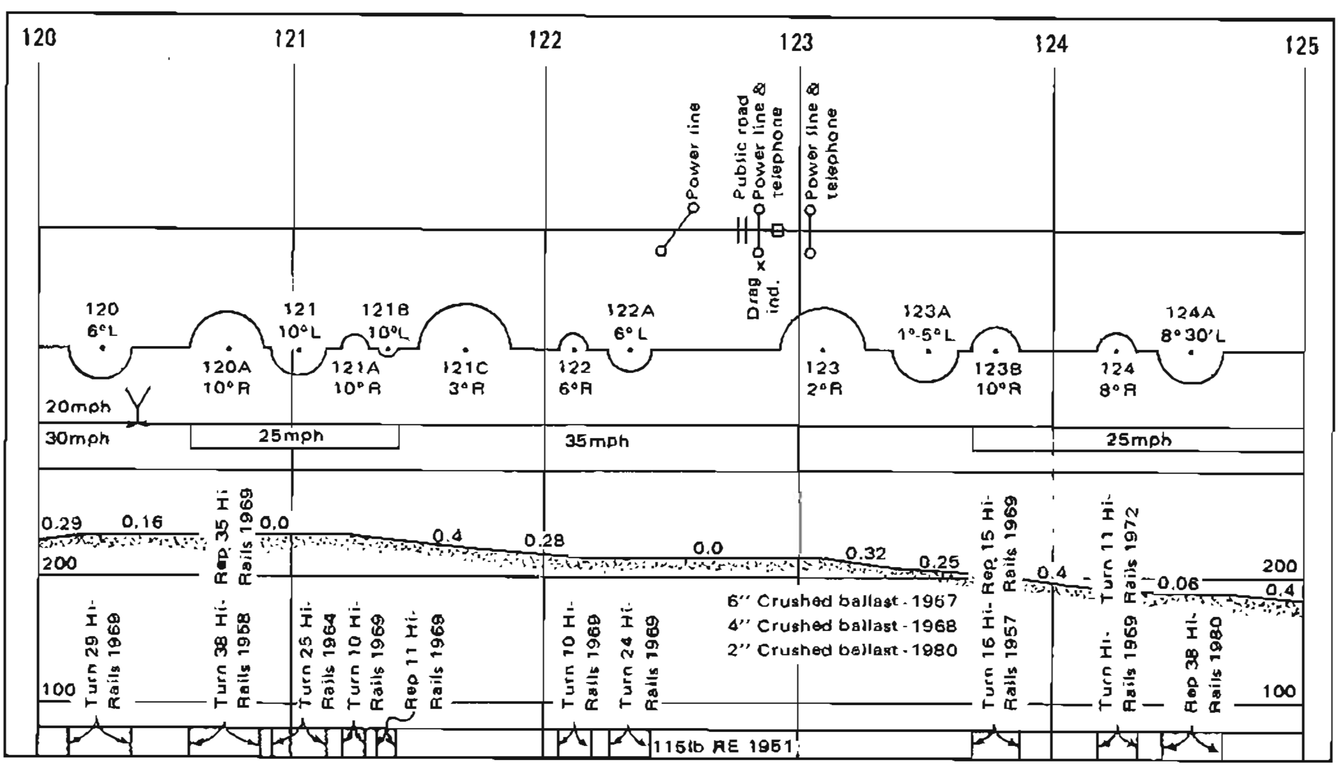


Figure 7. Track chart, Mile 120 to 125.

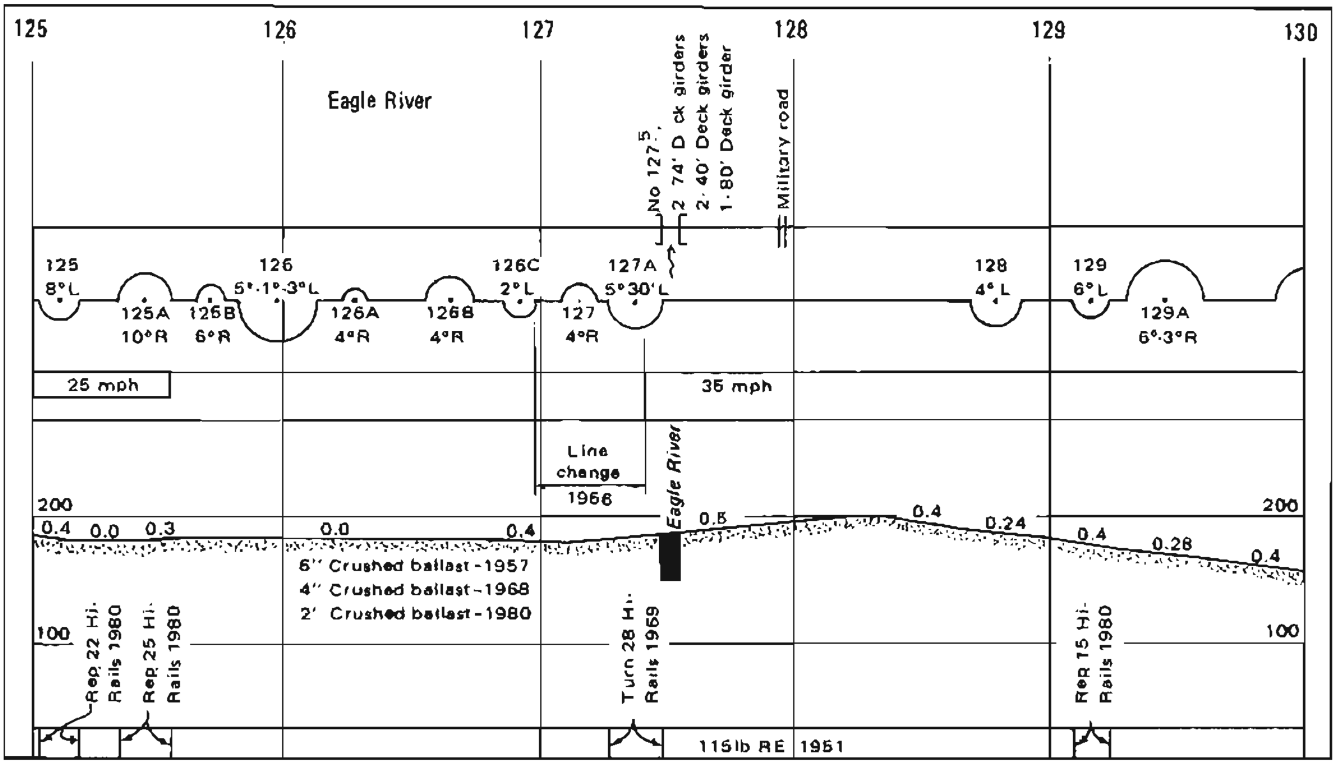


Figure 8. Track chart, Mile 125 to 130.

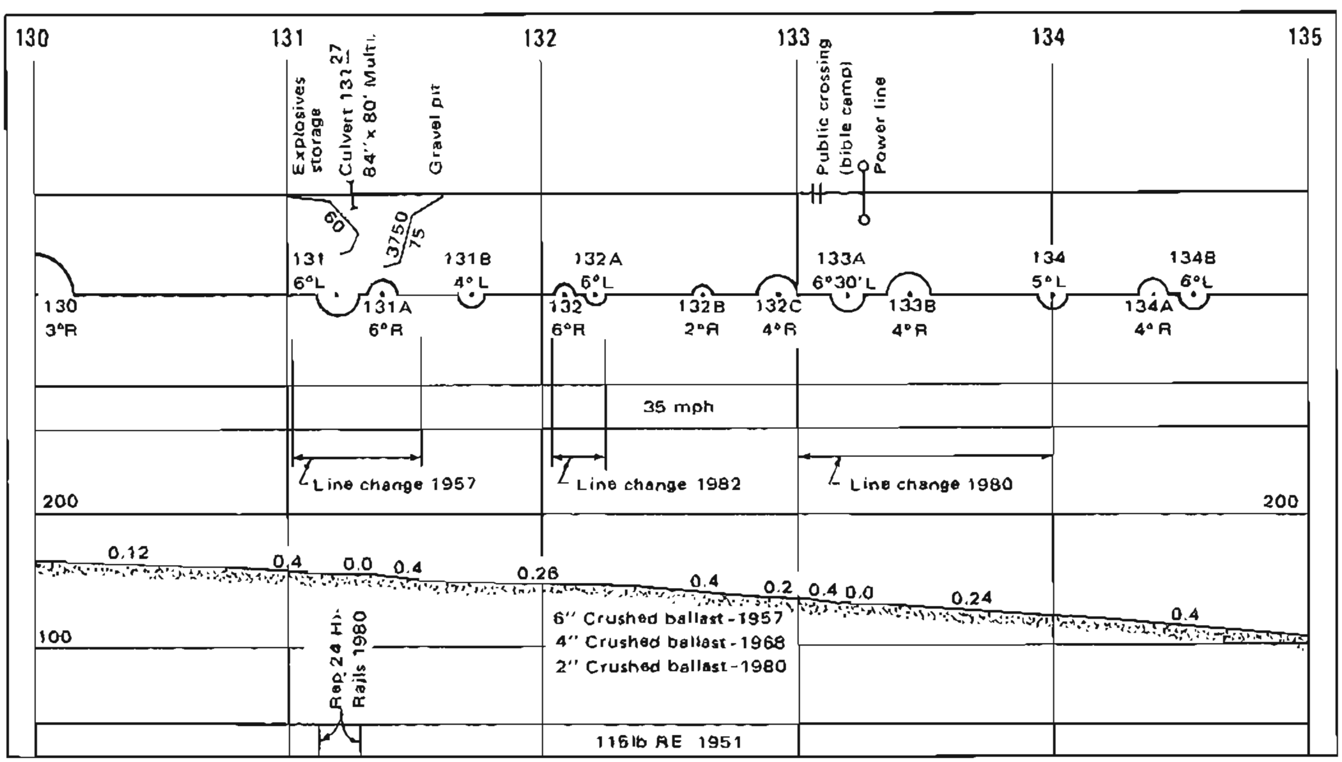


Figure 9. Track chart, Mile 130 to 135.

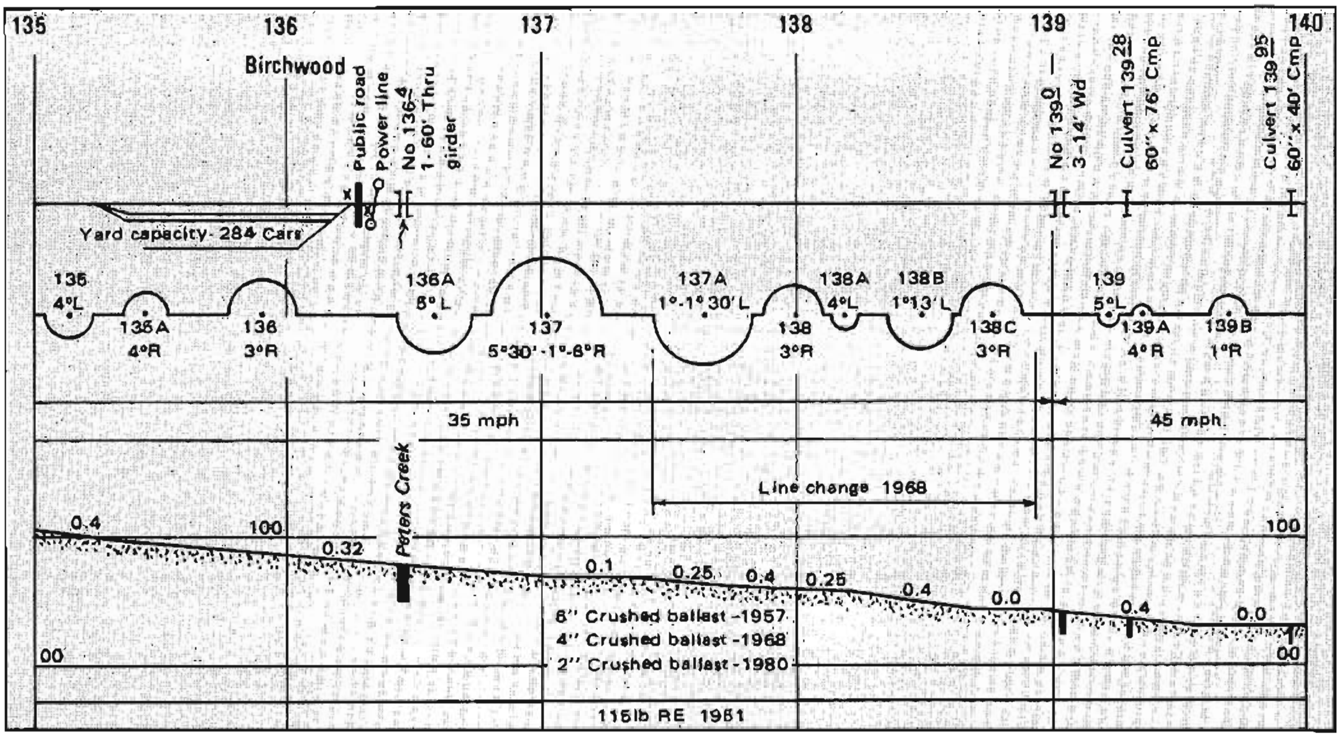


Figure 10. Track chart, Mile 135 to 140.

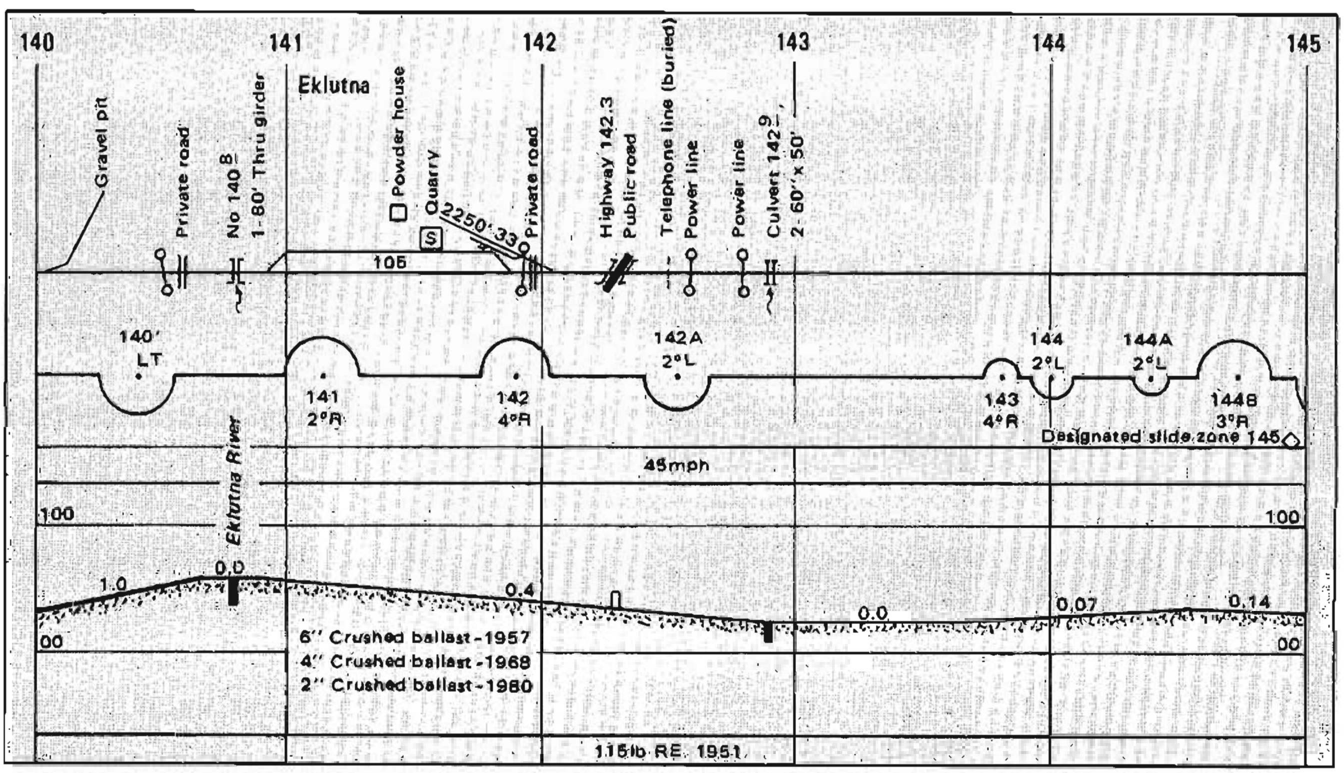


Figure 11. Track chart, Mile 140 to 145.

upper part of the river. The interruption of the normal flow of the Eklutna River and a diversion of its normal discharge through another hydroelectric facility may partly account for the change in tidal currents that subsequently led to the bank erosion discussed in the previous paragraph.

MILE 140. FORMER RAILROAD BALLAST PIT ON THE LEFT.

Processed gravel ballast (1.5 in. minus, that is, ballast passing a 1.5-in. screen) was prepared from outwash gravel that overlies the thick estuarian silts of upper Knik Arm. The outwash gravel ranges from 18 ft (5.5 m) thick near the track to 6 ft (2 m) thick near the shoreline.

MILE 140.8. CROSSING OF THE EKLUTNA RIVER.

Early construction drawings show extensive upstream wing walls and other evidence of a very active alluvial fan. When the underlying sediments were laterally displaced during the 1964 earthquake, they pushed the 80-ft-long (24 m) steel girders of the bridge toward each other.

MILE 141.8. EKLUTNA STATION.

First active section gang north of Anchorage. The railroad quarry on the left furnishes granite riprap that is used to protect railroad embankments from tidal erosion along Turnagain Arm and from river erosion at other locations along the line. The quarry site is an exposed granitic intrusion of Jurassic age that rises to an elevation of 150 ft (46 m) above the gravel plain. The nearby village of Eklutna is one of the largest Native villages in upper Cook Inlet; its history predates Russian settlement.

MILE 142.5 to 144. ELEVATED TIDAL FLAT UNDERLAIN BY ESTUARIAN SILT AND SAND.

The track surface and line are difficult to maintain because the embankment materials and underlying silt are continually subject to differential heaving and settlement. Early construction records and rectangular ponds on the right indicate that side-borrow techniques were used to obtain silty fill material. The track surface and line were badly damaged by the 1964 earthquake. When the railroad was repaired, the railbed was raised substantially to compensate for local subsidence and to protect it against extreme high tides. During the 1964 earthquake, a 112-ft-long (34 m) wood trestle at Mile 142.9, now replaced with a culvert, was compressed and arched 8.5 in. (21.6 cm) by lateral spreading of surficial materials. This part of the railbed is constantly shimmed, particularly at the north end of this segment (figs. 13 and 14). The Glenn Highway is on the left.

MILE 145.7. ENTER ANCHORAGE B-5 QUADRANGLE.

A bedrock knob of greenstone is visible on the left.

MILE 146. The railroad turns abruptly away from the north front of the Chugach Mountains and crosses the Knik and Matanuska Rivers. Relatively flat-topped islands rise 8 to 12 ft (2.5 to 3.8 m) above the braided river channels. Borings from the area indicate that 50 to 80 ft (15 to 25 m) of outwash gravel overlies fine-grained sediments of indeterminate thickness.

MILE 146.4. CROSSING OF THE KNIK RIVER.

The Knik River bridge has 10 through-girder spans [each 80 ft long (24 mi)] with a four-span wood trestle on the north end. Normal stream discharge is about 5,000 to 6,000 ft^3/s (140 to 170 m^3/s). Until 1965, the Knik River flooded every summer when water from Lake George overtopped the ice impounded at the head of the valley by the Knik River Glacier. This dramatic lake dumping began as early as June 26 (1962) and as late as August 13 (1949). The dumping increased stream discharge to 200,000 to 300,000 ft^3/s (5,700 to 8,500 m^3/s) and lasted from 8 to 18 days. In 1958, this discharge reached 359,000 ft^3/s (10,200 m^3/s) and caused severe scouring that exposed piling around piers 1, 8, and 9; the bridge had to be closed until emergency repairs could be made. Final repairs included replacing wood pilings with concrete piers poured on steel pilings. Since 1966, the Knik Glacier has been retreating and has not dammed Lake George. In 1914, when the lake dumping was first recorded, local residents reported that flooding occurred once every 15 to 20 yr.

MILE 147.1 to 147.5. THREE CROSSINGS OF SUBSIDIARY CHANNELS OF THE KNIK RIVER.

The bridges are through-truss spans [total opening of 1,270 ft (392 m)] that were constructed when the railroad was rehabilitated. The original timber trestles failed to provide sufficient opening during flood stages and collected debris that raised the flood stage upstream. The water flooded the railroad grade on the north edge of the flood plain and washed out track between Mile 148.8 and 150.

MILE 148.3. CROSSING OF THE MATANUSKA RIVER.

The Matanuska River bridge has through-truss spans with an 880-ft-long (270 m) timber approach trestle on the south with a total opening of 1,272 ft (393 m). All five bridges that cross the flats were damaged by the earthquake in 1964. Because of land spreading, piers were moved toward the river, abutments were jammed against the bridge steel, and the horizontal alignment of the bridge was displaced by up to 1 ft (30 cm). Pier 3 (Mile 147.1) sheared near the base at a pour joint that was moved about 1 ft (30 cm) toward the center of the river. Twelve spans (168 ft; 51 m) of the timber approach trestle to the bridge at Mile 148.3 were destroyed when the ground cracked. The trestle was temporarily repaired by dozing in an embankment section to permit traffic across the damaged section.

MILE 148.5 to 150. CROSSING OF THE NORTH EDGE OF MATANUSKA RIVER FLOOD PLAIN.

This area is underlain by estuarian silt and clay. Muskeg and marsh vegetation reflect the poor surface drainage. Since originally constructed, 120 spans (1,680 ft; 510 m) of timber trestle have been eliminated

Figure 12. View (to the north) from Mile 138.0. The southern shoreline of upper Knik Arm, visible in the distance, was once far north of its present location at the toe of the railroad grade. Photograph BL 79.1.15, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, October 12, 1918.

in this area. Because the area has been classified as 'wetlands,' all construction must be approved by the U.S. Army Corps of Engineers, which acts for various federal and state fish-and-game agencies. In 1947, a 3,000-ft-long (1,000 m) sheet-pile diversion dike was constructed 2 mi (3.2 km) to the east on the north bank of the Matanuska River to protect the railroad and the old town of Matanuska from flooding. Since then, the dike has required constant maintenance because the sheet-pile wall is continuously undercut. The wall was damaged extensively by the earthquake in 1964 and by erosion in 1974. In 1981, the railroad was allowed to repair the dike to protect the wetlands from natural overbank deposition by the Matanuska River during flood stage. The repair immediately benefited the railroad, but the continual diversion of an aggrading river could lead to a higher 'perch' for the riverbed with potential for a breakout.

MILE 150.7, MATANUSKA STATION.

Junction with the Palmer Branch line that serves the Matanuska Valley, which is also known as Alaska's 'breadbasket.' In 1963, farming in the area accounted for nearly 70 percent of the state's total farm income. Dairy and truck farming were the most important farm enterprises, with more than 12,000 cultivated acres (4,980 hectares). Although the Matanuska Valley has been farmed since 1900, the greatest impact on farming came during the Great Depression, when the Matanuska Colony was developed and federally sponsored. The Colony also supported the Alaska Railroad. In the spring of 1935, 202 families (mostly from northcentral states) were moved to the valley. They began intensive farming near Palmer and formed the nucleus of the current farming community.

During original construction, the Palmer Branch extended to the Matanuska coalfields, which included the U.S. Navy coal reserves at Chickaloon, a major objective of the Alaskan Engineering Commission. Development of the coalfield included construction of permanent crushing facilities; however, these facilities were abandoned before completion when the Navy converted its ships from coal to oil. Consequently, the Chickaloon Branch was abandoned, and the track was removed in 1938. The Glenn Highway occupies part of the old right-of-way along the floor of the Matanuska Valley.

The old Palmer-Sutton Branch was severely damaged between Mile A-0.5 and A-1.0 by the 1964 earthquake. During original construction, a timber trestle was driven as a relief opening for the Matanuska River flood plain. Later, the trestle was filled with train-haul material (a common railroad practice), which left the old structure buried in fill. The intense seismic shaking created by the 1964 earthquake caused the unconsolidated fill material to compact and settle 2 to 3 ft (60 to 90 cm). Consequently, the old timber trestle was

Figure 13. A 'spike-killed' tie. When track is shimmed in a frost-heave area or shim spot, track spikes are pulled out, a wooden shim is inserted under the tie plate, and track spikes are driven in. If frost heaving continues, additional shims are added. When the ground thaws, shims are removed, and the track is respiked. The location of shim spots seldom changes, but the heaving intensity may vary from year to year. Repeated spiking in a shim spot soon 'kills' the crosstie. The life of a treated crosstie that is repeatedly respiked may be as low as 6 yr, compared to 35 yr under ideal conditions. Photograph by Dave Atwood, 1982.

Figure 14. A short, heavy shim area, where shims remain in the track in July, long after spring breakup. The differential heaving that occurred here is called a sag. The least amount of heaving occurs under ties that have been shimmed; the greatest amount of heaving occurs on either side of the shimmed ties. When this heaved area has fully subsided, the last shims will be removed, and the track will revert to its summer profile. Photograph by Dave Atwood, 1982. See Mile 181.5 and 209 for further discussions on shimming.

exposed beneath a frozen crust of rail, ties, and ballast that could not support rail traffic. The roadbed was repaired by removing the rail and tie plates and using a crawler tractor to rip the frozen crust and ties away. The underlying bed of frozen ballast was smoothed with the tractor blade. The track was realigned on a lower grade, and traffic to the coalfield was restored by April 6, 10 days after the earthquake.

Most of the Matanuska Valley is mantled with loess derived from the barren flood plains of glacier-fed streams. Large amounts of windblown material are still being deposited by strong seasonal winds that originate in the canyons of the Knik and Matanuska River valleys, primarily during February and March. Cliff-head dunes form along the bluffs of these rivers. This wind-deposited material, mainly sand, is up to 50 ft thick (15 m). The mantle of wind-blown material thins rapidly and becomes more silty to the west; 1 or 2 mi from the source, the mantle is only about 30 in. (80 cm) thick. Near Wasilla, the mantle is about 10 in. (25 cm) thick.

MILE 151.2. TEST SECTION OF CONCRETE TIES (fig. 15).

When the original embankment material, which consisted of frost-susceptible soils, was removed from under an old road crossing and replaced with select gravel, almost 5 in. (13 cm) of differential heaving of the track occurred. The wide ditch in the marsh vegetation on the right indicates the source of borrow materials used in the original embankment.

MILE 152. ENTER ANCHORAGE C-7 QUADRANGLE.

MILE 152 to 160. ASCEND 'MATANUSKA HILL.'

The roadbed crosses this glacial moraine on a 1.0-percent ruling grade. It was built by sidehill construction along alternating deposits of gravelly till and outwash sand and gravel. Many restrictive curves could be reduced by line changes, but the net effect would be a shorter track with a higher ruling grade. Construction records for 1915 show the following unit prices:

.Common excavation	$0.35/yd^3
.Cemented excavation	$0.65/yd^3 (till?)
.Frozen excavation	$0.75/yd^3

MILE 155.6. Note the spur track to a newly developed commercial gravel pit on the left. Except for a few sand pits, gravel sources no longer exist in the Anchorage area. Pit-run gravel for road construction and

Figure 15. A short, very abrupt shim spot caused by severe differential heaving, Mile 151.2. Concrete ties were installed to test adjustable fasteners under extreme conditions. Shims up to 5 in. (12.7 cm) thick are required during the winter. See Mile 209 for further discussion of concrete ties. Photograph by Dave Atwood, 1982.

processed gravel for paving and concrete are now hauled to Anchorage by train from the Palmer-Wasilla area. Pioneer Peak and the Chugach Mountains are visible on the left.

MILE 159.8. WASILLA.

Formerly a village of a few hundred people and the supply center for the Willow Creek gold-mining area in the Talkeetna Mountains. Today, Wasilla is a thriving community of several thousand people. Lake Lucille is on the left. At Wasilla, the 59-mph (95 kmph) track for passenger trains and 49 mph (79 kmph) track for freight trains begins. The route traverses gently rolling to flat terrain floored by ground moraine and marked by numerous lakes. Vegetation is typical of a lowland spruce-hardwood forest interspersed with a low-brush bog-muskeg plant community.[6] The forest of evergreen and deciduous trees is dense to open and includes pure stands of black spruce. Black spruce usually occur in areas of shallow peat, glacial deposits, or on north-facing slopes. Willows and other brush species furnish shelter and browse for moose. The bog-muskeg community consists mostly of dwarf shrubs over a mat of sedges, mosses, and lichens. This type of vegetation occurs in wet, flat basins that are frequently too moist for tree growth. Ponds often occur in areas underlain by peat.

MILE 166.0. ENTER ANCHORAGE C-8 QUADRANGLE.

Northern limit of embankment failure during the 1964 earthquake.

MILE 166.5. PITTMAN.

MILE 167. For the next 4 mi (6.5 km), the railroad cuts through a series of low eskers composed of fine gravel. The eskers are aligned in the same northeast direction as Meadow and Beaver Lakes, which lie on opposite sides of the track. In 1950, a gravel pit that was developed by the railroad on a fairly large esker proved to be a disappointment when silty morainal material was excavated just below the level of the railroad's main line.

MILE 169. A small line change was made in 1969 to reduce a 6^{o} curve to 3^{o} and eliminate a severe shim spot. When the original roadbed was excavated, an old beaver dam was found beneath the ties.

MILE 170.5. In 1951, a similar line change was made here to permit an unrestricted speed of 59 mph (95 kmph). Such line changes are extremely beneficial to the railroad; running time is shortened by eliminating the time it takes to decelerate and accelerate an 80-car freight train through restricting curves.

MILE 173.3. Side-borrow excavation is visible on the gravel terrace. The borrow was hauled by train to fill the approaches to the Little Susitna River Bridge at Mile 174.3. The proposed site for a new state capital is 5 mi (8 km) north on Deception Creek in the foothills of the Talkeetna Mountains.

