DRAFT COMPREHENSIVE ENVIRONMENTAL EVALUATION FOR CONTINUATION AND MODERNIZATION OF MCMURDO STATION AREA ACTIVITIES

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Non-Technical Summary

Introduction, Purpose and Need

The United States has conducted scientific and educational programs in Antarctica continuously since the International Geophysical Year of 1957-1958 and is dedicated to continuing this mission as a matter of national policy[1] and to foster international cooperation. Over the last 60 years of United States research in Antarctica, science has increased in complexity and extent, requiring greater support over time.

McMurdo Station was established in 1955 on Ross Island in the southwestern Ross Sea, in the southernmost area of Antarctica accessible by ship. The station serves as a gateway to Antarctica for most United States scientific field teams and as a hub for most United States scientific activities on the continent. Much of the infrastructure at McMurdo Station supporting these programs dates back several decades and is nearing or has exceeded its intended life expectancy. Today, many components of the McMurdo Station infrastructure need to be upgraded to ensure that United States activities in Antarctica can continue uninterrupted. The National Science Foundation (NSF) proposes to modernize McMurdo Station while continuing the United States Antarctic Program (USAP) science and operational activities at McMurdo Station and at field sites and associated facilities the station supports.

The purpose of the proposed activity is to ensure that the USAP's resources at McMurdo Station continue to serve as viable and flexible platforms to support evolving scientific research efficiently and effectively. The proposed activity would implement modernization projects under the McMurdo Master Plan, including the subset of McMurdo Master Plan projects in the Antarctic Infrastructure Modernization for Science (AIMS) project, by replacing or substantially upgrading assets at McMurdo Station that are nearing or have exceeded their life expectancy. Proposed modernization activities would provide facilities and equipment that meet energy efficiency standards, logistical requirements, and environmental stewardship goals. In addition, the proposed activity would continue the USAP's science and operations at McMurdo Station and the facilities supported by the station at or near current levels.

Based on a preliminary environmental review, NSF determined that the proposed activity is likely to have a more than minor or transitory impact on the Antarctic environment. In response to this determination, NSF has conducted an in-depth environmental impact assessment (EIA), termed a Comprehensive Environmental Evaluation (CEE), to evaluate the potential impacts of implementing the proposed activity.

This CEE has been prepared in accordance with applicable provisions of Annex I, Article 3 of the *Protocol on Environmental Protection to the Antarctic Treaty*[2] (the Protocol); the *Guidelines for Environmental Impact Assessment in Antarctica*[3] (2016); the Antarctic Conservation Act, as amended by the *Antarctic Science Tourism and Conservation Act of 1996*, 16 United States Code (U.S.C.) § 2401 *et seq*. (ACA); and implementing regulations set forth in *Environmental Assessment Procedures for National Science Foundation Actions in Antarctica*, 45 Code of Federal Regulations (C.F.R.) § 641.

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[1] Presidential Memorandum 6646 (1982) and Presidential Decision Directive/NSC-26 (1994).

[2] *The Protocol on Environmental Protection to the Antarctic Treaty* (1991); http://www.ats.aq/e/ep.htm.

[3] Antarctic Treaty Secretariat (ATS), *Guidelines for Environmental Impact Assessment in Antarctica* (2016); http://ats.aq/documents/recatt/Att266_e.pdf.

Using the EIA process, the USAP has assessed and continues to assess the potential environmental impacts of specific, proposed projects while other assessments evaluate the impacts of recurring activities (e.g., deployment of remote equipment and automatic weather stations, establishment of field camps, building maintenance, and use of explosives). Informed by the EIA process, and with a focus on environmental stewardship in Antarctica, the USAP mitigates impacts from common sources, preventing and/or minimizing

- spills or other accidental releases;
- the introduction or distribution of non-native species;
- the release of materials or wastes to terrestrial or marine resources;
- physical disturbance of terrestrial areas;
- disturbance or contamination of sensitive environments (e.g., McMurdo Dry Valleys, subglacial lakes, geothermal resources);
- disturbance or injury to Antarctic flora and fauna wildlife;
- the release of emissions to the atmosphere;
- alteration to the terrain, either through expanding existing facilities or occupying new sites; and
- alteration to the visual landscape, wilderness, and aesthetic value of the Antarctic environment.

