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SKIWAY FOR C-130 AIRCRAFT AT PALMER STATION, ANTARCTICA

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Port Hueneme, California

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ABSTRACT

Palmer Station, Antarctica, which is located on Anvers Island west of the Antarctic Peninsula, has been supported entirely by ice-breakers and cargo ships during the austral summer; a capability for air support would extend this season, improve the movement of essential cargo and personnel, and provide for emergency support.

This technical note presents the feasibility of establishing a skiway for ski-equipped C-130 aircraft on the Marr Ice Piedmont about three miles from the station. It also describes the reconnaissance techniques used in February 1969 to locate the skiway site and safe access route through the marginal crevasse zone between this site and Palmer Station for one-ton capacity tracked carriers. If the procedures set forth in this technical note are followed, the skiway and access route at Palmer Station are safe for operational use. It is also concluded that most piedmont glaciers in polar regions can be used for ski-equipped C-130 aircraft landings when they meet the air and ground reconnaissance requirements described in this note for such landings.

INTRODUCTION

[illegible] ation, Antarctica is located near the center of the southwestern coast of Anvers Island on the Antarctic Peninsula. Since completion, the station has been supported only during the austral summer and entirely by icebreaker and cargo ship sailing mostly from Puna Arenas, Chile and occasionally from McMurdo Station, Antarctica. The capability of utilizing cargo aircraft would greatly improve personnel movement and logistic support requirements. In 1968 an investigation was requested by the U. S. Navy Antarctic Support Activities to determine the feasibility of landing heavy ski-equipped cargo aircraft on the ice cap near Palmer Station. This investigation was made in February 1969.

A relatively level, smooth, crevasse-free area was located by air about three miles northeast of Palmer Station. The feasibility of using this area, as well as access from Palmer Station, was verified by surface travel and the access route through a crevasse zone was located and mapped by stadia survey. This report describes the ice piedmont on Anvers Island, the proposed skiway and access route, and outlines the techniques used to locate and survey the skiway and access route.

BACKGROUND

Reconnaissance for a research station in the Antarctic Peninsula region was first initiated in January, 1963, by a National Science Foundation team working from the USS Staten Island. Access by ship and, if possible, also by aircraft were among the criteria used in searching for a potential station site. One of the most important conclusions resulting from the first reconnaissance was that snow fields suitable for ski-equipped cargo aircraft, in conjunction with a feasible access route to and from an acceptable station site, were to be found only in the Arthur Harbor area on Anvers Island and near the British base on Adelaide Island.

In January 1964, Navy and Coast Guard personnel from the USCGC Eastwind made a more complete reconnaissance in the Arthur Harbor area preparatory to selecting the final station site. Four helicoptor flights were made to search for and select a potential skiway on the ice piedmont east of Arthur Harbor. On the first flight it was found that a site suggested by the January 1963 reconnaissance was badly crevassed and not usable. The crevassed area is shown on the British Antarctic Territory Anvers Island map published in 1964. This map is based on vertical air photography taken in 1956 by Hunting Aero Surveys, Ltd. (British Antarctic Territory, 1964).

The second potential site that was briefly inspected lies 3.7 miles from the new Palmer Station on an azimuth of 57° true North. Even though four flights were made, bad weather prevented a comprehensive survey of this area and no final decisions were expressed regarding its suitability. Also, no attempt was made to traverse the marginal crevasse zone and reach the skiway site by surface travel. A snow ramp that could provide access from the station site to the upper ice piedmont was recognized and accurately described; however, unfounded doubts were expressed regarding its stability for vehicle traffic (Hoffman, 1964, encl. 4, p. 1).

LOCATION AND PHYSICAL SETTING

Anvers Island, with Palmer Station on its southern coast, is located on the western side of the Antarctic Peninsula between latitudes 64° and 65° South and longitudes 62°30' and 64°30' West (Figure 1). The island is among the largest in the region, having a length of about 36 miles and a width of 28 miles.

The coast of Anvers Island is extremely rugged, consisting of vertical ice cliffs, intensely crevassed glaciers, and small, scattered rock outcrops protruding beyond the margin of the ice cap. At rare intervals along the coast, an unbroken, narrow hill, or snow ramp, extends from a coastal rock outcrop to the upper ice piedmont (Figure 2). The eastern side of the island is mountainous with the ranges trending northeast and culminating in Mt. Francais, the highest peak with an elevation of 9,076 feet. The western side consists of a vast, gently undulating, unbroken ice cap known as the Marr Ice Piedmont. This ice cap varies in elevation from 60 to 240 feet at the coast to 2800 feet at the base of the mountains. The southwestern quarter of the ice piedmont is the most extensive; it has an area of about 225 square miles.