MILE 173.4. CASTLE MOUNTAIN FAULT (INFERRED LOCATION).

This active fault trends east-northeast along the Little Susitna River valley and the southern front of the Talkeetna Mountains. It is about 125 mi long (200 km) and is one of many large, linear faults in Alaska. East of the railroad, the fault's surface trace has been mapped as a single break along the front of the Talkeetna Mountains as far as Castle Mountain. To the west, the fault crosses the Susitna lowland and probably joins either (or both) the Lake Clark or Bruin Bay fault systems that are located to the southwest.

MILE 174.3. CROSSING OF THE LITTLE SUSITNA RIVER.

This 80-ft-long (25 m) through-girder bridge built in 1927 eliminated 1,652 ft (504 m) of approach trestle on the south end of the former bridge and 1,358 ft (1,414 m) on the north end. Despite its meandering course, the river has a steep gradient for several miles upstream from the railroad bridge. When flash floods occur, the water is quickly impounded behind the railroad embankment. In 1971, the weakened roadbed collapsed under a northbound freight train and caused a serious derailment.

MILE 175.3. HOUSTON.

MILE 175 to 177. This marks the western limit for the Matanuska coalfields in the Little Susitna mining district. In 1917, several attempts were made to develop the thin coal beds located in the benches on the right. When open-pit mining was attempted in the early 1950s, coal was loaded into railroad cars on a spur track at

[6] Vegetation of Alaska is described in appendix B (p. 76).

Mile 176.3. However, the beds were too thin and the coal of such poor quality that all operations ceased in 1954. Construction records for May 20 to August 24, 1917, noted that frozen borrow material was used to build the main line.

MILE 177 to 180. The roadbed is constructed on the edge of an old flood plain of the Susitna River. Culverts and short timber trestles are required at frequent intervals because of the numerous springs and small streams that issue from the moraine on the right. Mount Susitna is visible to the west on a clear day.

MILE 181.4. NANCY LAKE.

During original construction, sidehill excavation of the glacial till on the right created an unstable slope. Because excessive ground water caused slumping and mudflows, the track was lined away from the hill causing restrictive curvature. In 1962, slide material was removed so that the track could be lined back to its original position. The area was revegetated, and the slope is now stable. Although adequate ditch sections are a desirable feature of a good roadbed, particularly in snow country, this feature must be balanced against the danger of creating a constant maintenance problem by cutting into the toe of unstable slope material, especially if ground water is present.

MILE 181.5. Here, the roadbed ascends an upper bench that is cut through morainal debris. Because excessive ground water and poor embankment material cause severe frost heaving, the track must be heavily shimmed during winter. The amount of heaving depends on such factors as soil and drainage conditions, embankment width, conditions in sidehill cuts and throughcuts, and depth of clean ballast. Differential heaving is more common in fill embankments than in cut sections. This is particularly true on the Alaska Railroad, where a great variety of materials were used for fill. Many shim areas are irregular, and those that affect the cross-level of the track are the most dangerous. When the track-surface distortion becomes too extensive and irregular to be remedied by shimming, 'Slow Orders' are placed on the track, and train speeds are reduced (fig. 16). Figures 17 through 19 show how modern equipment can raise and line track on crushed-gravel ballast.

Numerous methods have been used on the Alaska Railroad to eliminate or reduce frost heaving in the roadbed; all are expensive. The most effective method is to excavate the frost-susceptible materials down to the frostline and replace them with clean pit-run gravel. However, the active layer along the railroad right-of-way in the Susitna lowland is generally more than 8 ft (2.5 m) thick, and the maximum depth attainable by the 'dig-down' method is usually 6 ft (1.8 m). Further, this method can only be used in areas where the track can be realigned on a temporary subgrade. The old roadbed is excavated by using crawler tractors; the track is then lined back to its original position on a new subgrade of pit-run gravel hauled by work train.

Other methods tested include using a vapor barrier (Mile 401.3), rigid insulation (Mile 439), or digging deep ditches to intercept ground water. However, the most practical method—one that can reduce shimming as much as 50 percent—is to widen shoulders and raise the track with select materials. As revenues permit, the Alaska Railroad will use the latter method to alleviate the problem of frost heaving.

MILE 184. Beaver houses are visible in the small lake on the left; an end moraine is visible in the background.

MILE 185.7. WILLOW.

Third active section gang north of Anchorage. The west front of the Talkeetna Mountains is visible to the right.

MILE 186. ENTER TYONEK D-1 QUADRANGLE.

Willow auxiliary airfield, on the left, was constructed during World War II on a gravel terrace of the Susitna River. For the next 40 mi (64 km), the railroad is aligned almost due north. The undulating grade line matches the gently rolling to flat terrain created by a succession of active and inactive river channels that incised the low gravel terraces of the Susitna River. Although gravel occurs at a shallow depth in the terraces, the original construction crews failed to remove all material down to the gravel. Consequently, the roadbed has severe differential heaving. As late as 1972, a 10-man extra gang was stationed at Kashwitna (Mile 193.9) to do the extensive shimming required to maintain the track through late winter and into the breakup period of late April and early May.

The 1917 valley alignment of the railroad with long tangents and light curvature forms an interesting contrast with the fairly winding alignment of the Parks Highway to the west. Unlike the railroad, the highway roadbed generally avoids muskeg swamps and is built on gravel terraces. The highway alignment was selected in 1958 by using aerial-photograph interpretation to locate favorable soil conditions.

The gravel terraces support a vegetation typical of an upland spruce-hardwood forest. The fairly dense, mixed forest is composed of white spruce, Alaska paper birch, quaking aspen, black cottonwood, and balsam poplar. These trees generally grow on deeply thawed, well-drained southern slopes and gravel terraces, particularly in areas that were extensively burned during the past 100 yr. The burning of a climax forest and subsequent understory growth of aspen, cottonwood, and poplar furnish browse for the moose population that peaked in the 1950s and 1960s.

The Alaska moose (*Alces alces*) is a large animal that weighs as much as 1,200 lb (572 kg). Its natural truculence in winter increases in direct proportion to snow depth, winter duration, and harassment by his natural enemy, the wolf (*Canis lupus*). While making his daily search for browse, a moose will frequently find the snow-cleared railroad track. Once there, he may be reluctant to leave the well-packed trail, where he can

Slow Order Report
As of 3/7/83

FHJ, FCW, JLC, HLR, RUS, DDL, JAH, DWJ,
PS, KAS, TH, GV, SL, HLW, RC

Milepost From	Milepost To	Slow order	Normal P	Normal F	Reason	Date order placed	Expected date for removal	Work plan
19.0	20.9	25	35	35	Frost heaves	1/21/83	6/15/83	Note A
89.0	95.6	35	45	40	Construction damage	4/8/82	6/83	Track to be surfaced 83 season
A5.85 - MEA industry track					Water-line failure	10/22/82	7/83	City of Palmer responsible for repairs
148.3	148.5	25	45	45	Bridge 148.3 stringer replacement	5/7/82	3/31/83	B&B 6 working on bridge
164.2	164.3	30	49	49	Crossing out of line	1/8/82	7/83	Crossing to be surfaced and lined
168.0	172.0	40	49	49	Frost heaves	1/31/83	7/83	Note A
214.0	Hwy Xg	10	49	49	Broken rail	3/9/83	3/15	Rail being replaced
223.6 - Pit and log track out of service - snow & ice						11/22/82	5/83	Upgrade and inspect
235.6	241.8	30	49	49	Frost heaves	2/1/83	6/83	Note A
257.7	262.3	25	35	35	Frost heaves	1/10/83	7/88	Note A
294.5	315.0	40	49	49	Frost heaves	12/14/82	7/83	Note A
303.5	305.0	30	45	45	Frost heaves	12/14/82	7/83	Note A (orig 40 mph)
315.0	320.0	30	45	45	Profile and alignment	10/15/82	7/83	Note A
327.8	330.4	325	35	30	Frost heaves	1/25/83	6/83	Note A
373.7	374.0	40	49	49	Frost heaves	1/22/83	5/31/83	Note A (orig 35 mph; includes Br 373.9
Nenana - waterfront track out of service 100 ft north of Standard Oil						11/2/82	5/83	Flange rail; remove ice and snow
425.0	427.2	40	49	49	Frost heaves	12/8/82	7/83	Note A

Note A: Section adjusting shims when necessary to maintain speed of slow order. Slow order to be removed after shims are removed and track surface corrected.

Figure 16. Example of a 'Slow Order' report, March 7, 1983.

outrun the wolf or have a better chance of fighting him off than in the deep snow. However, when a train approaches, the moose may bolt down the track and run for miles until exhausted or stopped by an open-decked bridge. The moose will then turn and challenge the engine—provided, of course, that the engineer has reduced speed in time. Unfortunately, the challenger loses. During severe winters, as many as 300 moose are killed. Attempts to solve this problem have been futile. Open-decked bridges were surfaced with aluminum sheets, turnouts were bulldozed into adjacent snow banks, various systems of flashing lights and audio signals were mounted on the engines to frighten the moose, but to no avail. Moose often refuse to leave the track (fig. 20). In the winter of 1953, a moose was hit at Houston by a south-bound passenger train. The impact threw the moose against a switch stand that was pulled loose from its fasteners. The switch points under the leading engine opened up, and the lead set of engine wheels continued on the main line, while the trailing wheels entered the spur track. The train was derailed, fortunately with no injuries—except to the moose, of course. In the Susitna valley, the only thing that has effectively reduced the railroad moose kill is the nearby Parks Highway and its tributary roads.

MILE 192 to 193.4. Original construction records show that the grade line barely skimmed the existing ground surface. The following quantities of material were excavated:

.Excavation	500 yd^3
.Excavation for borrow (loose rock) . .	3,459 yd^3
.Excavation for borrow (frozen).	3,002 yd^3
.Excavation for borrow (common) . . .	6,946 yd^3
Total	13,907 yd^3
	(10,640 m^3)

(or 2.2 yd^3/linear ft; 0.5 m^3/m).

This type of light grade work plus the failure to remove frost-susceptible materials are responsible for many shim spots in the Kashwitna area.

MILE 192 to 196. Here, the roadbed crosses the remnants of end moraines.

MILE 193.9. KASHWITNA STATION.

MILE 199. CROSSING OF THE KASHWITNA RIVER.

This is a fairly large meandering glacial stream that originates from a glacially modified valley in the Talkeetna Mountains.

MILE 199.6. Riprap from the Eklutna pit was dumped from the main line and bulldozed to the north bank of the Kashwitna River (on the right) to control bank erosion caused by lateral migration of a large meander of the river.

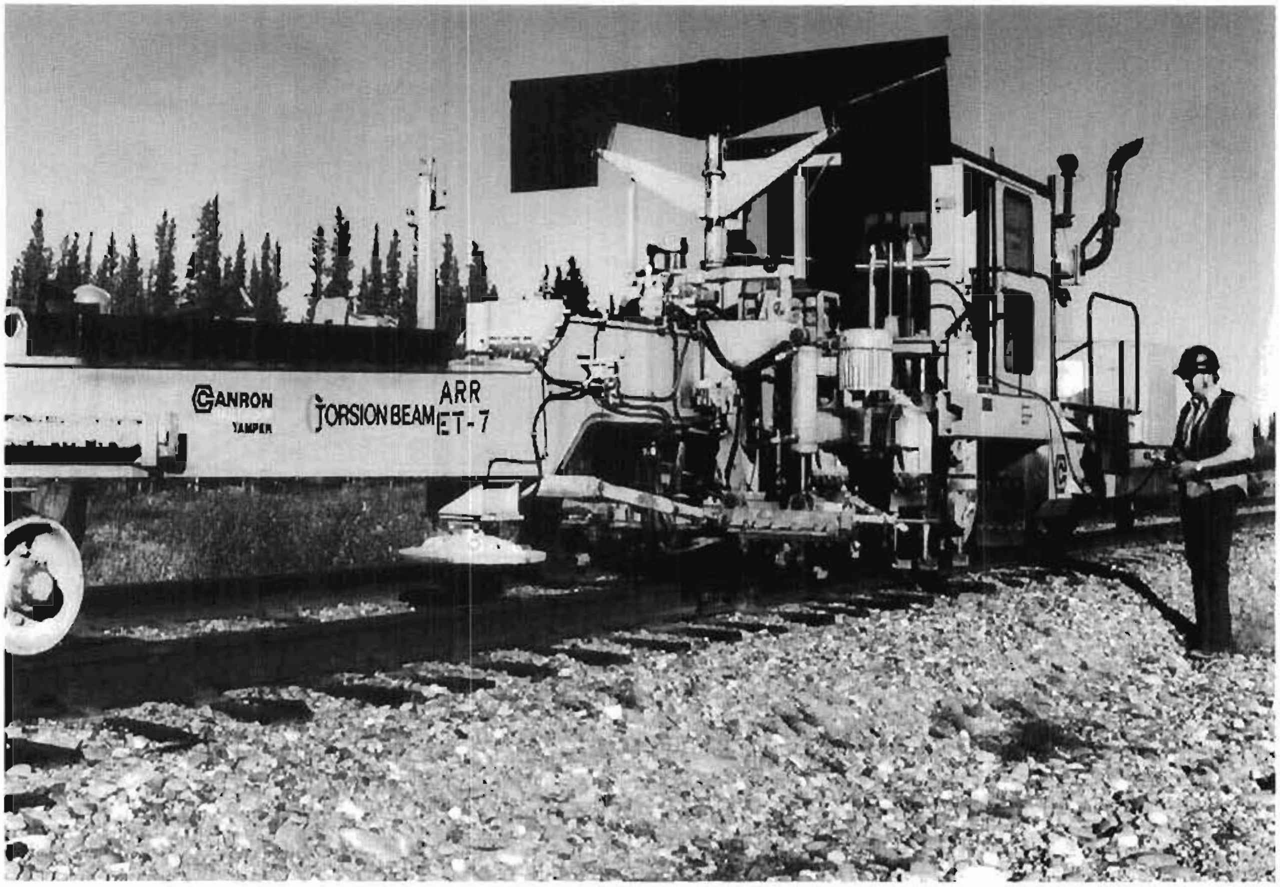


Figure 17. A third-generation automatic tamping machine used by the railroad to raise and line track on crushed-gravel ballast. The machine jacks the track up until the shadow boards mounted on the front of the cab intercept a sharply defined light beam that is transmitted from a forward buggy to receivers mounted on the rear of the cab. When the machine intercepts the light beam, the jacking movement stops, the tamping tools complete their cycle, and the machine automatically moves ahead to the next tie. The operator walks beside the machine and uses a remote control to interrupt, increase, or decrease any cycle He can control the machine as it increases the 'superelevation' through the spiral curve to the full superelevation required for the main body of the curve. A fully automated tamper gang with 10 men and ballast regulators can raise line and dress as much as 13,000 to 15,000 ft (3,960 to 4,570 m) of track each day, compared to 40 yr ago when a maximum of 5,300 ft (1,615 m) of track was lined and dressed by a 50- to 60-man extra gang. Photograph by Bill Coghill, 1980.

MILE 202.3. CASWELL STATION.

Beginning of a 46-mi-long (74 km) track section that received the design amount of gravel when shoulders were widened and sags were raised as part of the rehabilitation program in 1948 and 1950.

MILE 203.3. SHEEP CREEK.

MILE 207.8. GOOSE CREEK.

Goose Creek is a nonglacial stream that recently captured most of the discharge from the larger Sheep Creek, which is the outwash stream of Sheep Creek glacier located in the Talkeetna Mountains. Previous attempts to maintain a dike that separates the two streams 5 mi (8 km) east of the track have failed. The combined discharge of the two streams was excessive for the old 13-span timber trestle. In 1981, the wood trestle was replaced by a clear-span bridge with steel girders that were salvaged from another bridge. All bridgework on the Alaska Railroad is performed by special railroad crews that are equipped to handle all types of construction and make year-round emergency repairs.

MILE 208.5. Note the view of the west front of the Talkeetna Mountains. The smooth contours are unmistakable evidence of glaciation at 4,000-ft (1,220-m) elevation.

MILE 209. A test section of concrete crossties with special fasteners was installed in a shim area in 1973 (fig. 21). Because of severe differential heaving caused by frost action, the track line must be adjusted to maintain normal operating speeds. If the ties are frozen in the ballast, conventional methods of tamping and lining the track cannot be used. When this occurs (October through May), wood shims are used to adjust any vertical displacement, and spikes are driven in new wood surfaces to adjust any horizontal displacement. As heaving increases, new adjustments are made. When the temperature warms, shims are removed in stages until

Figure 18. View of power head of automatic tamper with tamping tools inserted into ballast. Ballast is compacted under the tie by squeezing and high-frequency vibrating of the tamping tools. This function was formerly handled by a 'gandy dancer' with a No. 2 shovel. Usually only two insertions are necessary to fully tamp the tie. Photograph by Dave Atwood, 1982.

Figure 19. The project buggy transmits light beams back to the automatic tamper with its shadow boards fully extended to raise and line track. Photograph by Dave Atwood, 1982.

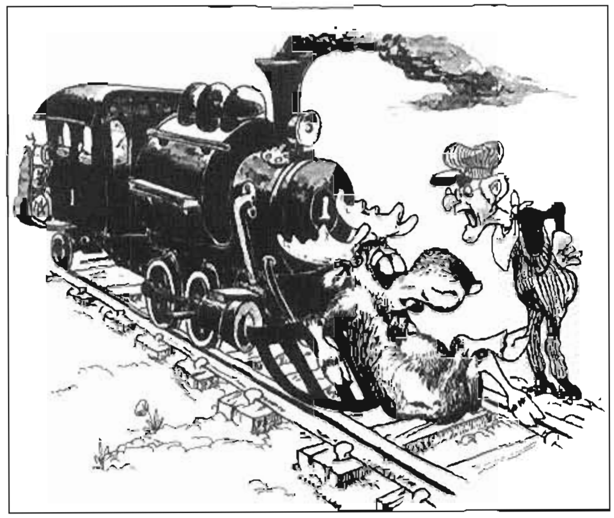


Figure 20. Moose often frustrate train operators by refusing to leave the track. Sketch by Gerrit Hjellen.

the track has returned to its original position. However, the repeated spiking leads to early failure of the spike ('spike-killing').

The test section was installed to determine if a concrete tie could withstand the stresses caused by deformation of the ballast and subgrade section. However, a concrete tie could only be used if the fastener had a considerable degree of vertical and lateral adjustment compatible with the ties. Criteria established by the Alaska Railroad for the test required a fastener that was capable of handling vertical deformations of 5 to 6 in. (102 to 152 mm) and lateral deformations up to ±2 in. (51 mm) to maintain operating speeds of 49 mph (79 kmph). Such deformations required that the holddown elements and associated tie anchorages accept stresses greater than normal. Moreover, the fasteners had to be simple so that they could be adjusted with hand tools under adverse climatic conditions.

The test section is 10 rail-lengths long, or 390 ft (119 m), and consists of 181 prestressed concrete ties that are uniformly spaced 26 in. (66 cm) apart. The ties are Gerwick RT-7S ties (fig. 22) that weigh 800 lb (363 kg) each and are produced by the Santa Fe - Pomeroy Company in California. A new uncanted fastening system (fig. 23) had to be designed for the test. The fastening system consists of a plate with two welded Pandrol-type shoulders for positioning the rail on the plate. Heavy-duty Pandrol spring clips are used to secure the rail to the plate, which has two slotted serrated holes. The plate is fastened to the tie with 10-in.-long (25.4 cm) coil bolts and adjustment blocks that have matching serrations to provide a positive lateral adjustment. A 1-in.-long (2.5 cm) coil bolt is threaded into a special coil anchor embedded in the tie.

Figure 21. Concrete-tie test section, Mile 209. Concrete ties have been used for many years by the railroad industry, particularly in countries where timber is scarce. They are used here because they have adjustable fasteners that permit shimming to correct differential heaving in a known shim spot. The center of the track received a light dump of ballast before it was raised by a surfacing gang. Photograph by Dave Atwood, 1982.

The test results clearly show that the concrete tie and special fasteners performed satisfactorily under frost-heave conditions and cold-weather working conditions.

MILE 209.3. MONTANA.

On the right is an Alaskan homestead.

MILE 211. CROSSING OF MONTANA CREEK.

This is a favorite fishing stream noted for its rainbow trout, grayling, and salmon. Vegetation along the Susitna River (to the left) is typical of a bottomland spruce-poplar forest. The tall, relatively dense forest contains white spruce locally mixed with large cottonwood and balsam poplar that are usually found on level flood plains and low river terraces. In some areas, a thick layer of active permafrost overlies perennial permafrost beneath this type of forest.

MILE 212. Over the next 4.5 mi (7 km), the railroad ascends a relatively high gravel terrace formed by the Susitna River as it meanders to the west. The rather abrupt north face of the bench (crossed by the railroad at Mile 216.2) lies almost perpendicular to the generally north-south trend of the river. The Parks Highway crosses the Susitna River 3 mi (5 km) to the west.

MILE 215.3. SUNSHINE STATION.

MILE 216.5. The roadbed traverses a low terrace of the Susitna River at water-level grade for the next 5.5 mi (9 km). An older, higher terrace is visible on the right. Although drainage in the area is poor and some ponds occur (fig. 24), the embankment section, which received a heavy raise of gravel during the rehabilitation period, has been relatively stable. Consequently, the railroad can maintain 59 mph[7] (95 kmph) with normal maintenance.

MILE 220.6. ENTER TALKEETNA B-1 QUADRANGLE.

MILE 222. The roadbed traverses another terrace of the Susitna River in the next 3 mi on a maximum 1.0-percent grade.

MILE 223. One of the oldest and most productive gravel pits along the railroad is on the left. Fluvial deposits along the Susitna River range from coarse to very fine gravel with some sand and very little colloidal material. Because of the thickness and quality of the materials, the Alaska Railroad has developed a high shovel face and can load directly into railroad cars. Here, the upland spruce-hardwood forest is well developed and extensive. Efforts to log the birch commercially have failed because of the generally overmature condition of the virgin forest.

MILE 224.5 Note the dramatic view of Mount McKinley with Mount Hunter and Mount Foraker to the left; the heavily braided Susitna River is in the foreground. At 20,320 ft (6,194 m), Mount McKinley is the highest mountain on the North American continent. The elevations of Mount Hunter and Mount Foraker are 14,573 ft (4,442 m) and 17,400 ft (5,304 m), respectively.

MILE 226.7. TALKEETNA.

Talkeetna is a small village that lies at the confluence of the Talkeetna, Chulitna, and Susitna Rivers. Historically, the village has been the supply center for the Dutch Hills - Peters Creek gold-mining area located to the west in the foothills of the Alaska Range. Talkeetna is known as the jumping-off spot for many climbing parties that come from all over the world each year to attempt to scale Mount McKinley. Climbers are usually flown to the 10,000-ft (3,000 m) level to begin their ascent.

MILE 227.1. CROSSING OF THE TALKEETNA RIVER.

Two mi (3.2 km) above the bridge, the Talkeetna River emerges from a well-defined channel and braids into a myriad of channels that merge before passing under the railroad bridge. The river shifts between the various channels depending on the debris accumulation that blocks one channel, then another. Occasionally, the westernmost channel will carry most of the water, thereby increasing the flow and the amount of debris in Billion Slough, which the railroad crosses on a timber

[7] Industry regulations permit a maximum speed of 59 mph (95 kmph) for passenger trains on railroads that operate without an automatic block signaling system; freight trains are restricted to 49 mph (79 kmph).

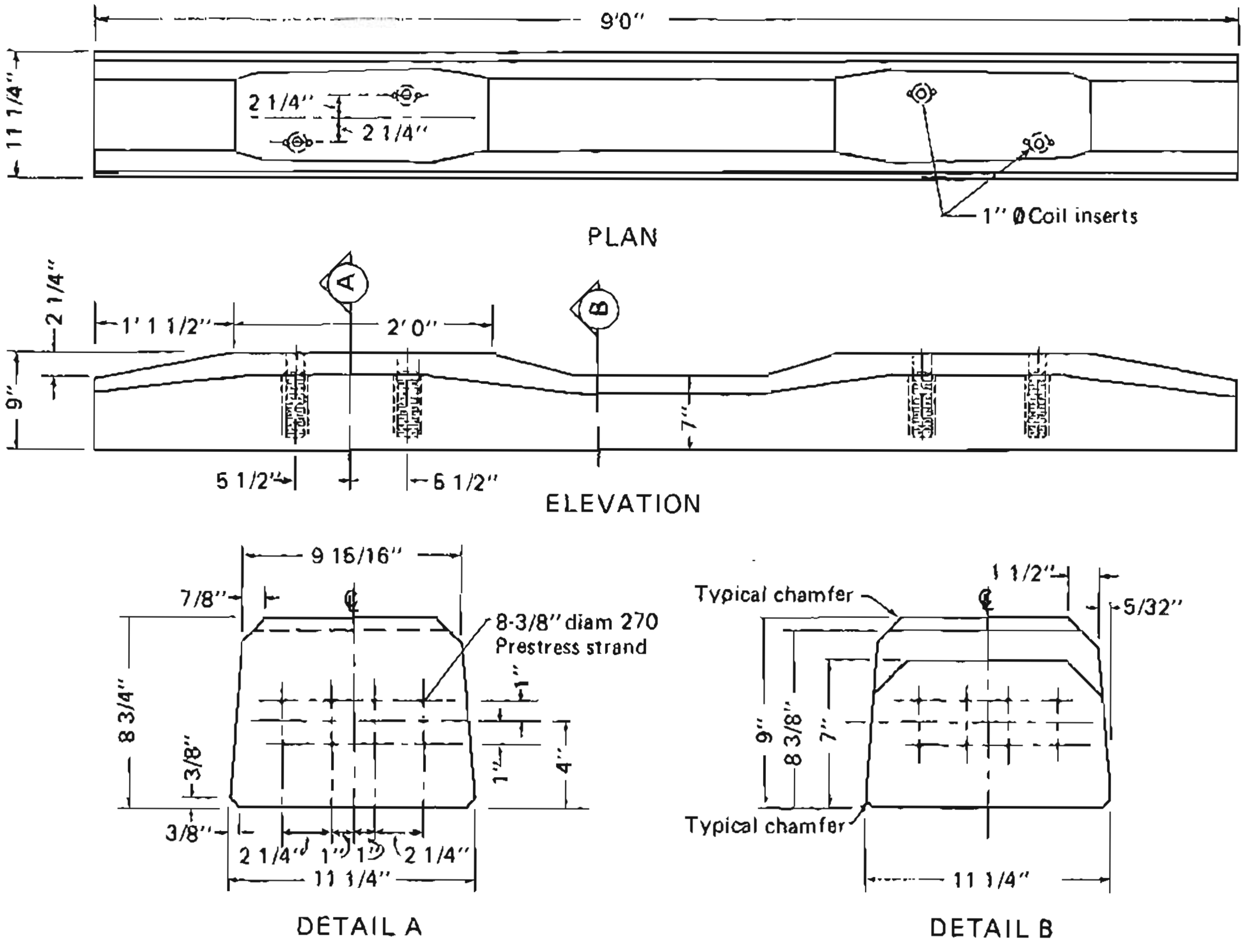


Figure 22. The Gerwick RT-7S concrete ties weigh 800 lb each.

trestle at Mile 227.9. There is a distinct possibility that the Talkeetna River could make a major shift and direct most of its discharge against the railroad at this point.

MILE 228. Beginning of a 4-mi-long (6.5 km) tangent or straight-line track on a stable embankment that crosses an old flood plain of the Susitna River. At Mile 229, the linear patterns in the vegetation suggest an earlier, more northern confluence of the Talkeetna and Susitna Rivers. Recent aerial photographs indicate that the railroad embankment has blocked surface water that originates on the east side of the track. As a result, a mature spruce-hardwood forest has developed on the west side of the track and contrasts sharply with the low-brush, bog-muskeg vegetation typical of poorly drained areas.

MILE 232. Note the railroad gravel pit on the right in high-terrace gravels. The gravels contain more colloidal material than the cleaner gravels at Mile 223 and serve as one of several stockpiles of crushed-gravel ballast along the main line.

MILE 233.5. CROSSING AN OLD FLOOD PLAIN OF THE SUSITNA RIVER.

This crossing required several bridges and a fairly high fill section. The wide ditch and rectangular ponds on the right indicate that unsuitable side-borrow materials were used.

MILE 234.3. The pond on the right was formed when beavers built their dam across the railroad drainage structure. Beaver dams are another perennial problem faced by railroad-maintenance crews. If a beaver dam is not removed from a culvert, the track could be washed out during a flood.

MILE 236.7. CHASE.