Proposed Activity and Alternatives

The proposed activity (Alternative A) would implement modernization projects under the McMurdo Master Plan (including AIMS), while continuing the USAP's science and operations at McMurdo Station and locations supported by the station. Proposed modernization projects would involve demolishing, constructing, renovating, and operating buildings and structures at McMurdo Station. Ongoing science and operations at McMurdo Station (and locations supported by the station) would be maintained at or near current levels throughout the approximately 15-20 year construction phase of modernization projects. Proposed modernization projects address

- construction and operational features to enhance safety and health for the USAP's participants and visitors;
- building placement to increase operational efficiency and function;
- energy conservation to increase efficiency and the incorporation of renewable energy sources;
- support functions, such as fire protection, materials storage and distribution, and electrical distribution to optimize infrastructure in support of research and operational activities;
- support for a population that should not exceed 1000 people during the austral summer;
- logistics management to optimize warehousing and delivery processes; and
- quality of life upgrades to improve the living and working experience of McMurdo Station residents.

The proposed new facilities and infrastructure would be built within the current footprint of McMurdo Station. Some facilities and functions at the station would be consolidated into new, centralized buildings to meet modernization objectives. When complete, it is estimated that the proposed improvements would result in enhanced safety, greater fuel use efficiency, lower air emissions, reduced power and heat requirements, fewer vehicle operation hours, and fewer support and maintenance personnel. For example, McMurdo Station modernization projects would yield an estimated 35% reduction in diesel fuel consumption (for heat, power, and water) compared to current levels, due to facility consolidation and reductions in terrestrial fleet vehicle use.

It is anticipated that science and operational activities at McMurdo Station and outlying facilities supported by the station would continue at or near current levels during the construction phase of modernization projects. It is also anticipated that baseline impact levels would remain relatively constant when implementing these modernization projects. In some cases, efficiencies gained through implementing modernization projects may extend to existing facilities, once construction is completed.

In Alternative B, no infrastructure modernization would be implemented and McMurdo Station would continue science support and operational activities. Alternatives Considered but not Carried Forward included building design and configuration options.

Initial Environmental Reference

The affected environment where the proposed activity would be implemented includes McMurdo Station and surrounding areas where remote facilities and activities are supported from McMurdo Station, including

- Ross Island;
- McMurdo Sound and the Ross Sea;
- McMurdo Dry Valleys; and
- deep-field sites across the Polar Plateau, the Transantarctic Mountains, glaciers, basins, and ice shelves.

McMurdo Station is located on Ross Island, at the southern tip of the Hut Point peninsula and within Antarctic Conservation Biogeographic Region 9 and Environment S of the Environmental Domains Analysis. McMurdo Station, which encompasses approximately 2.5 km^2 (1 mi^2), and its surrounding area are characterized as heavily disturbed. Ross Island holds many important ecological resources, such as algae, fungi, lichen, mosses, small invertebrates, seal colonies, and seabird colonies. Emperor penguins (*Aptenodytes forsteri*), Adélie penguins (*Pygoscelis adeliae*), and south polar skua (*Catharacta maccormicki*) breed at Antarctic Specially Protected Areas (ASPA) on Ross Island, including ASPA No. 124, Cape Crozier and ASPA No. 121, Cape Royds. The McMurdo Dry Valleys, within Antarctic Conservation Biogeographic Region 9, encompasses approximately 15,000 km^2 (5792 mi^2), comprises the largest relatively ice-free area on the Antarctic continent, and Antarctic Specially Managed Area (ASMA) No. 2, the largest ASMA in Antarctica. The McMurdo Dry Valleys are a cold desert ecosystem that contains important microbiological communities, including colonies of moss, algae, cyanobacteria, and nematodes. ASMA No. 2 also includes special geological features and minerals. Lakes within the McMurdo Dry Valleys support abundant, widespread growth of benthic cyanobacteria-dominated mats, which influence overall lake geochemistry.

The Ross Sea, including McMurdo Sound, is one of the most biologically productive regions in the Southern Ocean and includes a variety of benthic communities, marine mammals, penguins, fish, and invertebrates. Snow- and ice-covered deep-field sites in the Antarctic interior are generally devoid of flora or fauna. Numerous protected areas are present in the affected environment, including 20 ASPAs and five historic sites and monuments near McMurdo Station.

