Engineering for Polar Operations, Logistics and Research (EPOLAR)

Rock Material Management at McMurdo Station, Antarctica

Margaret A. Knuth and Terry Melendy

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Final report
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Prepared for National Science Foundation, Office of Polar Programs, Antarctic Infrastructure and Logistics Program
Under Engineering for Polar Operations, Logistics and Research (EPOLAR)
Abstract: To support the extensive science efforts at McMurdo Station, and a population of more than 1000 each austral summer, there is a large operational component. Locally sourced rock material is required for annual maintenance of the ice pier, general earthworks, and building construction. Collection and use of these rock materials is governed by programmatic and project specific environmental assessments; and currently, several locations around the Station are used for generating rock material, which is then collected by scraping or blasting. This report outlines historical use of rock material and provides recommendations on future efforts. In particular, over the long term, it is recommended that the US Antarctic Program employ alternative methods to annual material usage, establish a rock quarry at McMurdo to centralize material collection operations, and purchase a crusher to make better use of collected material.
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Preface

This study was conducted as part of Engineering for Polar Operations, Logistics and Research (EPOLAR).

The work was performed by Margaret A. Knuth and Terry Melendy (Force Projection and Sustainment Branch, Dr. Edel Cortez, Chief), U.S. Army Engineer Research and Development Center−Cold Regions Research and Engineering Laboratory (ERDC-CRREL). At the time of publication, Jennifer Mercer was the program manager for EPOLAR, Dr. Justin Berman was Chief of the Research and Engineering Division. The Deputy Director of ERDC-CRREL was Dr. Lance Hansen and the Director was Dr. Robert Davis. COL Kevin J. Wilson was the Commander and Executive Director of ERDC, and Dr. Jeffery P. Holland was the Director.

This work could not have been completed without the assistance of the staff of Raytheon Polar Services Company (RPSC). In particular, we would like to thank Martin Reed (Fleet Operations Supervisor), Nathan Biletnikoff (Environmental Lead), and James Story (Equipment Manager) for the data and assistance they provided. Carrie Vuyovich (CRREL) also supported this effort by creating of Figure 2.
# Unit Conversion Factors

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To Obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td>cubic yards</td>
<td>0.7645549</td>
<td>cubic meters</td>
</tr>
<tr>
<td>feet</td>
<td>0.3048</td>
<td>meters</td>
</tr>
<tr>
<td>inches</td>
<td>0.0254</td>
<td>meters</td>
</tr>
<tr>
<td>pounds (force)</td>
<td>4.448222</td>
<td>newtons</td>
</tr>
<tr>
<td>pounds (force) per square inch</td>
<td>6.894757</td>
<td>kilopascals</td>
</tr>
<tr>
<td>pounds (mass)</td>
<td>0.45359237</td>
<td>kilograms</td>
</tr>
<tr>
<td>yards</td>
<td>0.9144</td>
<td>meters</td>
</tr>
</tbody>
</table>
1 Introduction

McMurdo Station, the largest of the United States Antarctic Program (USAP) stations, is located on a mostly ice-free area on the southern end of Ross Island. Opened in the mid-1950s, the Station has a long history of development as a support center for Antarctic research in the region and around the continent (Klein et al. 2008). To support the extensive science efforts, and a population of more than 1000 each austral summer, the Station has a large operational component charged with station construction. This includes annual maintenance on the ice pier and roads and general earthworks and building construction. Locally sourced rock material is required for many of these tasks, including surface preparation and leveling, bulk fuel containment berms, and ditch intake and outfall protection.

Programmatic and project specific environmental assessments, as prescribed by the Protocol on Environmental Protection to the Antarctic Treaty, govern the collection and use of these rock materials. Currently, several locations around the Station are used for generating rock material, which is then collected by scraping or blasting. For several years, it has been recognized that the program required a comprehensive review of material collection and uses as well as a focused plan for the future (RPSC 2005).
2 Material Types and Usage

Material on Ross Island is volcanic rock classified by type (red or gray) and by size (coarse-grained material—greater than 3 in.; fines—3 in. minus). The material types are sourced from various locations on Station and have different material properties. Most notably, gray materials (vesicular basalt) weigh approximately 3000 lb/yd$^3$ versus reds (felsitic scoria) weighing approximately 2000 lb/yd$^3$ (i.e., grays are denser than reds) (RPSC 2005). Reds also have a higher tendency to be crushed because of their high porosity and many vesicles.