At Port Lockroy, 18 miles east of Palmer Station, the mean monthly temperatures for the summer months of October through March vary between a low of 25°F in October and a high of 37° in December. During the few days with no cloud cover and no wind, summer temperatures may rise to 40 or 50°F at elevations near sea level; however, at higher elevations on the ice cap and the mountains, temperatures are undoubtedly lower. Cloudy, windy weather conditions are normal in the Antarctic Peninsula area and precipitation consists mostly of snow, although an occasional rainfall has been noted. From October through February, there is an average of one clear day per month and 19 to 21 cloudy days per month based on weather records from 1944 to 1950.

During the January 1964 reconnaissance, average winds were less than 10 knots from the north, with sustaining winds from the northeast at less than 5 knots. Storm winds were from the northeast sector and averaged 20 knots with gusts to 40 knots (Hoffman, 1964, p. 4, encl. 4). Rundle (1969) reports light but persistent winds from the northeast for the period February 1965 to January 1967. The main storm and snow-bearing wind is from the north-northeast and a secondary wind, also a heavy snow-producing wind, is from the east (Rundle, 1969, p. 4). During mid-February 1969, it was noted that weather conditions were generally good early in the morning with increasing cloudiness and snow flurries later in the day.

Reconnaissance of the Marr Ice Piedmont

A reconnaissance flight was made during the morning of 19 February 1969 via helicopter from the USCGC Edisto anchored in Arthur Harbor. Following the flight, a surface investigation was made on skis. Weather conditions were excellent with clear skies and strong sunshine at a favorable angle for observing crevasses and other surface features on the ice piedmont. Crevasses were easily spotted as the snow-bridge covering them had either collapsed or sagged downward during the summer to form linear depressions in the surface (Figure 3). Crevasses only 2 or 3 inches wide were easily detected. The pattern northeast of Palmer Station consists of straight or arcuate crevasses parallel to the calving ice cliffs along the coast and is such that a safe route could be selected to a skiway area.

Access. East of Palmer Station, the ice cap extends from the coastal rock contact to an elevation of about 350 feet in the form of a buttress-shaped ice hill situated between vertical ice cliffs 80 to 100 feet high (Figure 4). This hill, known as The Ramp, is free of crevasses for a width of at least 600 feet and provides an excellent and stable access route to the upper ice piedmont. The trail up the ramp trends almost due east for about 3,000 feet with slopes varying between 5 and 7 degrees from the horizontal. The trail then curves to approximately true north where it goes between two large crevasses that are about 150 feet apart and 300 feet long (Figure 5).

After passing through the crevasse zone, the trail again trends northeast for 7,000 feet and rises from an elevation of 500 feet to 1,500 feet in a series of broad, rounded hills having short slopes of 4 to 5 degrees separated by long, gentle slopes of 1 to 3 degrees (Figure 6). No crevasses were observed for distances of at least 600 feet on either side of the access route above the crevasse zone. The survey data in Table I is simplified from the field notes and will enable others to relocate the trail if the existing markers become buried during the winter.

Table 1. Azimuths and distances to Skiway, Palmer Station, Antarctica

Station	Foresight	Azimuth	Slope distance	Remarks
0	1	97°16'	626 (ft.)	Surveyed 24 Feb 69
1	2	87°39'	413	
2	3	81°10'	2264	Slope varies between 5°00' and 7°33'
3	4	54°37'	817	
4	5	39°09'	840	
5	6	13°55'	656	
6	7	18°42'	712	
7	8	350°32'	1047	Crevasse Zone
8	9	19°42'	1106	Crevasse zone
9	10	21°50'	3438	Slopes from 1°30' to 5°45'
10	11	39°25'	2438	
11	12	37°46'	3609	Skiway area, slope does not exceed 2°00'

Notes: Azimuths are from grid north and were corrected for declination by adding 17°07' to east bearings and subtracting for west bearings. Elevation of station 11 is 1,577 ft; at station 12 it is 1,704 ft.

Crevasses. Safe access to the upper ice piedmont depends upon the avoidance of crevasses which, in turn, requires a basic understanding of their formation. Crevasses are often related to the surface topography of a glacier or moving ice cap and usually occur where the ice moves over subsurface terrain that causes tensile stresses in the surface. When the stress exceeds the tensile strength of the snow and/or ice, failure occures and a crevasse forms. The length and width of crevasses vary widely depending upon the local stress pattern. Newly formed crevasses are usually narrow at first and widen as movement progresses, although exceptions occur depending upon subsurface terrain. As ice movement continues, flow conditions may change so that compressive forces prevail and the crevasses will close; this usually occurs downstream from crevasses that are caused by an abrupt hill or cliff beneath the ice.

After a crevasse is formed, wind-driven snow often bridges the crack and effectively hides it from visual detection. Even crevasses up to 6 feet wide may be completely bridged and perfectly hidden. Cold snow, driven and packed by high-velocity winter winds, is most effective in bridging crevasses. As summer progresses and surface snow temperatures rise, the snow bridges may weaken and begin to sag into the crevasses. Under ideal light conditions, even a slight depression will appear as a linear feature in the surface and warn of potential trouble. Later, sagging may become quite obvious or the snow bridge may collapse completely. Travel in glacier or ice-covered regions is usually safest later in the summer when most of the existing crevasses can be detected.

