Engineering for Polar Operations, Logistics, and Research (EPOLAR)

Snow-Road Construction and Maintenance

Sally A. Shoop, Julia Uberuaga, Wendy L. Wieder, and Terry D. Melendy

December 2016

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Snow-Road Construction and Maintenance

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Final Report

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Under Engineering for Polar Operations, Logistics, and Research (EPOLAR)
Abstract

The snow roads at McMurdo Station, Antarctica, are the critical transportation corridors for moving personnel and material to and from the airfields servicing intra- and intercontinental air traffic. The construction, maintenance, and condition of these roads were analyzed during the Snow Roads and Transportation (SRT) program to develop the specific construction and maintenance guidelines presented here. These guidelines aim to allow yearlong transport by the vehicles in the McMurdo fleet and to prevent significant deterioration during the warmer periods of the Antarctic summer. This guidance was provided to the National Science Foundation in 2013 and serves as a Standard Operating Procedure (SOP).

This document expands on the SOP, providing a thorough strategy for constructing and maintaining snow roads, including additional background information and discussion not included in the SOP. While the methodology is aimed at construction, maintenance, and repairs of the snow roads on the Ross Ice Shelf at McMurdo Station, the information is applicable to other compacted-snow structures, especially those exposed to ground and air vehicle traffic.
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Preface

This study was conducted for National Science Foundation (NSF), U.S. Antarctic Program (USAP), Division of Polar Programs (PLR), under Engineering for Polar Operations, Logistics, and Research (EPOLAR) EP-ANT-13-03, “Snow Roads and Transportation Monitoring and Guidance.” The technical monitors were Margaret Knuth and George Blaisdell, Chief Program Managers, NSF-PLR, USAP.

The work was performed by Dr. Sally A. Shoop, Dr. Wendy L. Wieder, and Terry D. Melendy (Force Projection and Sustainment Branch, Dr. Sarah Kopczynski, Chief), U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL); and Julia Uberuaga, Antarctic Support Contract (ASC). At the time of publication, the Deputy Director of ERDC-CRREL was Dr. Lance Hansen, and the Director was Dr. Robert Davis.

We worked closely with personnel at NSF, Raytheon Polar Service Company (RPSC), and ASC on all aspects of this project and would specifically like to thank George L. Blaisdell and Margaret Knuth of NSF; Renee Melendy of CRREL; and Martin Reed and Bill Ames, Fleet Operations Managers at McMurdo Station. Amy Burzynski, Nicole Buck, and Matthew Bigl of CRREL assisted with the imagery.

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COL Bryan S. Green was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.
Acronyms and Abbreviations

ASC       Antarctic Support Contract
CBR       California Bearing Ratio
CIH       Clegg Impact Hammer
CRREL     U.S. Army Cold Regions Research and Engineering Laboratory
EPOLAR    Engineering for Polar Operations, Logistics and Research
ERDC      Engineer Research and Development Center
g/cc      Grams per Cubic Centimeter
HMW       High Molecular Weight
INTX      Intersection
kgf       Kilograms Force
kph       Kilometers per Hour
LDB       Long Duration Balloon
MP        Mile Post
NSF       National Science Foundation
PLR       Division of Polar Programs
R         Rammsonde Hardness Number
RPSC      Raytheon Polar Service Company
SBT       Scott Base Transition
SOP       Standard Operating Procedure
SRT       Snow Roads and Transportation
USAP      United States Antarctic Program
Winfly    Winter Fly-In
1 Introduction

1.1 Background

The snow roads at McMurdo Station, Antarctica are the primary transportation corridors for moving personnel and material to and from the airfields servicing intra- and intercontinental air traffic. The majority of the approximately 20-mile (32 km) road system is made of snow overlying a snow and ice subsurface. In addition, the 1000 ft (305 m) diameter Long Duration Balloon (LDB) Pad serves as a large “paved” snow area for the launching of large, instrumented monitoring balloons. Annually, the construction and maintenance of these snow roads and the LDB Pad require approximately 4000 operator and equipment hours between 1 September and 28 February.

During the austral summer, McMurdo snow roads are subjected to higher summer temperatures that can be above freezing for several days at a time. Above freezing temperatures result in severely reduced road strength, compound any snow-road construction or maintenance challenges, and make the snow roads and LDB Pad more susceptible to failure. Depending on temperatures, in some years, the snow roads fully support wheeled traffic for the entire summer season; and in other years they cannot. The cost of snow-road failure is significant. In the worst case, nearly all transport of personnel and supplies to and from aircraft servicing McMurdo must be via a few specialized, slow vehicles. This results both in delays due to limited vehicle resources and extra transportation time needed.

1.2 Objective

This document provides background and guidance for constructing and maintaining or repairing snow roads at McMurdo Station, Antarctica. These procedures will help maintain snow-road quality and extend the life expectancy of these roads for year-round use.

1.3 Approach

The use and maintenance of the snow roads and the transportation needs at McMurdo station were initially studied by Shoop et al. (2010) and
Seman (2012). These studies were used to develop a Snow Road and Transportation (SRT) research program (Shoop et al. 2009) to be integrated with the Single Airfield Concept study. As part of this study, a monitoring program was developed to evaluate snow-road use, maintenance, and conditions over the period of 2009 to 2013 and to integrate best practices needed for year-round maintenance and use of the snow roads as the major logistics and transportation corridor to McMurdo Station, the largest logistics hub in Antarctica.

This report presents guidance for snow road construction and maintenance based on the equipment used by the fleet operations department to construct surfaces able to withstand traffic from the modern vehicle fleet using the snow roads. The information and discussion included herein is also applicable to the construction and maintenance of other layered snow structures, especially those subjected to air and ground vehicle traffic.

The LDB Pad and the airfields are included in this report only in so far as they impact tasking (as mentioned in the seasonal task requirements). Although some of the procedures for the LDB Pad and airfields may be similar, they are not specifically addressed in this report.