Here, the railroad enters the Susitna River canyon, a glacially modified structural basin in the Talkeetna Formation. In this area, the formation consists primarily of slate, argillite, and graywacke, with occasional schist and phyllite that is overlain by glacial till and terrace gravels. The uniform backslope, which is mantled by thick vegetation, suggests that the bench on the east

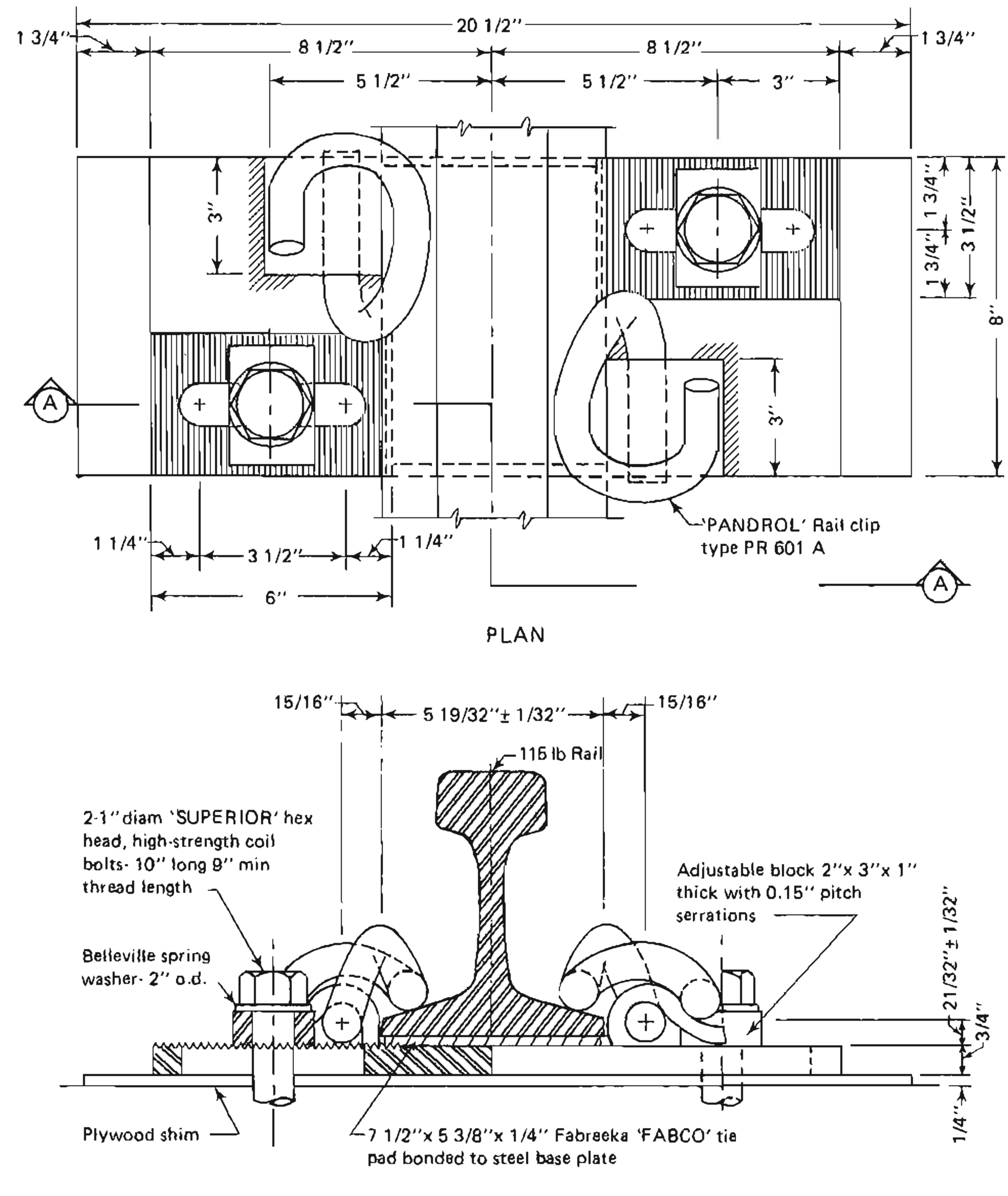


Figure 23. An adjustable fastening system for holding the rail to the tie was specially designed for the concrete-tie test section, Mile 209.

Figure 24. Side borrow, Mile 215. The source of the silty, organic material in the embankment section is the shallow, water-filled pit on the right. Photograph AEC G657, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, 1918.

has a stable angle of repose. However, ground water constantly carries fine-grained silt from the overlying moraine downslope. The silt fills the ditch along the track and the voids in the crushed-gravel ballast. If the ditch section is cleared, the mantle of soil and vegetation may be undercut. When the mantle is lubricated by ground water, it slides downhill in wide swaths, exposing the underlying bedrock and often covering the track with mud and trees. When the roadbed between Mile 236 and 239.7 was constructed during the winter of 1919 to 1920 by the Alaska Engineering Commission, a steam shovel was used to make the necessary sidehill excavation. However, the roadbed on either side of this section was built earlier by station contract in 1916. There appears to be no economical way to stabilize the slope (fig. 25).

MILE 237.4. Very thin layers of low-grade coal are visible in the bedrock exposure on the right. During original construction, specially designed riverboats brought supplies this far and would 'bunker-up' on the coal for the return trip to Susitna Station on the lower Susitna River (fig. 26). Before the railroad was rehabilitated, track maintenance was extremely difficult and expensive. Culverts were useless, and open track boxes were spaced 100 ft (31 m) apart to carry off water and silt. During rehabilitation, the roadbed between Mile 236.5 and 241.5 was raised by at least 3 ft (1 m) with gravel. During spring breakup, ice jams on the Susitna River are a problem (fig. 27). In 1981, the track at this location was under water for 2 days before the ice jam broke downstream and flood waters subsided.

MILE 239.3. ENTER TALKEETNA C-1 QUADRANGLE.

MILE 241. Glacial erratics of granite are visible on the right.

MILE 241.5. A good bedrock exposure capped with outwash gravel is visible on the right.

MILE 244.5 The clearly defined terraces on the right indicate that the Susitna River once carried a heavy load of glaciofluvial sediments. At its head, the river is still fed by two large glaciers, the Susitna and the Maclaren. The river flows south in a braided pattern over a broad flood plain. Below the great bend where it begins to flow west, the Susitna River deposits most of its coarse debris and flows in a single, deeply incised channel that extends almost to its confluence with the Chulitna and Talkeetna Rivers. These rivers transport large quantities of outwash gravels, and below the village of Talkeetna, the main Susitna River has developed another broad, braided flood plain.

MILE 246.7. The former Curry rock quarry on the right is a large granitic intrusion that rises 1,200 ft (364 m) above the valley floor. The material is of excellent quality; however, the existing quarry face is too high to work safely, and extensive site preparation would be required to reopen the quarry. All riprap used by the railroad is produced at the Eklutna pit.

MILE 248.5. CURRY.

Once this was a division point, complete with houses, shops, an enginehouse, a water tower, and a beautiful hotel. Travelers would arrive from Seward, spend the night at Curry, and depart to Fairbanks the following day. Tourists could cross the Susitna River on a footbridge and climb the west ridge to a lookout point that provides a spectacular view of Mount McKinley. The hotel burned down in 1963, and most other buildings have since been removed; only the unoccupied barracks building remains. Curry is located within a federal wildlife preserve that was established in 1933.

MILE 248.7. Deadhorse Creek is the source of an active alluvial fan that has forced the Susitna River against the canyon's west wall.

MILE 249. ENTER TALKEETNA MOUNTAINS C-6 QUADRANGLE.

The flat-floored, U-shaped, glacial canyon is up to 1 mi (1.6 km) wide, which allows ample room for a generally favorable alignment on the gravel terraces. However, in a few restricted areas, the river lies against the canyon's east wall.

MILE 256.9. Note the Beaver dam on the right.

MILE 257.7. SHERMAN.

The track is located on an alluvial fan that has clearly defined terraces on the right. The smooth, rounded contours of the ridge to the west that divides the Susitna and Chulitna Rivers clearly indicate that the ridge was completely overridden by ice during Pleistocene time.

MILE 259. Here, the roadbed is constructed in a bedrock cut section (fig. 28). Excessive ground water seeps into the shallow subgrade and ballast section and causes severe differential heaving. In addition, hydrostatic pressure forces the water to flow from the vertical rock face above the track level. The water causes a wall icing, which can result in side-clearance problems. Icings are common in winter and potentially hazardous to safe winter operations (fig. 29). Even during extreme cold spells, ground water continues to flow from the ground. If not checked, the icing will continue to build, fill the ditch, and reach the track, where an accumulation of only 1 or 2 in. can derail the heaviest locomotive. Because nearly all icings are remote from electrical power, standard thawing equipment on the Alaska Railroad has become the ubiquitous 'Alaska daisy,' which is a 55-gal (210 l) fuel-oil barrel that is cut in half and filled with charcoal briquets that are kept burning continuously. Rock salt is also used to encourage meltwater to flow into ditches and culverts. The severity of the icings varies, but is at its worst during a winter of light snowfall and extended stretches of cold weather. Thick snow, if undisturbed, will insulate the ground and allow ground water to flow through culverts under the track. During a bad year, the railroad may burn as many as 24,000 10-lb bags (240 tons or 220 mt) of charcoal. Under certain conditions, prima-cord explosives and a ditcher (an on-track power shovel) are used to break up ice in the ditches.

MILE 262.5. ENTER TALKEETNA MOUNTAINS D-6 QUADRANGLE.

Note the well-defined terraces on the right.

MILE 263.2. GOLD CREEK.

Figure 25. Heavy ditching is required to protect the roadbed and ballast section from the silt and debris in mudflows that originate on the high face above the track between Chase (Mile 236.7) and Mile 241.5. Photograph by Dave Atwood, 1982.

This station could become the railhead for transportation to the proposed dam site at Devils Canyon, located 17 mi (27 km) up the Susitna River.

If adopted, the two-dam hydroelectric project would be an arched structure 645 ft (196 m) high by about 1,500 ft (457 m) long at the crest, with an installed capacity of 600 MW. The reserve behind the dam would be about 26 mi (42 km) long. Located farther upriver, the second proposed dam, Watana, would be an earth-filled structure with a maximum height of 885 ft (270 m), a length of 4,100 ft (1,250 m) at the crest, and a total volume of 62 million yd^3 (47,740,000 m^3). Installed capacity would be 1,020 MW, and the reservoir would be 48 mi (72 km) long.

Within the Talkeetna Mountains Quadrangle, large-scale geologic structures, such as the Susitna and Chulitna River valleys to the west, have the same southwest orientation as the Denali fault system. This parallel pattern was probably caused by a massive collision when the Pacific plate was subducted beneath the North American plate.

MILE 264.1. CROSSING OF THE SUSITNA RIVER.

The roller nests and expansion on this 504-ft-long (153.5) through-tress span were affected by the 1964 earthquake and had to be reset. This structure was the first steel bridge constructed on the railroad north of Anchorage and is listed in the National Historical Register.

MILE 266. The ascent of the Indian River canyon begins here. The beautiful clear-water stream

Figure 26. A riverboat 'taking on coal' opposite Mile 231. Numerous lignite veins are located here. The vessel had a special stern tunnel design to operate on the Susitna River. Photograph AEC H94, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, August 31, 1918.

originates in the northwest corner of the Talkeetna Mountains. When the Susitna River canyon was selected as the railroad corridor north of Talkeetna, a northbound ruling grade of 1.75 percent was needed to reach the uplands of upper Chulitna valley and cross the Alaska Range through Broad Pass. The ruling grade's effect on train operations is shown in the following comparison of tonnage ratings for the 3,000 hp engines now being used to haul freight:

.Portage to Potter
Level grade; 4,560 tons (4,135 t)
.Anchorage to Gold Creek
1.0 percent grade; 2,100 tons (1,910 t)
.Gold Creek to Colorado
1.75 percent grade; 1,255 tons (1,136 t)

Locating a railroad route through mountainous terrain required great skill on the part of the locating engineer. Northbound and southbound ruling grades vary within the same district. Here, numerous sharp curves had to be made to follow the general course of the narrow Indian River valley and develop a line long enough to meet a vertical rise of 1.75 ft (53 cm) for every 100 ft (30 m) on tangent track. Resistance to a train moving through a curve further reduces the engine-tonnage rating. To maintain the tonnage rating, the grade line through the curves was reduced by 0.04 percent for each degree of curvature. Thus, the grade line through the compound 14° curve at Mile 269.6 is 1.19 percent, less than the average grade of the Indian River.

MILE 268.4. CANYON.

MILE 269.1 to 270. Three crossings of the Indian River show tightly folded and jointed bedrock of graywacke, slate, and argillite. With its steep gradient, the Indian River occasionally overflows its banks of loose, unconsolidated gravel north of Mile 270.2 and causes serious erosion problems along the roadbed.

MILE 272.1. Severe differential heaving occurs along this curve because of excessive ground water in the underlying soils. Ditches were recently dug here to intercept ground water that flows from the base of the stream-deposited gravel on the left.

Figure 27. Results of an ice jam during breakup of the Susitna River, Mile 237.5. Note the high water formed by ice floes on the island to the left. Photograph AEC G1754, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, May 17, 1921

MILE 273.6. OLD RAILROAD GRAVEL PIT

Outwash gravel in this area is very coarse and of limited use; the pit was last used in 1954.

MILE 273.8. CHULITNA.

MILE 276.3. CROSSING OF PASS CREEK.

This creek drains into the Chulitna River. An old trapper's cabin is on the right. The ascent of Chulitna hill begins on a 1.75-percent compensated grade with restrictive curves. The south face of the Alaska Range (to the left) shows the extreme relief from the 500-ft (150 m) elevation of the Chulitna River to the 20,320-ft-high (6,194 m) summit of Mount McKinley, a mere 35 mi away (56 km).

MILE 279.[8] On the left, the south and north peaks of Mount McKinley are visible. Viewed from a distance, the mountain system is an abrupt and chaotic mass of peaks that differ substantially in elevation. Sculptured by erosion, sheer granite walls rise to elevations of 2,000 to 8,000 ft (600 to 1,200 m) and are surmounted by innumerable pinnacles. Peaks with elevations of 5,000 to 11,000 ft (1,500 to 3,300 m) commonly rise 4,000 to 8,000 ft (1,200 to 2,800 m) above their bases. Within this range of mountains, glaciers wind downward from the flanks of Mount McKinley. The topography of a large part of the area has been glacially modified, and cirques, aretes, truncated spurs, and U-shaped valleys with oversteepened slopes are common. Only a small part of Eldridge Glacier, one of Mount McKinley's largest ice fields, is visible above the shoulder of a high ridge. The lower 10 mi (16 km) of the glacier are covered with an ablation moraine, and the ice is exposed only on the margins or in fissures that extend through the moraine. A lack of vegetation on the moraine suggests recent activity at the front. No terminal moraine exists beyond the glacier front; the volume of meltwater that rises in a great upwelling or fountain at the glacier front is apparently large enough to remove the morainal material as quickly as it accumulates.

MILE 280. Although the grade is nearly level, poor subgrade conditions restrict train speeds to 35 mph (56 kmph). Exposures indicate that the upper Chulitna valley is floored with morainal material. Surface drainage

[8] Abstracted from Capps, 1933.

Figure 28. The station contractor had workers use picks, shovels, and wheelbarrows to excavate a sidehill cut, Mile 259. Photograph AEC G1186, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum. March 6, 1919.

is poor, and there are indications of discontinuous permafrost at shallow depth. Vegetation is typical of a lowland spruce-hardwood forest with pure stands of black spruce (figs. 30 and 31).

MILE 282.7. Frost jacking has exposed several poles of a two-pole light trestle used by station men when the original embankment section was constructed.

MILE 283.2. ENTER HEALY A-6 QUADRANGLE.

MILE 283.7. The grade descending toward Hurricane Gulch required a throughcut that exposed ground moraine underlain by a peat layer more than 10 ft thick (3 m).

MILE 284.2. HURRICANE GULCH BRIDGE. This structure is a 384-ft-long (117 m) deck-arch that is 290 ft (88 m) above the floor of the gulch. On the right, a bedrock landslide is visible on the north bank. On the left, the Chulitna River alternately flows between rock walls of canyons and more open stretches; it emerges as a braided river on a wide flood plain. Because many tributary streams issue from glaciers, the river carries large quantities of sediment and is constantly shifting its course, cutting into its banks, and forming bars in its flood plain. The gravel and rock walls that extend several hundred feet above the Chulitna River form benches on which the railroad is located. The benches represent the floor of a broader, older valley that was larger and more mature than the old Susitna River valley. The benches suggest that although the Susitna River now carries more water, the Chulitna River may have once been the main stream.

MILE 285.5. Begin descent on a 1.5-percent, southbound ruling grade to cross Honolulu Creek on a 150-ft-long (45 m) through-truss span near the floor of the Chulitna valley (fig. 32). This alignment avoided crossing several deep gorges on the higher bench of the original location. The original drawings show that several alternate locations were investigated, one of which involved building six tunnels, three on each side of the approaches to the gulch. The construction of the Parks Highway in this area involved a similar exercise in selecting a final alignment.

MILE 286. The old footbridge across the Chulitna River afforded early miners and prospectors access to the south end of the Chulitna mining district. This

Figure 29. An icing at Mile 260 Photograph AEC G1189, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, March 6, 1919.

district, roughly 30 mi (48 km) long by 10 mi (16 km) wide, extends northeast from Eldridge Glacier along the southwest flank of the Alaska Range. Records indicate that gold, silver, and copper were produced from the Golden Zone Mine. Coal was produced at the Dunkle Mine and brought to the railroad at Colorado Station (Mile 297.1). Development of the Chulitna mining district was actively promoted by the railroad in the 1930s.

MILE 288.7. For the next 3 mi (5 km), the railroad follows the Chulitna River flood plain on a good subgrade. Several small bridges deemed necessary during original construction have been replaced with culverts as drainage conditions changed.

When the railroad was constructed, wood trestles were driven across most drainage ways. For the next several years, stream runoff was observed under peak conditions. On the basis of these on-going observations, the original structures were either redriven or replaced with a culvert.

MILE 292.1. In 1921, a 15-person work crew excavated a throughcut and found almost all of the ground was frozen; this may have been the railroad's first large-scale excavation in permafrost.

MILE 292.2. Beaver dams and ponds are visible on both sides of the track.

MILE 292.3. CROSSING OF THE EAST FORK CHULITNA RIVER.

At the west valley wall, the ascent to the Broad Pass area begins on a 1.75-percent compensated grade. Tan stream gravel overlain by blue-gray glacial till and outwash gravel is visible in both walls of the East Fork valley. The gravel pit on the left at Mile 293 has occasionally been used to widen shoulders. Soil borings and the steep, natural slope indicate a high content of colloidal material that makes this pit an undesirable source of crushed-gravel ballast.

MILE 293.7. ENTER HEALY A-5 QUADRANGLE.

MILE 294.4. The broad, flat-floored valley and gentle terrain through Broad Pass are more typical of the lower Susitna valley than of a pass through a major mountain system. Here, the railroad alignment has long tangents and shallow curves. Train speeds of 49 mph (79 kmph) are maintained for 9 mi (14.5 km) and then

Figure 30. Station workers excavate a throughcut in glacial till, Mile 282 to 283. The material was loaded into horse-drawn carts and hauled south to build the fill shown in figure 31. Photograph AEC G1567, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, May 25, 1920.

reduced to 45 mph (72 kmph) for the following 15 mi (24 km). Short, abrupt frost heaves develop quickly in this area and require prompt attention.

MILE 295.1. This is the first in a series of rock glaciers that are visible in the high valleys of the Talkeetna Mountains to the east (fig. 33). In this area, stands of timber in which black spruce is the predominate species have been referred to as 'tiaga,' the Russian word for a typical boreal forest.

MILE 297.1. COLORADO STATION.

An access trail to the Chulitna mining district starts here.

MILE 301. To the east, the Middle Fork Chulitna River valley has the typical U-shaped cross section of a glaciated valley. The old railroad gravel pit on the left is one of the few gravel deposits in the Broad Pass area clean enough to produce crushed-gravel ballast. The entire deposit of stream gravel west of the track was used to produce 135,000 yd^3 (105,000 m^3) of ballast. Although the undulating grade line between Mile 299.7 and 303.2 is on tangent track, it is still undesirable. On long freight trains, couplers accumulate considerable slack and cars tend to 'run in' and 'run out,' depending on their distance from the engines and whether the grade ascends or descends. This makes it difficult for the train engineer to get the proper throttle setting required to maintain a uniform speed, particularly with the old steam engines. In 1946, shoulders were widened as much as 30 ft (9 m) to support a fill section that would eliminate the sags. However, the program was never completed because of insufficient funds and the advent of modern diesel electric locomotives. A solar-powered highway warning system used at remote crossings is shown in figure 34.

MILE 304.3. BROAD PASS STATION.

Eighth active section crew north of Anchorage. The roadbed and buildings are located on the flood plain of the Middle Fork Chulitna River, which has a high water

Figure 31. Station workers at Mile 282. Photograph AEC G1568, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, May 25, 1920.

table. A heavy shim area exists at the north end of the yard because of the poor subgrade conditions and the high water table.

MILE 305.5. ENTER HEALY B-5 QUADRANGLE.

MILE 305.7. CROSSING OF THE MIDDLE FORK CHULITNA RIVER.

The steep slopes in the cutbank on the right are typical of the Broad Pass gravel, which is cemented by colloidal material. Squaw Creek, on the right, carries an annual run of king salmon as far as beaver dams permit. Isolated stands of black spruce merge into alpine tundra that is composed mostly of low, herbaceous and shrubby plants. Alpine tundra typically occurs on mountains above 2,500 ft (800 m) elevation. Small, white alpine flowers (avens) are common on ridges and slopes in the Alaska Range. Plant regeneration is often extremely slow after fire, mechanical damage, or overgrazing. Lichens may require more than 60 yr to fully recover. Occasionally, small bands of caribou (probably stragglers from the main herd in Denali National Park, to the west) move into the area.

MILE 310.2. SUMMIT OF BROAD PASS.

This pass is 2,363 ft (719.5 m) above sea level. Summit Lake (on the right) drains north to interior Alaska and then to the Bering Sea. Topographic and other surface features of the area, such as elongated lakes, vegetation strands, streams, and smooth, linear ridges, all trend southwest. This orientation was caused when the south branch of the Nenana Glacier moved southwest and joined the large ice sheet that occupied the Susitna basin during the last glaciation. Broad Pass also serves as a spillway for weather. Large low-pressure systems moving into the Gulf of Alaska bring heavy precipitation and develop strong winds north of the pass. During long periods of intense cold in the Tanana Valley, a pressure gradient develops, and cold winds spill through the pass from the north. These winds can last for 6 wk and exceed 40 mph (64 kmph).

Figure 32 Sidehill excavation in glacial drift on 'Honolulu Hill,' Mile 287. Photograph AEC G1807, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, June 20, 1921.

A Jordan spreader, pushed by an engine, is the standard equipment used for snow removal on the main line. The spreader has a high-nose plow and adjustable wings that can push snow as much as 20 ft (6 m) from the track. However, in the Broad Pass area, strong north winds can create snow drifts up to 15 ft (5 m) deep. Then, a rotary snowplow and two or three crawler-tractors ('cats') must be used to remove the snow. The rotary snowplow cuts a trench through the drifted area; on its next pass, the cats work ahead and doze the drifted snow into the trench. The rotary snowplow picks up the snow and blows it aside in a long plume, 40 to 50 ft (12 to 15 m) from the track. This process opens the track and permits the snow to blow by. In these conditions, it is desirable to have the track on a fill section, and brush should be removed. Snow fences are no longer used on the Alaska Railroad. The line change at Mile 308 was constructed in 1952 to avoid a cut section along Squaw Creek (on the left).

MILE 312.5. SUMMIT STATION.

The former Federal Aviation Agency facility on the left includes a 5,000-ft (8,045 m) landing strip built on a gravel terrace in 1943. During breakup, the strip is soft and much of it cannot be used. Panorama Mountain is visible to the north.

GLACIAL HISTORY OF THE NENANA RIVER VALLEY[9]

Four glaciations have been recognized in the Nenana River Valley. They are named after Alaska Railroad place names according to their advance northward down the Nenana River canyon. The most extensive (and oldest) major glacial advance is the Browne Glaciation, which formed an ice lobe 16 mi (26 km) wide [near Lignite (Mile 363)] that terminated a few miles north of Browne (Mile 381.2). At that time, the Alaska Range consisted of low ridges and broad valleys dominated by

[9] Modified from Wahrhaftig and Black, 1958.

the Mount McKinley group of mountains to the west and the Mount Hayes group east of the Nenana River.

An uplift and northward inclination of the Alaska Range that began before the Browne Glaciation continued, raising the Healy area 700 ft (215 m) and tilting the Nenana River 25 ft/mi (4.4 m/km) to the north.

The next oldest glacial advance is the Dry Creek Glaciation, during which ice moved as far as Mile 361 (near Dry Creek), just 3 mi (5 km) north of Healy. During this glaciation, the coastal mountains that border the Gulf of Alaska were uplifted, as was the Alaska Range. At this time, the Alaska Range probably received less snow because the coastal mountains intercepted more moisture from the Pacific Ocean. Thus, later glaciations were less extensive. During a period of uplift, the northern foothill belt of the Alaska Range was inclined northward about 17 ft/mi (2.8 m/km), and Healy was elevated another 500 ft (150 m).

The third oldest glaciation is the Healy Glaciation, during which the topography of the Alaska Range was similar to that of today. Most ice of the Nenana Glacier probably moved southwest down Broad Pass and joined the ice sheet that occupied the Susitna basin. However, a branch that flowed north down the Nenana canyon was joined by ice from Yanert Fork and Riley Creek. This ice issued from the narrow gorge between the Denali National Park and Preserve and Healy (known as 'Healy Canyon' by the railroad) and formed a large piedmont lobe. Although most material deposited during the Healy Glaciation was removed by erosion, some deposits remain on gently sloping areas near Healy. After the ice retreated, Lake Moody occupied 'Healy canyon.'

The youngest and least extensive glacial advance is the Riley Creek Glaciation, during which the glacier built its terminal moraine at the mouth of Riley Creek (Mile 347.4) almost 10,600 yr ago (based on a radiocarbon age dating). During its retreat, the glacier staged a readvance north from Windy (Mile 326.7) to a point 4 mi (6 km) north of Carlo (Mile 334.4). After the glacier retreated, a glacial lake that extended as far south as Windy formed.

MILE 312.5. SUMMIT STATION.

MILE 313. The rock glacier on the right overrode a small glacial moraine midway up the east wall of Broad Pass.

MILE 314. Beginning of descent through morainal material.

MILE 316.4. CROSSING OF THE CANTWELL RIVER.

This glacial outwash river flows from Denali National Park and Preserve.

MILE 317.7. ENTER HEALY B-4 QUADRANGLE.

MILE 319.5. CANTWELL STATION.

Cantwell is a small village that lies just off the junction of the Parks Highway and the Denali Highway. Survey crews traveled to Chitina on the Copper River and Northwestern Railroad. From Chitina, they traveled to the Broad Pass region where they located a section of the Alaska Railroad in 1914. The Athapascan Indians, who now live in Cantwell, are descended from the Copper River Indians who followed this same trail to help construct the Alaska Railroad and work in the Valdez Creek mining area to the east. Thawing permafrost affects the main line and siding and has caused formation of a 'sinkhole' 200 ft (61 m) north of the south switch to the siding.

Figure 33. Mile 295.1, the first of a series of rock glaciers visible in the high valleys and cirques along the west front of the Talkeetna Mountains. Rock glaciers usually form below talus cones and aprons at the head of valleys or cirques and along lower valley walls. Their slow downslope flow, external shape, and tongue or lobate form also characterize glaciers. Photograph by Dave Atwood, 1982.

MILE 319.7. This small, shallow stream ices heavily in the winter, and the ice frequently tops the bridge caps. Firepots are used above and below the bridge to keep a narrow thaw-channel open. The old section house on the left is abandoned and will be removed unless it is classified as a National Historical Landmark. The Jack River emerges from its canyon mouth in the northwest corner of the Talkeetna Mountains, which are visible 6 mi (9.7 km) to the southeast.

MILE 321. Bedrock exposures on the left are undifferentiated sedimentary, metamorphic, and volcanic rocks of the Alaska Range.

MILE 323. CROSSING OF WINDY CREEK.

This creek formerly marked the southeastern boundary of Mount McKinley National Park, now known as Denali National Park and Preserve. Recent additions have increased the park by 5,800 mi^2 (15,000 km^2), an area equal to the size of Massachusetts.

MILE 324. Several limestone ledges are visible to the west on ridges 600 to 1,200 ft (180 to 365 m) above the track. The limestone, which occurs as lenses in the

Figure 34. Solar panels (at left) on the Alaska Railroad provide year-round power for automatic highway-crossing signals at remote locations. Despite the winter's low sun angle, the solar panels, augmented by a bank of storage batteries, operate the signals in winter as well as summer. Photograph by Bill Coghill, 1982.

nearly vertical slate bedrock, was once evaluated for possible commercial development. Other limestone deposits occur farther up Windy Creek, northwest of Cantwell.

MILE 325. Here, the railroad crosses the McKinley strand of the Denali fault, a large, active fault that can be traced east almost continuously through the crest of the Alaska Range into Canada. West of the railroad, the fault abruptly swings southwest and continues through Foggy Pass and down the Alaska Range toward Bristol Bay. The railroad crosses the fault (at a slight angle) near a short slide area off the right shoulder of the roadbed. Initially the slide was attributed to river erosion at the toe of the slope; however, the slide could be related to activity along the fault. The shoulder was rebuilt with riprap from Eklutna. Schist Creek (to the east) and the toe of the dividing ridge between Bain Creek and the railroad on the left define the trace of the McKinley strand.

MILE 326.7. WINDY.[10]

The railroad enters the Nenana River canyon at Windy siding, which is located on alluvial-fan deposits of Bain Creek. Panorama Mountain is on the immediate right. The Nenana River originates at the Nenana Glacier on the south side of the Alaska Range, 47 mi (76 km) to the east. The Nenana River is joined by the Jack River at Windy and then turns abruptly north. For the next 10 mi (16 km), the river flows through a U-shaped glaciated valley. The valley floor is nearly flat and almost 1 mi (1.6 km) wide; its walls rise 2,000 to 3,500 ft (600 to 1,100 m) above the river. Here, the river gradient is slight and few rapids occur. Maximum train speed for the next 20 mi (6 km) is 35 mph (56 kmph) because of generally poor subgrade conditions and a winding alignment with many sharp curves. Permafrost is discontinuous throughout this region.

MILE 329.5. The railroad crosses a dark-brown-weathering greenstone intrusion for the next 2 mi (3 km). The southern half of the intrusion contains a coarse-grained massive rock that is suitable for riprap. The northern half, which includes the 'badlands,' is composed of a fine-grained greenstone with veins of quartz and calcite that have decomposed and weakened the rock. Because alluvial material in the badlands is very susceptible to frost heaving, the track must be extensively shimmed where it crosses these materials.

MILE 329.5. ENTER HEALY C-4 QUADRANGLE.

The Cantwell Formation, 60 percent of which is composed of massively bedded sandstone and conglomerate, is exposed in this area. The formation also contains shale, coaly shale, and coal.

MILE 330. A pronounced sinkhole and shim spot caused by degrading permafrost are marked by thaw ponds on both sides of the track.

MILE 330.5. An old gravel borrow pit with a high shovel face is visible on the left.