Skiway Area

The proposed skiway area (Figure 7) trends northeast in accordance with the prevailing wind and is located on the upper ice piedmont between elevations of 1,550 and 1,700 feet. The skiway area was marked with two tripods constructed with 6-foot lengths of 2- by 2-inch lumber. The closest tripod is 2.7 miles from Palmer Station and is at an elevation of 1,577 feet. The second tripod is 3,600 feet farther to the northeast at an elevation of 1,704 feet. The difference in elevation between the tripods is 127 feet with slopes not exceeding 3 degrees. The actual skiway can be up to 9,000 feet long by extending it northeast beyond the second tripod. This extension would have a slope of 1 to 2 degrees. There is also ample crevasse-free area to the southeast for a crosswind skiway that would rise no more than 3 degrees.

There are no obstacles rising above the piedmont surface within an 8-mile radius of the skiway area. The nearest obstacle, Mt. Moberly, has an elevation of 5,030 feet and is about 8 miles grid east of the skiway area. Mt. Helen is about 4,000 feet above sea level and is 15 miles northeast of and in line with the skiway.

Snow Conditions. Snow conditions for surface travel were ideal during the brief time spent on the ice piedmont. A hard, uniform, non-breakable crust prevailed that was covered with 7 inches of new snow by intermittent snow flurries occurring between 20 and 25 February, 1969. The surface, however, remained smooth and maintained a relative relief of less than 3 inches (Figure 8).

Annual snowfall is extremely high and increases markedly with elevation above sea level. Above 900 feet, annual accumulation is about 5.6 feet, increasing to 11.5 feet about the 1,500-foot level and to 14.8 feet at the 2,000-foot level. In the skiway area, snowfall has varied from a low of 7 feet in 1966 to a high of 12 feet in 1967. As the ice piedmont is considered to be in equilibrium, surface elevations do not increase because this heavy snowfall is dissipated by natural compaction, downhill movement at depth, and calving at the coastal ice cliffs (Rundle 1968). As a result of this mechanism, the existing surface for any one year becomes buried at progressively increasing depths depending upon annual snowfall.

Winter and early spring snow conditions are unknown; however, it is likely that wind-packing is sufficient so that aircraft skiis would not sink more than 6 or 8 inches. Rundle (1968) gives surface snow densities averaging $0.45 g/cm^2$ between elevations of 1,400 and 2,100 feet. Based on data obtained in the McMurdo area, this high density indicates a snow pack more than adequate for safe landings with a LC-130F ski-equipped aircraft.

Subsurface snow conditions were determined from a pit dug to a depth of about 4 feet at the second skiway tripod. The following snow stratigraphy was recorded:

0 - 7 inches	New snow, moist with occasional wind and sun crusts.
7 - 31 inches	Hard, uniform, granular snow, grains 2 to 3 mm in diameter. No ice layers or lenses evident.
31 - 32 inches	Depth hoar. Granular and soft.
32 - 45 inches	Hard, uniform, granular snow, grains up to 4 mm in diameter.

The depth of this pit is probably less than one-half the annual accumulation; however, the density, strength, and compact nature of the snow to a depth of 45 inches also indicates sufficient bearing capacity for ski-equipped cargo aircraft.

Personnel and Cargo Transportation

Future cargo handling requirements between Palmer and the skiway are not known; however, it is assumed that transportation needs will be mostly for personnel and light cargo. The steep gradient of the ramp would require a tracked vehicle powerful enough to pull a fully loaded 1-ton sled up a 7 degree slope and stable enough to turn on or traverse the hillside. A commercially available 10-passenger 1-ton tracked vehicle would probably be sufficient for this work.

Trail Marking. The trail shown in Figure 5 should be marked with a single line of bamboo poles spaced no more than 200 feet apart and well flagged. During travel, the vehicle driver should keep the trail on his left and not wander more than 30 feet from the flagged poles on either side of the trail. During February 1969, the surveyed route was traveled several times with a heavily loaded motor toboggan and is considered safe for light to medium-weight tracked vehicles; however, short-cuts should not be attempted under any circumstances.

Skiway Marking. Unusual problems in skiway marking and maintenance are caused by the nearly constant winds, frequent snow storms, and the high annual snow accumulation. Skiway markers should not cause large snowdrifts and should be easily replaceable because they will be buried during the winter storms. Well-flagged tripods constructed with 8- to 10-foot lengths of bamboo poles should be used as skiway markers at Palmer Station. A bamboo tripod will cause minimum drift in the skiway area regardless of shifting winds and will be easy and economical to replace as they become snowed under. Large wood panels, such as those at McMurdo Station, should not be used; these have not caused serious drift problems at McMurdo because of the low annual snowfall and the availibility of snow removal equipment.