The size of the material is classified by picking up scoops with the bucket loader and dumping it over a metal screen known as a “grizzly.” Several screens, produced by Snowline Manufacturing Inc., are on Station, with the most critical being the $3/8$-, $3/4$-, and 3-in. screens (Reed 2011a). A 5-in. screen had also been heavily used prior to its being broken, and it has not been repaired to date. Oversized material is handled with the dozer.

Rock material (coarse-grained and fines) is used annually to “sand” the roads and pedestrian paths for personnel safety, to repair local roads, to restore land to sea-ice transitions, to complete pad maintenance, and to protect the ice pier’s surface. Other, irregular, uses include replacing losses from wind storms, culvert work, new fuel tank pads and berms, project specific pad construction (e.g., SuperDARN, T-1 and T-5, day tank upgrades), and historical landfill capping. Gray materials are preferred for the larger construction projects because of their higher density and strength, but material type is limited by the collection locations.
3 Collection: Past and Projected Use

A variety of documents were reviewed: the most relevant environmental documentation is summarized in Table 1. Most of these documents state the need for a programmatic, long-term plan for material collection and use. In addition, they recommend that a database of collection and use should be instituted. To date, this has not been put in place. In an attempt to capture use trends, information was pulled from any available source. Besides the estimates in the environmental documents, this included various personal communications with the contract staff in McMurdo. This resulted in five seasons of use data in ten seasons of projected needs (Fig. 1). From 2003–2009, projected materials have been underestimated by 3000–8000 yd$^3$ (though, conversely, 2011 shows a serious decrease in material use). This underestimate was recognized in the most recent environmental documents; and, combined with anticipated project construction, the estimated material needs will rise to approximately 26,000 yd$^3$ through the 2012–13 season (NSF 2010). Current and past collection locations are defined in Figure 2. An overview and analysis of these locations are presented in Appendix A.

![Graph of material use](image-url)
Figure 2. Past and present rock material collection locations (as of 2011).
<table>
<thead>
<tr>
<th>Document tracking number</th>
<th>Title</th>
<th>Date approved</th>
<th>Duration of activities</th>
<th>Other Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td>IEE for the Proposed Replacement, Operation, and Decommissioning of Ice Wharves at McMurdo Station, Antarctica</td>
<td>5/23/92</td>
<td>Lifetime?</td>
<td>Reviews capping of wharf with fines—with material being removed and stockpiled for the following season at the end of each offload period.</td>
</tr>
<tr>
<td>MCST0500. R02</td>
<td>Gathering Fines Adjacent to Fortress Rocks for Maintenance and Improvement to the Former Landfill and Waste Processing Area, McMurdo Station, Antarctica</td>
<td>10/22/04</td>
<td>10/2004–10/2007</td>
<td>Fines collection and use for landfill cap and grading around fortress rocks. Scraping of loose material covered. Over 3 years, 43,312 yd³ projected for this project. Estimated completion of Rock Material IEE by FY05.</td>
</tr>
</tbody>
</table>

Upon initial report development, these were the only existing environmental documents available. However, on completion of a draft report in August 2011, an additional environmental document, MCST120.IEE: Collection of Rock Fines at McMurdo Station, Antarctica, was developed using much of this information as a reference and signed 19 November 2011.
4 Rock Material Production

4.1 Equipment

Current material production techniques include scraping and blasting. In scraping, ice-free surfaces are scoured down a few inches over a large area. With this method, the intent is that the “original” surface profile can be maintained while providing a very small amount of material over a large area of disturbance. Little rip rap, large rock material, is produced with this method. The second method, blasting, provides rock material as a result of the development of other projects or specifically for the collection of the material. Depending on the location, blasted material can be very icy and may require thawing before use. Blasting may also produce large material and fewer fines than the scraping technique. RPSC (2005) also discusses collecting loose rock by hand but notes it as an extremely inefficient process and will not be discussed further here. After collection, material must be passed through the grizzlies for classification for further use or storage until needed in future projects.