Identification and Prediction of Impacts

Potential impacts were evaluated by considering the context in which they would occur, as well as their extent, duration, intensity, and probability. Impacts from construction activities were evaluated, including building demolition, site preparation, soil fill and fines management, explosives use, importation of materials (as a potential introduction of non-native species), building construction, vehicle/heavy equipment use, traverse operations, and aircraft operations. Impacts were evaluated with respect to

- wildlife disturbance;
- air quality;
- noise;
- altered land contours;
- quality of terrestrial or marine environments;
- introduced non-native species;
- waste management;
- historic or aesthetic resources; and
- cumulative impacts resulting from relevant past, present, or reasonably foreseeable future projects.

Impacts resulting from the proposed activities could potentially be less than the impacts analyzed in this CEE. Impacts would be spread across the approximately 15-20 year construction phase of modernization projects. As a result of efficiency gains from modernization projects, impacts from continuing science and station operations are expected to be reduced compared with existing impact levels, while providing improved support for science.

Impacts from proposed modernization activities at McMurdo Station would include altering and modernizing the visual characteristics of the station and physically disturbing rock and soil in work site areas, including the generation of fines, releasing airborne pollutant emissions from construction vehicles and equipment, and generating construction waste, which requires handling and removal from Antarctica. These impacts would generally be confined to proposed project sites and would cease upon completion of modernization activities. Mitigation measures would further reduce potential impacts from the proposed activity.

Following the completion of demolition and construction activities, disturbed areas would either be regraded to the approximate original contour or prepared for new construction. The station modernization activities would improve visual sightlines when approaching the station from McMurdo Sound, thereby resulting in a beneficial impact to the aesthetic values of Ross Island.

During the multi-year construction phase, the proposed modernization activities would generate construction and demolition debris in excess of the non-hazardous solid waste currently generated annually at McMurdo Station. All construction and demolition waste would be packaged and removed from Antarctica. Following completion of proposed modernization improvements, the amount of solid waste generated by ongoing science and operational activities would return to an amount similar to or below the amount currently generated. Thus, the proposed activity would have no long-term impacts from waste generated at McMurdo Station during modernization projects.

The use of mechanized equipment and associated fuel combustion would result in the unavoidable release of exhaust byproducts into the atmosphere during both modernization activities and ongoing science and operational activities. However, the multi-year timeframe for modernization activities would allow emissions to effectively disperse and only cause a localized impact that is consistent with normal emissions at McMurdo Station. Thus, emissions would not degrade local or regional air quality. Further, efficiencies gained through modernization activities, including an anticipated reduction of the vehicle fleet, would result in reduced fuel use and thus a reduction in associated air emissions from ongoing science and operational activities.

Proposed modernization activities would ultimately result in a reduction of impacts by

- consolidating and replacing aging structures;
- constructing new, better-insulated, and more-efficient facilities;
- upgrading power distribution to include smart grid systems;
- consolidating existing functions into a smaller developed footprint;
- reducing the amount of fuel used to generate heat and electricity;
- reducing the vehicle fleet and associated air emissions; and
- slowing snowmelt runoff drainage, thus reducing the scouring and erosion of drainage canals at McMurdo Station.

Cumulative and Unavoidable Impacts

Cumulative impacts are the effects of past, present, and reasonably foreseeable future activities that may occur over time and space and be interactive. McMurdo Master Plan (including AIMS) construction activities would be phased over time and would only occur on previously disturbed land within the McMurdo Station footprint to minimize impacts to the environment. Continued science and operations during and after modernization would result in impacts to the environment and contribute to cumulative impacts in the area. Continuing mitigation measures, monitoring, and cleanup of past-contaminated areas would reduce these impacts.

Unavoidable impacts directly resulting from implementing the proposed activity include physical disturbance of surfaces (fines and rock harvesting) in the McMurdo Station facility zone, air emissions (including fuel use and dust generation), releases to the environment (including spills and wastewater releases), waste generation, and noise. The proposed activity would not result in impacts that are substantively new or different from those already occurring. The USAP is committed to making the proposed improvements to better serve new and continuing research and to enhance stewardship of the Antarctic.