The Fleet Operations department is responsible for all construction, maintenance, and repairs to the McMurdo road system. However, all snow-road users are responsible for keeping their vehicles clean and driving responsibly to minimize impacts on the snow roads and land–ice shelf transition areas.

This report serves as an accompaniment to Antarctic Support Contract (ASC) Manuals for construction and maintenance of the Scott Base Transition and the snow-road system in general (ASC 2014a, 2014b).
2 Equipment

Constructing, maintaining, and repairing the snow roads at McMurdo Station requires several pieces of equipment. The equipment being used as of 2015 is grouped below based on their primary function. Because the equipment will change from time to time, the rest of the report is written primarily in terms of function rather than for specific pieces of equipment.

2.1 Prime movers

- **Challenger**: The Caterpillar Challenger 95 is a dual-rubber-tracked agricultural tractor modified to operate in harsh Antarctic weather conditions. These tractors are designed to pull agricultural and construction equipment, trailers, and sleds.
- **Bulldozer**: The current Caterpillar low-ground-pressure D8 and D7 bulldozers replaced older models designed for work in Greenland in the 1950s that had primarily been used for equipment hauling. The new models are used for snow-road and snow- and ice-runway construction.
- **Case Quad Tracks**: These Case tractors operate on four tracks and are similar to the Challenger 95 but with more towing power and increased ground pressure. They were added to the ice shelf fleet in 2015.
- **Delta**: A smooth-tired Canadian Foremost Delta is sometimes used to harden the wearing surface of snow roads. These can also be used to pull implements.

2.2 Leveling planes

- **Goose**: This custom snow plane removes snow from the “peaks” of bumps and deposits it in the “valleys” between. The Goose can also be used to scrape snow and to move it laterally from one side of a road to the other, which is good for removing windrows.
- **Artsway and Eversman**: These pieces of equipment are two additional leveling planes used primarily on the airfields but occasionally on the roads. Their advantage over the Goose is that they can level a wider path and will smooth roughness of a longer wavelength.
2.3 Smoothing

- **Drag**: This device smooths the surface of the snow roads. It is sometimes as simple as a beam mounted on skis of adjustable height. It is commonly used to redistribute snow evenly over the road surface following a snow storm or wind event but can also be used as a finishing tool as the last step in road construction. In addition to smoothing the surface, using a drag on fresh snow reworks the snow and increases the density. It is also feasible to use a simple bar drag behind a Delta.

2.4 Compaction

- **Load cart**: Also called an oxcart, it is a box mounted on pneumatic tires and is used to carry various amounts of weight. A lightweight cart (35,000 to 45,000 lb [15,900 to 20,400 kg]) is used for initially building strength on the roads. The heavy 50-ton (45,000 kg) pneumatic-tired load cart is used for deeper compaction of snow once the road surface is able to support the cart’s weight. It has also been used as a “proof” cart to test the bearing support of a road, skiway, or runway prior to opening them for airplane and heavy-vehicle traffic.
- **Sheepsfoot roller**: Used to knead and compact, the depth of kneading depends on the length of the feet (tines) on the roller. This leaves a rough surface so should be followed by a smoothing process before the snow hardens (within a day).
- **HMW sheets**: These sheets of high molecular weight (HMW) plastic were originally tested for use on the South Pole traverse. They can be loaded with weight and efficiently pulled for surface compaction. This is most effective after the road is level and smooth and is particularly useful during higher temperatures when other compaction methods tear up the road surface.

2.5 Mixing, milling, leveling, and compacting

- **SnowPaver**: The SnowPaver completes snow milling, leveling, and compacting in one pass. The SnowPaver is an experimental piece of equipment evaluated on site during 2009–2011 (Shoop et al. 2014a) but is not permanently part of the McMurdo vehicle fleet.
2.6 Strength measurement

- **Rammsonde snow penetrometer**: The Rammsonde snow penetrometer has been used to assess snow strength for many years. The cone size that works best for the snow roads is smaller than that used in avalanche studies, however, and requires an adjustment in the strength calculation equation (see Appendix A). The Rammsonde measures a profile of the road strength but is not well suited for measuring at the surface.

- **Clegg Impact Hammer**: The 5 lb (2.25 kg) Clegg Impact Hammer is an effective measure of snow surface strength (Shoop et al. 2012) and is easily converted to the California Bearing Ratio (CBR) (Appendix A).
3 Road Layout

3.1 The McMurdo Ice Shelf road system

There are basically two major roads that compose the snow road system of the McMurdo Ice Shelf: the Pegasus Road and the LDB Road. The Pegasus Road runs the entire 14 miles (22.5 km) from the Scott Base Transition (SBT) to the Pegasus Airfield. Locations along the Pegasus Road are designated by Mile Post (MP) from 1 to 14. A few of the intersections are also named (such as the Happy Camper and LDB INTX [intersection]). The LDB Road splits from the Pegasus Road at approximately MP 3. Additional transient or temporary roads are the Pegasus Short Cut going from McMurdo to Pegasus over the sea ice and the LDB Short Cut going from the LDB town site to the Pegasus Road near MP 5. The short cut roads are not used to the same extent as the Pegasus and LDB Roads (i.e., the short cut roads are used only by tracked vehicles, are used only during a limited timeframe, or are not heavily trafficked). The ice shelf infrastructure and road system change over time; Figure 1 shows the configuration from 2012 to 2013. Appendix B provides maps from prior year’s operations.

3.2 The Scott Base Transition Area

The conditions at the SBT area are much different than for the rest of the snow-road system (e.g., the SBT has nearby cliffs, dirt tracked onto the snow, and significant melting and drainage issues) and require different procedures for both the dirt and the ice shelf portions of the transition. The Scott Base Transition Construction and Maintenance Manual (ASC 2014a) and Shoop et al. (2014b, 2015) document these requirements.
Figure 1. The 2012–2013 McMurdo road system map.
4 Season-Based Activities

There are three seasons of operations at McMurdo Station:

- **Winter**—The Antarctic Winter season runs from late February through mid-August. There is less traffic through any of the land–ice shelf transitions during this time.