To accommodate a projected average yearly usage of 26,000 yd$^3$, we investigated alternate ways for producing material. Current methods are time consuming and not guaranteed to meet construction volume needs. An alternative method of creating this material is by digging or blasting rock and then crushing it into desirable sizes. There are multiple ways of crushing material, including a portable crusher (Fig. 3, left), which is secured to a trailer for easy transportation, or newer style conveyor crushers (Fig. 3, right), which are built on tracks and are self propelled. An alternative to conveyor style crushers is the bucket crusher, which is available in two types, jaw and rotary styles (Fig. 4). This type of rock processor is installed on the boom of an excavator, such as a Cat 336E, connecting into existing hydraulics for the normal bucket use.
With the expected arrival of the Cat 336E to McMurdo Station soon, the method we suggest for crushing rock based upon cost, production rate, and expected maintenance is a bucket rotary type crusher. The maintenance on this machine, in comparison to the other options, is expected to be less time consuming and costly; and the attachment can be removed in under an hour for quick return to its normal, excavator function (Melendy
2011). Additionally, if a crusher was used and the remnants dumped directly into a dump truck, or onto a stock pile, you would remove the need for a loader to move the material. We recommend this over the jaw type bucket, which can crush rocks up to 30,000 psi (versus the rotary crusher up to 20,000 psi), as the jaw type is less able to take the abuse of water, dirt, and clay that may bind up the internal mechanics of the machine. The portable crushers are capable of producing similar amounts of product as the bucket crushers but at a much higher price. The self-propelled crusher’s production rate is considerably less than that of the portable and bucket crushers, which would increase production time and maintenance to do the same tasks. However, the advantage to the self-propelled unit is that it is capable of sieving the material through screens after it is crushed. This would reduce the handling time and the need for a second piece of equipment to separate the material. One disadvantage of either bucket attachment is that it will tie up, though for only a short time if material is ready, the excavator. In addition to a cost and production comparison, emissions from each machine should be compared.

Using grizzly screens is the current method for rock sieving and separation (Fig. 5). These steel screens are extremely labor intensive and require a substantial amount of maintenance to keep them operational. This method also requires two people to maintain productivity: one loading the screen and pushing material through and one removing the runoff to keep it from piling up where the work is being completed.

Options that exist to replace the grizzly type screen are vibratory screens (Fig. 6) and buckets. This type of machine vibrates the screens, requiring less work to be completed by the operator, and increases production rates. Another advantage of vibratory screening is that multiple screens can be
swapped in or out of the machine depending on the desired production size; or, in some cases, these machines have double-deck screens so that two classes of material can be separated in one operation.

Figure 6. Vibratory screen (left) and vibratory double deck screen with conveyor (right).

<table>
<thead>
<tr>
<th>Option</th>
<th>ROM Price ($K)</th>
<th>Number of Screens</th>
<th>Screen Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grizzly Screen</td>
<td>6.5</td>
<td>1</td>
<td>5ft × 6ft</td>
</tr>
<tr>
<td>Vibratory Screen model 550</td>
<td>9.5</td>
<td>1</td>
<td>5ft × 4ft</td>
</tr>
<tr>
<td>Vibratory Screen model 1000xl</td>
<td>25</td>
<td>2</td>
<td>6ft × 5ft</td>
</tr>
<tr>
<td>Vibratory Screen model 1200xl</td>
<td>39.5</td>
<td>2 with Conveyor</td>
<td>6ft × 5ft</td>
</tr>
<tr>
<td>Vibratory Screening Bucket</td>
<td>6</td>
<td>1</td>
<td>1 yd³</td>
</tr>
</tbody>
</table>

The method we suggest for rock separation is via a vibratory screen. The disadvantage to using a bucket type screen is if the current bucket attachment would have to be taken off of a particular loader and be dedicated (for a time) to the screening operation. Thus, a portable trailer screen is the most viable option with its ability to screen for two different size materials at the same time, needing only one operator. Additionally, the use of a conveyor that moves the desired product away from the stock piles would be advantageous.