MILE 331. On the left, an old rock quarry is visible in the talus slope that consists of Cantwell Formation rock. Material from this quarry was used by the railroad

[10] Engineering problems and geologic descriptions discussed over the next 65 mi rely extensively on Wahrhaftig and Black, 1958.

for riprap during early construction. Lichens that grow on the upper face of the talus apron give it a dark color. The lighter color of the old quarry face is due to the absence of lichens, even though the quarry has been abandoned since 1925; this indicates that it takes more than 50 yr for lichens to reestablish themselves or that conditions for their growth have changed.

MILE 331.5. Lake-deposited silt and sand are exposed in the terrace on the left. The roadbed alignment, which includes a series of sharp curves, is complicated by the presence of permafrost.

MILE 333.7. CARLO SECTION FACILITY.

The high terrace of outwash gravel just north of the section house contains fine-grained sand and gravel. The same terrace is exposed north of Carlo Creek on the east side of the river opposite Mile 334.0. Bedrock is the Cantwell conglomerate (Cantwell Formation).

MILE 334.4. CARLO STATION.

MILE 336. A high bank of outwash gravel in the same terrace is visible on the left. Excessive ground water made this location one of the most active icing sites on the railroad. In winter, prevailing winds down the Nenana River and fairly low precipitation keep snow cover at a minimum, and icings frequently occur. In addition to firepots, portable 'prospector's boilers' are used to thaw out culverts. In 1953, the track was realigned away from the hill to solve the icing problem.

MILE 336.8. The severe icings that occur in the outwash gravel extend into this area. Because of the more favorable terrain, a deep ditch was dug above the track to intercept and collect water; castovers were placed on a levee between the ditch and the track. During winter, ice nearly crests the levee.

MILE 338.2. A large bedrock slide occurred around 1950 on a high ridge west of the track. The talus includes a large block of Cantwell Formation and intrusive andesite. The cause of the slide and the extent of further movement is unknown.

MILE 338.6. A 15-ft-thick (5 m) gravel terrace overlies 50 ft (12 m) of lake-bed clay. The Yanert Fork valley (to the right) extends 30 mi due east to its source at the foot of the Yanert Glacier. The Yanert Fork is the largest tributary of the Nenana River.

MILE 340.9. On the left are remnants of an old coal tipple that was used during early attempts to develop a seam of low-grade coal.

MILE 341.3. The silt-mantled talus slope on the left made an excellent borrow pit for the fill required to make the 1953 line change at Mile 336.

MILE 341.5. To the right, the Parks Highway crosses the Nenana River. Degrading permafrost has caused the slumping and mud flows that are visible south of the bridge in the throughcut approach and on the old abandoned grade to the north.

MILE 342.7. OLIVER.

When this siding was recently constructed, the underlying glacial till was excavated and permafrost was found. Degrading permafrost has caused the track to settle. In this area, permafrost is frequently preserved by sphagnum moss to within 1 ft (30 cm) of the surface. Consequently, the area is characterized by low hummocks and depressions typical of ground moraine; numerous kettle lakes or ponds are also present. Peat deposits are encountered at Mile 345.0 and 346.0. Numerous sinkholes occur in the main line and must be raised frequently. A former melt pond that occurs at Mile 344.8 indicates that local permafrost under the track may have completely thawed.

MILE 346.3. The old landslide on the right is typical of slides that are triggered when the Nenana River undercuts the high face of a glacial moraine (fig. 35).

MILE 347.1. The railroad enters a throughcut in an end moraine that was deposited behind an irregular ridge of Birch Creek Schist during the Riley Creek Glaciation. The contact between the moraine and schist is visible to the east, on the south bank of Riley Creek at Mile 347.4.

MILE 347.4. North of the throughcut, the railroad emerges onto a ridge of Birch Creek Schist and the south-approach fill to the Riley Creek bridge. For the past several years, the outside shoulder of the approach has continued moving, even after steel piling was driven into the underlying bedrock in an attempt to retain the shoulder. In 1982, borrow material from the throughcut in the end moraines was used for a buttress fill along the west side of the approach. Discontinuous permafrost was encountered during excavation.

The railroad crosses the Hines Creek strand of the Denali fault system along the contact between the Birch Creek Schist and the Cantwell Formation. Deformation

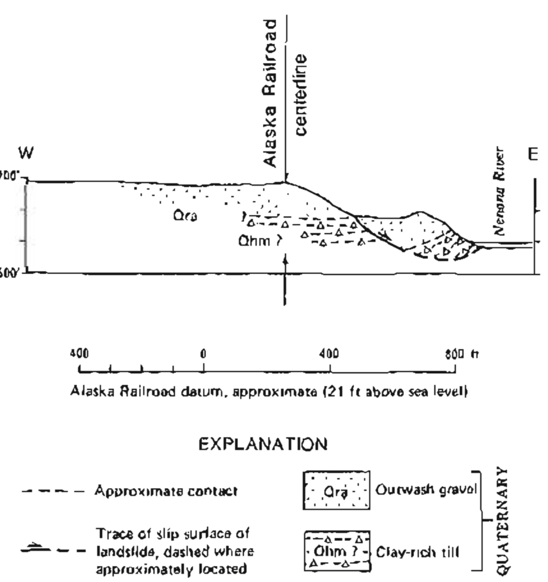


Figure 35. Geologic cross section of a landslide, Mile 346.3. From Wahrhaftig and Black, 1958.

of alluvial gravels in the area indicates that the fault has been active since deposition of the Carlo outwash and subsequent retreat of the glaciers. The Precambrian Birch Creek Schist is the oldest formation traversed by the Alaska Railroad. The schist is composed predominately of quartz and fine-grained mica and breaks up rapidly when exposed to air and frost action. The schist is inherently weak and easily separates along its foliation planes, which are formed by pronounced cross joints and the orientation of mica flakes. The mica is green when fresh, but weathers brown or red and stains the schist. Where pyrite occurs, the schist forms unstable debris that will flow when saturated.

The railroad crosses Riley Creek on a viaduct that consists of 12 deck girders 30 to 60 ft (9 to 18 m) long. The girders rest on steel towers that are supported by four concrete piers. The exposed piers conduct the heat away from the silty gravels beneath them, causing seasonal differential heaving. As a result, the towers have tilted from their vertical axes and caused horizontal movement in the bridge spans and track. The track alignment can vary as much as 3 in. (8 cm); the variations can be quite sharp when one tower tilts to the east and the next one tilts to the west. The towers also tip north or south along the bridge's center axis, thereby jamming the bridge steel together. The bridge has been shimmed to correct excessive variations. Heavy jacks are used to raise the tower legs above the piers while metal shims of varying thicknesses are inserted or removed. In 1953, adjustments were required every year; however, since 1980, shimming has not been required. Tower 2 was raised 4 in. (10 cm) in 1960 to correct for settling of the underlying schist. In 1966, stream-bed gravel was dozed up around the piers to insulate them, but flood waters removed the gravel the following year.

MILE 347.7. DENALI PARK STATION.

Location of park headquarters and road access to the Denali National Park and Preserve.

DENALI NATIONAL PARK AND PRESERVE

In the late 1800s, a prospector named William A. Dickey traveled north from Cook Inlet and saw what he thought must be the highest mountain in North America; it rises about 16,000 ft (4,800 m) above the surrounding terrain and 20,320 ft (6,194 m) above sea level. He named the mountain after William McKinley, who had just been nominated for the presidency. On January 24, 1897, a New York newspaper published an account of Dickey's findings. The article received wide notoriety, and several expeditions to Alaska followed. Charles Sheldon, a noted naturalist who visited the area in 1906, 1907, and 1908 to study Dall sheep and other wildlife, was the principal figure in advocating that the area be made into a national park. On February 26, 1917, just 20 yr after the newspaper article was published, President Wilson signed into law the bill creating the Mount McKinley National Park, at that time one of the nation's largest parks.

Mount McKinley has been known to Alaskan Indians by the name 'Denali,' which means 'The Great One' or 'The High One.' Consequently, a debate took place about whether the name 'McKinley' should be dropped in favor of 'Denali.' However, 'McKinley' is accepted in most areas of the world, and there was a reluctance to change it. In 1980, as part of the Alaska National Interest Land Conservation Act, the name of the park—not the mountain—was officially changed to 'Denali National Park and Preserve.'

The park, which includes 5,696,000 acres (2,305,000 hectares), is blessed with an abundance of wildlife, including bear, moose, wolf, fox, caribou, Dall sheep, and about 150 species of birds.

HEALY CANYON (NENANA RIVER GORGE)

From Denali Park Station (Mile 347.7) to Healy (Mile 358.7), the Nenana River flows in a two-story canyon known to railroad workers as 'Healy Canyon.' The outer canyon is a glacier-carved U-shaped valley with broadly flaring walls and truncated spurs that rise 2,500 ft (770 m) above the 0.6- to 0.75-mi-wide (0.8 to 1.2 km) canyon floor. At the beginning of the canyon and again in its last 5 mi (8 km), the river flows in a 500-ft-wide (150 m) inner gorge that has walls 200 to 300 ft (60 to 90 m) high. In other parts of the two-story canyon, the inner gorge broadens to nearly the full width of the outer gorge. The river gradient through the canyon averages 37 ft/mi (6.8 m/km).

A variety of geologic processes and landforms that are of great interest to the geologist are represented in the canyon. However, the canyon has been a continual problem to the railroad because of the landslides, sinkholes that develop overnight, tunnel cave-ins, washouts, and icings. In addition, there are long-term problems: deep-seated landslides triggered by heavy rainfall, bridge piers and abutments that move downslope because of degrading permafrost, unstable bedrock, and a constantly downcutting and eroding river that upsets the often delicate equilibrium that exists in landslide areas. Even the track's alignment is threatened as the river forces the railroad to move away from the active slide areas into progressively more restrictive curvature. As a single-track railroad without the alternate rail network usually found in the 'Lower 48,' the Alaska Railroad is exceedingly vulnerable to events that occur in the 'Healy Canyon.'

Train service has frequently been delayed in the canyon for several days at a time. Shortly after the grade at Mile 353.0 was constructed, it gave way, and 420 ft (128 m) of timber trestle was required to bridge the slide area. Until the depression was filled in 1943, engineers were advised to cross the bridge at speeds of 5 mph (8 kmph) due to poor alignment and a long, deep sag caused by settlement of the underlying clays. The locomotive engineer of a southbound train had to exceed this speed considerably to pull his train out of the sag and up a 0.9-percent grade. Because of rough track and the mud and clay that reached the top of the rail on the bridge approaches, the engineer was never sure whether he was still on the rail or on the ground.

Recently, a slide area at Moody (Mile 353.2) was reactivated after heavy rains during the summer of 1967. The only way service could be maintained was to 'bunch up' trains to move through the canyon after track crews restored the track to a temporary line and grade. Within a few hours, the track would deteriorate. Temporary restoration continued into fall freezeup. Rockfalls at the north portal of Garner Tunnel (Mile 356.3) have caused similar delays. On August 20, 1950, 150 ft (47 m) of track was buried under 30 ft (9 m) of debris.

The undesirable aspects of a railroad route through the canyon were apparent to the locating engineers in 1914. One survey party spent several weeks trying to find a route from Broad Pass directly to Fairbanks by way of the Wood River. Their efforts proved futile.

As the ice retreated after the Healy Glaciation, 'Healy Canyon' was occupied by Lake Moody. The lake, 0.3 mi (0.5 km) wide by at least 9 mi (14 m) long, extended from Riley Creek north beyond Garner (Mile 355.7) and closely coincided with the Nenana River canyon. North of Moody, the lake was located 0.1 to 0.5 mi (0.2 to 0.8 km) west of the present Nenana River. The lake's surface was at an elevation of 1,750 ft (535 m). Before the river began to cut down the lake's outlet, the lake was completely filled with clay and gravel. After the lake filled with sediment, alluvial fans built by tributaries from the west forced the river to cut into the Birch Creek Schist against the east wall of the canyon (fig. 36). The slumps and earthflows encountered by the railroad in 'Healy Canyon' are located primarily in the lakebed clay deposited in Lake Moody.

Almost all active slides and slumps in this area existed when the railroad was built. In slump areas, trees are tilted and overthrown, and vegetation mats that overlie the surface are torn and disrupted. Most spruce trees that grow in active slump areas in the canyon are inclined upslope. On some old landslides, trunks of spruce trees are bent downslope and then abruptly up, which indicates fairly rapid movement when the trees were young.

The slump and earthflows along the Nenana River range from a few feet to 1 mi (1.6 km) wide and from 400 to 2,000 ft (120 to 610 m) in length. Movement in an active slide area ranges from a few feet per year to a few feet per hour. The effect of earth movements on the railroad depends on the track's location as it crosses the unstable area. Generally, the railroad crosses the middle or upper part of a landslide. In this case, the track's movement is downward with only a slight, lateral movement, which results in a sinkhole that must be raised repeatedly.

Where the railroad crosses the lower part of a large slide, such as at Moody (Mile 353.5), the track is moved downward and laterally toward the river. Consequently, the track has a dogleg and a sinkhole. The most rapid movement occurs in late summer and fall, after cyclonic storms, or during an early freezeup. One of the most active periods of slumping occurred after several severe earthquakes on October 19, 1947. Subsidence at Mile 351.4 was as much as 4 ft/day (1.2 m). An 80-person extra gang was needed to raise and line the track to maintain service. The primary causes of slumps and earthflows along the railroad are lateral erosion and downcutting by the Nenana River. Both processes undermine and steepen the canyon walls. The unconsolidated glacial deposits and poorly consolidated material from the Birch Creek Schist are incapable of maintaining stable, relatively gentle slopes, particularly when the underlying material is saturated. Most landslides occur on the convex side of sharp river meanders. Figure 35 shows a cross section of a typical landslide (Mile 346.3) in which a large meander of the Nenana River undermined a bank of clay-rich till overlain with outwash gravel. The weight of the gravel caused a typical slip-circle slide along planes within the till. Because permafrost exposures have been recorded at scattered locations in the canyon, permafrost was thought to be prevalent throughout the clay and till. When undisturbed, permafrost contributes to slope stability; however, when permafrost is disturbed, melting ice lubricates the slip planes and increases pore-water pressure, which results in instability. When a railroad consultant drilled a series of deep test holes in 1967, he encountered far less permafrost than he expected. This may be attributed to general degradation of permafrost during the 20 yr that followed the first detailed geologic mapping of the canyon.

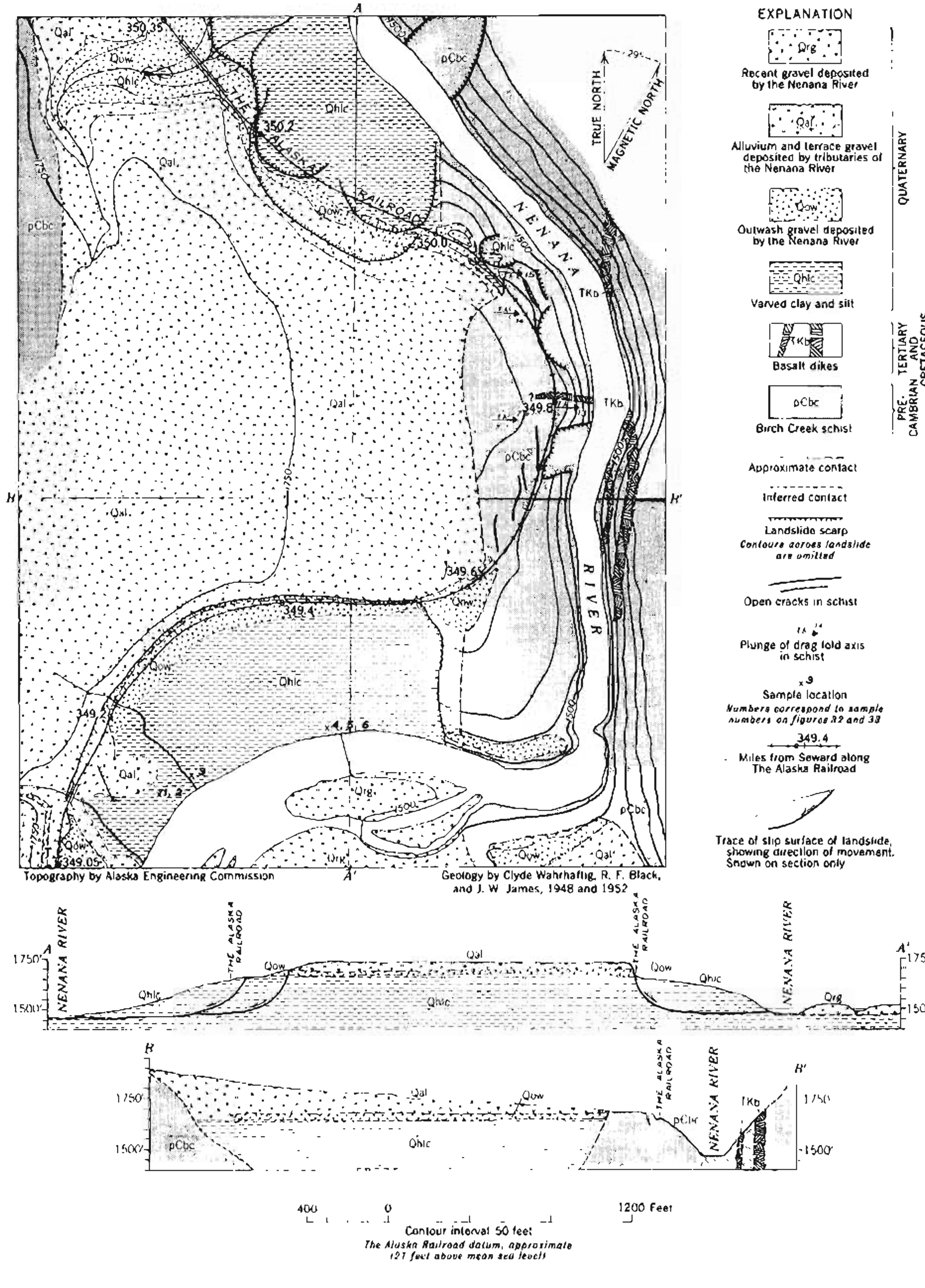


Figure 36. Geologic map and cross sections of landslides between Mile 349.1 and 350.3 along the Alaska Railroad. From Wahrhaftig and Black, 1958.

RAILROAD LOG AND LOCALITY DESCRIPTIONS: DENALI PARK STATION TO FAIRBANKS

MILE 347.7. DENALI PARK STATION.

MILE 348.7. The Horseshoe Lakes are visible to the right. The lakes are 'oxbow' remnants of old meanders of the Nenana River. To the north, the railroad traverses a relatively high bench in a long semicircular loop between Mile 349.1 and 350.3. A cross section of the ancient, clay-filled gorge of the Nenana River (fig 36) is visible. Along the east side of the bench is a segment of Birch Creek Schist that is about 300 ft (90 m) long at the top and less than 200 ft (60 m) wide at the base. The clay is capped with outwash gravel. Overlying the outwash gravel is a layer of yellowish-brown gravel that was deposited on an alluvial fan by a tributary stream from the west (Mile 350.3). The Nenana River flows from the southeast and impinges the west canyon wall at Mile 348.7; the river then meanders sharply to the east and follows the toe of the bench in an active cutbank to the canyon's east wall. From there, it flows north through the narrow gorge cut in the Birch Creek Schist.

MILE 349.1 to 349.6 This is an active slide area where numerous spruce trees below the track have abruptly bent trunks, indicating that slope movement occurred long before the railroad was built. After the railroad was constructed, a sinkhole developed that required filling and raising. By 1945, the subsidence rate had increased, and a new grade was cut north into the bench. Before the railroad could be realigned to the new grade, large cracks opened and further realignment was necessary; however, subsidence continued. By the summer of 1948, the track was 15 to 20 ft (5 to 6 m) below the grade and had to be realigned 74 ft (23 m) north on a new bench beyond the area of subsidence (fig. 37). Further realignment was required in 1947 and 1950. A sinkhole still persists in this area, but it subsides at a very slow rate. In the 1940s, the diversion of surface water on top of the bench towards the track probably contributed to the rapid subsidence caused by melting permafrost within the slide area. The

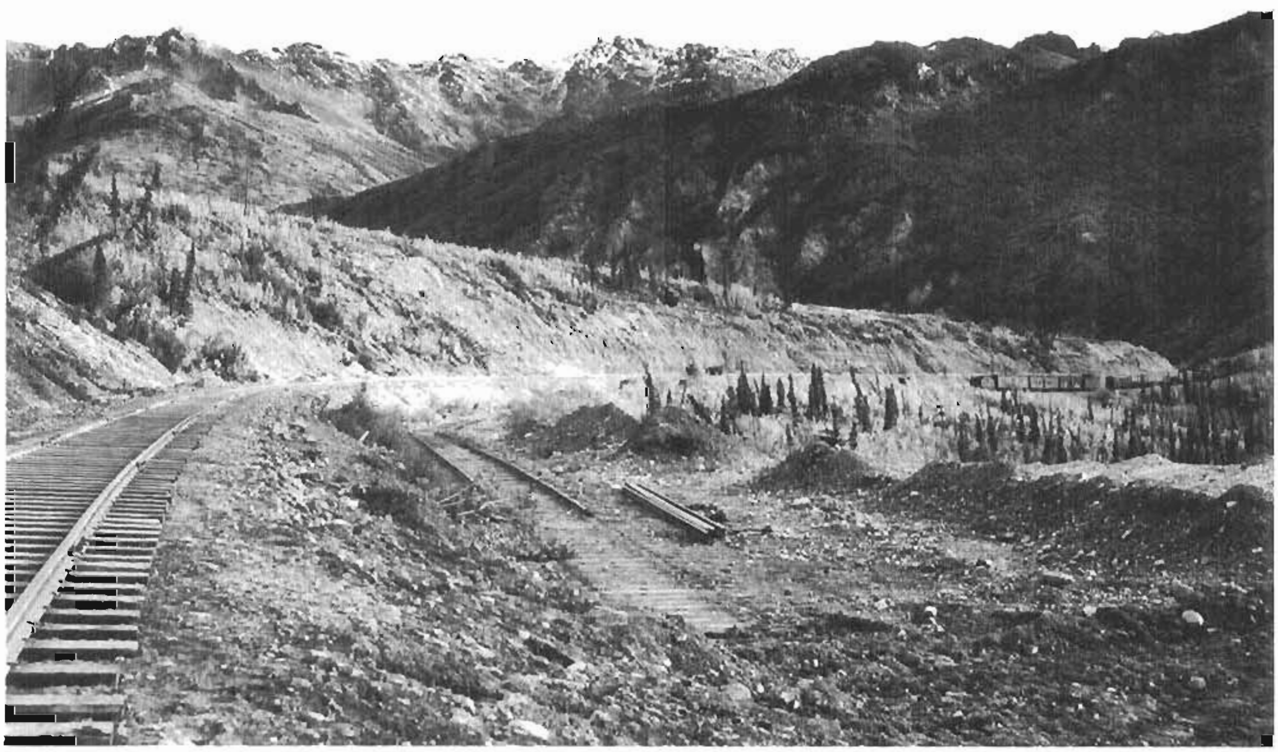


Figure 37. View of an ancient clay-filled gorge of the Nenana River. The amount of subsidence is apparent at the extreme right, where the present track is visible above the 14-ft-high (4.3 m) outfit cars that sit on the abandoned track. Photograph BL 79.2.2966, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, August 26, 1948.

slide cannot be retained by piling, and the cost of protecting the toe of the slide from further river erosion is prohibitive. Moreover, any further appreciable retreat into the hillside would result in very restrictive track curvature.

MILE 349.7 to 349.8. The railroad is built on a narrow portion of Birch Creek Schist that has become narrower as large blocks of schist separate and slide downslope along bedding planes. On the east side of the river, the high backslopes cut into the schist in 1971 are the source of continual rockfalls on the Parks Highway. The layers of dark rock in the schist are basalt dikes.

MILE 349.9. A short slide area where a wall of schist was breached, which allowed lakebed sediments under the track to slide north into the river. Steel X-piling [30 ft long (9 m)] was driven on 3-ft (1 m) centers on both sides of the track in 1972. The pilings on the outside of the track are cabled to those on the inside, which serve as anchor piling or 'deadmen.' If curvature permits, realigning the track may be the only solution to the longterm problem.

MILE 350 to 350.3. The active slump area here is similar to that between Mile 349.1 and 349.6, where tree tilt and abruptly bent trunks of spruce trees indicate creep, slump, and earthflow that occurred before the railroad was constructed. Rapid activity occurred after construction and again in 1948. The track settled up to 2 ft/yr (0.6 m) from 1950 to 1952. During the same period, excavated material that was placed on the east side of the approach to the bridge at Mile 350.3 settled 15 ft (5 m).

MILE 350.7. A typical 'mud bridge' constructed with 30-ft-long (9 m) treated-timber piling was driven on both sides of the track across an active slump area and was then tied back with steel cables. No attempt was made to drive through the slip plane of the slide; the pilings merely anchor the more active surface material to the slower moving, deep-seated slump.

MILE 350.9. Several sinkholes became more active in 1972 after the Parks Highway was constructed. Large quantities of waste material have been stockpiled on the active flood plain of the Nenana River. This stockpile, which is being replenished yearly from rockfalls on the highway opposite Mile 349.8, deflects the Nenana River against the west wall of the canyon during flood stage.

MILE 351.3. Here, severe slumping reached a rate of 3 ft/hr (1 m) after the earthquake on October 19, 1947. By October 30, most slumping had ceased, but on September 20, 1948, railroad service was interrupted again when the same area rapidly slumped over a 5-day period. In this area, Birch Creek Schist is generally overlain with up to 200 ft (60 m) of gravel and lake sediments. The bedrock surface slopes 25 to 35° toward the river.

MILE 351.4. When the three-span steel bridge was constructed here in 1948, the track had to be realigned 30 ft (9 m) west of its original location. Permafrost lenses [15 to 20 ft (5 to 6 m) thick] were encountered at depths that ranged from 6 to 15 ft (2 to 5 m) below the level of the track. One test hole north of the bridge was churn drilled through 100 ft (30 m) of permafrost before unfrozen gravel and ground water were reached. The north pier and north abutment of the present bridge are built on clay. Figures 38 and 39 show construction details of the bridge. The north pier (No. 3) has been moving slowly downslope since the bridge was constructed in 1949. The steel tower has been repeatedly shifted to maintain a true line through the bridge. Periodically, small slumps cause material to fall against the north pier, and the material must be removed. Running water, an indication of degrading permafrost, has been observed near the pier. In 1969, three thermal tubes were installed next to the north pier to reestablish a permafrost regime. This effort failed, and in 1976, the concrete pedestals were increased in area to permit the greater lateral adjustments needed to offset the downslope movement of the pier. After this work, pier 3 was shifted 12 in. (30 cm) west to offset previous downhill movement. Small adjustments are made periodically in the south pier and the north and south abutments.

MILE 352.7 to 353.6. MOODY SLIDE AREA.

The railroad crosses the face of a glacial gorge from the west side of the canyon to the narrow, steep-walled gorge on the east. The gorge is now filled with lake sediments similar to those between Mile 349.2 and 350.3 and between Mile 351.2 and 351.5. The sediments, which are 150 ft (48 m) above the river level,

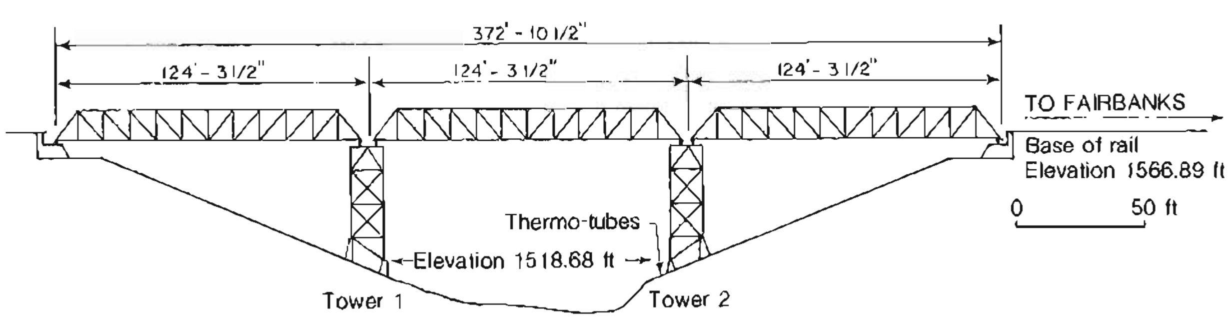


Figure 38. Side-view plan of the Alaska Railroad Bridge, Mile 351.4.

are capped by a thick layer of outwash gravel and talus that is overlain with alluvium from the tributary stream on the west. The stream forced the Nenana River east into the narrow gorge that it cut into the Birch Creek Schist along the east canyon wall. The topography in the Moody slide area exhibits the irregular hummocky surface and crescent-shaped headwall scarps typical of an ancient landslide. Low ridges on the slide surface are parts of rotated landslide blocks that parallel the railroad alignment (fig. 40). Abandoned roadbeds, now overgrown with vegetation, also account for the irregular 'terraces' located immediately east of the track. The original roadbed was constructed on a steep bank of clay that slid into the river in 1923 (fig. 41). The long wooden trestle at Mile 353 was driven to replace the missing grade, but was built on clay and required continual maintenance until it was abandoned in 1943. Currently, the most active part of the Moody slide area is between Mile 353.3 and 353.5. In 1967, 35-ft-long (11 m) piling was driven into the outside shoulder of the roadbed where it was anchored to piling driven into the inside shoulder (fig. 42). Since then, the pilings have subsided and moved laterally. Efforts to keep the track in service during the wet summer of 1967 were concentrated in this area. Saturated clay flowed from beneath the roadbed, and the ground next to the piling sank as much as 8 ft (2.5 m). In 1938, this track segment sank 30 ft (9 m) in 15 days. In 1974, more piling of the same length was driven into the inside shoulder on 6-ft (1.8 m) centers. Much of the activity within the slide area is attributed to ground water and decaying permafrost. Surface water drains from the upper slopes and runs into the scarps at the heads of many slump blocks. Water also collects in sag ponds on the slides, and several springs emerge at irregular intervals. Attempts have been made to divert the water across the track with flumes. However, the flumes separate when the ground settles or when the springs shift locations or dry up. Vertical, 20-ft-long (6 m) drains were installed at intervals on the inside ditch to collect ground water. Of the 34 vertical drains installed, only 10 collect enough water to be pumped periodically.