- **Winter Fly-In (Winfly)**—This is a 6-week period beginning about 20 August and ending about 1 October. Historically, the influx of crew during this time provided the numbers to reopen station infrastructure and to construct the ice runway.

- **Main Body**—This period runs from 1 October to Late February and is the austral summer season, bringing a mass influx of personnel and the bulk of construction and research activities. The latter half of this period is also the most critical and debilitating to the entire snow-road system.

The following lists the procedures required for the routine maintenance of the snow roads. Additional maintenance for specific problems should occur as needed. LDB and Airfields are mentioned only for awareness of resource scheduling (equipment and operator), not for specific construction needs for these sites. LDB and snow-road duties are often combined during Winter and Winfly.

4.1 Winter

1. Drag LDB pad once per month. This takes approximately three days each time.
2. Drag at least one lane of the roads twice per month and after storms
3. Alternate which lanes are dragged so all lanes are worked over the Winter.
4. Drive on each of the lanes during the winter so as to use all lanes.

4.2 Winfly

1. Level and compact LDB, roads, and airfields once or twice per month in August and September and after snowfall. The LDB pad, Pegasus Road to MP 7, and the LDB Road each require two Challengers.
2. Compact, drag or Goose, let set to sinter, and repeat as per the routine maintenance procedure outlined in the next section.

4.3 **Main Body**

Continue with compaction, leveling, sintering, and repairs throughout Main Body by following the routine maintenance and repair procedures discussed in the Sections 5.3 and 5.4.
5 Procedures

Each time new construction, maintenance, or repair is required on the snow-road network at McMurdo Station, completing a maintenance form will allow tracking of problematic areas and will record the procedure is completed. This information is essential to improving the construction and maintenance procedures. Appendix C provides the current maintenance form used by the ice-shelf fleet-operations staff and illustrates the type of analysis used to document and optimize procedures by using the data from 2010 to 2013.

5.1 General guidelines for snow compaction, age hardening, and strength

Snow that is age hardened (sintered) for a long period at lower ambient temperatures achieves a higher strength than snow age hardened at higher temperatures (Drope 1977). This can be used to an advantage for a strong road surface by (1) leveling and compaction during the cold winter because the roads can sinter during the long periods when they are not in use and (2) moderate but significant strength gains from short sintering times during the warmer months when the roads are heavily used. The following are useful guidelines:

- Temperatures between $-40^\circ F$ and $25^\circ F$ ($-40^\circ C$ and $-4^\circ C$) are suitable for construction and hardening (Abele 1990).
- The age hardening of snow is slow in temperatures ranging from $-20^\circ F$ to $-40^\circ F$ ($-29^\circ C$ to $-40^\circ C$) and extremely slow below $-40^\circ F$ ($-40^\circ C$).
- The ideal temperature range for snow-road construction is $14^\circ F$ to $23^\circ F$ ($-5^\circ C$ to $-10^\circ C$) (Abele 1990).
- Temperatures greater than $25^\circ F$ ($-4^\circ C$) retard hardening and promote sublimation (Gow and Ramseier 1964).
- Compaction at temperatures greater than $25^\circ F$ ($-4^\circ C$) is possible and can be effective if compacting against a competent base layer or if the road is not used again until refrozen.

The minimum allowable density for constructed snow roads is 31 lb/ft$^3$ (0.5 g/cc). Although Drope (1977) recommends a Rammsonde hardness number of 450 units to a depth of 10 in. (25.4 cm), we effectively operate with the current vehicle fleet at strengths much softer than this; and the roads are not generally considered weak until the $R$ values is less than 60.
California Bearing Ratio (CBR) is a common strength index used for road and airfield design. Rammsonde can be converted to a CBR by using the equation below:

\[
\text{CBR} = 1.44 R^{0.48}
\]

with CBR (%) and Rammsonde hardness, \( R \) (kgf).

Road or airfield snow-strength requirements are based on usage (vehicle type, loading, and number of passes). Table 1 gives guidelines for strength requirements and associated maintenance and usage based on the snow-road measurements and observations made during the SRT program.

Table 1. Snow-road strength guidelines based on typical vehicle usage during 2009 to 2014.

<table>
<thead>
<tr>
<th>California Bearing Ratio (CBR, %)</th>
<th>Rammsonde ((R)), kgf</th>
<th>Road status</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 or more</td>
<td>150 or more</td>
<td>Excellent. Roads are usable for all vehicles</td>
</tr>
<tr>
<td>10 to 16</td>
<td>60 to 160</td>
<td>Very Good. Roads are usable for normal snow road vehicle use. Use snow-road use procedures (Raytheon 2009) to ensure continued good road conditions throughout the season.</td>
</tr>
<tr>
<td>3 to 10</td>
<td>5 to 60</td>
<td>Marginal. Monitor for weak areas. Implement controlled use of roads and modified vehicle operations (reduced speed and traffic) as needed. See also Shoop et al. (2013b, 2014b) for reducing vehicle impacts on roads.</td>
</tr>
<tr>
<td>3 or less</td>
<td>5 or less</td>
<td>Weak. Expect frequent road failures and stuck vehicles. Implement “warm weather” road use procedures, such as low contact pressure or over snow vehicles only, lower speeds, and limited traffic.</td>
</tr>
</tbody>
</table>

5.2 New snow-road construction

The procedure for construction of new snow roads is as follows:

1. Survey the road alignment, marking the target road-surface elevations on the location stakes for compaction and leveling reference.
2. If significant ice or other layering exists, cut or rip the snow (e.g., use ripper teeth on a dozer) to a suitable depth (24 to 30 in. [61 to 76 cm]) to ensure base strength and stability (homogeneous snow strength with depth) (Barthelemy 1975). This avoids unknowingly creating any strong surface or intermittent layer with weak underlying snow, which could cause problems later on.
3. Use the sheepsfoot roller to knead (mix and compact) the snow.
4. Compact the area, starting with a light (or empty) cart and then compacting with increasing weight to ensure maximum compaction in the base layer.
5. Smooth and level the base (Goose and drag).
6. As uniformly as possible, drag, push, or blow snow over the compacted base to form a layer approximately 6 in. (15 cm) thick.
7. Compact the layer of snow with the pneumatic weight cart, again starting with the light cart and working up in weight. It may require multiple passes with the same weight before a section will be able to support a heavier load.
8. Level and smooth the surface.
9. Repeat steps 6 through 8, placing, compacting, and leveling snow in 6 in. (15 cm) lifts until the roadway is built up to the surrounding snow elevation. (Alternately, a SnowPaver could be substituted for mixing, leveling, and compacting the 6 in. [15 cm] lifts.)
10. Allow the newly constructed roadway to sinter two to three weeks, closed to traffic, with only minimal or no maintenance of the surface. Work in new snowfall by smoothing and leveling drifts. Major snowfall depths will require additional compaction, and this could break up the earlier road surface if sintering is not adequate. Ideally, the snow-road strength should be monitored until an adequate strength is achieved (strength requirements are traffic load dependent, as discussed earlier).

It is essential that once the snow-road construction process is started, it be completed as quickly as possible to reduce the possibility of snowdrifts forming. The construction of the road should be completed in sections proportioned in size to accommodate the crew and machinery available. If this procedure is done over the course of the winter months or Winfly, the technique can be adjusted by leveling and compacting new snowfall, using it as lifts to gradually build up the depth of competent snow. The compacting should be done immediately after leveling and smoothing to allow maximum sintering time. Some tasks can also be combined into a single pass with implements in tandem, such as a sheepsfoot roller followed by a drag.

Construction speed is generally between 5 and 8 mph, with lower speeds used for compaction and higher speeds for implements such as the drag or SnowPaver. The impacts of speed depend on the snow temperature and specific conditions but has not been thoroughly quantified.
5.3 Routine maintenance

Once the initial roadway is constructed, maintain the road as follows:

1. Keep roadway lanes level and smooth (Goose and drag or SnowPaver).
2. Periodically test road stability and strength (weekly or more during the warm season); the minimum density should be 31 lb/ft³ (0.5 g/cc) and a Rammsonde hardness number of 60 R (CBR > 10) to a depth of 6 in. (15 cm) depending on road use expectations (see Table 1). If road stability and strength meet the minimum road requirements, continue with step 4. If not, continue compaction.
3. Compact the roadway. Aim for the heaviest weight possible with the progression starting at (1) sheepsfoot roller, (2) light cart, (3) empty heavy cart, and (4) heavy cart with weight. You may skip the sheepsfoot roller and light carts if the road will support the heavy carts.
4. Keep the surface smooth and level, working in new snowfalls quickly. A light surface compaction may be needed after snowfalls greater than 2 in. (5 cm). Snowfalls greater than 2 in. (5 cm) or accompanied by winds will usually need to be leveled and/or smoothed before compaction.
5. Allow the lane to sinter once reconstructed. A sintering (hardening) time of 3–4 days for age hardening is ideal (Barthelemy 1975). At lower temperatures, it may take longer to achieve adequate hardening (Abele 1990). A minimum of overnight is absolutely required even for light vehicle traffic.

When maintaining the roads, consider the following, also:

1. If the snow is old, it may be metamorphosed into crystals with minimal strength and will not compact or sinter unless it is milled to smaller grains or mixed with new snow to increase the number of grain-to-grain contacts.
2. Warm-snow operations often include limiting vehicle traffic to slower speeds or only over-snow vehicles. See the snow-road operating manual and snow-road training presented in Appendix E.
3. Even slight temperature drops of 2°F or 4°F (1°C or 2°C) during the austral summer nights will help the snow harden and may produce a surface strong enough for night or early morning operations.

5.4 Road distresses and repairs

Several types of problem areas, called road distresses, typically occur on the snow roads. The distresses cataloged during our study include washboards, potholes, blow outs, snow drifts, fresh snowfall, ruts and dirt on
the snow roads. Figure 2 shows some of the distresses. The major snow-road distresses and guidelines for repairing them follow.

Figure 2. Select snow-road distresses. Washboards freeze after forming from excessive speed in soft snow (upper left), rutting (upper right), dirt on the snow causing melt (middle), potholes (can be over 2 ft deep) near the transition chutes area (lower left), and drift accumulation caused by a rutted surface (lower right).
5.4.1 **Soft spots and pot holes less than 6 in. (15 cm) deep**

1. Close down the affected lane.
2. Use a bulldozer or tractor with blade to push and drag snow to fill the area affected by soft spots.
3. With the weight cart, compact the location by using increasing loadings, starting with track packing or the sheepsfoot.
4. Smooth and level the surface (Goose and drag).

An alternate method for steps 3 and 4 is to mill, level, and recompact using the SnowPaver.

5.4.2 **Soft spots deeper than 6 in. (15 cm) (blow outs)**

1. Close down affected lane.
2. Use a bulldozer or tractor with blade to cut down to the deepest affected location in the roadway.
3. With the weight cart, compact the affected area by using increasing loadings, starting with track packing or the sheepsfoot.
4. Push or drag 6 in. (15 cm) lifts of snow over the area.
5. Compact the lift by using increasing load levels.
6. Repeat steps 4 and 5, adding lifts (layers) until the repair is level with the roadway surface.
7. Level and smooth (Goose and drag) the surface.

An alternate method for steps 5 to 7 is to mill, level, and compact using the SnowPaver.

For all depths of soft spots and blow outs, the affected area should be compacted to 31 lb/ft³ (0.5 g/cc) and may need to age harden for 3–4 days with no traffic until it reaches a suitable hardness, depending on expected traffic loading (see Table 1).

5.4.3 **Snow drifts**

For small drifts, level and smooth (Goose and drag) the affected area.

Complete the following if the drift is greater than 6 in. (15 cm) in depth:

1. Level the surface and compact using increasing loadings.
2. Level and smooth as needed after compaction.
3. Allow the snow surface to sit for 3–4 days to age harden with no traffic. The time for age hardening may differ depending on the ambient temperature. Ideally, the road is designed so that only one lane will catch most of the drift so that the other lane can be used while the drifts are being re-worked.