4.2 Cost estimate

In an effort to compare the current cost of production to the cost of using this recommended equipment, we did a quick analysis. Our goal production rate was 22,000 yd³/yr (this is greater than that used in the past several years but less than that projected for the next three) and assumes that a crusher would work at a rate of 60 yd³/hr (to be conservative). It also assumes, and again this is considered conservative, that the amount of time
for sorting would be equal to the time for crushing. As there were no records kept in the past for production, we can only very loosely compare the labor costs of the two methods. No effort was made to compare equipment usage costs at this time.

Table 4. Cost comparison for labor to complete annual rock material production.

<table>
<thead>
<tr>
<th></th>
<th>Fines produced</th>
<th>Labor (hours)</th>
<th>Labor (weeks)</th>
<th>Fulltime persons/season</th>
<th>Rough cost²</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006–07 Actual¹</td>
<td>unknown</td>
<td>2259</td>
<td>42</td>
<td>~2</td>
<td>$45k</td>
</tr>
<tr>
<td>2008–09 Actual¹</td>
<td>unknown</td>
<td>1114</td>
<td>20.6</td>
<td>~1</td>
<td>$22k</td>
</tr>
<tr>
<td>2009–10 Actual¹</td>
<td>unknown</td>
<td>1231</td>
<td>22.8</td>
<td>1</td>
<td>$25k</td>
</tr>
<tr>
<td>2010–11 Actual¹</td>
<td>unknown</td>
<td>2398.5</td>
<td>44.4</td>
<td>2</td>
<td>$48k</td>
</tr>
<tr>
<td>2011–12 Actual¹</td>
<td>unknown</td>
<td>1231</td>
<td>22.8</td>
<td>1</td>
<td>$25k</td>
</tr>
<tr>
<td>Future with Crusher</td>
<td>22,000 yd³</td>
<td>733</td>
<td>13.6</td>
<td>0.6</td>
<td>$15k</td>
</tr>
</tbody>
</table>

¹The actual data includes both crushing and sorting, but the total produced was not tracked.
²Estimate that the average heavy equipment operator is paid $20/hr.

From this quick analysis, it is clear that the purchase of a crusher would reduce the labor needed to produce rock material for Station construction by 25-50%. We also expect that the operational costs of the equipment would be reduced. For example, we estimate that the excavator with the crusher costs about $50/hr to operate, while the cost for other equipment currently used for this effort is much higher. Based on a recent assessment that accounts for a 3-year average, loaders cost about $24/hr and the D9N and D8 (used for scraping) cost $175/hr and $87/hr respectively (Melendy 2012). Thus, we would expect that the equipment operating costs would also be reduced significantly with the purchase of the crusher.

4.3 Location

To be more efficient and reduce the footprint of rock material collection activities from a wide variety of areas around the Station, we recommend a quarry that would centralize rock material production. This was previously discussed in McMurdo in the early 1990s but was subsequently stopped.
due to safety and health concerns (RPSC 2005). Since that time, blasting in the program has been better managed; and equipment technology has also changed significantly. A quarry would be a trade off: it would greatly impact a single site versus many locations around the Station. Casey and Davis Stations of the Australian Antarctic Division successfully quarry and crush rock to maintain service roads (AAD 2006). However, it is unknown at this time what their production requirements are; though these much smaller stations likely require less.

In picking a quarry location, it is important to consider the total capacity of the location (i.e., how many years could this solution support demand), the location relative to other Station activities (because of dust or noise concerns), and the ability to create usable space as the quarry develops. Fortress Rocks and just north of the Twin Lakes site (Fig. 7) are the two sites that seem to best meet these goals. Based on local topography (without really knowing the subsurface conditions or water/ice content of the location, we assumed a 20% loss of material), we calculated that Fortress Rocks would produce 224,000 yd$^3$ of material and Twin Lakes approximately 192,000 yd$^3$. At a conservative usage rate of approximately 22,000 yd$^3$/yr, this would provide about 10 and 9 years of new material, respectively. This assumes that no material is reused, and no minimization strategies (discussed below) are employed.

Each site has other pros and cons. Quarrying Fortress Rocks would provide usable space for waste and other storage. It is also close to Station activity, so material would not have to travel far from the quarry to where it will be used. However, being close to the Station, the blasting and crushing would create noise and dust pollution that may be unsatisfactory for daily Station life. The Twin Lakes area does not provide any particularly usable space but is further removed from daily activity, which could reduce the noise and dust pollution. In both sites, the new drainage paths resulting from a quarry would also have to be addressed. This is particularly true, based on known drainage paths, at Fortress Rocks (Affleck et al. 2012). However, as drainage issues currently exist at this site, a quarry would not cause new problems but would likely provide a timely opportunity to address old ones.