SUMMARY

Aircraft transportation is one of the most efficient methods of providing logistic support for polar operations. Large glaciers. snowfields, lake ice, and sea ice have often been used as landing areas both in the arctic and antarctic. The reliability of landing heavy cargo aircraft on any of these surfaces depends upon local conditions that require careful assessment. For example, sea ice is safe for heavy aircraft from August through December at McMurdo Station but it never attains sufficient thickness for heavy aircraft at Palmer Station.

Aerial reconnaissance is often sufficient to locate a landing area that appears to be safe; however, surface investigation is necessary to verify the safety of an area and to provide wind-direction indicators and runway marking. The aerial and surface reconnaissance accomplished at Palmer Station indicates that a landing area for ski-equipped L-130 cargo aircraft can be established on the Marr Ice Piedmont. Also, an access route through a crevasse zone is feasible and safe for medium-weight vehicles. This skiway and access route can be successfully used to support Palmer Station if the following procedures are utilized:

(1) The access route to the skiway should be relocated using the data in Table I.

(2) A single row of flags, spaced at 200-foot intervals, should be used to mark this route.

(3) When traveling over this route, the vehicle driver should adhere closely to the flagged trail.

(4) The skiway markers should consist of flagged, bamboo-pole tripods to minimize drift.

(5) Permanent facilities at the skiway should not be considered because of the heavy annual snowfall.

(6) Skiway markers and route flags will require annual replacement because of the heavy snowfall.

CONCLUSIONS

1. Piedmont glaciers have been used for small lightweight ski-equipped aircraft landings: they can also be used for ski-equipped C-130 aircraft landings when they meet the air and ground reconnaissance requirements described in the technical note.

2. A skiway on the piedmont glacier above Palmer Station is suitable for ski-equipped C-130 aircraft resupply of the Station and the access route from Palmer Station to this site is suitable for safe travel by 1-ton capacity tracked vehicles if the procedures set forth in this note are followed.

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Rundle, A. A., 1969. Snow accumulation and ice movement on the Anvers Island Ice Cap, Antarctica: A Study of Mass Balance. Contribution No. 138 of the Institute of Polar Studies, the Ohio State University, Columbus, Ohio. Unpublished thesis.