In November 1967, a series of test holes up to 100 ft (30 m) deep were drilled in the Moody slide area (fig. 43). The borings confirmed earlier geologic interpretations, namely, that this area has been an active landslide area for hundreds of years, as demonstrated by the considerable amount of peat that has accumulated in one area. Figures 44, 45, and 46 are borehole logs of the Moody landslide area, which is shown in figures 47 and 48. Boring 1, at river level, revealed that bedrock of the ancestral Nenana River valley is more than 110 ft (34 m) below the present valley floor. The shear planes along which slide fractures move are deep seated. The probable shear zone found in boring 2 was 190 ft (59 m) below the ground surface, or about 65 ft (20 m) below the valley floor. Due to the extreme depths of the active shear planes and the tremendous mass of material within

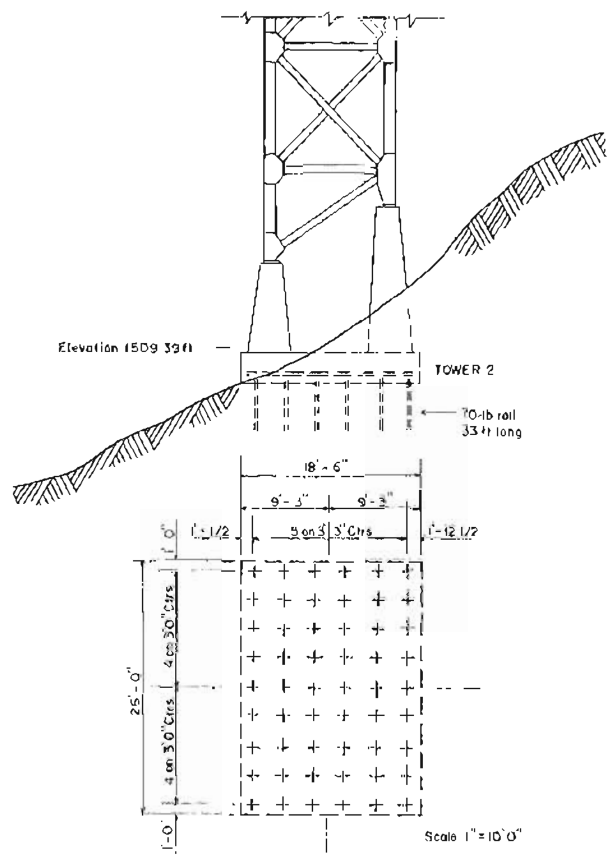


Figure 39. Pile plan for tower 2 on the Alaska Railroad Bridge, Mile 351.4.

the active slide area, there is no feasible way to solve the landslide problem in the railroad's present location. Because far less permafrost was encountered than expected, refreezing this slide remains hypothetical.

MILE 353.3 to 353.5 This was once the area of a very active earthflow, but is now relatively stable, probably due to the retreat of the west bank of the Nenana River. A small archaeological site was excavated in the silt mantle that overlies the bench to the left of the track (fig. 49).

MILE 353.5. HIGHWAY BRIDGE CROSSING.

MILE 353.6. The Moody tunnel is lined with timber.

MILE 353.8 to 355.2. Cribbing or piling (or both) are required to retain the roadbed fill across several 'chutes' in the underlying bedrock.

MILE 355.7. GARNER.

MILE 356.2 to 356.6. GARNER TUNNEL SLIDE.

The railroad passes through a timber-lined tunnel in a hill of Birch Creek Schist that rises 500 ft (150 m) above the track. Much of the southeast side of this hill is an active landslide that involves 1,000,000 to 3,000,000 yd^3 (800,000 to 1,600,000 m^3) of rock. The slide debris consists of large schist blocks that part from the cliff at the head of the slide and slowly topple into a

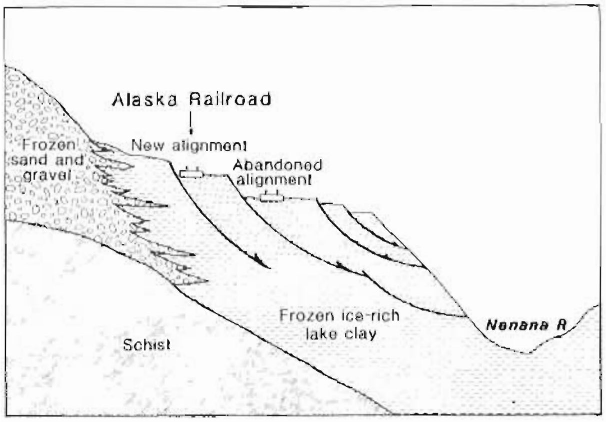


Figure 40. Diagrammatic sketch of landslides along the Alaska Railroad in perennially frozen lake clay. After the vegetation is removed, the heat that is absorbed from the channeled surface-drainage water thaws the lake clay. As the clay thaws, large blocks of sediment slip toward the Nenana River canyon, and the railroad track must be realigned.

great mass of talus that the railroad crosses 500 ft (150 m) north of the tunnel. The weight of these huge blocks forces the talus to move down and out toward the swiftly moving river. Consequently, the toe of the slide erodes as quickly as it advances. At times, river erosion exceeds the slide's advance rate and undercuts part of the roadbed; thus, the railroad is forced deeper into the talus slide. A permanent sinkhole that exists across the talus slide requires periodic track raises. Rockfalls from the vertical face above the north portal have caused numerous train delays. At times, rockfalls have buried the track to depths of 30 ft (9 m) and crushed the timber crash sets that were erected to deflect falling rock. In 1971, a railroad contractor trimmed the rock face above the portal to a 1/8-to-1 backslope and left a lower bench to catch falling rocks (figs. 50 and 51).

MILE 357 to 358. Fourteen terrace levels have been identified in the immediate area. Here, the river and railroad complete their convex curves to the north and east and finally emerge from the narrow rock gorge that they have been following for the last 5 mi (8 km). The series of terraces to the right above the south bank of the river indicates that the river migrated to the north as it cut the narrow gorge. The bench on the north bank of the river is a slump block of a landslide that the railroad crosses at Mile 357.5. The highly weathered schist that lies next to the Tertiary coal-bearing formation was exposed to erosion when the river migrated northward. The schist slumped and flowed under the great weight of the overlying outwash gravel and sand dunes. Since 1967, the slide area has become relatively stable, and further track realignment has not been required. However, a moderate sinkhole must occasionally be brought up to grade.

MILE 358. OLD HEALY YARD.

The old post office originally located here was called Healy Forks. The Tertiary coal-bearing formation

Figure 41. 'Daylight track' was created in 1923 when the roadbed suddenly failed at Mile 353. The roadbed was built on lakebed clays and was oversteepened by erosion. A 420-ft-long (128 m) wood trestle that was built to bridge the ravine remained in service until the ravine was filled in 1943. Photograph from the Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, June 16, 1923.

along the north side of Healy valley is visible to the northeast.

MILE 358.7. HEALY (figs. 52 and 53).

This is a major railroad division point with a classification yard that was built to handle coal cars that originate from the Suntrana Branch line (Mile D-4.8), a 4.5-mi-long (7 km) spur that was originally constructed on the Healy River in 1923. By then, the expensive thawing and drifting methods used in the Fairbanks mining district had exhausted the high-grade gold deposits, and mining sharply declined. However, coal from Suntrana made it possible to generate the power to mine the extensive low-grade placer deposits with six large dredges that were freighted to the Fairbanks area where they were assembled. Between 1928 and 1948, over $100 million worth of gold (at $35/oz) was recovered, and Fairbanks was rescued from becoming a ghost town.

MILE 359. A vertical face of Nenana Gravel is visible on the left. The gravel was recently excavated when the tracks at Healy yard were rebuilt. The Nenana Gravel, the major bedrock formation along the Nenana River north of Healy, consists of poorly consolidated, moderately well-sorted conglomerate and sandstone pebbles from the Cantwell Formation and quartz, schist, and pebbles of igneous rocks from other sources. Claystone beds are abundant and support steep cliffs 50 to 100 ft (15 to 30 m) high. The Nenana Gravel is characteristically yellow or buff because the iron-bearing minerals in its pebbles and sandy matrix are oxidized. Although this gravel is easily excavated and can be used as embankment material, it is unsuitable for loading and hauling by railroad car. The vibration caused by rail movement compacts the material in the hopper cars and makes it extremely difficult to dump through the bottom doors, particularly if the gravel is wet.

MILE 359. JUNCTION, SUNTRANA BRANCH.

MILE 360. From here, the Nenana River follows an almost straight course of N. 25° W. for 23 mi (37 km) across the northern foothill belt of the Alaska Range. Within this foothill belt, the river occupies a broad valley with gentle, terraced walls that rise from a few hundred to 2,500 ft (770 m) above the river. The valley, including its terraces, ranges from 6 to 10 mi (10 to 16 km) wide. Some terraces are more than 1 mi (1.6 km) wide.

MILE 360.1. HIGHWAY OVERPASS.

The high, almost vertical bluff opposite Mile 360.1 is an indication of the recent large-scale erosion of the Nenana Gravel. The Nenana River has extensively undercut the east bank during the last 10 to 15 yr. The truncated alluvial fan of Poker Creek has also been heavily eroded, and the bed of Poker Creek hangs above the valley floor.

MILE 360.9. CROSSING OF DRY CREEK.

This creek is aptly named except when it runs bankfull after a period of heavy rain. The railroad descends into the valley on a generally shallow grade that varies with the topography of the underlying outwash terraces. However, the grade never exceeds 1.0 percent, which is the ruling grade for northbound and southbound traffic.

Figure 42. Pilings (35 ft long; 11 m) were driven on the outside shoulder of the track and tied back to 'deadmen' driven on the inside shoulder. The irregular alignment of the piling is due to further movement within the slide area. Photograph by Dave Atwood, 1982.

MILE 361.7. ENTER HEALY D-5 QUADRANGLE.

MILE 362.3. On the right is the track for the Usibelli Coal Mine tipple, a recently constructed installation for loading coal from Lignite Creek (formerly Hoseanna Creek) directly into railroad cars. A conveyor belt across the Nenana River is used to transport the coal to the tipple.

MILE 364. Exposures of the Tertiary coal-bearing formation are visible in the bench along the east bank of the Nenana River. Except for an occasional restrictive curve, alignment and grade permit a speed of 49 mph (79 kmph) for the next 46 mi (74 km).

MILE 366.2 to 367. The railroad ascends to an upper terrace of frozen outwash gravel to avoid a long westward deflection of the Nenana River. Despite repeated measures by the railroad to control erosion, the river continues to undercut the unfrozen coal-bearing formation beneath it and threaten the main line. The elevation of the track above the river makes it difficult to work from the track with traditional methods, such as side dumping riprap from air-dump cars. One of the most effective 'river-training' devices is dumping scrapped railroad cars over the side with a crane and then cabling them together in the desired location using the heavy sets of wheels as tiebacks. However, recent state regulations prohibit this practice.

MILE 368.7. Note the interceptor ditch on the left. A common form of icing occurs in muskeg areas on open hillsides on the north slope of the Alaska Range. During winter, water trickles downslope through the vegetation mat without forming distinct channels and is kept from freezing by the insulating effect of the saturated vegetation. When the water is intercepted by a ditch line or embankment, the water pools and freezes. As the water continues to flow from the muskeg, layers of ice form an icing. If not controlled, the icing will block culverts and bridges and cover the track. Here, a long ditch was excavated above the track to intercept the water so that it will freeze behind the levee. The ditch slopes north at a 1-percent grade. Two construction seasons were required to excavate the ditch in the perennially frozen outwash gravel.

MILE 369.7. An old wooden-bulkhead wall along the former west bank of the river is now overgrown with vegetation. The initial problem of bank erosion in this area appears to be solved.

MILE 369.9. ENTER FAIRBANKS A-5 QUADRANGLE.

The new Ferry section house (on the left) is constructed on a gravel terrace.

MILE 370.6. CROSSING OF THE NENANA RIVER.

This is the third bridge constructed at this site; it consists of two 200-ft-long (61 m) through-truss spans. Scour and bank erosion of upstream terrace gravel on the west bank are hazardous to the south approach as the river erodes to a lower skew angle at the crossing. The north abutment, which rests on Nenana Gravel, has also been scoured.

MILE 371.2. FERRY.

Railhead for roads to gold fields in the Bonnifield mining district to the east.

MILE 372. The beginning of a long, gentle descent on a low outwash terrace of alluvial gravel.

MILE 373.2 to 374.2. During severe winters, open-field icing will develop in the flat area to the right of the track.

MILE 374.4. A peat bog with a well-defined terrace of Nenana Gravel on the right. To the west, the north-sloping foothills of the Alaska Range rise 800 to 900 ft (245 to 275 m) above the valley floor.

MILE 376 to 377. This is the location of one of the most severe examples of open-field icing along the railroad. Under extreme conditions, ice fills the small stream channel crossed by the railroad at Mile 376.5. The overflow seeps through the vegetation toward the track and forms a sheet of ice that extends from Mile 376 to 377. A steel culvert carries the water through the roadbed at Mile 376.5. Because firepots are inadequate, a portable generator is used to keep a thaw channel open through the culvert.

MILE 377.5. Sinkholes have developed here on degrading permafrost.

MILE 379.5. Here, the railroad has been exposed to severe bank erosion. A wood-pile jetty filled with rock was originally constructed upstream to deflect the river away from the underlying gravel terrace. Now, however, the main channel of the Nenana River has migrated north and flows directly against the railroad embankment at Mile 379.7. To combat the erosion, several trainloads of Eklutna riprap were dumped here to protect the bank. A permanent solution is to divert the river into an older channel to the west. This work should be done in late fall, when freezeup in the higher elevations lowers the water level in the streams. Heavy permafrost would be encountered if a line change were constructed east of the river.

MILE 381.2. BROWNE.

This station is named after Fredrick D. Browne, the engineer who supervised construction at the north end of the railroad after Riggs left to become Territorial Governor. The oldest glaciation in the Nenana River valley is named after this station.

MILE 382. The large, granitic glacial erratic on the right probably slid down to the track from the upper terrace. These large granite blocks, which range up to 40 ft diam (12 m), occur at widely scattered localities on both sides of the Nenana River valley from Healy north to the north edge of the foothills. They are usually associated with the Browne Glaciation and occur as high as 2,000 ft (610 m) above the present valley floor.

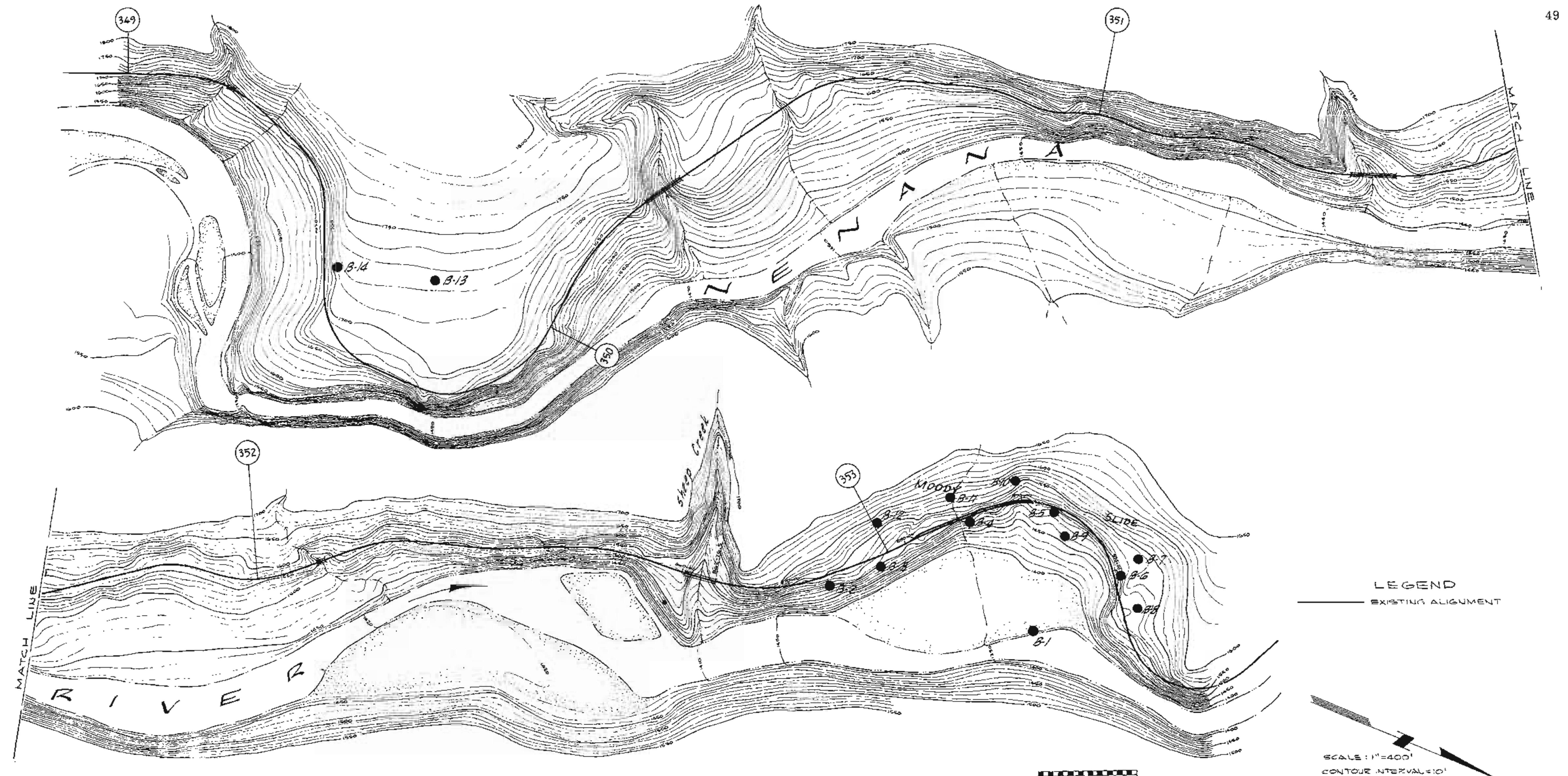
MILE 383. Shallow permafrost was encountered when the hillside on the right was excavated to reduce alignment curvature. After the permafrost was exposed during the summer, it thawed, and the material was excavated.

The upper northeast-trending terrace on the right is composed of Nenana Gravel capped by a terminal moraine of the Browne Glaciation. The railroad continues on a lower terrace of frozen Nenana Gravel and outwash gravel, where local sinkholes in the track are caused by degrading permafrost.

MILE 385.5. The railroad leaves the foothills of the Alaska Range and enters the Tanana lowlands on an extensive plain of outwash gravel.

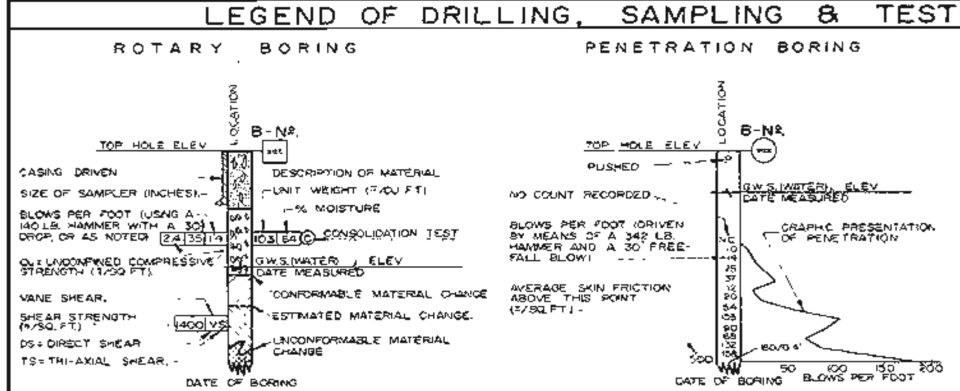
The following description is from Wahrhaftig and Black, 1958.

"The north slope of the Alaska Range is typical of unglaciated lowlands. Many of the streams have their source in a glacier. They brought and are still carrying large quantities of sand and gravel and finely ground rock flour from the glaciers. Where the river enters the lowland and encounters a change in gradient, the coarse material is deposited in the form of broad, low fan-shaped deposits (outwash fans) that are crossed by the bare flood plains of the braided rivers. The gravel deposits raise the beds of the rivers, causing them to overspill their banks and change their courses to flow through adjacent lower areas. Such a shift of the Nenana River in late 1917 destroyed 21 mi (34 m) of the newly



BORING PLAN

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS



- PLAN OF ANY BORING
- PENETROMETER (FLUSH-COUPLED)
- 2 1/4" CONE PENETROMETER
- SAMPLER BORING (DRY)
- ROTARY BORING (WET)
- AUGER BORING (DRY)
- JET BORING
- DIAMOND CORE BORING
- TEST PIT

BIT SIZES; (O.D.) "AX" = 1 13/16", "BX" = 2 9/32", "NX" = 2 29/32".
CASING SIZES; (O.D.) "BX" = 2 7/8", "NX" = 3 1/2".

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW	WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP	POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOIL	SW	WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP	POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM	SILTY SAND, SAND-SILT MIXTURES.
		SC	CLAYEY SAND, SAND-SILT MIXTURES.
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML	INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL	INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL	ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT
		CH	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
		OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT
HIGHLY ORGANIC SOILS		PT	PEAT AND OTHER HIGHLY ORGANIC SOILS

ROCK CLASSIFICATION

NAME
IGNEOUS ROCK
SEDIMENTARY ROCK
METAMORPHIC ROCK

NOTE:
CLASSIFICATION OF EARTH MATERIAL SHOWN ON THIS SHEET IS BASED UPON FIELD INSPECTION UNLESS NOTED OTHERWISE.

SOIL CONSISTENCY CLASSIFICATION

CONSISTENCY GRANULAR	CONSISTENCY COHESIVE	* BLOWS PER. FT.
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT (140 LB HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

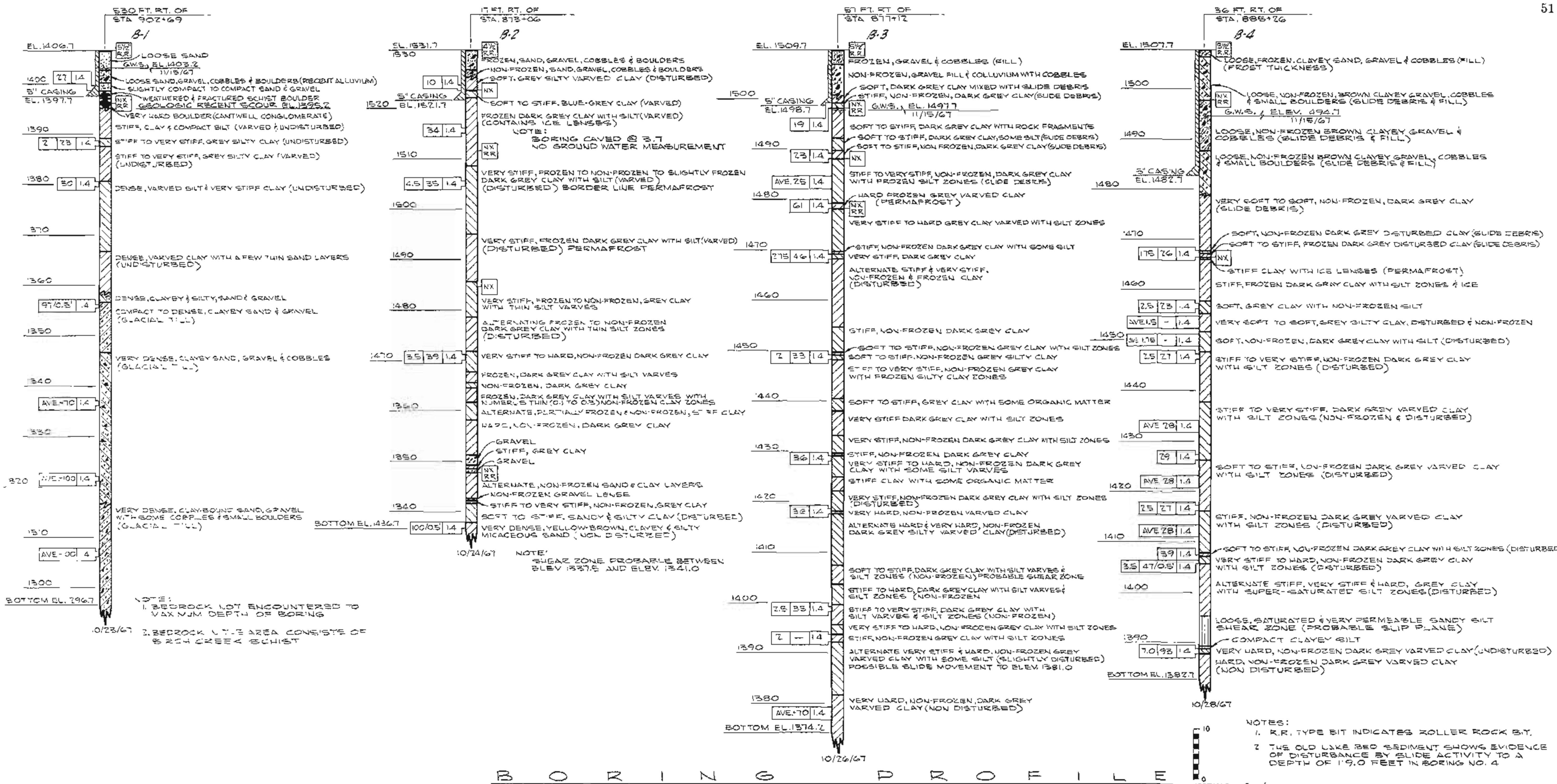
DWN. RRK/NSW
CHK. [signature]
DATE JAN. 1968
REG CIVIL ENG NO 5438
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1525 COURT STREET REDDING, CALIFORNIA

LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

DWG. NO. B-1 OF 5
C-1181.01

Figure 43. Map of Moody landslide area showing the location of the railroad alignment and boreholes.

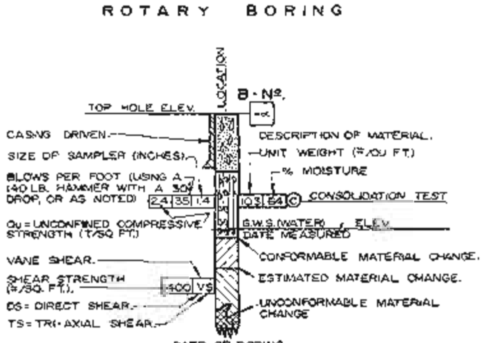


B O R I N G   P R O F I L E

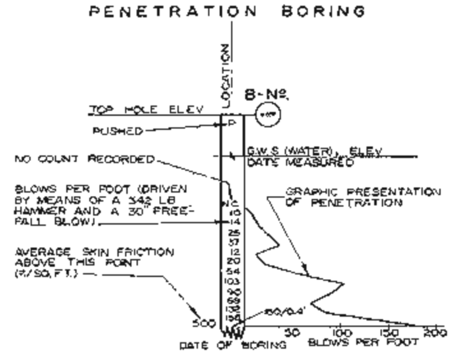
SCALES: HORIZ. NONE
VERT. 1"=10'

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS

ROTARY BORING



PENETRATION BORING



- PLAN OF ANY BORING
- PENETROMETER (FLUSH-COUPLED)
- 2 1/4" CONE PENETROMETER
- SAMPLER BORING (DRY)
- ROTARY BORING (WET)
- AUGER BORING (DRY)
- JET BORING
- DIAMOND CORE BORING.
- TEST PIT

BIT SIZES; (O.D.): "AX" = 1 13/16", "BX" = 2 5/32", "NX" = 2 29/32".
CASING SIZES, (O.D.): "BX" = 2 7/8", "NX" = 3 1/2".

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	SYMBOL	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW		WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP		POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GM		SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC		CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOIL	SW		WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP		POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM		SILTY SAND, SAND-SILT MIXTURES
		SC		CLAYEY SAND, SAND-SILT MIXTURES

MAJ. DIV.		LETTER	SYMBOL	NAME
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML		INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL		INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL		ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH		INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT.
		CH		INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
		OH		ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
HIGHLY ORGANIC SOILS		PT		PEAT AND OTHER HIGHLY ORGANIC SOILS

ROCK CLASSIFICATION

SYMBOL	NAME
	IGNEOUS ROCK
	SEDIMENTARY ROCK
	METAMORPHIC ROCK

NOTE: CLASSIFICATION OF EARTH MATERIAL SHOWN ON THIS SHEET IS BASED UPON FIELD INSPECTION UNLESS NOTED OTHERWISE.