5.4.4 Post storm (fresh snowfall)

1. If there are less than 2 in. (5 cm) of snowfall, compact the surface by using low-tire-pressure over-snow vehicles (e.g., Deltas and Kress described in Appendix A), a smooth-tired roller, SnowPaver, or other light-pressure compaction equipment. The lane can remain open to light traffic as needed.
2. If snowfall is greater than 2 in. (5 cm) in depth, immediately work in the new snow by smoothing (drag and Goose).
3. Weight-cart compact or roll the lanes by using increasing loadings if needed.
4. Level and smooth again if necessary, or tow the drag behind the weight cart in tandem.

An alternative method is to use the SnowPaver to level and compact.

5.4.5 Ruts and washboards

Address ruts as soon as possible to limit traffic in the failed areas, reducing damage to the snow roads and potential damage to vehicles.

If the rut or washboard is less than 6 in. (15 cm) in depth, level and smooth the location (Goose and drag or SnowPaver).

Complete the following if the rut is greater than 6 in. (15 cm) in depth:

1. With a bulldozer, cut down ruts greater than 6 in. (15 cm) in depth to the deepest affected spot of the rut or washboard.
2. Push or drag 6 in. (15 cm) lifts of snow over the area.
3. Weight-cart compact the location of failure by using increasing loadings, starting with track packing or the sheepsfoot.
4. Repeat steps 2 and 3 until natural snow elevation is reached.
5. Level and smooth the surface.
6. The affected area will not be open to regular traffic other than maintenance for 3–4 days to allow for age hardening.
Alternatively, substitute the SnowPaver for steps 3 to 5.

5.4.6 Dirt on the road

1. Dirt clumps should be picked up and removed from the snow road.
2. Large affected areas, such as at land–ice shelf transitions, should be covered with clean stockpiled snow in 6 in. (15 cm) lifts by using a bull dozer.
3. With increasing loadings, use weight-cart compaction over the area.
4. Repeat steps 2 and 3 until the dirt is buried (ideally 1.5 to 2 ft [46 to 61 cm]) below the road surface to limit burn through.
5. Assessing and repairing specific problem areas

We also developed a methodology similar to that used in rating unsurfaced roads (Eaton, et al. 1987) to easily visually assess the distresses on the roads and to color code the need for repairs based on the severity of the distress: red needs immediate attention, yellow indicates to watch the area and repair when convenient, and green indicates no repair is needed. Table 2 shows this assessment system. Table 3 illustrates how the assessment applied to the snow roads. Appendix D shows how this assessment can be used to track the health of the snow roads over time.

Table 2. The severity levels for the major snow-road distresses (top), and the color bar used to assess the snow brightness (related to albedo) on a scale of 1 to 10 (bottom).

<table>
<thead>
<tr>
<th>Severity Rating</th>
<th>Whiteness Value using color bar below</th>
<th>Rutting (depth, in.)</th>
<th>% of Lane Impassible</th>
<th>Snow—Drifting or Fresh (depth, in.)</th>
<th>Potholes (depth, ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green = Good</td>
<td>0–2</td>
<td>0–2</td>
<td>0–24</td>
<td>0–2</td>
<td>0–1</td>
</tr>
<tr>
<td>Amber = Caution</td>
<td>3–5</td>
<td>0–10</td>
<td>25–49</td>
<td>3–5</td>
<td>2–3</td>
</tr>
<tr>
<td>Red = Needs Attention</td>
<td>6–10</td>
<td>10+</td>
<td>&gt;50</td>
<td>6+</td>
<td>3+</td>
</tr>
</tbody>
</table>

![Color bar image]
Table 3. An example of applying the snow-road condition assessment along the snow road.

<table>
<thead>
<tr>
<th>Snow Road Conditions</th>
<th>Name: Maggie</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Date: 1/9/12</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>MP12</td>
<td>MP10</td>
</tr>
<tr>
<td>Time:</td>
<td>1015</td>
<td>1015</td>
</tr>
<tr>
<td>Open Wheeled Lane (A,B,C, Track)</td>
<td>Track</td>
<td>Track</td>
</tr>
<tr>
<td>Color (0=white, 10=black)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Rutting (depth in inches)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% of lane impassible</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>Snow - drifting or fresh (depth in inches)</td>
<td>2.5</td>
<td>4</td>
</tr>
<tr>
<td>Potholes (depth in feet)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
6 Summary

This report provides specific guidance and procedures to make the best decisions regarding the construction, maintenance and use of the snow roads. Additionally, it offers methods to track or monitor road maintenance, use, and conditions to ensure passable snow roads are available throughout the Antarctic summer. With adequate attention to snow-road construction, maintenance, and use guidance, the snow roads will remain usable throughout the year.
References


MVM BNI JV Ltd. 2016. CBR (less than 50) and the Medium (2.25 kg – 5 lb) Clegg Impact soil tester. Developed for the Dublin Light Rail Transit Project, Track and Building Works C600. Perth, Western Australia: Dr. Baden Clegg Pty Ltd.


Appendix A: Snow-Road Maintenance Equipment

Many pieces of equipment are used to construct and maintain the snow roads, and we briefly describe these below.

Prime movers

Prime movers serve as the backbone of the ice-shelf vehicle fleet. They pull a variety of pieces of equipment (implements), depending on the need. Several types of prime movers are used on the ice shelf, but the bulk of the heavy lifting is currently done by the Challenger tractors.

- The machines in highest demand during the summer season are the Challenger tractors. The Caterpillar Challenger 95 is a rubber-tracked agricultural tractor modified to operate in harsh Antarctic weather conditions. With a drawbar pull of 60,000 lb (27,215 kg), these tractors are designed to pull agricultural and construction equipment, trailers, and sleds. Prior to the introduction of more modern, heavy, off-road tractors, the Challengers were the backbone of the McMurdo heavy-construction fleet.