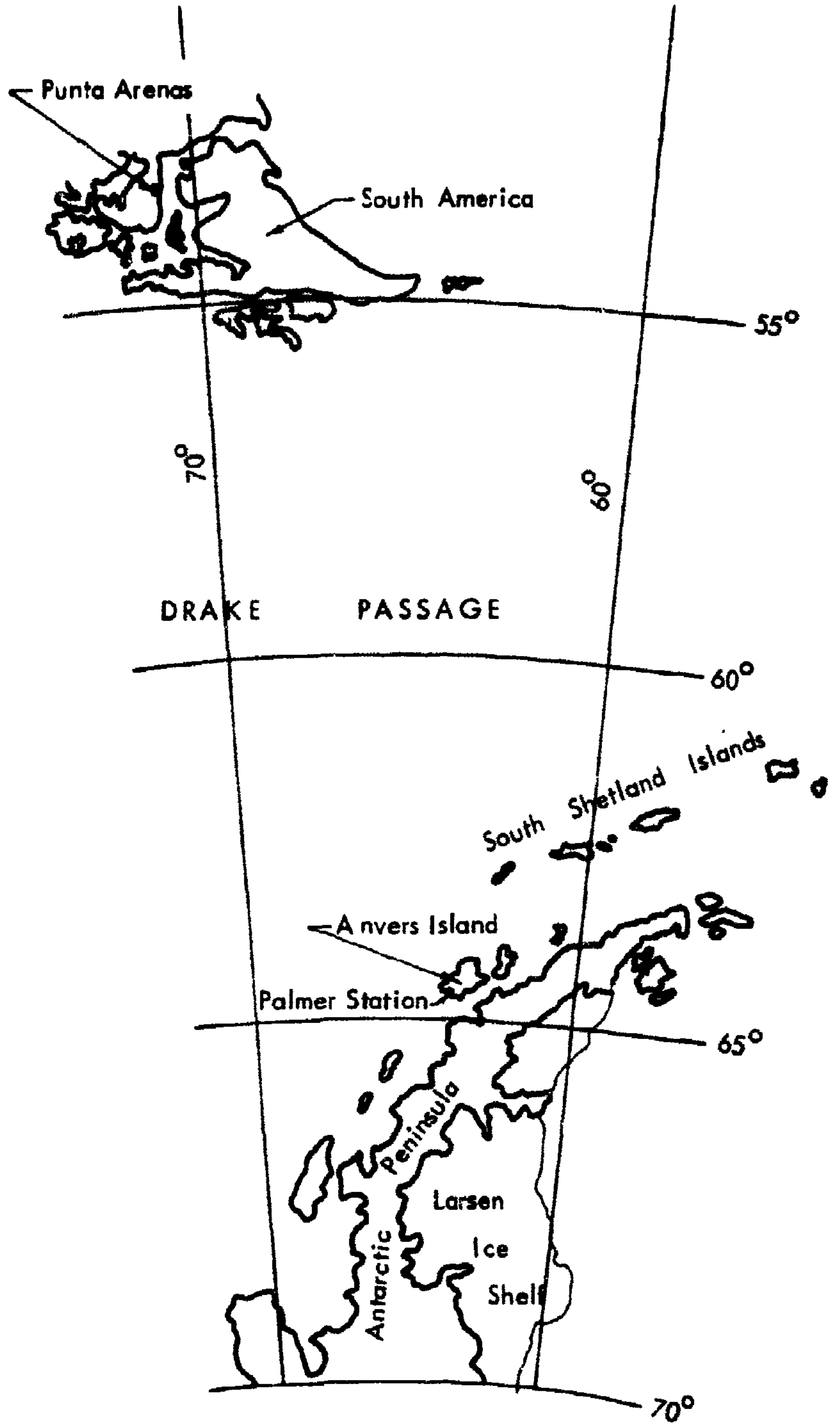

Figure 1. Index map of the Antarctic Peninsula showing the location of Anvers Island and Palmer Station.

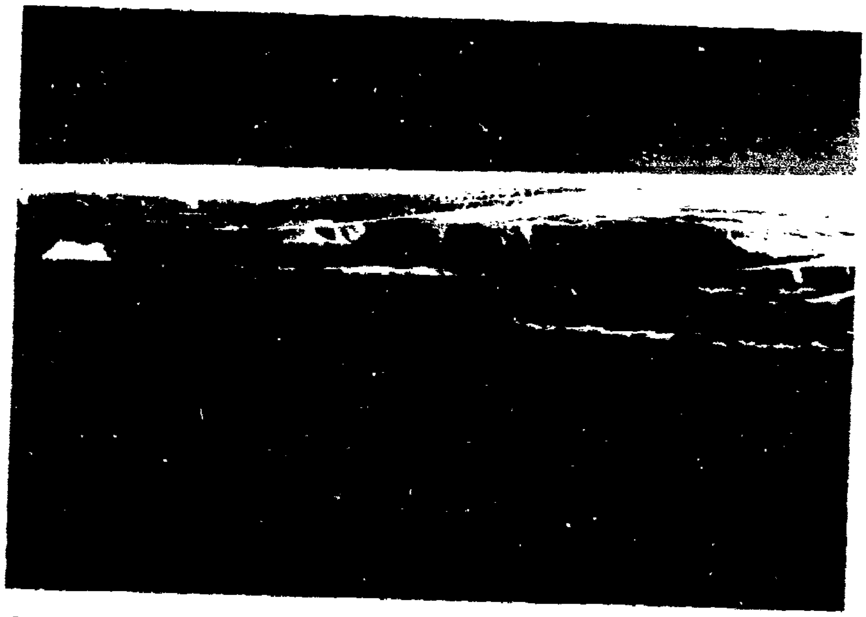

Figure 2. Terrain around Palmer Station showing snow ramps, ice cliffs, and crevasses in the ice piedmont.

Figure 3. Crevasses along the trail to the proposed skiway above Palmer Station.