Mitigation Measures and Monitoring

As applicable, personnel implementing proposed modernization improvements would adhere to established general and/or facility-specific procedures, best management practices, and mitigation measures to minimize impacts from building demolition and construction, site preparation, explosives use, import of materials, and vehicle use. These measures would be consistent with procedures routinely implemented by the USAP and would be documented accordingly. As necessary during implementation, activities would be monitored to ensure that mitigation measures are implemented and that resulting impacts are consistent with those identified in this CEE.

Gaps in Knowledge and Uncertainties

Uncertainty and unknowns are inherent in the environmental analysis of the proposed activity. The greatest uncertainties and gaps in knowledge relate to the methodology used to estimate impact parameters, the precise timing of modernization activities, construction conditions, weather, and future science requirements. Impacts described in this CEE account for a range of conditions during facility modernization, including the service life of the facility. Therefore, variations or uncertainties that do not involve major changes to the proposed activities are not expected to significantly affect the impacts of those activities or alter the conclusions of this CEE. Additionally, if project-specific plans are refined or changed, the USAP EIA process would be implemented and updated or new EIA documentation may be prepared to meet the requirements of Annex I of the Protocol and in accordance with the ACA and its implementing regulations set forth in 45 C.F.R.§ 641.

Conclusions

This CEE identifies impacts potentially resulting from the proposed activity, which would implement modernization projects at McMurdo Station over a period of approximately 15-20 years and continue ongoing science and operations at McMurdo Station and the area it supports.

The proposed activity (modernization and continuing operations) is not anticipated to expand the operational footprint of McMurdo Station or fixed facilities supported by McMurdo Station. Similarly, the proposed activity would not result in impacts that are substantively new or different from those that have already occurred. Impacts from the proposed activity are projected to be localized and either contained and removed from the continent (e.g., solid and hazardous waste) or at a level that the environment is able to absorb without change at the regional level (e.g., wastewater effluent and air emissions). However, some impacts would result in more than minor or transitory impacts, even with proposed mitigations. Therefore, the proposed activity is likely to result in some long-term, adverse impacts on the Antarctic environment, although any such impacts would be less than current operations.

The proposed activity would result in substantial improvements in environmental performance, and consistent use of mitigations and monitoring would further minimize impacts. Benefits would include continuing substantive scientific and logistic collaboration with other Antarctic programs and increased potential for enhanced international collaboration as new science and logistical opportunities arise.

The major benefits of modernization components of the proposed activity are

- improved capacity for the USAP's research in concert with continuing international collaborations in scientific and operational activities;
- enhanced safety performance in the USAP;
- increased operational efficiency (12% reduction in support staff; 40% reduction in maintenance staff);
- increased logistical efficiency (20% reduction in building square footage);
- reduced outdoor storage (at least 35%, and up to 90%, reduction);
- reduced energy consumption (35% reduction in station fuel consumption; 20% reduction in vehicle fuel use);
- reduced carbon emissions; and
- reduced long-term environmental impact.

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1. Introduction, Purpose and Need

1.1 National Science Foundation and United States Antarctic Program Background

The National Science Foundation (NSF) Office of Polar Programs (OPP), which operates the United States Antarctic Program (USAP), has prepared this draft Comprehensive Environmental Evaluation (CEE) to assess the potential environmental impacts associated with the modernization of McMurdo Station infrastructure and the continuation of the USAP's activities in the McMurdo Station area.

1.1.1 History of Program and Development at McMurdo

The USAP was established in 1959, following the success of scientific activities around the world during the International Geophysical Year of 1957–1958. United States policy regarding Antarctica is set forth in Presidential Memorandum 6646 (1982), and Presidential Decision Directive/NSC-26 (1994), which provides that "The United States Antarctic Program shall be maintained at a level providing an active and influential presence in Antarctica designed to support the range of United States Antarctic interests."