Overall, noise and dust pollution could be reduced or mitigated by using appropriate equipment. Standard operating procedures (SOP) could be developed that limit quarry activities to low- or no-wind days. Based on
the numbers provided above in Table 4, as production is estimated to take half of the season or less, it would be possible to be conscientious of environmental conditions. Alternatively, production could be completed at a high pace for one season and put on hold for one to two seasons until rock material is needed again.

Figure 7. Potential quarry locations outlined in red: Twin Lakes at the top of the picture and Fortress Rocks in the middle.
5 Recommendations

Rock material use in McMurdo is essential but, to date, has been lacking a management plan to meet Station needs and satisfy environmental goals. To better manage rock material, we provide several recommendations below.

5.1 Near term

- Start a database of rock material use to better understand Station material needs (Appendix B). These data would require Fleet Ops staff to count buckets as they use them each day.
- For current operations, scraping and using grizzlies to sort, it is imperative to keep equipment in working order. For example, at the time of this writing, the rip rap grizzly is no longer functional and the next largest available grizzly is much smaller at 3 in. For projects that need larger material (e.g., lining ditches and gabion baskets at the intakes), appropriate, consistently sized, material cannot be provided.
- If scraping is to be continued, we have identified three locations as having the best future potential for material (see top three in Appendix A). These were the “Gray’s Chute,” “Haz Yard Rock Quarry,” and the “Reds 2004 ROER” locations. Based on the historically disturbed area, and assuming that each time we scrape to 4-in deep, the material available at each location (per scrape) is 2500 yd³, 2450 yd³, and 650 yd³, respectively. Expansion of these areas could provide more material. For example, if cabling, which is currently located up the west side of the Gray’s Chute area, were relocated to the east side, more space could be available for material collection.
- Continue rock material loss mitigation:
  - Continue using the soil cooker to clean old material for re-use.
  - Refine and implement engineering best management practices on Station, including the use of sediment traps and detention basins, proper slope for ditches, and slope stabilization (Affleck et al. 2012) to collect material and reduce loss in drainage situations. In the development of detention basins, material could also be gained if site excavation was required.
5.2 Long term

- Employ alternative methods to annual material use:
  
  o One of the greatest annual fines uses is for resurfacing the ice pier (approximately 4000 yd$^3$). This protects the pier surface as well as provides traction for personnel and equipment while working on the pier. While the current practice is to remove material at the end of the season and reuse it the following year, material is inevitably lost in this process (e.g., in transfer, pushed into the water, etc.). We suggest that a “dura-base” type mat be investigated as an alternative. This mat would also need to be placed and removed annually but would remove the need for fines.
  
  o Several thousand yd$^3$ of material are used each year to maintain roads around the Station. This could be reduced by keeping tracked (steel, in particular) vehicles staged in locations around the perimeter of the Station. Additionally, enforcing walking to and from work centers and the Station center could cut down on the wear and tear on the roads.

- Establish a rock quarry location at McMurdo to centralize material collection operations. Both locations described above provide a source for many years of material in one centralized location.

- Purchase a crusher to make better use of collected material. At this time, we do not immediately recommend a vibratory screen. We suggest a few years of use with a crusher first and then a review of the operation to determine if a screen is still needed.
References

Affleck, R. C. Vuyovich, M.A. Knuth and S. Daly. 2012. Drainage assessment and flow monitoring at McMurdo Station during Austral Summer. ERDC/CRREL TR-12-3. Hanover, NH: U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory.


Melendy, T. 2011. Personal communication. 29 June. CRREL.

Melendy, T. 2012. Personal communication. 11 September. CRREL.


National Science Foundation (NSF). 2011. Collection of Rock Fines at McMurdo Station, Antarctica. MCST1201.IEE.

Reed, M. 2011a. Personal communication. 13 June. McMurdo Station.