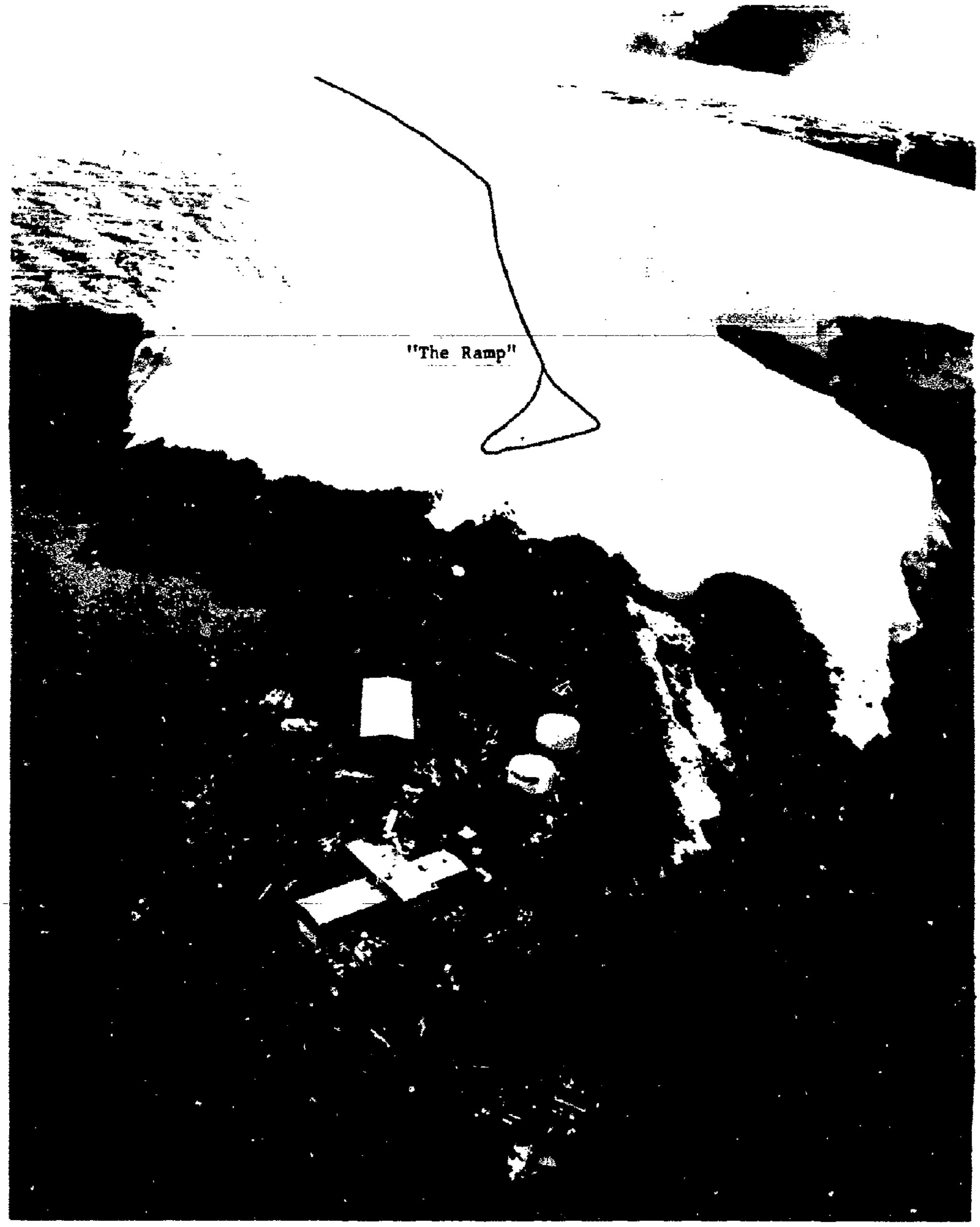

Figure 4. The snow ramp providing access to the upper ice piedmont from Palmer Station.