McMurdo Station was established in 1955 on Ross Island in the southwestern Ross Sea, the southernmost area of Antarctica accessible by ship. The station serves as a gateway to Antarctica for most United States scientific field teams, as a hub for most United States scientific activities on the continent, and is required to support South Pole Station. McMurdo Station has evolved over a period of 60 years based on the changing needs of research and changes in operational requirements. McMurdo Station currently occupies a developed footprint of approximately 2.5 km^2 (1 mi^2) on Ross Island, as well as two airfield facilities located on the nearby McMurdo Ice Shelf.

The McMurdo area USAP population is primarily present during the austral summer (October through February). The average McMurdo Station austral summer population, based on the most recent five-year average, is approximately 950 personnel.

1.1.2 Scientific Goals of the USAP at McMurdo and Field Locations Supported by the Station

The USAP's scientific goals are to

- understand Antarctica and its associated ecosystems;
- understand the region's effects on and responses to the global system, such as climate, space weather, and sea level; and
- use Antarctica's unique features as a platform to conduct research in areas of scientific interest that cannot be studied elsewhere.

USAP research encompasses wide-ranging areas of science, including astrophysics and geospace science, Antarctic earth sciences, glaciology, Antarctic integrated system science, Antarctic ocean and atmospheric sciences, and Antarctic organisms and ecosystems. Each research discipline is represented in the McMurdo area or at field locations supported by McMurdo Station, including one Long-Term Ecological Research (LTER) program (established in 1992) in the McMurdo Dry Valleys (MDV).

1.2 Purpose and Need for the Proposed Activity

NSF proposes to modernize McMurdo Station and continue McMurdo area operational activities. Much of the McMurdo Station infrastructure is 30-50 years old and is nearing or has exceeded its life expectancy, thus requiring frequent maintenance and repair. Currently, McMurdo Station has more than 100 buildings, covering an area of 0.62 km^2 (0.1 mi^2). Many of the aging facilities, originally constructed on an as-needed basis, were not designed to meet energy efficiency standards or provide effective support for scientific research. The purpose of implementing the proposed activity is to continue providing facilities and support at McMurdo Station that effectively, efficiently, and safely supports current and evolving NSF Antarctic science objectives and meets the USAP's goals of environmental stewardship in Antarctica.

Proposed modernization activities would provide facilities, equipment, and infrastructure to replace or substantially upgrade assets that are nearing or have exceeded their life expectancy. Providing facilities, equipment, and infrastructure that meets or exceeds current energy efficiency and logistical requirements also meets the goal of providing viable support for the USAP's science and operational activities at McMurdo Station and the areas directly supported by the station.

Over the last 60 years of United States research in Antarctica, science has increased in complexity and extent, thus requiring increasingly sophisticated support over time. During each of the past five austral summers, the USAP supported an average of 72 science projects from McMurdo Station, including more than 40 field camps and remote operational facilities outside of the station footprint and both airlift and overland traverse support. The demand for scientific and educational programs in Antarctica is expected to continue to evolve over the next few decades.

Recent studies by the National Research Council, the USAP Blue Ribbon Panel (BRP), and the National Academies that analyzed the USAP's mission to support and pursue science in Antarctica have guided development of the modernization plan at McMurdo Station. In particular, the BRP report *More and Better Science in Antarctica through Increased Logistical Effectiveness* (BRP, 2012) identified steps to increase the efficiency and effectiveness of logistics and the operational support of science in Antarctica. Recommendations in the report included

- increasing the efficiency of science support by upgrading or replacing aging facilities at McMurdo Station;
- broadening environmental stewardship programs;
- increasing energy efficiency; and
- enhancing renewable energy technologies to reduce operational costs.

In response to the study recommendations, the USAP updated the McMurdo Master Plan in December 2015 (NSF 2015a). The McMurdo Master Plan aims to guide consolidating and modernizing facilities at McMurdo Station to more effectively and efficiently support NSF Antarctic science objectives. The proposed activity in this CEE includes the planned modernization projects under the McMurdo Master Plan, including the McMurdo Master Plan subset of projects in the Antarctic Infrastructure Modernization for Science (AIMS) project, and continuing ongoing USAP science and operational activities. Modernization projects included in the AIMS subset of the McMurdo Master Plan would be an approximately eight-year effort to replace and modernize critical infrastructure and facilities at McMurdo Station. Additional improvements and modernization activities identified in the McMurdo Master Plan would be implemented over the seven years following AIMS completion. Modernization projects would also support the USAP's goal of continually improving environmental stewardship in Antarctica, thereby meeting the purpose and need for the proposed activity in this CEE.