Reed, M. 2011b. Personal communication. 3 July. McMurdo Station.
## Appendix A: Review of Past and Current Rock Material Collection Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>Method of collection</th>
<th>Type of material sourced</th>
<th>Used in last 2 years?</th>
<th>Potential with current methods?</th>
<th>Potential if new methods or equipment were provided?</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray's Chute</td>
<td>Blast: X Scrape: X</td>
<td>Red: X</td>
<td>Yes</td>
<td>Good to Fair</td>
<td>Best site potential.</td>
<td>Great site if cables could be moved.</td>
</tr>
<tr>
<td>Haz Yard Rock Quarry</td>
<td></td>
<td></td>
<td></td>
<td>Fair to Good</td>
<td>Small area needs to be surveyed for safe benches.</td>
<td>Creates more staging area.</td>
</tr>
<tr>
<td>Reds 2004 ROER</td>
<td>Blast: X Scrape: X</td>
<td></td>
<td>No</td>
<td>Fair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larryville Rubble Pile</td>
<td>Blast: X Scrape: X</td>
<td>Red: X</td>
<td>No</td>
<td>Fair (Ice conglomerate?)</td>
<td></td>
<td>If it doesn't turn out to be an ice core moraine, has a close proximity to a future job site and will eliminate long hauling.</td>
</tr>
<tr>
<td>Twin Lakes Expansion</td>
<td></td>
<td></td>
<td>No</td>
<td>Good</td>
<td>Limited, science soil sample site.</td>
<td>Possible MAISR Site.</td>
</tr>
<tr>
<td>Surveyor's Quarry</td>
<td></td>
<td></td>
<td></td>
<td>Fair</td>
<td></td>
<td>Losing most of the area to NPOESS, SuperDARN receivers.</td>
</tr>
<tr>
<td>2004 Previous</td>
<td></td>
<td></td>
<td></td>
<td>Steep becoming dozer limited</td>
<td>Survey, blast, bench, contour.</td>
<td></td>
</tr>
<tr>
<td>2005 ROER</td>
<td></td>
<td></td>
<td>No</td>
<td>Poor, Ice conglomerate</td>
<td>Poor.</td>
<td>Leveled for vessel containers storage.</td>
</tr>
</tbody>
</table>

---

1 Adapted from email communications, Marty Reed, 3 July and 9 September 2011.
<table>
<thead>
<tr>
<th>Location</th>
<th>Method of collection</th>
<th>Type of material sourced</th>
<th>Used in last 2 years?</th>
<th>Potential with current methods?</th>
<th>Potential if new methods or equipment were provided?</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2010) 08 Audit</td>
<td>Blast</td>
<td>Scrape</td>
<td>Red</td>
<td>No</td>
<td>Currently Off Limits</td>
<td>Possible with crusher.</td>
</tr>
<tr>
<td>Big Range Basin</td>
<td></td>
<td></td>
<td>X</td>
<td>No</td>
<td>Currently Off Limits</td>
<td>Footprint is large, closed access by fuel line.</td>
</tr>
<tr>
<td>Arrival Heights Ridge</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>No</td>
<td>N/A</td>
<td>SuperDARN, Hiking Trail, Cables, Clean Air.</td>
</tr>
</tbody>
</table>
Appendix B: Database for Rock Material Management\(^1\)

\(^1\) Image only. File “Rock Material Management Database.xlsm” available upon request.
### Abstract

To support the extensive science efforts at McMurdo Station, and a population of more than 1000 each austral summer, there is a large operational component. Locally sourced rock material is required for annual maintenance of the ice pier, general earthworks, and building construction. Collection and use of these rock materials is governed by programmatic and project specific environmental assessments; and currently, several locations around the Station are used for generating rock material, which is then collected by scraping or blasting. This report outlines historical use of rock material and provides recommendations on future efforts. In particular, over the long term, it is recommended that the US Antarctic Program employ alternative methods to annual material usage, establish a rock quarry at McMurdo to centralize material collection operations, and purchase a crusher to make better use of collected material.

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### Subject Terms

- Antarctica
- Coarse-grained gravel
- Fines
- McMurdo Station
- Rock crushing

### Distribution / Availability Statement

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### Supplementary Notes

Engineering for Polar Operations, Logistics and Research (EPOLAR)