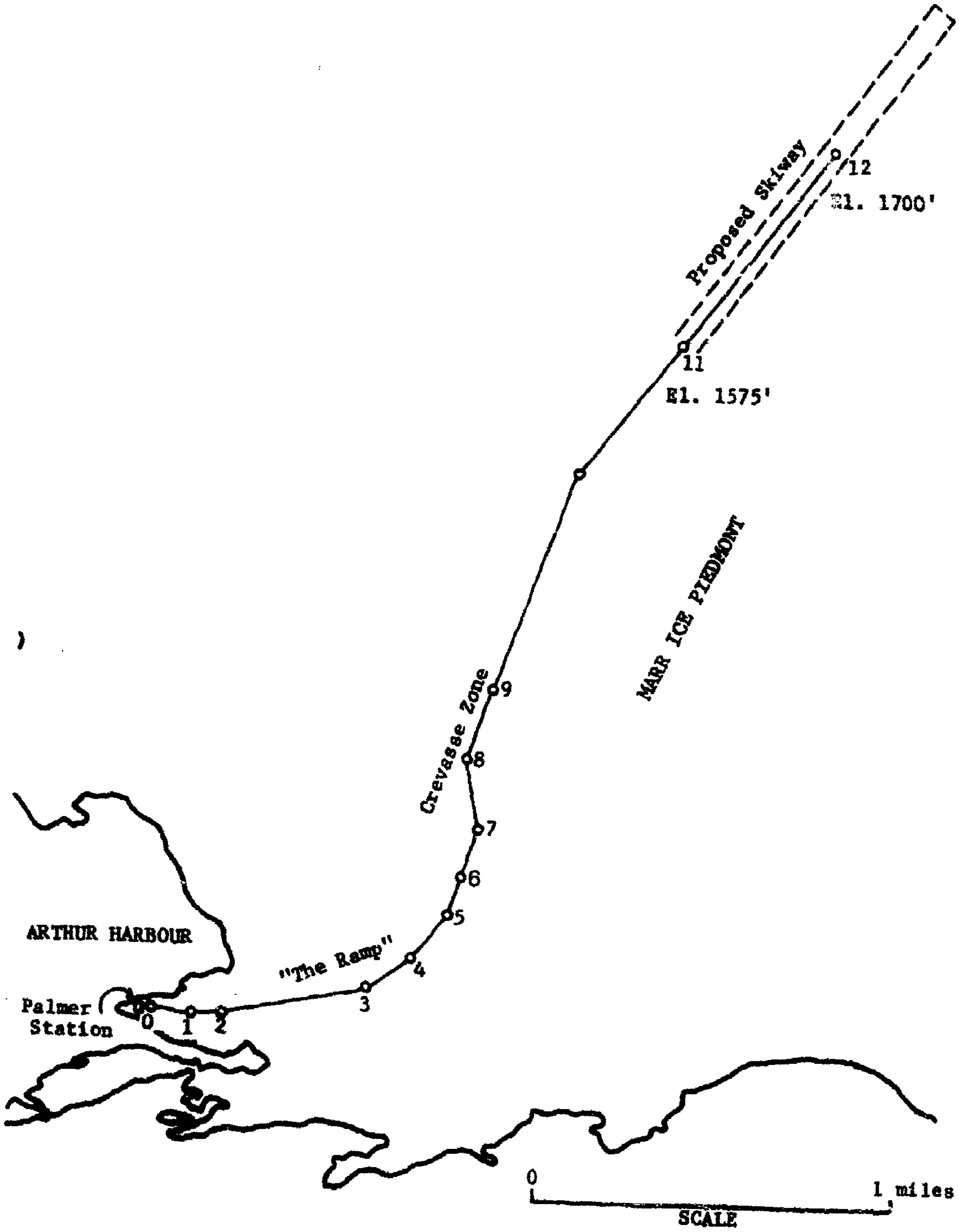

Figure 5. Surveyed route to the proposed skiway on the Marr Ice Piedmont.

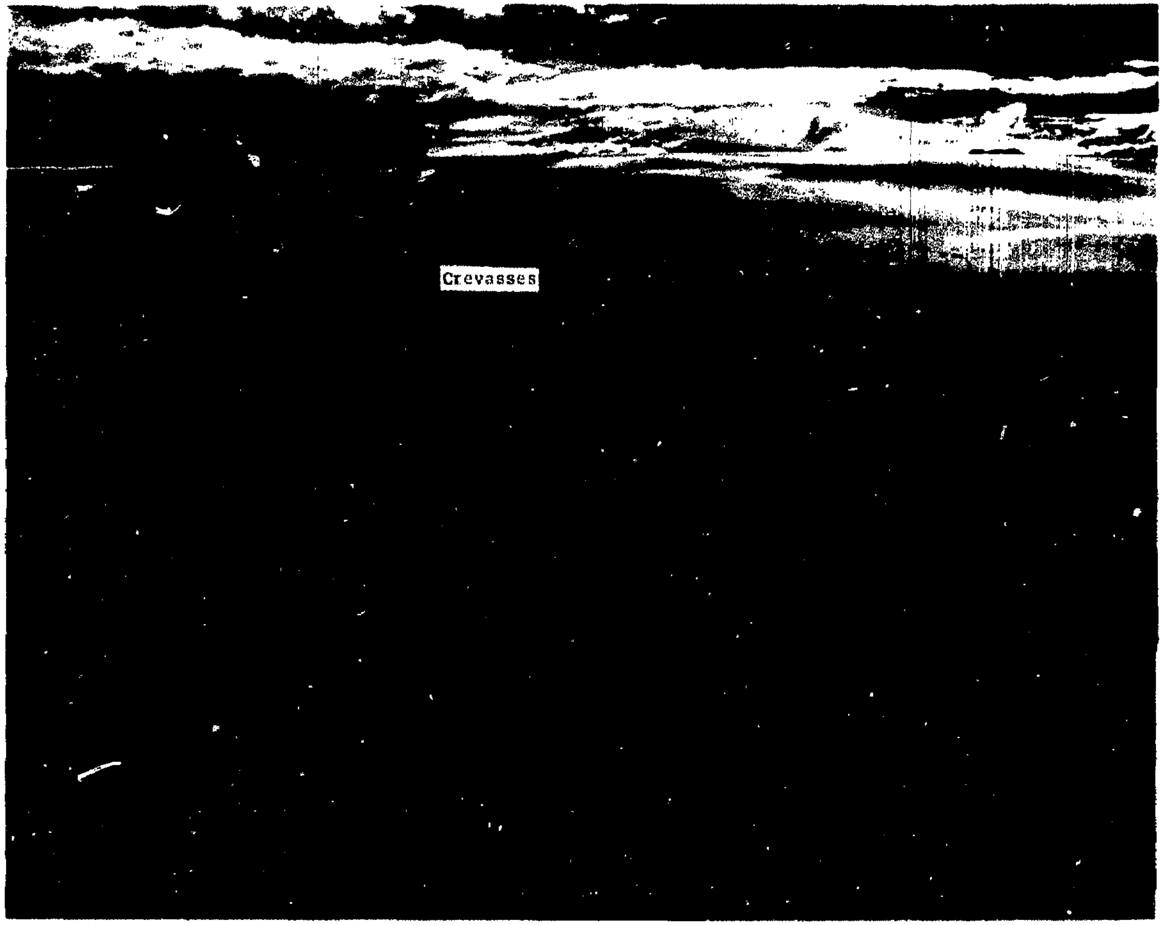

Figure 6. Aerial view of the trail to the skiway area near Palmer Station, Antarctica.