1.3 Scope of the Comprehensive Environmental Evaluation

This CEE has been prepared in accordance with the applicable requirements in Annex I, Article 3, of the *Protocol on Environmental Protection to the Antarctic Treaty* (Protocol; Antarctic Treaty Secretariat [ATS], 1991); the *Guidelines for Environmental Impact Assessment in Antarctica* (ATS 2016a); the Antarctic Conservation Act, as amended by the *Antarctic Science Tourism and Conservation Act of 1996*, 16 United States Code (U.S.C.) § 2401 *et seq.* (ACA); and implementing regulations set forth in *Environmental Assessment Procedures for National Science Foundation Actions in Antarctica*, 45 Code of Federal Regulations (C.F.R.) § 641.

1.3.1 Scoping Process

A Notice of Intent was published in the *Federal Register* on August 24, 2016 (NSF 2016) to announce the beginning of the scoping process, solicit public comments, and identify issues to be analyzed in this CEE (Appendix A).

1.3.2 International and Domestic Obligations

USAP activities are conducted in accordance with applicable international and domestic laws, including, but not limited to, the Antarctic Treaty of 1959, the Protocol (ATS 1991), the ACA, and its implementing regulations.

Environmental protection has been a central theme of cooperation among the Antarctic Treaty Parties. The adoption of the Protocol in 1991 (ATS 1991) and its entry into force in 1998 provided a modern framework for the comprehensive protection of the Antarctic environment. Annex I of the Protocol defines the requirements for an environmental impact assessment (EIA) and is implemented domestically by the ACA (45 C.F.R. § 641).

The USAP implemented and has continued to execute a comprehensive EIA process to provide a systematic review of all proposed USAP research and operational activities and to identify potential impacts to the Antarctic environment. Typically, the USAP reviews between 100 and 200 proposed operational and research projects annually. The EIA process is consistent with Committee for Environmental Protection (CEP) EIA guidance (ATS 2016a).

1.3.3 Organization of Document

This CEE is organized as follows:

- Non-technical Summary (which includes a non-technical summary of the information in this CEE)
- Section 1 – Introduction, Purpose and Need
- Section 2 –Operational Developments in the USAP during the Past Three Decades in the McMurdo Area
- Section 3 – Proposed Activity and Alternatives

- Section 4 – Initial Environmental Reference/Affected Environment
- Section 5 – Identification and Prediction of Impacts
- Section 6 – Mitigation Measures
- Section 7 – Environmental Monitoring
- Section 8 – Decommissioning of United States Antarctic Program Facilities in the McMurdo Area
- Section 9 – Gaps in Knowledge and Uncertainties
- Section 10 – Conclusions
- Section 11 – Preparers of the CEE
- Section 12 – Glossary of key terms used in the CEE
- Section 13 – References
- Section 14 – Appendices, including
    - Appendix A (A summary of the public scoping process.)
    - Appendix B (Acronyms and abbreviations used in the document and their definitions.)
    - Appendix C (Supplemental material.)

2. Operational Developments in the USAP During the Past Three Decades in the McMurdo Area

2.1 Introduction

The USAP's facilities and operations based at McMurdo Station have evolved over the years in direct response to the changing needs of scientific research conducted in Antarctica. The evolution has included integrating environmental protection measures and best management practices into operations and science support to reduce the impact of these activities. Environmental stewardship in the USAP incorporates the EIA process (ATS 1991, 2016a), mitigation measures, training, and impact monitoring. These changes have increased operational efficiencies and environmental protection at McMurdo Station and in the McMurdo area.