- Bulldozers are the second preferred method for snow-road construction and maintenance. Their sizes range on site, but Caterpillar D-7 and D-8 models are stationed on the permanent ice shelf and are responsible for assisting with pulling implements and with constructing the transition (section of road that connects the permanent ice shelf to Ross Island). The drawback to using bulldozers is their inability to travel at speeds over 7 mph (11.3 kph). However, they are capable of pulling heavy implements and loads for compacting, smoothing, and planing and in tandem to improve efficiency.

- A smooth-tired Canadian Foremost Delta is sometimes used to harden the wearing surface of snow roads. These can also pull implements.

- Recently, the Caterpillar Kress tractor unit has been used as a prime mover when not hauling cargo or passengers. The Kress tractor is a Caterpillar 730 articulating dump truck frame and cab with an eight-person carrier on the back. This tractor has a wheelbase of 17.1 ft (5.2 m) and a length 35.7 ft (10.9 m). The height is 12.3 ft (3.7 m), and it has a width of 11.3 ft (3.4 m) and weighs approximately 72,400 lb (32,840 kg).
• The Case Quadtrack 535 tractor has a wheelbase of 5.1 ft (1540 mm) and a length of 3.7 ft (1120 mm) and weighs approximately 70,000 lb (31,750 kg). These are also occasionally used when they are in town and available as they are also used for traverse applications.

Figures A-1–A-5 are pictures of each of the prime movers.

Figure A-1. Caterpillar Challenger 95E at McMurdo, January 2014.

Figure A-2. Caterpillar D-7 Bull Dozer with sheepfoot and drag, November 2011.

Figure A-3. Delta with added weight for compacting, November 2010.
The snow-road implements currently used at McMurdo Station are separated into three different groups: compaction, smoothing, and planning equipment. Each category of attachments aids in constructing and maintaining snow roads.

**Compaction**

The sheepsfoot roller (Figure A-6) weighs approximately 15,000 lb (6804 kg) and has two steel drums with 6 in. (15 cm) tines. The roller weight can be increased by adding a non-freezing fluid, such as glycol, into the drum. The intended use of the sheepsfoot is for precompacting the snow road in soft snow conditions. This is often (but not always) followed by the use of an oxcart.
The other main compaction tools used on the snow roads are the oxcarts (Figure A-7), which are pneumatic tired and can be loaded in excess of 60,000 lb (27,200 kg). There are two oxcart weight carts at McMurdo, and they often are loaded at different weights and used to progressively compact the roads.

For near-surface compaction or compaction during warm periods, the smooth-tired delta or a high molecular weight (“magic carpet”) sheet carrying an evenly weighted load can be used.

**Smoothing**

Smoothing the surface is achieved using primarily steel drags (Figure A-8) that can be towed solo or in tandem behind a compaction implement. The drags are typically 15 to 20 ft (4.6 to 6.1 m) wide. A drag is used to smooth the surface of the snow roads and is most commonly the last piece of con-
struction equipment used during road construction. It is also used to re-
distribute snow evenly over the road surface following a snowstorm or
wind event.

Figure A-8. A variety of drags are used on the ice shelf, depending on the application.

The drags at McMurdo have various features (height adjustments, a range
of widths, and serrated or smooth) for different needs (roads, town sites,
or pads).

**Planing**

The Goose (Figure A-9) is capable of removing bumps, also referred to as
“rollers,” or large snow drifts. The Goose is a custom snow plane used to
remove long-wavelength “bumps” on snow and ice roads. It is designed to
remove snow from the “peaks” of bumps and deposit it in the “valleys” be-
tween. The Goose can also be used to scrape snow and to move it laterally
from one side of a road to the other.

The Goose has a 15 ft (4.6 m) wide serrated cutting blade with skis to slide
along the road surface. Artsway and Eversman land planes (Figures A-10
and A-11) are bump-removal implements similar to the Goose but have 24
ft to 30 ft (7.3 m to 9.1 m) serrated cutting blades and are capable of re-
moving longer-wavelength oscillations on the snow surface. The removal
of these bumps is important because they can lead to pot holes or “blow outs” due to vehicle bouncing. Bumps are also particularly dangerous to operators in flat light conditions.

Figure A-9. The Goose behind a Challenger.

Figure A-10. Artsway behind a Challenger.

Figure A-11. An Eversman behind a Challenger.
SnowPaver

The SnowPaver (Figure A-12) is an experimental implement designed by Michigan Technological University Keweenaw Research Center and evaluated by CRREL over the course of the 2010–2011 summer season. The SnowPaver was designed to be capable of smoothing, grading, milling, and compacting in one pass. This would historically take three passes to complete the same tasks. During testing, the proof of concept had issues with producing enough hydraulic pressure and flow to operate all of the different functions at once but was effective for plate vibratory compaction of the surface and for grading. An on-board power pack was designed and installed on the SnowPaver in November of 2012. The upgrade consisted of a new motor with enough power for all the paver functions to operate at the same time, independent of the tow vehicle. The new power pack enables the SnowPaver to be used with a wider range of tow vehicles (Shoop et al. 2013a, 2014a).

![Figure A-12. The SnowPaver, November 2012.](image)

Snow Moving

At times, snow needs to be moved from one place to another and the Reynolds, Bronco, or other boxes are used (shown in Figure A-13).
Figure A-13. Various box implements for moving large quantities of snow.
**Strength monitoring**

The U.S. Army adapted the Rammsonde, seen in Figure A-14, from an instrument originally used in the Swiss Alps for estimating avalanche danger and for determining allowable wheel loads on artificially compacted-snow pavements. The Rammsonde that is usually used on snow roads has a smaller cone with a diameter of 0.94 in. (2.4 cm), a height of 1.54 in. (3.9 cm), a total length of 1.97 in. (5 cm), and a 60° conical tip. The smaller cone is more sensitive to snow strength in the range seen on snow roads and is also easier to use (both to insert and to remove) on compacted-snow surfaces. The Rammsonde hardness number, $R$, is an index that indicates the snow’s resistance to the vertical penetration (in kilograms force, kgf). The hardness reading is calculated from the number of hammer blows (drops) required to penetrate a measured distance (Figure A-15). The penetration force is obtained using a slide hammer of specific weight dropped from a measured height.