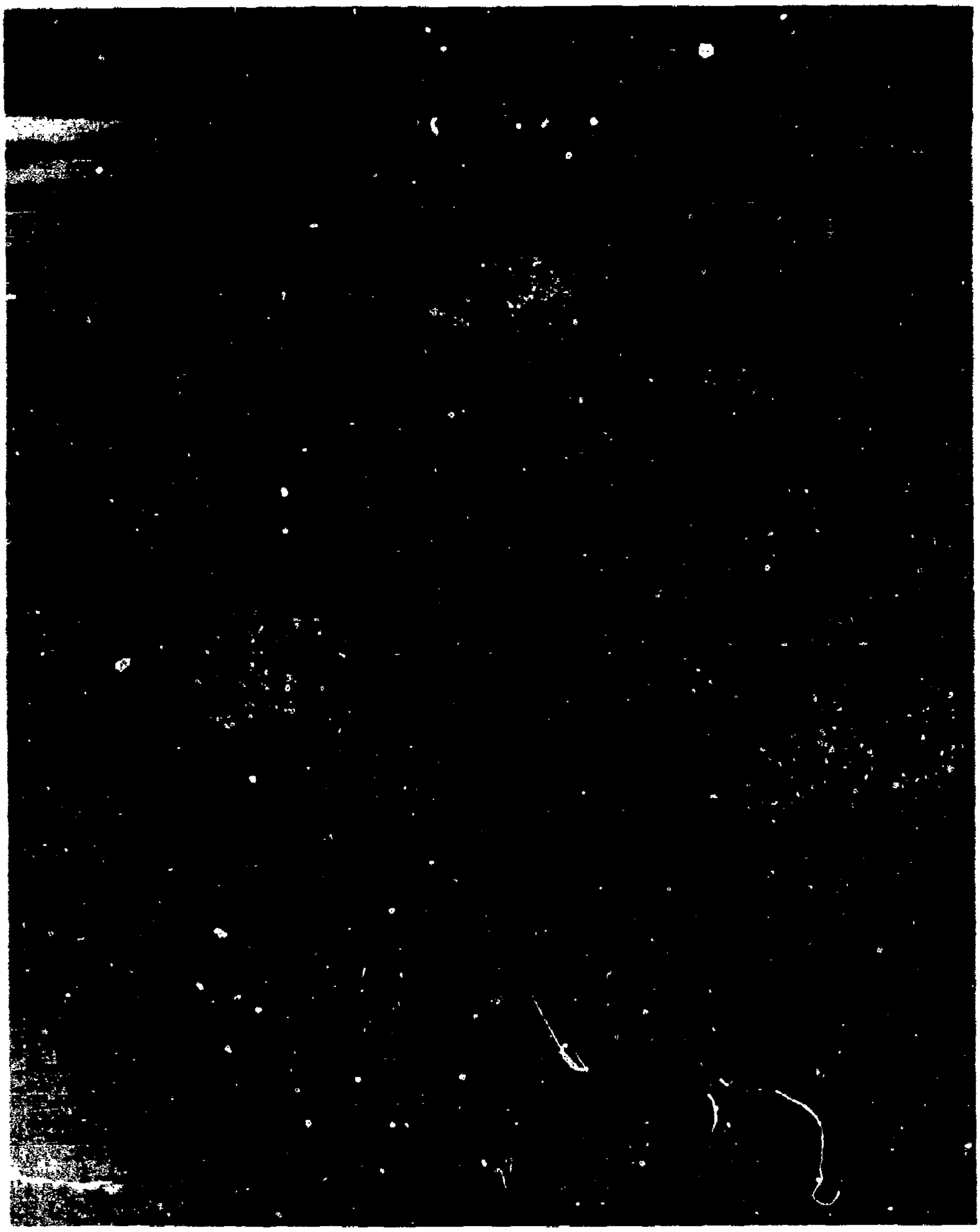

Figure 7. Aerial view, looking southwest, of the proposed skiway on the Marr Ice Piedmont.

Figure 8. Surface snow conditions at the proposed skiway during February, 1969.

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13. ABSTRACT

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Feasibility						
Skiways						
Runways						
Cargo aircraft						
Aircraft skiis						
Palmer Station						
Polar regions						
Antarctic regions						
Glaciers						
Ground reconnaissance						
Airial reconnaissance						
Tracked vehicles						
Cargo transportation						
Passenger transportation						
Logistics support						
Cargo vehicles						
Aircraft						