SOIL CONSISTENCY CLASSIFICATION

CONSISTENCY		* BLOWS PER FT.
GRANULAR	COHESIVE	
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT (140 LB HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

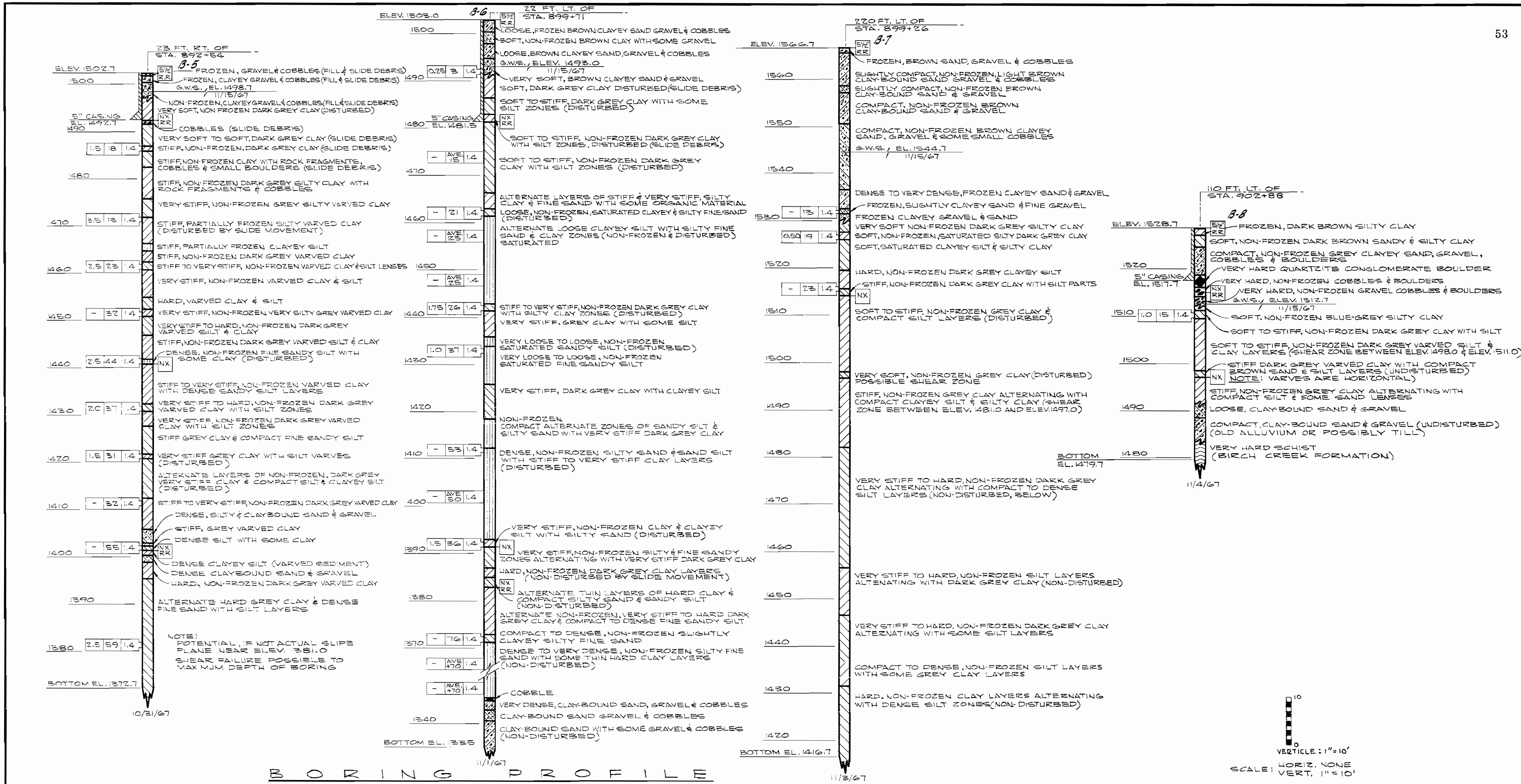
DWN. [signature]
CHK. [signature]
DATE JAN., 1968
Clair A. Hill
REG. CIVIL ENG. NO 5438
[signature]
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1526 COURT STREET — REDDING, CALIFORNIA

LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

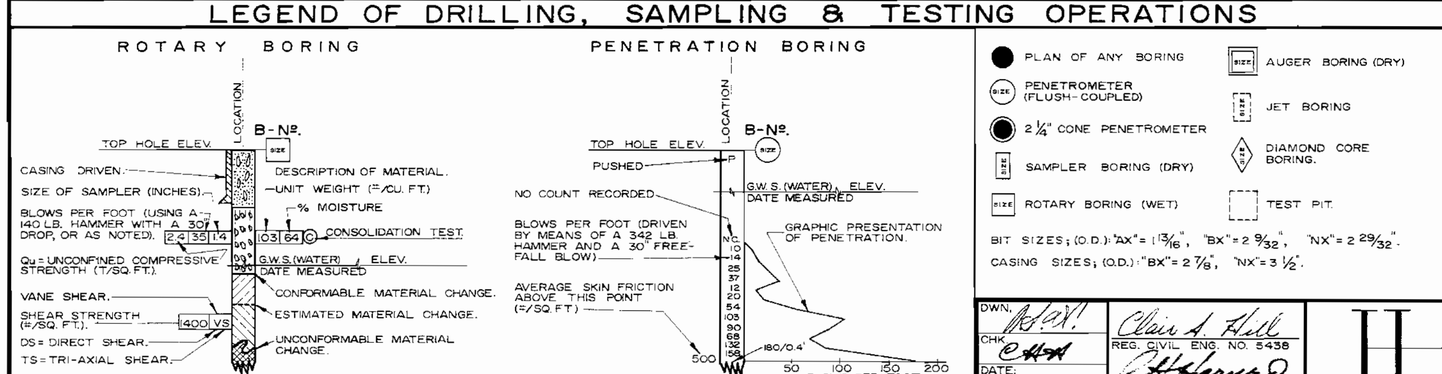
DWG. NO. B-2 OF 3
C-1131.01

Figure 44. Logs of boreholes B-1, B-2, B-3, and B-4, Moody landslide area.



BORING PROFILE

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS



BIT SIZES; (O.D.) "AX" = 1 7/8", "BX" = 2 5/32", "NX" = 2 29/32".
CASING SIZES; (O.D.) "BX" = 2 7/8", "NX" = 3 1/2".

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	SYMBOL	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW		WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP		POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GM		SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC		CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES.
	SAND AND SANDY SOIL	SW		WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP		POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM		SILTY SAND, SAND-SILT MIXTURES.
		SC		CLAYEY SAND, SAND-SILT MIXTURES.
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML		INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL		INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL		ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH		INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT.
		CH		INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY.
		OH		ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
HIGHLY ORGANIC SOILS		PT		PEAT AND OTHER HIGHLY ORGANIC SOILS.

ROCK CLASSIFICATION

SYMBOL	NAME
	IGNEOUS ROCK
	SEDIMENTARY ROCK
	METAMORPHIC ROCK

NOTE: CLASSIFICATION OF EARTH MATERIAL SHOWN ON THIS SHEET IS BASED UPON FIELD INSPECTION UNLESS NOTED OTHERWISE.

SOIL CONSISTENCY CLASSIFICATION

CONSISTENCY		* BLOWS PER. FT.
GRANULAR	COHESIVE	
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT. (140 LB. HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

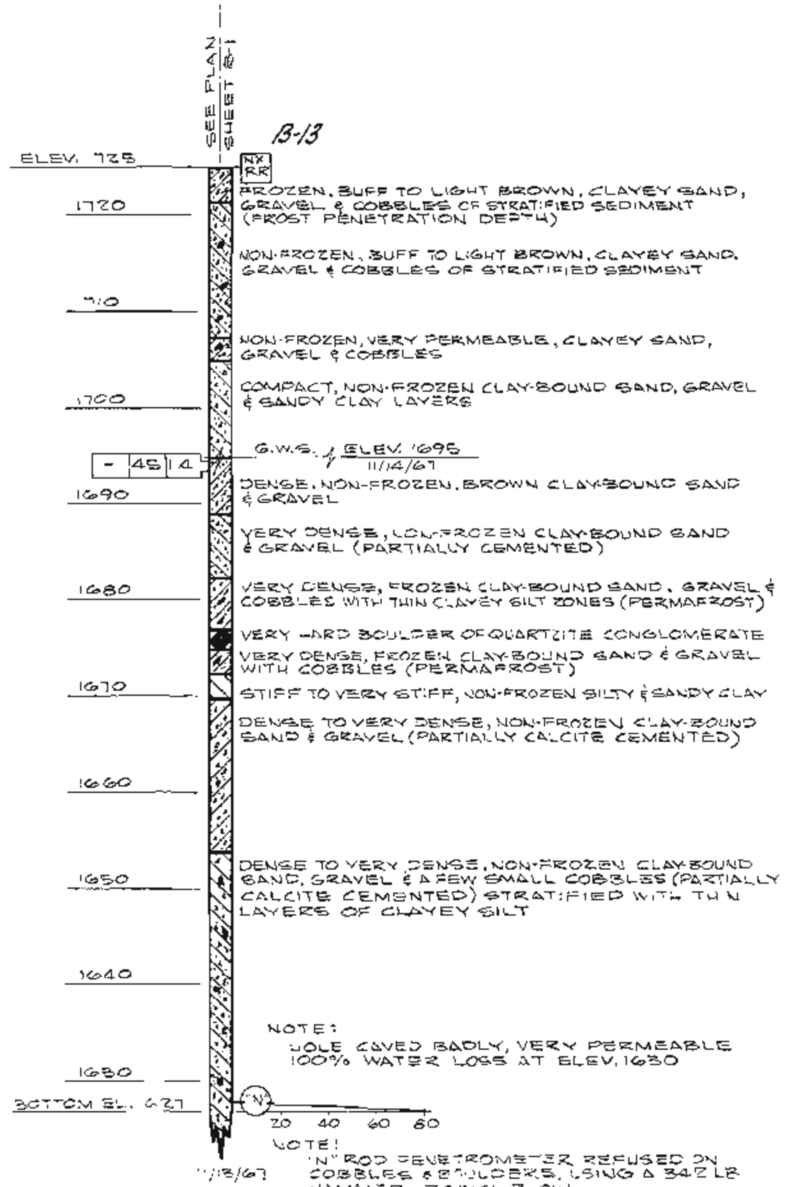
DWN. [signature] CHK. [signature] DATE: JAN., 1968 — Clair A. Hill, REG. CIVIL ENG. NO. 5438 — [signature] ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1525 COURT STREET — REDDING, CALIFORNIA

LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

DWG. NO. B-3 OF 5
C-1131.01

Figure 45. Logs of boreholes B-5, B-6, B-7, and B-8, Moody landslide area.

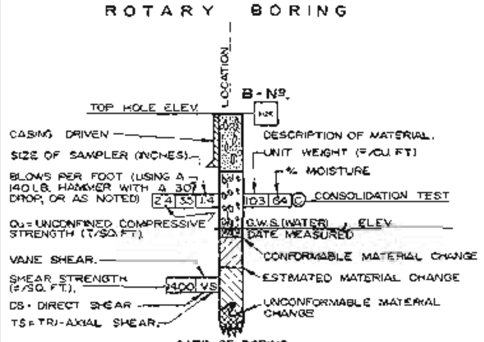


B O R I N G   P R O F I L E

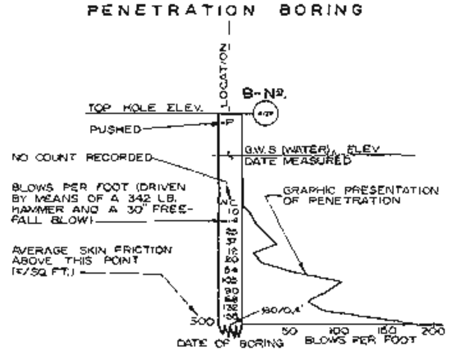
SCALES: HORIZ. NONE
VERT. 1"=10'

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS

ROTARY BORING



PENETRATION BORING



- PLAN OF ANY BORING
- PENETROMETER (FLUSH-COUPLED)
- 2 ¼" CONE PENETROMETER
- SAMPLER BORING (DRY)
- ROTARY BORING (WET)
- AUGER BORING (DRY)
- JET BORING
- DIAMOND CORE BORING
- TEST PIT

BIT SIZES; (O.D.) "AX" = 1 13/16", "BX" = 2 9/32", "NX" = 2 29/32".
CASING SIZES, (O.D.) - "BX" = 2 7/8", "NX" = 3 ½".

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW	WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GP	POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GM	SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC	CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOIL	SW	WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP	POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM	SILTY SAND, SAND-SILT MIXTURES.
		SC	CLAYEY SAND, SAND-SILT MIXTURES
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML	INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL	INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL	ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT
		CH	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
		OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT
HIGHLY ORGANIC SOILS		PT	PEAT AND OTHER HIGHLY ORGANIC SOILS.

ROCK CLASSIFICATION

NAME
IGNEOUS ROCK
SEDIMENTARY ROCK
METAMORPHIC ROCK

NOTE: CLASSIFICATION OF EARTH MATERIAL SHOWN ON THIS SHEET IS BASED UPON FIELD INSPECTION UNLESS NOTED OTHERWISE.

SOIL CONSISTENCY CLASSIFICATION

CONSISTENCY GRANULAR	CONSISTENCY COHESIVE	* BLOWS PER FT.
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT (140 LB HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

DWN.
CHK. Oxford
DATE: JAN, 1968

Clair A. Hill
REG. CIVIL ENG. NO 5436
R. Harmes
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1526 COURT STREET — REDDING, CALIFORNIA

LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

DWG. NO. B-5 OF 5
C-1151.01

Figure 46. Logs of boreholes B-13 and B-14, Moody landslide area.

Figure 47. View of the Moody landslide area, beginning on the left at Sheep Creek (Mile 352.8) and ending in the mudflow at Mile 353.4, on the extreme right. The irregular exposed benches that lie below the track and the high terrace of outwash gravel, talus, and alluvium are a series of abandoned roadbeds and old castovers of thawed material that traveled down from the near-vertical face of the terrace. The near-vertical face was developed when the railroad made a substantial line change into the frozen terrace in 1949. When ditch lines are cleaned out with on-track power shovels, the railroad commonly casts material into spoil piles on the outside shoulder of the track and then dozes the material farther out. This added weight on the outside shoulder, combined with lateral erosion of the river, overloads the unstable slope above the river and causes a series of typical slumps and slides in the clay-rich glacial deposits. Photograph by T.L. Péwé, June 25, 1981.

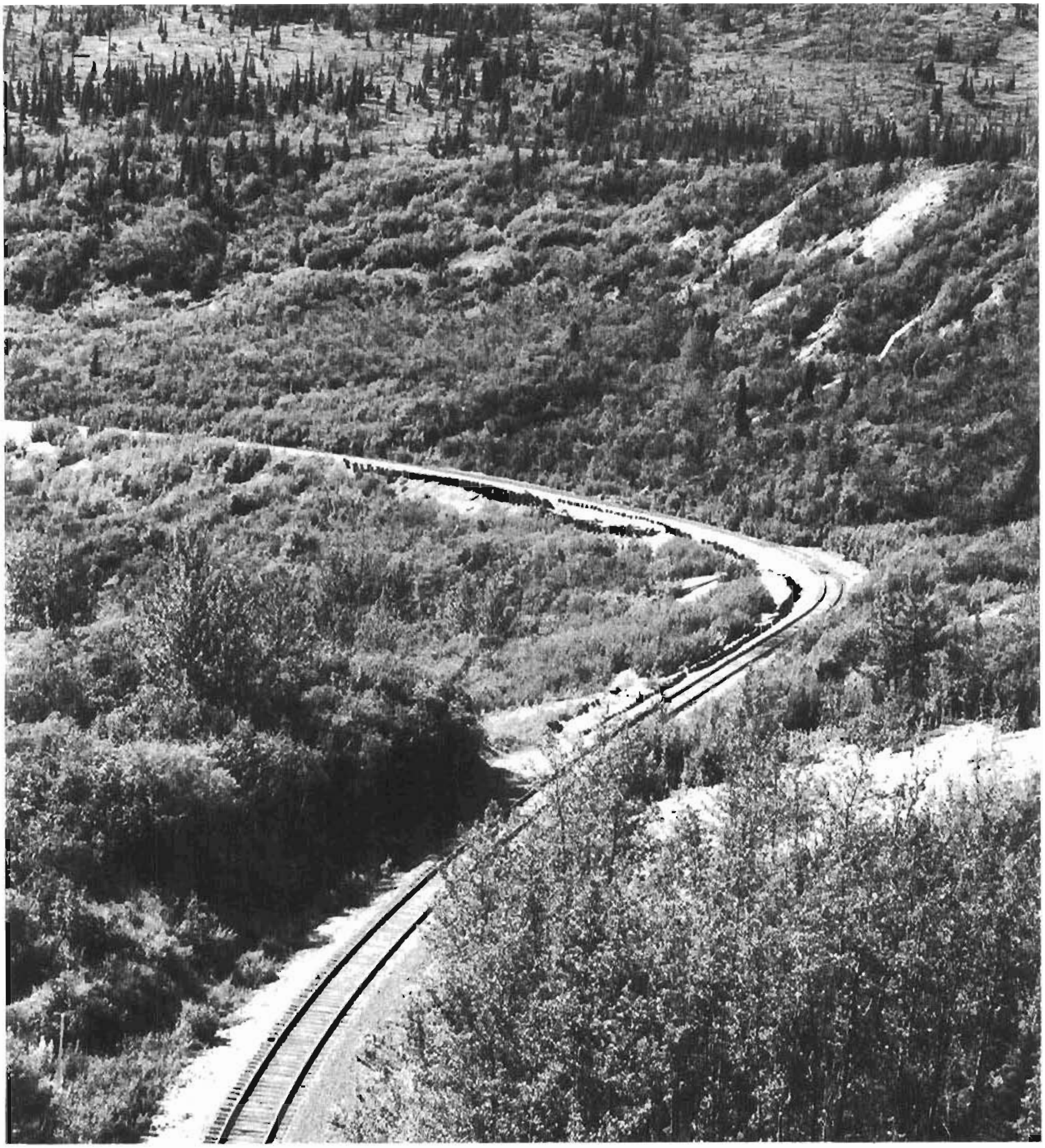


Figure 48. View of the most critical section of the Moody landslide area. The railroad leaves the west canyon wall at Mile 353.0 on a long curve to the right and traverses thick lake-clay deposits before it reaches the schist bedrock in the immediate foreground, formerly the east wall of the ancient river gorge. In addition to lateral erosion of the Nenana River, much activity within the slide area is attributed to ground water that originates as surface water on the upper slopes. The railroad has tried to divert this water into flumes or vertical standpipes drilled next to the track on the inside ditch line. To prevent the track from sliding downhill in 1967, timber pilings were driven on the outside shoulder of the track and then tied back with cable to a row of pilings ('deadmen') driven on the inside shoulder. Further sliding occurred and additional 'deadmen' were added in 1974. Many 'deadmen' driven in 1967 have rotated downhill and are now beneath the track. Photograph by T.L. Péwé, June 22, 1981.

Figure 49. View (to the south from Mile 353.4) up the Nenana River, the Moody landslide area is on the right. The slumps and earthflows along the railroad through Healy Canyon are primarily caused by lateral erosion and downcutting by the Nenana River, which undermines the unconsolidated glacial deposits. These clay-rich deposits are incapable of maintaining stable, relatively gentle slopes, particularly when saturated. The gravel bar (foreground) is an abandoned river meander and represents a retreat of the river away from the toe of the Moody landslide, a position it occupied in the 1950s and 1960s. Coinciding with this retreat and after the last period of intense sliding in 1967, landslide activity has declined in the Moody landslide area. Photograph by Dave Atwood, 1982.

built Alaska Railroad. This shifting of the streams builds the outwash fan. Most of the fans were built during the Pleistocene ice advances, when the rivers were much more heavily laden than they are now. Because they have less material to carry from the glacier, the streams have removed some of the material and now flow through the upper parts of the outwash fan in terraced valleys a few feet to a few hundred feet deep and 0.25 to 4 mi (0.4 to 6 km) wide.

"Downstream from the fans, the rivers carry silt and clay. Banks of these compact materials are not as easily eroded as the banks of loose gravel and sand. Consequently, the rivers cannot spread freely over their flood plains in networks of small channels but instead concentrate in one or two large channels which meander across the silt-covered plain."

MILE 386.7. The abandoned 'Lost Slough' alignment continues on a north tangent, and the present track curves to the right. The tangent is now used as a winter trail.

MILE 387.2. REX STATION.

MILE 388. The large, well-drained railroad gravel pit on the right is in outwash gravel that is mantled with up to a few feet of wind-blown silt and sand. The outwash gravel consists of interbedded coarse sand and sandy gravel. The pebbles are angular to well rounded; some pebbles are greater than 10 in. (26 cm) long. The outwash gravel crushes well and produces good, durable ballast.

MILE 388.5. ENTER FAIRBANKS B-5 QUADRANGLE.

MILE 388.8. Here, the railroad leaves the 1918 alignment and begins an 8-mi-long (13 km) line change around the Ballistic Missile Early Warning Site at Clear. The railroad site was built in 1959 on level terrain with ideal embankment material. All vegetation and fine-grained soils were removed down to the undisturbed gravel, and the railroad embankment material was then placed in a series of compacted lifts. Maintenance since 1959 has been minimal, and the track is good for 59-mph (95-kmph) operation.

MILE 392.9. CLEAR SITE.

MILE 395. OLD CLEAR.

This site is located on the 1918 alignment. Heavy shim spots exist because the original station workers were not selective when they added side-borrow material

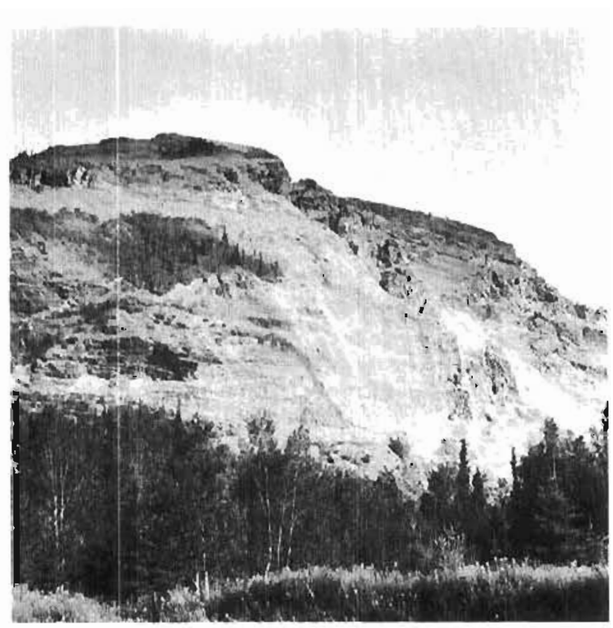


Figure 50. View (to the north from Mile 355.5) of the Garner Tunnel rock slide. Huge blocks of cliff-forming schist topple to the head of the slide (right), where the railroad crosses at Mile 356.2 to 356.6. At center right, the high rock face was trimmed back to prevent rock from falling directly onto the north portal of the Garner Tunnel. Formerly, rockfalls at the north portal buried the track by as much as 30 ft (9 m) and delayed traffic for several days. Photograph by Dave Atwood, 1982.

Figure 51. Station workers used light pole trestles to construct high fill sections, Mile 357.5. The hill of schist bedrock has been considerably altered by slides and slumps since this picture was taken. Photograph AEC G1683, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, October 1, 1920.

to the embankment. Shallow organic silts underlie the ballast material.

Gravel pits to the right were used until 1959 when they were abandoned by the railroad. The pit material is similar to the outwash gravel at Mile 388, but is not as coarse because it has been transported farther from its source. The floor of the pit is near the water table, and railroad workers reported shallow permafrost in the 1950s.

MILE 397. For the next 10 mi (16 km), the railroad traverses a low-lying area floored with fine-grained channel sand and interchannel silt that was transported beyond the fan of outwash gravel. Permafrost is prevalent within 3 to 4 ft (1 to 1.2 m) of the surface. Drainage is sluggish, and water collects in the low-brush bog and muskeg. The stand of lowland spruce and hardwood includes stunted tamarack. The track must be constantly maintained to permit the train to operate at the posted speed of 49 mph (79 kmph). Shoulders of the railroad embankment must be replenished with gravel frequently because of local subsidence caused by thawing permafrost. The subsidence can continue long after freezeup. In 1977, slow orders were placed on more than 9 mi (15 km) of track that had lost 'cross-level' because the subgrade had differentially settled; the slow orders were not lifted until after breakup. The Tortella Hills of the Tanana upland are visible to the north.

Until 1976, only pit-run ballast was used to maintain the track surface north of Clear (Mile 395). Railroad

Figure 52. Alaska Railroad passenger train 6, northbound out of the Healy yard for Fairbanks. Healy Canyon (Nenana River gorge) lies directly to the south. Photograph by Bill Coghill, 1980.

officials felt that expensive crushed gravel should not be used on track affected by permafrost, especially through subsiding areas that required frequent raises. However, it was increasingly difficult to give the track the low, 2- to 3-in. (5 to 8 cm) running raises that the new surfacing equipment was designed to make when the coarse material from the pit at Mile 388 was used. Equipment maintenance was high, and the line and surface of the track did not hold up under the posted speeds because the track 'skated' or shifted on the coarse gravel. Therefore, since 1976, crushed-gravel ballast has been used north of Clear as part of the normal track-maintenance program.

MILE 401.3. JULIUS.

Julius is the former site of a siding and the location of a 'dig down' that was made to eliminate differential heaving caused by saturated materials at shallow depth in the roadbed. Trains were rerouted through the siding while the main line was excavated and the unsatisfactory material was removed. A plastic membrane was installed to reduce water migration toward the active frostline, and the area was backfilled with select gravel. Although shimming was reduced, the membrane did not work as well as expected.

MILE 406.8. ENTER FAIRBANKS C-5 QUADRANGLE.

MILE 408.5. From 1969 to 1970, a preliminary survey was made to locate a proposed 580-mi (933 km) extension of the Alaska Railroad to Prudhoe Bay on the Beaufort Sea. The proposed route left the main line at this location and headed almost due west across the Nenana River to the Yukon River near the village of

Figure 53. A four-engine 'consist' comprised of 3,000-hp diesel electric locomotives is ready to make up a train in the Healy yard. Photograph by Bill Coghill, 1980.

Tanana. From there, the route headed north to the Koyukuk River, then along the Middle Fork Koyukuk River to Atigun Pass through the Brooks Range, and thence almost parallel to the route used by the Trans-Alaska Pipeline to Prudhoe Bay. A 140-mi (225 km) branch-line extension was also surveyed from near the village of Alatna across a low divide to the rich copper deposits at Bornite on the upper Kobuk River.

MILE 409. The heavy bank erosion on the left is caused by a generally northward migration of a wide meander of the Nenana River. Here, the river has an average gradient of 5 ft/mi (0.9 m/km).

MILE 411.7. NENANA.

The town of Nenana, like Anchorage, was established by the Alaska Engineering Commission and is the second largest townsite along the railroad. Nenana served as headquarters for much of the construction on the north end of the railroad. Construction equipment, bridge materials, supplies, and rolling stock came north by steam ship from Seattle to St. Michael. The materials were then moved by river boat up the Yukon and Tanana Rivers and off-loaded on docks constructed by the Commission. Today, Nenana is the transshipment point for cargo destined for villages and installations along the lower Yukon River as far as Marshall, about 640 mi (1,030 km) downriver (fig. 54).

Riverboat traffic on the Tanana River begins shortly after the river ice goes out in late April or early May and lasts until early September. Guessing the day, hour, and minute of breakup on the Tanana River has been a popular annual event since 1923. This event is known as

Figure 54. A tug and barge leave the Nenana docks loaded with freight destined for villages on the lower Tanana and Yukon Rivers. Photograph by Bill Coghill, 1980.

the Nenana Ice Pool, and the lucky winners usually share over $100,000 in prize money garnered from the sale of tickets all over Alaska.

MILE 412.5. At 25 mph (40 kmph), the train ascends the approach to the Tanana River bridge through a 180° curve. The approach was first constructed as a trestle, but was later filled in. The railroad is generally laid with jointed 115-lb (52 kg) rail that comes in standard 39-ft (11.9 m) lengths. This length is very close to the standard 40-ft (12.2 m) length between truck centers on present-day railroad cars. The joints are the weakest part in the track and tend to develop flat or low spots under impact loads from the wheels. At speeds between 12 and 22 mph (19 and 35 kmph), the direct relationship of rail length to truck centers becomes critical because a harmonic oscillating motion develops in the cars due to the low staggered joints. Unless disrupted, this motion, particularly in the jumbo 20,000-gal (91,000 l) tank cars, increases until the leading wheel on the superelevated side of the track can be lifted high enough so that the wheel flange clears the rail, drops over to the other side, and causes a costly derailment. To combat this common problem, the railroad has begun to use 78-ft (23.8 m) rail lengths in areas of critical speeds, such as this bridge approach.

MILE 413. OPPOSITE MISSION SLOUGH.

Because of a series of shifts in the braided channels farther up the river, this small slough captured the main stream of the Tanana River in the late 1950s and caused a dramatic increase in stream velocities along the west bank of the river north to the railroad bridge. The heavy erosion, which continued below frostline during the winter, moved the west bank farther west so that the buildings at St. Marks Mission had to be vacated and moved. Shortly before breakup in 1965, the railroad excavated several trenches just inland from the west riverbank and installed a series of river-training structures with Kelner jacks. The jacks are spider-like arrangements of scrap steel, wire, and cable designed to cause sediment deposition (by slowing the rate at which the water moves) and catch debris. Unfortunately, a parallel field of jacks failed to halt the erosion, and the field was destroyed. In addition, two fields of jacks that were intended to act as jetties were never exposed because the river extended its meander to the south and then rebounded to the east bank opposite the Old Mission grounds. A new bar is beginning to form where the Old Mission grounds were located, and the vertical east bank shows an active erosional face.

MILE 413.7. CROSSING OF THE TANANA RIVER ON MULTIPLE SPANS.

The main span, a 702-ft-long (214 m) through-truss, is the second longest single-span railroad bridge in the United States. The steel was erected during the winter of 1922-23 by using falsework built on the river ice. To celebrate the completion of the Alaska Railroad, President Harding drove a golden spike just north of the bridge on July 15, 1923. The site is marked by a sign on the left. A fishwheel used by local Indians to catch fish is visible just upstream from the bridge on the north bank.

During the 1914 route studies, location surveys were made up the north bank of the Tanana River along the Tortella Hills to Fairbanks and also along part of the south bank as an alternative to the present route through Goldstream valley. Because very heavy sidehill construction would be needed here and at other similar locations upriver, the route through Goldstream valley was favored, despite the difficulties encountered by the Tanana Valley Railroad in constructing a roadbed out of 'muck.'

MILE 413.9. Here, a throughcut in Birch Creek Schist exposes a mantle of Fairbanks loess, a massive homogeneous silt that occurs on upper slopes and hilltops in the Fairbanks area. The thickness of the loess and retransported silt north of the Tanana River ranges from 3 ft (1 m) on the upper hillsides to 200 ft (60 m) on the lower hillslopes.