Surface strength is best measured using a Clegg Impact Hammer (CIH) (Figure A-16). The CIH consists of a cylindrical mass hammer that is dropped within a guide tube from a set height. We found that the medium 5.0 lb (2.2 kg) CIH was the most suitable for characterizing the snow-road strength. All of the CIHs have the same diameter: 17/8 in. (4.76 cm). Shoop et al. (2012) give a more detailed analysis of the use of the CIH on snow and a comparison of the three CIH sizes and their use on the snow roads.

*Figure A-14. Rammsonde snow-hardness-profiling measurement.*
Strength conversions

For roadway applications, CBR is a common parameter for indicating the road’s ability to bear traffic. Therefore other strength measurements, such as those taken with the Rammsonde and CIH are converted to CBR.
Abele (1990) gives the following equation for converting the Rammsonde $R$ into CBR:

$$CBR = 1.44R^{0.48} \quad (A1)$$

CBR may be calculated from the CIH data by using one of the more recent models that relates CIH data to soil strength. For the 2.25 kg (5 lb) CIH, the equation was developed by the contractor for the Dublin Light Rail Transit Project for clay materials in that city with CBR less than 50 and mostly in a range of less than 15% CBR. The correlation was generated between the laboratory-measured CBR and the 3rd drop of the 2.25 kg (5 lb) CIH (MVM BNI JV Ltd. 2016). The equation developed was presented in the following form:

$$CBR = e^{\left(10 \times CI V - 14.936\right)/79.523} \quad (A2)$$

where $CI V$ is the Clegg Impact Value, the value for the third drop of the 2.25 kg (5 lb) CIH from a height of 0.45 m (17.7 in.).
Appendix B: Annual McMurdo Snow-Road-System Maps
## Appendix C: Sample Snow-Road Maintenance Form and Data Analysis*

<table>
<thead>
<tr>
<th>Operator</th>
<th>Name</th>
<th>Date</th>
<th>Shift</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ New Construction</td>
<td>□ General Maintenance</td>
<td>□ Post Storm Maintenance</td>
<td>□ Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Vehicle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Challenger_____</td>
<td>□ Dozer_____</td>
<td>□ Delta_____</td>
<td>□ Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Towed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Goose</td>
<td>□ Drag</td>
<td>□ Bronco Box</td>
<td>□ Culvert</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Eversman</td>
<td>□ Artsway</td>
<td>□ Sheepfoot</td>
<td>□ Maxi Groomer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Light Cart (34400#)</td>
<td>□ Heavy Cart (42280#)</td>
<td>□ PEG Cart (144000#)</td>
<td>□ Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Added Weight (lbs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road/Runway Name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Pegasus Road</td>
<td>□ LDB</td>
<td>□ Pegasus Short Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ White Ice Runway</td>
<td>□ Skiway</td>
<td>□ Sea Ice Runway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Peg Town Site</td>
<td>□ LDB Town Site</td>
<td>□ Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Designation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Track</td>
<td>□ A</td>
<td>□ B</td>
<td>□ C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mile Point Start</td>
<td></td>
<td>→</td>
<td>□ Silver City Intersection</td>
<td>□ LDB Town</td>
<td></td>
</tr>
<tr>
<td>Mile Point Stop</td>
<td></td>
<td>→</td>
<td>□ Silver City Intersection</td>
<td>□ LDB Town</td>
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</tr>
<tr>
<td>Other Info:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Maintenance Data Collection

- **FY10 (2009/2010)**
  - Initial maintenance tracking reporting efforts, filled out by several folks, computer entry by Angela.

- **FY11 (2010/2011)**
  - Improved forms with automatic spreadsheet entry. Filled out by several folks, input by whoever had time.

- **FY12 (2011/2012)**
  - Forms filled out by all, entered by Brett

- **FY12 Winter, first time ever!**

- **FY13 – fully ASC (Greg Murphy)**
FY13: Season Maintenance Record

FY13: Frequency of Equipment Use
FY13: MP2 and MP10

FY13 Compaction

Pegasus Road Compaction Events

Sheepsfoot Early

Increase Compaction Weight

SnowPaver for warm surface compaction

# of Events


Lt. Cart Hr. Cart Sheepsfoot SnowPaver
3 Year Comparison by Lane

![Bar chart showing the comparison of events by lane over three years (FY11, FY12, FY13).]

3 Year Comparison by MP

![Bar chart showing the comparison of events by MP over three years (FY11, FY12, FY13).]
**Comparing Compaction Events**

**Winter Maintenance FY12**

- First time winter crew using forms
- Monthly rpts to Marty/Sally from Robert Teoucher
- Winter Crew: Fogg, Shaw, Nash, Long, Barcomb, Ellingson, Harter
Winter Maintenance FY12

Summary of observations:

- 5 Sheepsfoot LDB Rd (April & May 2012)
  - Lane A: 1 x
  - Track Lane: 4 x

- Drag to LDB 22 x April to Aug
  - Lane A: 6 x
  - Lane B: 3 x
  - Tx Lane: 12 x

- Drag entire Pegasus Rd 46 x April to Aug
  - Lane A: 14 x
  - Lane B: 7 x, Lane C: 1 x
  - Tx Lane: 24 x
Season Maintenance Record

Full 11-12 Record

Frequency of Equipment Use

FY13 Oct-Feb
FY13 SnowPaver Use

- 40 Events including:
  - All Sections of Rd
  - LDB Shortcut
  - Mad Mile
  - 3 new construction uses
  - 3 post storm uses
  - 2 skiway uses
- All by Carney, except
  - 1x Alger, 2x Ridley, 1x Hobson
Appendix D: Assessment Criteria for Snow-Road Condition*