MILE 414.3. This is the beginning of a line change that was constructed in 1967 to accommodate the approach to the highway bridge on the left. Because of the adverse dip and instability of the schist bedrock (visible in the old railroad pit on the right), the backslope of the sidehill excavation was laid to a relatively low angle that is more common to earthwork than rock excavation.

MILE 415.4. NORTH NENANA.

Track construction south from Happy (Mile 463) reached this point in late 1919. Standard 8-ft-long (2.4 m) crossties were used, but the rail was laid to the 3-ft (1 m) gauge needed to accommodate the Tanana Valley Railroad equipment that was used until the Tanana River bridge was completed in 1923 (fig. 55). Before the bridge was completed, passengers and freight (including coal from the Suntrana Mines) were hauled across the river on a temporary track laid over the ice during the winter months.

In April 1923, all traffic was suspended north of this point until June 15, when the rails were regauged to the standard width. Track with a maximum speed limit of 49 mph (79 kmph) begins here.

MILE 417.8. The track crosses the Parks Highway, which ascends to the crest of the Tortella Hills to the east, and then follows the crest in a sinuous alignment until it descends into Fairbanks through the old dredge tailings of Ester Creek.

MILE 420. For the next 12 mi (19 km), the railroad skirts the edge of Minto Flats on a stable roadbed built on silt retransported from nearby hillsides. The silt seems to be free of ice-rich permafrost except in the flat, poorly drained area (Mile 425 to 426.8) that is characterized by small thaw ponds, usually on the east side of the track.

MILE 421.1. ENTER FAIRBANKS C-4 QUADRANGLE.

The Tortella Hills are to the right.

Figure 55. View (to the south) toward the Nenana townsite and shoulder construction at Mile 413. Photograph AEC C2024, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, August 27, 1922.

MILE 425.5. Thaw ponds in permafrost are on the right.

MILE 426.5. In this short shim area, the railroad crosses a well-defined linear thaw pond that probably originates from a thawing ice wedge in the forest on the left.

MILE 430.4. ENTER FAIRBANKS D-4 QUADRANGLE.

MILE 431.6. DUNBAR.

Beginning of Goldstream valley and 40-mph (65 kmph) track.

MILE 432.1. CROSSING OF GOLDSTREAM CREEK.

MILE 432.6. DUNBAR SECTION HOUSE.

Enter Goldstream valley. This is the beginning of the 'permafrost track' that is built on the ice-rich, undifferentiated silts typical of the valley (fig. 56). The rolling grade line reflects the sags caused by thawing permafrost; meltwater stands at the toe of the roadbed in many locations. Differential settlement of the track continues after freezeup, and the track needs to be shimmed frequently. Surface drainage is poor.

Because this is 'warm' permafrost, thermal equilibrium cannot be economically achieved. However, the thawing rate can be retarded if the shoulders are extended well beyond the standard roadbed prism to encourage revegetation. Great care must be exercised to prevent differential heaving that may affect the cross level of the track. In 1919, the roadbed was constructed primarily on an embankment section along the north edge of Goldstream valley at the base of a low range of hills to the north. An occasional low throughcut or sidehill excavation furnished some material for the embankment; however, the rest was 'borrowed' from the ground next to the track. Other than the permafrost found in the throughcuts and sidehill excavation, the original construction records listed all borrow materials between Mile 432 and 452 as either 'common' borrow or 'wet' borrow (taken from saturated materials on the valley floor). From Mile 452 to 463, all borrow material is listed as wet borrow; there was no waste material. From these records and from looking at Goldstream valley, one can appreciate the very poor materials used by the station workers when the original roadbed was built.

MILE 439. INSULATED-TRACK TEST SECTION (fig. 57).

On May 25, 1976, the Alaska Railroad, in collaboration with Dow Chemical Company, insulated a test section of roadbed with rigid styrofoam at a location where the roadbed emerges from a throughcut onto fill. The severe differential heaving at this location required

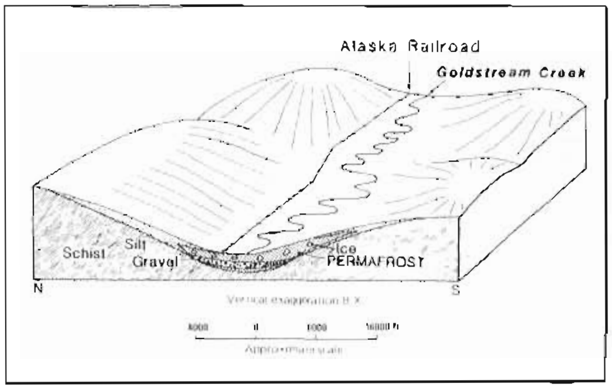


Figure 56. Diagrammatic sketch that shows the permafrost distribution in the Goldstream valley near Fairbanks. Modified from Péwé, 1963.

at least 5 in. (13 cm) of shimming because of seasonal frost heaving and permafrost degradation. Frozen ground was encountered when the instruments were installed. The instruments consist of three sets of 16 thermistors each that were installed under the styrofoam and two control strings of 13 thermistors each that were installed beyond the insulated areas. The thermistors measure the heat flow in the roadbed and around and under the styrofoam to a depth of 10 ft (3 m). Weekly readings are taken, and air temperatures are continuously recorded on a thermograph. Quarterly surveys are made to record any settlement.

The styrofoam was installed in varying thicknesses and patterns and with side slopes in some areas to determine the best design (figs. 58 through 61). Once the disruption caused by the construction of the test sections has dissipated, heat-flow data from the thermistor strings will be analyzed. Ultimately, a set of new design criteria will probably be developed for construction of railroad roadbeds in permafrost areas.

Figure 57. View of test section of insulated track with a recording thermograph on the right, Mile 439. The test section is not subject to the severe differential heaving visible in figure 63. Photograph by Dave Atwood, 1982.

MILE 439.5. STANDARD.

The continuing subsidence that affects the railroad in Goldstream valley is illustrated by the side track on the left, which receives considerably less maintenance than the main line.

MILE 440.4. ENTER FAIRBANKS D-3 QUADRANGLE.

Here, much of the valley was burned over by a large fire in 1966. Mudflows from melting permafrost were observed in fire trails that were dozed by crawler tractors to contain the fire away from the track.

MILE 445. In addition to meltwater from thawing permafrost, surface runoff of normal precipitation from the hills on the left collects along the low railroad embankment. The natural gradient through Goldstream valley is very slight. Because of differential settlement caused by thawing permafrost, lateral drainage is poor, and water collects in ponds. Ditches originally excavated to carry runoff from the drainage structures through the roadbed to Goldstream Creek have filled in with vegetation and now block the drainage.

MILE 448. The difference between the track's low profile and the surrounding terrain indicates the extent of subsidence by the roadbed.

MILE 449. Figure 62 shows borrow operations during the original construction.

MILE 450.8. SAULICH.

Poor track conditions caused by thawing permafrost are readily apparent. (Note the 'tilting' coffee in your cup, if you have one.) The side track on the right shows poor track conditions that would result if the main line were not maintained (fig. 63).

MILE 452.2. In 1971, a short section of the outside shoulder (on the right) caved in suddenly and left a 20-ft-deep (6 m) hole by the track. Because no evidence of lateral displacement of material below the affected area is visible, the cave-in probably occurred when a large ice mass under the roadbed thawed.

MILE 456.2. DOME.

Speed must be reduced to 30 mph (48 kmph) for the next 7 mi (11 km) because of the severe differential settlement of the roadbed. Birch Creek Schist was exposed at a shallow depth when a water line to the section house was built.

MILE 456.7. To the right are bridge pilings and the embankment of a proposed line change that was constructed to final grade from 1948 to 1950 and was then abandoned because of insufficient funds. No special construction methods were used in building the roadbed. The irregular profile reflects more than 30 yr of differential settlement caused by thawing of the disturbed permafrost.

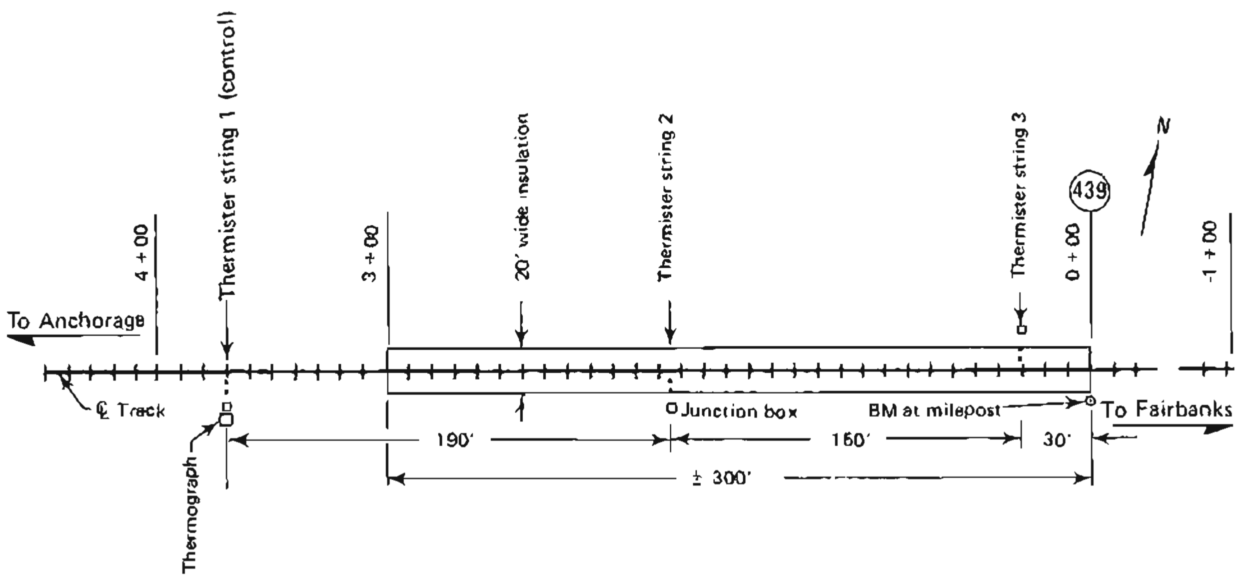


Figure 58. Plan of an insulated-track test section, Mile 439.

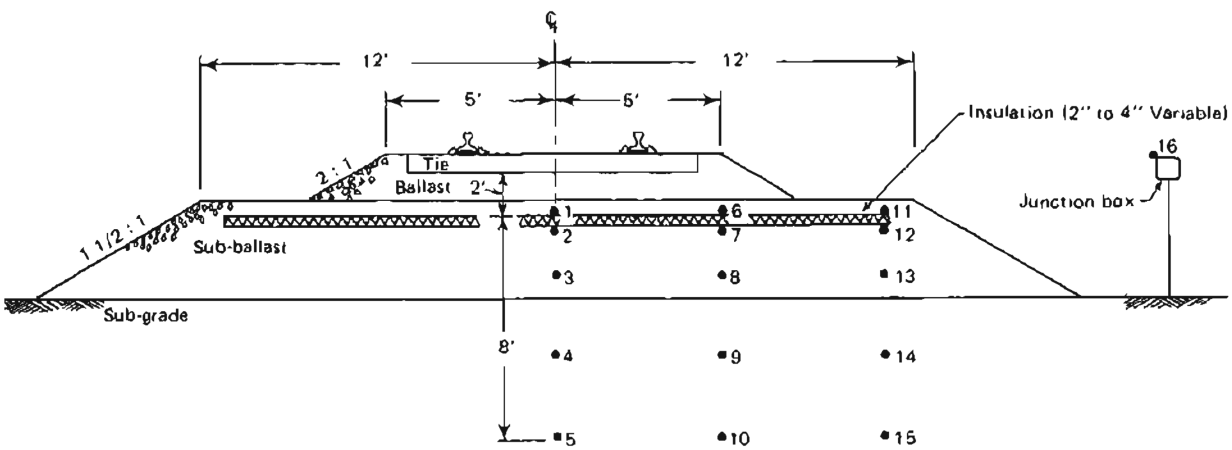


Figure 59. Typical plan for spacing thermisters at an insulated-track test section, Mile 439.

MILE 457.3.[11] Another maintenance problem that results from constructing the railroad on the fine-grained silts in Goldstream valley is frost heaving of bridge pilings. When the ground freezes, it is displaced upward. This displacement is called 'frost heaving' and is partly due to moisture freezing in the soil. The fine-grained silts of Goldstream valley offer ideal conditions for the growth of ice segregations and subsequent frost heaving.

Ice segregations form in sediments when water is drawn from adjacent unfrozen ground and migrates to a point where freezing occurs. The water can migrate over 30 ft (9 m) and at temperatures below 32°F (0°C). The three most important factors for the formation of ice segregations are air temperature, soil texture, and moisture content of the soil.

Engineering structures, such as the railroad's standard wood-pile trestle, can be displaced upward by frost heaving.[12] The amount of upward force that affects the piling in the seasonally frozen ground depends on the volume of clear-ice segregations, the adfreezing strength

[11] Modified from Péwé, 1963.

[12] See appendix C (p. 80) for description of frost heaving of bridge pilings at Milepost 458.4.

(bond) between the surface of the pile and the ground, and the surface area of the piling within the ground. Normally, the upward force is opposed by the bond developed by the piling in the unfrozen ground below the seasonal frost line. Where piling has been driven into the permafrost, the upward force caused by seasonal frost heaving can be reduced or overcome by the tangential bond between the perennially frozen ground and the piling's surface. The greater the surface area of the piling within the permafrost, the greater the bond.

Continued frost heaving (or frost jacking) of the piling can raise the bridge deck above the desired grade line. Also, the amount of heaving varies with each bent (row of five piles with cap), which further distorts the line and grade across the bridge. When the distortion becomes too great, the tops of the pilings must be cut off to reestablish a uniform grade across the bridge and its approaches. Eventually, the pilings lose their bearing and throw the bridge out of line; consequently, new piles must be installed. Steam is still used to thaw and penetrate the permafrost so that piles can be driven vertically, butt-end down for greater surface area.

Steam was also used to thaw the underlying permafrost when timber pilings were driven to support the many small bridges installed during original construction. Most of these bridges have been replaced with culverts. Of those that remain, several continue to be affected by frost heaving, although to a lesser degree than 30 yr ago, when more than 12 in. (31 cm) of heaving in a single year would be reported. The bridge at Mile 457.3 requires the most maintenance. The piles were redriven in 1954, but the tops of the piling must be cut off from 4 to 6 in. (10 to 15 cm) every 3 yr. These cutoffs are limited to bents 2 and 3; bents 1 and 4 (the south and north abutments, respectively) heave only slightly, if at all. The bridge piling at Mile 460.1 needs about 4 in. (10 cm) cut off every 4 yr; piles for this bridge were redriven in 1976. The bridge pilings at Mile 460.4 show very little movement; they were redriven in 1976 after the bridge was severely burned.

Three wood-pile bridges (at Mile 456.7, 458.4, and 460.4) were systematically observed by T.L. Péwé (app. A) for three winters in the mid-1950s to see what effect frost heaving had on the pilings. Of the three bridges, only the one at Mile 460.4 remains. Culverts, which are 6-ft-diam (1.83 m) steel caissons, were placed at the other two locations, and the bridged gaps were filled with gravel to eliminate expensive bridge maintenance.

MILE 459.2. ENTER FAIRBANKS D-2 QUADRANGLE.

MILE 461 to 462.5. Words are not necessary to describe this stretch of 'permafrost' track. In 1970, a railroad consultant studied the roadbed at Mile 462.3 to gain basic information on the degradation of permafrost soils under granular or gravel embankments and determine the existing gravel distribution after about 40 yr of settlement, annual shoulder dumping, and sag raising. Three borings were made through the shallow railroad embankment, one on each shoulder and the third

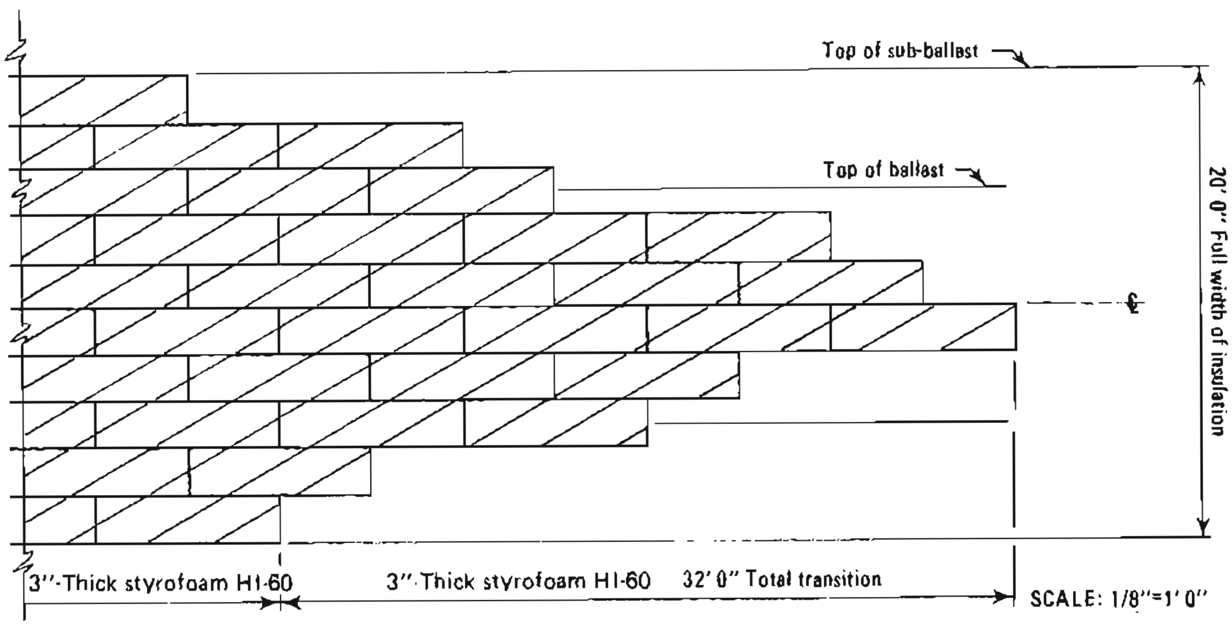


Figure 60. Cross section showing the placement of styrofoam insulation at the east transition of an insulated-track test section, Mile 439.

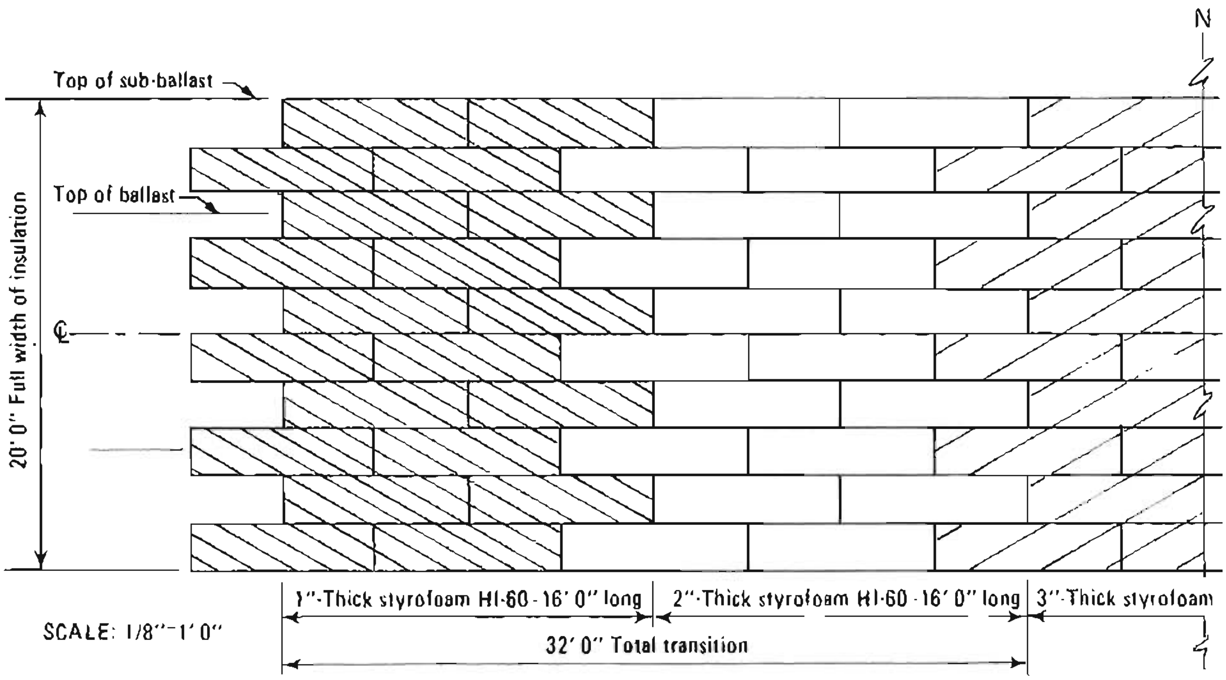


Figure 61. Cross section showing the placement of styrofoam insulation at the west transition of an insulated-track test section, Mile 439.

Figure 62. Borrow-pit operations at Mile 449. Dynamite was used to break up frozen silt in the low hillside to the left so that the silt could be loaded into the narrow-gauge equipment of the Tanana Valley Railroad. Part of the main line was first constructed on the light timber trestle visible in the background; it was then filled by work-train. To the right, native timber tripods that adjust readily to differential settling carry communication lines. Photograph from Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, July 26, 1919.

through the center of the track. A fourth boring was made 85 ft (26 m) east of the track in an undisturbed area.

The first two borings on the shoulders of the embankment encountered 15 ft (5 m) of unfrozen, loose sand, gravel, and cobble material that overlie 1.5 to 3 ft (0.5 to 1 m) of sand with some fine gravel (probably Tanana River gravel hauled in by a work train from the Fairbanks area). Below this layer, the underlying silts were not frozen; permafrost was encountered 21.5 to 24 ft (6 to 7 m) below the roadbed surface. The upper 10 ft (3 m) of coarse gravel directly under the track was more dense because of repeated compaction by rail traffic over the years. However, the remaining material down to 21.5 ft (6 m) below the roadbed surface was loosely compacted and rested essentially on pure ice.

The boring made to the east of the track encountered permafrost in the silt at 18 ft (6 m) below the ground surface, 7 to 10 ft (2 to 3 m) higher than the permafrost level under the track. As suspected, borings 1, 2, and 3 indicate that an unfrozen 'bulb' of gravel [16 to 21 ft (5 to 6.5 m) deep] probably underlies the track through much of Goldstream valley.

MILE 463.0. HAPPY.

Formerly the junction of the old Chatanika Branch Line (earlier the Tanana Valley Railroad) that served the gold-mining towns of Fox and Gilmore, to the east. The branch line, which continued operating on narrow-gauge track until 1930, required a special three-rail track into the Fairbanks yard. Turnouts to handle both standard- and narrow-gauge equipment were included. The track gradually descends 'Happy Hill' at 40 mph (64 kmph) into the Tanana River basin and the city of Fairbanks. Figure 64 is a generalized permafrost map of the Fairbanks area.

MILE 466. This station point was formerly known as Ester, where students attending the University of Fairbanks would debark. To encourage enrollment, students were granted special fares on the railroad. The university now operates its experimental farm in this area. The Geophysical Institute building complex is visible to the left on the crest of the hill.

MILE 467. The Fairbanks campus of the University of Alaska is on the left.

MILE 467.1. COLLEGE.

MILE 467.9. BEGINNING OF FAIRBANKS YARD.

Figure 65 shows borrow-pit operations in this area in October 1917.

MILE 470.3. FAIRBANKS.

End of the line. Thanks for riding with us.

Figure 63. Example of track deformation at Saulich (Mile 450.8) that was caused by differential settlement due to degrading permafrost. Photograph BL 79.2.3055, Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, May 1949.

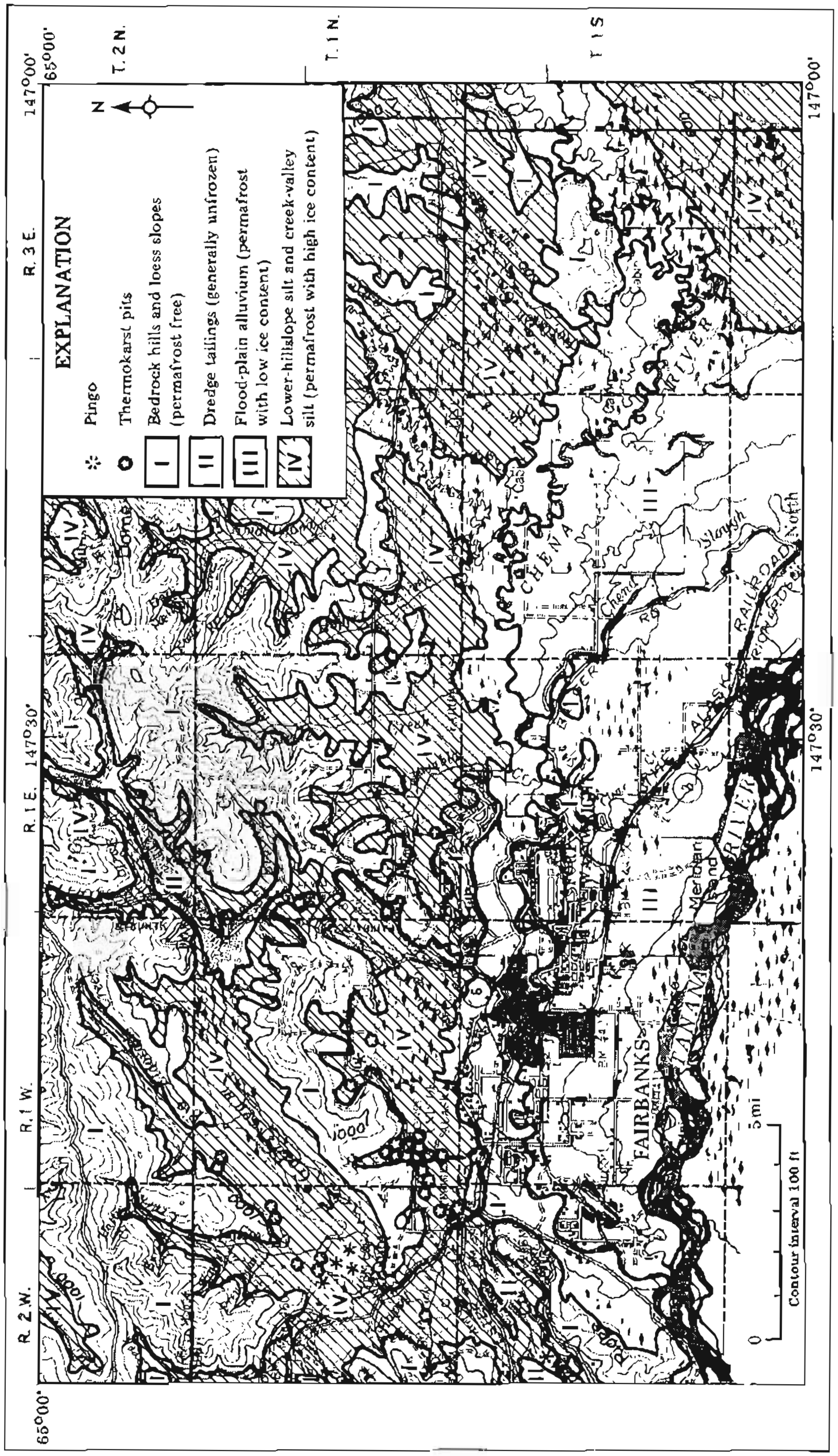


Figure 64. Generalized permafrost map of the Fairbanks area, Alaska. From Péwé and Reger, 1983.

Figure 65. Early borrow-pit operation in flood-plain deposits of silt, sand, and gravel near Fairbanks. Narrow-gauge equipment from the Tanana Valley Railroad is used. Photograph from Alaska Railroad Collection, Anchorage Historical and Fine Arts Museum, October 13, 1917.

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APPENDIX A: EFFECTS OF THE GREAT ALASKA EARTHQUAKE, MARCH 27, 1964[13]

"In the 1964 Alaska earthquake, the federally owned Alaska Railroad sustained damage of more than $35 million: 54 percent of the cost for port facilities; 25 percent, roadbed and track; 9 percent, buildings and utilities; 7 percent, bridges and culverts; and 5 percent, landslide removal. Principal causes of damage were: (1) landslides, landslide-generated waves, and seismic sea waves that destroyed costly port facilities built on deltas; (2) regional tectonic subsidence that necessitated raising and armoring 22 mi of roadbed made susceptible to marine erosion; and (3) of greatest importance in terms of potential damage in seismically active areas, a general loss of strength experienced by wet waterlaid unconsolidated granular sediments (silt to coarse gravel) that allowed embankments to settle and enabled sediments to undergo flowlike displacement toward topographic depressions, even in flat-lying areas. The term 'land-spreading' is proposed for the lateral displacement and distension of mobilized sediments; landspreading appears to have resulted largely from liquefaction. Because mobilization is time dependent and its effects cumulative, the long duration of strong ground motion (timed as 3 to 4 minutes) along the southern 150 mi of the rail line made landspreading an important cause of damage.

"Sediments moved toward natural and manmade topographic depressions (stream valleys, gullies, drainage ditches, borrow pits, and lakes). Stream widths decreased, often about 20 in. but at some places by as much as 6.5 ft, and sediments moved upward beneath stream channels. Landspreading toward streams and even small drainage ditches crushed concrete and metal culverts. Bridge superstructures were compressed and failed by lateral buckling, or more commonly were driven into, through, or over bulkheads. Piles and piers were torn free of superstructures by moving sediments, crowded toward stream channels, and lifted in the center. The lifted piles arched the superstructures. Vertical pile displacement was independent of the depth of the pile penetration in the sediment and thus was due to vertical movement of the sediments, rather than to differential compaction. The fact that bridge piles were carried laterally without notable tilting suggests that mobilization exceeded pile depths, which averaged about 20 ft. Field observations, largely duplicated by vibrated sandbox models of stream channels, suggest that movement was distributed throughout the sediments, rather than restricted to finite failure surfaces.

"Landspreading generated stress that produced cracks in the ground surface adjacent to depressions. The distribution of this stress controlled the crack patterns; tension cracks parallel to straight or concave streambanks, shear cracks intersecting at 45° to 70° on convex banks where there was some component of radial spreading, and orthogonal cracks on the insides of tight meander bends or islands where spreading was omnidirectional.

"Ground cracks of these kinds commonly extended 500 ft, and occasionally about 1,000 ft, back from streams, which indicates that landspreading occurred over large areas. In areas of landspreading, highway and railroad embankments, pavements, and rails were pulled apart endways and were displaced laterally if they lay at an angle to the direction of sediment displacement. Sediment movement commonly skewed bridges that crossed streams obliquely. The maximum horizontal skew was 10 ft.

"Embankment settlement, nearly universal in areas of landspreading, also occurred in areas where there was no evidence for widespread loss of strength in the unconsolidated sediments. In the latter areas embankments themselves clearly caused the loss of bearing strength in the underlying sediment. In both areas, settlement was accompanied by the formation of ground cracks approximately parallel to the embankment in the adjacent sediments. Sediment-laden ground water was discharged from the cracks, and extreme local settlements (as much as 6 ft) were associated with large discharges.

"Landspreading was accompanied by transient horizontal displacement of the ground that pounded bridge ends with slight or considerable force. The deck of a 105-ft bridge was repeatedly arched up off its piles by transient compression. Bridges may also have developed high horizontal accelerations. One bridge deck, driven through its bulkhead, appears to have had an acceleration of at least 1.1 to 1.7 g; however, most evidence for high accelerations is ambiguous.

"Limited standard penetration data show that landspreading damage was not restricted to soft sediments. Some bridges were severely damaged by displacement of piles driven in sediments classified as compact and dense.

"Total thickness of unconsolidated sediments strongly controlled the degree of damage. In areas underlain by wet water-laid sediments the degree of damage to uniformly designed and built wooden railroad bridges shows a closer correlation with total sediment thickness at the bridge site than with the grain size of the material in which the piles were driven.

"Local geology and physiography largely controlled the kind, distribution, and severity of damage to the railroad. This relationship is so clear that maps of surficial geology and physiography of damaged areas of the rail belt show that only a few geologic-physiographic units serve to identify these areas.

1. Bedrock and glacial till on bedrock, no foundation displacements, but ground vibration increased toward the area of maximum strain-energy release.

[13] From McCullough and Bonilla, 1967.

2. Glacial outwash terraces. Landspreading and damage ranged from none where the water table was low and the terrace undissected to severe where the water table was near the surface and the terrace dissected by streams.
3. Inactive flood plains. Landspreading, ground cracking, flooding by ejected ground water, and damage were generally slight but increased to severe toward lower, wetter active flood plains or river channels.
4. Active flood plains. Landspreading, ground cracking, and flooding were nearly universal and were greater than on adjacent inactive flood plains.
5. Fan deltas. Radial downhill spreading and ground cracking were considerable near the lower edges of the fan deltas and were accompanied by ground-water discharge. Landslides were common from edges of deltas.

"Damage, landspreading, ground cracking, vibration, and flooding by ground water generally increased with (1) increasing thickness of unconsolidated sediments, (2) decreasing depth to the water table, (3) proximity to topographic depressions, and (4) proximity to the area of maximum strain-energy release."

APPENDIX B: VEGETATION OF ALASKA[14]

Alaska is a land of contrasts—contrasts in climate, physical geography, and vegetation. Containing 365.5 million acres (146 million hectares), Alaska has the highest mountain in North America, as well as hundreds of square miles of boggy lowlands. The climate varies from mild and wet to cold and dry. In the interior, the temperature range may exceed 150°F (83°C) in 1 yr and precipitation may be less than 10 in. (250 mm) annually In contrast, temperatures in the southeastern coastal area may vary 70°F (38°C) with 150 in. (3,800 mm) annual precipitation. Spanning nearly 1,300 mi (2,100 km) of latitude and 2,200 mi (3,500 km) of longitude, Alaska's vegetation varies from the towering fast-growing forests of the southeastern coast through the low, slow-growing boreal forests of the interior to the treeless tundra of the north and west.

Approximately 119 million acres (48 million hectares) in the state are forested. Of these, 28 million acres (11.2 million hectares) are classified as 'commercial forests.' These great timber reserves provide the basis for one of the State's largest industries, one that will continue to expand in size and importance as the timber demands of the heavily populated areas of the world increase.

ALASKA TREES

Thirty-three of the 133 species of woody plants in Alaska described here reach tree size, although several are commonly shrubby and a few are rare. Only 12 tree species in Alaska are classified as large, that is more than 70 ft (21 m) high. However, two conifers of the southeastern coastal forests become very large: 1) Sitka spruce reach heights of 225 ft (69 m) with trunk diameters of 8 ft (2.4 m) or more; 2) western hemlock reach heights of 190 ft (58 m) with trunk diameters of 5 ft (1.5 m) or more. Near Haines, a giant, black cottonwood with a broken top is 101 ft (30.8 m) high and has a trunk with a circumference of 32½ ft (9.9 m).

Sixteen tree species are less than 30 ft (9 m) high. All eight species of tree willows, as well as eight others, are classified as shrubs and trees. Three other species sometimes reach tree size. In favorable sites, Grayleaf willow may form a small, shrubby tree up to 20 ft (6 m) high with a 5 in. (12.5 cm) trunk diameter. Some Pacific red alder and Greene mountain-ash have reached the same height in southeast Alaska.

The 33 species of Alaska trees belong to 17 genera in eight plant families. However, the pine family contains nine species, and the willow family 11 species. The largest genera are the willow with eight tree species, and the spruce, poplar, and alder with three species each.

Nearly all commercial timber in Alaska is produced by 10 tree species; six are conifers and four are hardwoods. The coastal spruce-hemlock forests of southeastern Alaska consist of five important conifers: Sitka spruce, western hemlock, mountain hemlock, western red cedar, and Alaska-cedar. The lone commercial hardwood in southeast Alaska is black poplar. In the interior spruce-hardwood forests, the commercially important species are white spruce, balsam poplar, quaking aspen, and paper birch.

The number of tree species native in any area of Alaska is relatively small. Many localities have fewer than 10 tree species; great expanses of tundra above tree line have none.

The extensive spruce-hardwood forests of interior Alaska are composed of three coniferous tree species (white spruce, black spruce, and tamarack), three hardwoods (balsam poplar, quaking aspen, and paper birch), up to five species of willow, and two species of alder.

GEOGRAPHIC DISTRIBUTION

Many species of Alaska's arctic shrubs and herbs are widely distributed in the far northern regions of the world. Other Alaskan species extend only to northern Europe, while several extend west into Siberia. The arctic-alpine species occur in the alpine zone of the Rocky Mountains and high peaks of New England. Hulten (1968) published a small map that shows the entire natural distribution of each Alaska species around the North Pole.

[14] Modified from Viereck and Little, 1972.

The only Alaska tree species native in the Old World is Sitka alder, which ranges into northeastern Asia. Some authors classify thinleaf alder with the Old World species of European speckled alder. Pacific red alder has also been classified as a variety of European red alder in Eurasia.

Six tree species of the interior spruce-hardwood forest are widely distributed in northern coniferous forests ('north woods' or boreal forest) from Alaska across Canada east to Labrador and Newfoundland and south into the northeastern states. Bebb willow are small trees that have a similar distribution.

Three tree species have a large north-south distribution. Lodgepole pine and black cottonwood range south in coastal forests from Alaska to California and beyond into the mountains of northern Baja California. Quaking aspen, the tree species with the greatest geographic extent in North America, has a north-south range of about 48° from Alaska and northwestern Canada south to the mountains of Mexico. Sandbar willow, a species of shrub that grows along the banks of the Yukon River in central Alaska, seems equally adapted as a small tree along the Mississippi River in Mississippi and Louisiana and ranges also into northern Mexico.

Woody-plant species of Alaska can generally be separated into two groups that correspond to forest regions within the State. Many are confined to the coastal spruce-hemlock forests of southeast Alaska. Others are characteristic of the spruce-hardwood forests of the interior or the tundra of northern and western Alaska. However, some species occur in two regions or extend a short distance into the other. Of the 33 species of trees native to Alaska, 20 are confined to the coastal region; the other 13 occur in the interior, but 11 of these also extend at least a short distance south to the Pacific coast.

All tree species of Alaska range south across Canada to other states with the exception of five species: three species of willow that are usually shrubby and two varieties of paper birch. Nineteen species grow wild in California.

LOCAL AND RARE SPECIES

Few species of native trees and shrubs in Alaska are restricted in distribution or endangered. Nearly all woody species range beyond the State's boundaries and are not endangered. Most occur in Canada, but a few occur in Asia. About 25 species of trees and shrubs have local ranges in Alaska.

OTHER USES

In addition to the timber values, the forest and tundra areas of Alaska have many other important uses. Much of Alaska is still wilderness, and the value of undisturbed areas may someday far outweigh the potential value of lumber and pulp production. An increasing number of people look to Alaska for wilderness areas that are no longer present in the more developed areas of the world. Thus, it is important to retain some natural forest land in Alaska. Tourism in Alaska is an important and growing industry that is primarily based on scenic, wilderness, and wildlife resources.

One of the most important resources of Alaska forests is the wildlife that inhabits them. Forests provide homes for numerous birds and mammals that are directly or indirectly dependent on woody plants for food or shelter. Even big game animals, such as mountain sheep, mountain goat, and musk ox, often use low woody plants for food even though they spend much of their lives above treeline.

The moose is probably the most abundant and wideranging large mammal in the interior forests; occasionally its range extends into the coastal areas. During winter, moose browse primarily on willows and other shrubs, especially in areas where shrubs grow thickly after a forest fire and in willow thickets along the rivers. In coastal areas, blacktail deer feed primarily on blueberry and other shrubs when snow covers the low vegetation. In summer, deer feed mainly on herbaceous plants that grow in the open areas in coastal forests. Even caribou, often considered tundra animals, spend winter in the open forested areas next to treeline, especially where lichen growth is abundant. In summer, caribou may eat several woody shrubs, especially resin and dwarf arctic birch and willows, as well as herbaceous tundra. Throughout winter, small red squirrels, which are also a source of food for larger furbearers, are dependent on seeds from spruce cones stored beneath the ground.

Several bird species survive through the Alaskan winters primarily by eating woody plants. Ptarmigan feed on willow and shrub-birch buds; ruffed and sharp-tailed grouse forage for berries from the past summer and feed on the buds of shrubs and trees. The spruce grouse of the interior and the blue grouse of the coastal areas feed largely on needles and buds of the spruce trees and berries and buds of many shrubby species.

In summer, insects abound in the forests and serve as food for many small birds that nest and rear their young before they migrate south in the fall. In addition, the Alaskan forests and tundra are dotted with lakes that serve as nesting places where waterfowl rear their young during the short summer season.

FORESTS

This section lists the main vegetation types of Alaska and the most important trees and shrubs in each area.

COASTAL FORESTS

The dense forests of western hemlock and Sitka spruce are a continuation of similar forests along the coast of British Columbia, Washington, and Oregon. These forests extend about 900 mi (1,440 km) along the coast from the southeastern tip of Alaska to Cook Inlet and Kodiak Island. Commercial stands occur from sea level to about 1,500 ft (460 m) elevation, but scattered trees occur up to timberline at 2,000 to 3,000 ft (460 to 915 m).

The coastal forests are characterized by steep, rugged topography. In many areas, only a narrow band of trees exists between the ocean and the snowclad mountains above. The scenic grandeur of the region is unsurpassed. Narrow waterways with steep forested slopes, rugged high mountains, numerous glaciers that extend through forested valleys to the coast, and abundant streams and lakes offer a wealth of recreational opportunities to Alaskans and tourists.

The climate is cool and cloudy in summer, and winters are mild. Snowfall may be heavy in some forested areas in the northern part of Alaska, but much of the precipitation is rain. Annual precipitation varies from as much as 222 in. (5,640 mm) on the seaward coast of the southeasternmost islands to 25 in. (630 mm) at Homer, which is on the boundary between coastal and interior forests. The mean annual temperature in the coastal forests ranges from 46^{o}F (8^{o}C) at Ketchikan to 37^{o}F (3^{o}C) at Cordova. Summer temperatures range from 55 to 60^{o}F (13 to 16^{o}C), and winter temperatures for the coldest month range from 20 to 35^{o}F (-7 to 2^{o}C).

In the southern part of Alaska, coastal forests are primarily composed of western hemlock and Sitka spruce with a scattering of mountain hemlock, western red cedar, and Alaska-cedar. Red alder is common along streams, beach fringes, and on soils recently disturbed by logging and landslides. Black cottonwood grows on the flood plains of major rivers and recently deglaciated areas on the mainland. Subalpine fir and Pacific silver fir occur occasionally at treeline and near sea level, but are not abundant enough to be of commercial value. Blueberry, huckleberry, copperbush, devilsclub, and salal are the most important shrubs. Because of the high rainfall and resultant high humidity, mosses grow in great profusion on the ground, fallen logs, lower branches of trees, and open areas in the forest.

In poorly drained areas at low elevations, open muskegs with low shrubs, sedges, grasses, and mosses are common. These areas are treeless or may have a few scattered shrubby trees of shore pine (lodgepole pine), western hemlock, mountain hemlock, Alaska-cedar, and Sitka spruce.

In the northern and western sections of the coastal forests, the tree species change. Western red cedar does not occur north of Frederick Sound, and Alaska-cedar does not occur at Prince William Sound. Cottonwood, which is extensive near glacial outwash along rivers, is commercially important in the Haines area and on the alluvial terraces to the west. Western hemlock is less extensive to the west, but occurs as far as Cook Inlet. Only Sitka spruce remains abundant in the coastal forests west of Cook Inlet; it is the lone conifer on Afognak and Kodiak Islands. Douglas-fir, which is characteristic of the coastal forests of Oregon, Washington, and southern British Columbia, does not grow in Alaska.

INTERIOR FORESTS

The white spruce - paper birch forest that extends from the Kenai Peninsula to the southern slopes of the Brooks Range and west almost to the Bering Sea is called the boreal forest or taiga, the Russian equivalent. These forests cover about 32 percent of the area or about 106 million acres (42.4 million hectares). However, only one-fifth of the area is classified as commercial-forest land.

Characteristic forest stands occur in the Tanana and Yukon valleys. Here, climatic conditions are extreme. The mean annual temperature is 20 to 30^{o}F (-7^{o}C to -1^{o}C), but winter temperatures below -40^{o}F (-40^{o}C) are common; the coldest month averages -10 to -20^{o}F (-23^{o} to -29^{o}C). In contrast, summer temperatures may reach into the 90s (above 30^{o}C), and the warmest month of the year averages 60^{o}F (16^{o}C). Permafrost is discontinuous in the southern part of the interior forests and nearly continuous in the northern sections. Although precipitation is light, 6 to 12 in. (150 to 300 mm) per year, evaporation is low, and permafrost forms an impervious layer. Consequently, bogs and wet areas are common. In Fairbanks, the average snowfall is 55 in. (140 cm) per year, but the snow cover usually persists from mid-October until mid- to late-April. In the boreal forest regions, nearly 24 hr of daylight are available for plant growth in June, but only a few hours of sunlight are available during the winter months.

Forest fires are also an important aspect of the interior-forest environment in Alaska. Even with modern fire-detecting and fighting techniques, more than 4 million acres may burn in a single summer.

Because some areas have been extensively burned during the past 100 yr, large areas of the interior are in various stages of forest succession. The succession that follows a fire is varied and depends on topography, previous vegetation, severity of burn, and available seed source at the time of burn. In general, fires are followed by a shrubby stage that consists primarily of light-seeded willows.

Vegetation types in interior Alaska form a mosaic that is related to past fire history, slope and aspect, and the presence or absence of permafrost. Most forest stands are mixtures of at least two tree species, but are usually classified by the dominant species.

Closed spruce-hardwood forests

White spruce In general, the best commercial stands of white spruce occur on warm, dry, south-facing hillsides and next to rivers where drainage is good and permafrost is absent. These stands are generally open under the canopy, but may contain rose, alder, and willow shrubs. The forest floor is usually carpeted with a thick moss mat. In some areas, 100- to 200-yr-old spruce with trunks 10 to 24 in. (25 to 60 cm) diam may average 10,000 board feet/acre (58 m^3/hectare). Stands in which commercial white spruce is dominant occupy 12.8 million acres (5.1 million hectares) in interior Alaska.

Quaking aspen After a fire and initial willow stage, fast-growing aspen stands develop in upland areas on south-facing slopes. The aspen mature in 60 to 80 yr and are eventually replaced by white spruce, except in excessively dry sites where the aspen may persist. Occasionally, aspen stands also follow fire on well-drained lowland river terraces and are usually replaced by black spruce in the successional sequence. Stands in which aspen is dominant occupy about 2.4 million acres (960,000 hectares) in central Alaska.

Paper birch After a fire, paper birch is the common invading tree on east- and west-facing slopes and occasionally on north slopes and flat areas. This species may occur in pure stands, but is generally mixed with white spruce, aspen, or black spruce. Shrubs may be similar to those under an aspen canopy, but usually Labrador-tea and mountain-cranberry are more common. Paper birch trees may be 60 to 80 ft (18 to 24 m) tall and have diameters up to 18 in. (46 cm), but an average diameter of 8 to 9 in. (20 to 22 cm) is generally more common in interior birch stands. Stands dominated by paper birch occupy about 5 million acres (2 million hectares) of interior forests and are especially widespread in the Susitna River valley.

Balsam poplar Balsam poplar is also an important species in closed spruce-hardwood forests in interior Alaska. This species reaches its greatest size and abundance on the flood plain of meandering glacial rivers. The balsam poplar invades sandbars and grows rapidly to a height of 80 to 100 ft (24 to 40 m). Trunks may reach 24 in. diam (60 cm) before the species is replaced by white spruce. Balsam poplar also occurs in small clumps near the altitudinal and latitudinal limit of trees in the Alaska Range and north of the Brooks Range. Commercial stands occupy 2.1 million acres (840,000 hectares), primarily along the Yukon, Tanana, Susitna, and Kuskokwim Rivers. In the Susitna River valley, balsam poplar is often replaced by black cottonwood or a hybrid of the two.

Open, low-growing spruce forests

On north-facing slopes and poorly drained lowlands, forest succession leads to open stands of black spruce and bogs, usually underlain by permafrost. Black spruce grows slowly and seldom exceeds 8 in. (20 cm) diam; a tree that is 2 in. (5 cm) diam is often 100 yr old. Black spruce grows abundantly after fire because its persistent cones open and spread seed over the burned areas. A thick moss mat, often composed of sphagnum mosses, sedges, grasses, and heath or ericaceous shrubs, is usually the subordinate vegetation of open black-spruce stands. Slow-growing tamarack is associated with black spruce in wet bottom lands. As with black spruce, tamarack trees are of little commercial value because they seldom reach more than 6 in. (15 cm) diam.

TREELESS BOGS

Coastal areas

Within the coastal forests, treeless areas occur in depressions, flat areas, and on some gentle slopes where drainage is poor. The vegetation is variable, but generally consists of a thick sphagnum-moss mat with sedges, rushes, low shrubs, and fruticose lichens; this vegetation is locally called 'muskeg.' Often, a few slow-growing, poorly formed shore pine, western hemlock, or Alaska-cedar grow on the drier sites. In more exposed areas and in the driest areas, shrubs may be dominant over the sedge and herbaceous mat. Ponds often occur in the peaty substrate.

Interior areas

Within the boreal forest, extensive bogs occur where conditions are too wet for tree growth. In unglaciated areas north of the Alaska Range, bogs occur on old river terraces and outwash (in-filling ponds and old sloughs) and occasionally on gentle north-facing slopes. They are also common south of the Alaska Range, on the fine-clay soils formed in former glacial lake basins, on morainal soils in glaciated areas, and on extensive flat areas along the lower Yukon and Kuskokwim Rivers.

Bog vegetation consists of various grasses, sedges, and mosses, especially sphagnum. Often the surface is made uneven by stringlike ridges. Much of the bog surface is too wet for shrubs, but numerous heath or ericaceous shrubs, willows, and dwarf birches grow on drier peat ridges.

SHRUB THICKETS

COASTAL ALDER THICKETS

Dense thickets of shrubs occur in many sites in all major vegetation zones in Alaska. In the coastal areas of Alaska, extensive alder thickets grow between the beach and forest and between treeline and alpine-tundra meadows; they often extend from treeline down through the forest in avalanche shoots and along streams. Shrub thickets commonly occur in many open areas in southeastern Alaska. The alder thicket is almost impenetrable because boles of shrubs tend to grow horizontally and vertically. Travel through the thicket is difficult because spiny devilsclub and salmonberry frequently occur. Beneath the alder canopy, a well-developed grass and moss layer often occurs, as well as numerous herbs and shrubs.

FLOOD-PLAIN THICKETS

Flood-plain thickets are another major shrub type that occurs on river flood plains. Flood-plain thickets are similar from the river flood plains of the southern coastal areas to the broad, braided river flood plains north of the Brooks Range. They often form on newly exposed alluvium that is periodically flooded. The thickets develop quickly and may reach heights of 15 to 20 ft (4.6 to 6 m) in southern and central Alaska and heights of 5 to 10 ft (1.5 to 3 m) along rivers north of the Brooks Range. The dominant shrubs are willows and occasionally alders with numerous kinds of lower shrubs under the canopy.

BIRCH, ALDER, AND WILLOW THICKETS

Birch, alder, and willow thickets occur near treeline in interior Alaska and beyond treeline in extensive areas of the Alaska and Seward Peninsulas. They consist of resin birch, alder, and several willow species, and usually form thickets that range from 3 to 10 ft (1 to 3 m) tall. The thickets may be extremely dense or open and are interspersed with reindeer lichens, low-heath shrubs, or patches of alpine tundra. The alders tend to occupy the wetter sites, the birch the somewhat moist sites, and the tundra the drier or wind-exposed areas. The thickets extend below treeline where they are often associated with widely spaced white spruce.

TUNDRA

Three types of low tundra include moist tundra, wet tundra, and alpine tundra. Within each major type are subtypes that are related to differences in topography, slope, aspect, and substrate.

MOIST TUNDRA

Moist tundra occurs in foothills and lower elevations of the Alaska Range as well as extensive areas on the Seward and Alaska Peninsulas, the Aleutian Islands, and islands in the Bering Sea. The tundra varies from almost continuous, uniformly developed cottongrass (*Eriophorum*) tussocks with sparse sedges and dwarf shrubs to stands where dwarf shrubs are dominant and tussocks are scarce or lacking. Cottongrass tussocks are the most widespread of all vegetation types and occur over wide areas in arctic Alaska. In northern areas, the tundra is often dissected by polygonal patterns that are created by underlying ice wedges. On the Aleutian Islands, the tundra consists of tall-grass meadows interspersed with dense, low heath.

WET TUNDRA

Wet tundra includes the low coastal marshes of southern Alaska and is most extensive along the coastal plain north of the Brooks Range, the northern part of the Seward Peninsula, and on the broad Yukon delta. Wet tundra usually occurs in areas that have shallow lakes and little topographic relief. Standing water is generally present in summer, and in northern areas, permafrost is close to the surface. Peat ridges and polygonal features related to frost action and ice wedges provide microrelief. The vegetation is primarily a sedge and cottongrass mat. The few woody plants occur on the driest sites where the microrelief raises them above the standing water table.

ALPINE TUNDRA

Alpine tundra occurs in all mountain ranges of Alaska and on exposed ridges in the arctic and southwestern coastal areas. Much of these areas consist of barren rocks with herbaceous and shrubby low-mat plants interspersed between bare rocks and rubble. Low mats of white mountain-avens (a small white flower) are dominant in northern areas and the Alaska Range. They may cover entire ridges and slopes along with many mat-forming herbs, grasses, and sedges. In the southeastern coastal mountains and the Aleutian Islands, the most dominant plants are the low-heath shrubs, especially cassiopes and mountain-heaths. The shrubs are most abundant where snow accumulates in the winter and lingers into late spring. On the Aleutian Islands, the shrubs consist primarily of crowberry, bog blueberry, mountain-cranberry, alpine-azalea, and several kinds of dwarf willow.

APPENDIX C: FROST HEAVING OF BRIDGE PILINGS AT MILEPOST 458.4 NEAR FAIRBANKS, ALASKA[15]

DESCRIPTION

"The bridge at milepost 458.4 is 71 ft long and is supported by 6 bents of wooden piles. It spans a small creek that drains the hills to the north and empties into Goldstream Creek. This unnamed creek lies in a flat-floored valley 11 ft below track level and flows southward between two gently sloping alluvial fans of silt.

GEOLOGY OF THE SITE

"A gold prospect drill hole 600 ft west of the bridge shows that there is 28 ft of organic silt overlying 14 ft of creek gravel, which, in turn, lies on bedrock.

[15]From Péwé and Paige, 1963.

PERMAFROST

"Permafrost extends from within 2 ft of the surface down to more than 52 ft, the total depth of the prospect hole. The base of the permafrost was not reached. Permafrost is near the surface, except in the drainageway. On September 29, 1954, the permafrost table was about 11 or 12 ft below ground surface at the ends of the bridge, but was 13 ft deep under the creek. Permafrost determinations on September 27, 1955, indicated the permafrost table to be within 4 in. of that measured in 1954.

"The temperature and moisture-content conditions of the perennially frozen ground at this locality are similar to the conditions given for the bridge at milepost 456.7.

AUFEIS

"Aufeis, or overflow ice, is a common feature on many streams in Alaska. Because of the long duration of intense cold, streams freeze to the bottom forcing water to overflow and form ice on top of the original ice. This process continues throughout the winter with the development of several layers of ice, some of which are separated by moving water. Little or late snowfall favors the formation of aufeis. It is not unusual for great thicknesses of aufeis to form on streams, and such ice may cover structures or objects built or left near the river.

"Aufeis was 5 ft thick in the drainageway in March 1954. During the winter of 1955 only about 3 ft formed. On February 21, 1956, the amount of aufeis penetrated in auger holes A, B, and C was 2 ft 9 in., 3 ft 3 in., and 3 ft, respectively.

SEASONAL FROST

"The moisture content and thickness of the seasonal frost in this drainageway under the bridge was determined on February 21, 1956. No temperature measurements were taken.

"Hole A was drilled between bents II and III on the west side of the little valley. The hole penetrated 2 ft 9 in. of aufeis and 2 ft 11 in. of seasonal frost. The seasonally frozen ground is organic silt, except for the upper 6 in. which contains some gravel from the roadbed. A silt sample taken 2 ft below the surface contained 64.9 percent moisture.

"Hole B was drilled between bents III and IV in the center of the valley. Aufeis, 3 ft 3 in. thick, overlies 3 ft of seasonally frozen organic silt containing a few twigs and wood fragments. The upper 6 in. of the ground contains a few pebbles. A sediment sample taken 10 in. below the surface contained 42.3 percent moisture.

"Hole C was drilled between bents IV and V on the east side of the valley. The hole penetrated 3 ft of aufeis and 3 ft 6 in. of seasonally frozen silt. As in the previously drilled holes, the upper 6 in. of the ground contained a small amount of gravel. The moisture content of a sediment sample taken a foot beneath the surface was 51.6 percent.

UNFROZEN GROUND

"About 10½ ft of unfrozen ground is present between the seasonally frozen ground and the perennially frozen ground at hole A. A sample of ground taken 6 in. below the base of the seasonal frost contained 57 percent moisture. At hole B, 11 ft of unfrozen silt occurs between the seasonal frost and the permafrost. This hole is in the middle of the drainageway and the unfrozen ground is very wet. Five in. below the base of the seasonal frost, the ground contained 60.9 percent moisture, and a silt sample taken 20 in. below the base of the seasonal frost contained 70.7 percent moisture. Near hole C there is 9 ft of unfrozen silt between the seasonally and perennially frozen ground. The moisture content of the ground at a point 8 in. below the base of the seasonal frost was 61.1 percent.

HISTORY OF BRIDGE

"This wooden-pile bridge, which was built originally in 1917, is affected more by frost heaving than any other pile bridge of The Alaska Railroad. Serious frost heaving of the bridge has occurred for many years and has caused expensive maintenance. The earliest record of pile replacement is in 1923 when new piles were driven for all bents. These piles were emplaced to depths ranging from about 12 to 23 ft. The greatest penetration was under the end bents. These piles were installed by the same method as those on bridge 456.7; some of them penetrated 6 or 8 ft of permafrost, but others, especially in the middle of the bridge, did not penetrate permafrost at all. It is assumed that the permafrost level was approximately the same in 1923 as it was in 1955 because there were no great changes in the vegetative cover, drainage, or climate between 1923 and 1955.

"The piles installed in 1923 were greatly affected by frost heaving. During the winter of 1952-53, for example, the center of the bridge was frost heaved 14 in. This displacement produced a sharp hump in the track, sharp enough to uncouple train cars. It was necessary to saw off 14 in. from the top of the piles to restore the track to grade. This action, plus the stresses on the bridge over the preceding years, must have considerably weakened the structure. During the winter of 1953-54 the piles began to be pushed up in December. This is a little unusual because in most years the elevating of piles by frost heaving is not evident until January. However, during October 1953 the air temperature was colder than usual and the snowfall was lighter. This colder weather coupled with the reduced insulation of the ground by snow may have permitted more ground freezing and ice accumulation than in normal years. By February 1954, the center of the bridge was pushed up 9 in. In the latter part of February new piles were installed and the bridge lowered. These piles were installed in the manner described for bridge 456.7; they penetrate the ground to depths ranging from 18 to 30 ft. None of the piles in the center of the bridge penetrate permafrost very far, and some do not penetrate the permafrost at all. Most of the piles in the end bents are placed deeply in permafrost. The piles of this bridge were not frost heaved during the winter of 1954-55.

"During the second winter (1955-56) after pile installation, the effect of frost heaving on the bridge was very evident. By February 3, 1956, the bridge had been elevated 3 in. at bent III, and by the end of the winter it was elevated 5 in."