Road Condition Monitoring – Visual Assessment

**GOAL:** A quick (drive by) and easy way to-
- Document state of the roads (location, date) for planning purposes
- Document road repair and maintenance needs

**Distresses:**
- Rutting, Potholes
- Drifting, Tigertraps
- Melt pockets
- Dirt on roadway, Albedo
- Washboard, roostertails

* Shoop, S. 2012. SRT FY12 Monitoring & Maintenance. CRREL presentation to NSF. Hanover, NH: U.S. Army Engineer Research and Development Center.
Road Distresses

Rutting, potholes, tigertraps
Drifting, snowfall
Melt pockets, lensing (greenhouse effect)
Dirt on roadway, low Albedo
Washboards, roster tails

Guidelines for Maintenance

Yellow = keep an eye out!
Red = immediate attention
Green = good

<table>
<thead>
<tr>
<th>Location</th>
<th>MP12</th>
<th>MP10</th>
<th>MP6</th>
<th>MP4</th>
<th>MP2</th>
<th>MP0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Lane</td>
<td>Track</td>
<td>Track</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Surface color (0=white, 10=black)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rutting (&lt;2 inch, &lt;=6 inch, &gt;6-10 in. &gt;10 inch)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ditch on road / Ditch craters (diameter, width)</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Snow drifting (max depth)</td>
<td>None</td>
<td>0-4 cm</td>
<td>4-22 cm</td>
<td>11</td>
<td>6 cm</td>
<td>8 cm</td>
</tr>
<tr>
<td>Fresh snow fall (depth)</td>
<td>None</td>
<td>3-10 cm</td>
<td>6 cm</td>
<td>8 cm</td>
<td>1 cm</td>
<td>1 cm</td>
</tr>
<tr>
<td>Soft Spots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potholes (&lt; 3 ft), blowouts (&gt; 4 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tiger Traps</td>
<td>One near MP 3.5</td>
<td>One near MP 3.5</td>
<td>One near MP 3.5</td>
<td>One near MP 3.5</td>
<td>One near MP 3.5</td>
<td>One near MP 3.5</td>
</tr>
<tr>
<td>Melt Pockets, Lensing or Greenhouse effect under smooth, shiny snow in warm temps (&lt; 1 ft &gt; 2 ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Example Results - Rut depths at a glance

<table>
<thead>
<tr>
<th>Date</th>
<th>MP 12</th>
<th>MP 10</th>
<th>MP 8</th>
<th>MP 4</th>
<th>MP 2</th>
<th>MP 0.5</th>
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<tr>
<td>Saturday, November 12</td>
<td>1</td>
<td></td>
<td>1</td>
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</tr>
<tr>
<td>Wednesday, November 16</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wednesday, November 23</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Monday, November 28</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Friday, December 02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tuesday, December 06</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Wednesday, December 07</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<td>0</td>
</tr>
<tr>
<td>Friday, December 09</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tuesday, December 13</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tuesday, December 20</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wednesday, December 21</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Friday, December 23</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Monday, December 28</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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Appendix E: Snow-Road User Training*

Snow Roads are made of packed snow
- The hard top layer is about 12” thick
- This layer is very fragile To conserve the road:
  - Stay in 4-wheel drive
  - Do not speed
  - Vehicle must have large tires for use on snow roads
- There are two lanes for pick-ups and vans, and one lane for tracked vehicles, including MATTRACKs and Pisten-Bullys
- The TRACK lane is for track vehicles (unless directed otherwise)


SNOW ROADS

The lanes will be marked
YES (green) = OPEN
NO (red) = CLOSED

Drive on the open lane.
Do not change lanes
because you will get
stuck.

DRIVING ON
SNOW AND ICE

- A few tips for driving in ice and snow:
  - Down shift to slow down on hills
  - Do not step hard on the brake, pump, or pulse the
    brakes instead
    - Anti-lock brakes will not stop a skid
  - Turn into a skid
  - Slow down, what’s the hurry?
Snow Road Preservation Training

Snow Roads: A Melting Road During Austral Summer

1. Snow roads are constructed by compacting the grains and leaving them to sinter (fuse) together.

2. Snow (and the sintered bonds) deform easily from vehicle loading, especially during warm or sunny days at McMurdo (or anywhere else!)

3. Our road system contains over 14 miles of roads made of snow to travel to Pegasus Airfield

4. Starting December, our summer resupply and all staff comes into and out of Pegasus and must travel on these snow roads to get in or out of McMurdo Station

5. Therefore, preserve our snow roads! They are the transportation lifeblood for operating McMurdo!!!
Why Speed Damages the Road

20 mph leaves only tire imprint

25 mph leaves "rooster tails"

It’s not just about driving on slippery surfaces, it’s about preserving the road!

Bouncing the vehicle by speeding will destroy the snow bonds creating a weak surface for those behind you

Later freezing up for a frozen washboard
Other Distress Examples

Only you can prevent snow road deterioration

- Low Speed (25 mph)
- Low Tire Pressure (18 psi)
- Clean & Wash Vehicles
- Limit Traffic
- Limited to Wide Tire Vehicles
- Use the entire lane to smooth ruts with large tires
Everyone gets stuck …
Fleet Ops, Channel 5
The snow roads at McMurdo Station, Antarctica, are the critical transportation corridors for moving personnel and material to and from the airfields servicing intra- and intercontinental air traffic. The construction, maintenance, and condition of these roads were analyzed during the Snow Roads and Transportation (SRT) program to develop the specific construction and maintenance guidelines presented here. These guidelines aim to allow yearlong transport by the vehicles in the McMurdo fleet and to prevent significant deterioration during the warmer periods of the Antarctic summer. This guidance was provided to the National Science Foundation in 2013 and serves as a Standard Operating Procedure (SOP).

This document expands on the SOP, providing a thorough strategy for constructing and maintaining snow roads, including additional background information and discussion not included in the SOP. While the methodology is aimed at construction, maintenance, and repairs of the snow roads on the Ross Ice Shelf at McMurdo Station, the information is applicable to other compacted-snow structures, especially those exposed to ground and air vehicle traffic.