Using the EIA process, the USAP has assessed, and continues to assess, potential environmental impacts from proposed activities, including those at McMurdo Station. Environmental assessments include reviews of McMurdo Station operations and facility construction to evaluate specific projects. Other assessments evaluate the impacts of recurring activities (e.g., deployment of remote equipment and automatic weather stations, establishment of field camps, building maintenance, and use of explosives). Informed by data provided in environmental assessments, the USAP environmental stewardship program mitigates impacts from common sources and prevents and/or minimizes

- spills or other accidental releases;
- the introduction or distribution of non-native species;
- the release of materials or wastes to terrestrial or marine environments;
- physical disturbance of terrestrial areas;
- disturbance or contamination of sensitive environments (e.g., MDV, subglacial lakes, ice caves, geothermal areas);
- disturbance or injury to Antarctic flora and fauna;
- the release of emissions to the atmosphere;
- alteration to the terrain, either through expanding existing facilities or occupying new sites; and
- alteration to the visual landscape, wilderness, and aesthetic value of the Antarctic environment.

2.2 McMurdo Station Developments

Over the last thirty years, changes implemented at McMurdo Station and associated support facilities have provided the logistical support systems and infrastructure for the current level of operations in the area. As a USAP research and supply hub, McMurdo Station also provides resources to area support facilities, including the Black Island Telecommunications Facility (BITF) and the Marble Point Refueling Facility. In addition, McMurdo Station provides logistical support (e.g., personnel transport, fuel, cargo, and supplies) to field camps and the Amundsen-Scott South Pole Station, via airlift and overland traverses.

2.2.1 Initial Station Layout and Operation

Since McMurdo Station was established in 1955, station growth and layout were developed on an as-needed basis, with certain facilities (e.g., warehouses, cargo yards) located away from the main station. This non-optimal layout decreases efficiency by increasing transport time for storage, collection, or distribution of materials. In addition, older structures installed at the station were not energy efficient, and numerous buildings have been utilized for functions that differ from their original purpose.

Between 1955 and 1990, (prior to the Protocol) McMurdo Station grew to operate within a footprint of approximately 2.5 km^2 (1 mi^2), with more than 100 structures and ancillary facilities. Key facilities included the Eklund Biological Laboratory and the Thiel Earth Science Center. The station also included several other science buildings, a Vehicle Maintenance Facility (VMF), a kitchen/eating facility, six dormitories, and temporary berthing in Jamesways.

Other structures and work areas included a power plant, water plant, waste handling facilities, storage yards, fuel tanks and associated pipelines, an ice pier, a helicopter pad, skiway (Williams Field), and an annual (seasonal) sea-ice runway (Figure 2-1). Station power was provided by six diesel-electric generators, each having a capacity of 800-900 kW. The water plant contained two desalination units that could produce 277,000 L/day (74,000 gal/day) of potable water, and the water storage capacity was 760,000 L (200,000 gal).

By 1990, McMurdo Station was generating approximately 2,810,400 kg (6,195,871 lb) of solid waste and 134,600 kg (296,800 lb) of hazardous waste each year. Wastewater treatment was limited to maceration, and up to 300,000 L (80,000 gal) of effluent was discharged each day into Winter Quarters Bay from one outfall. McMurdo Station had 18 steel, bulk-fuel tanks with a combined capacity of 34,000,000 L (9,000,000 gal). These tanks were single-walled and had no secondary containment. Approximately 400 ground vehicles were used to transport people and material and to support construction projects. At that time, McMurdo Station supported an average population of approximately 1200 people during the peak of the austral summer (October to February) and up to 250 people during the austral winter.

Thirty years ago, intercontinental airlift support to McMurdo Station was provided by wheeled C-5, C-141, C-130, and ski-equipped LC-130 aircraft. During 1989, there were 18 C-141, two C-5, and 14 Royal New Zealand Air Force C-130 round trips between McMurdo Station and Christchurch, New Zealand. Intracontinental support was provided by LC-130s, Twin Otters, and UH-2N helicopters. Wheeled aircraft were supported at the seasonal sea-ice runway each year, while ski-equipped, fixed-wing aircraft operated from the Williams Field skiway. Both the sea-ice runway and Williams Field had support structures and resources (e.g., generators, fuel tanks) appropriate for the level of operations. Aircraft operations were limited to the austral summer months (August through February).

Sealift support to McMurdo Station was provided during each austral summer and consisted of a refueling tanker, a resupply vessel, and an icebreaker. The annual resupply vessel delivered material and removed waste, excess material, and equipment. The tanker would deliver fuel to McMurdo Station, and the icebreaker would deliver fuel to Marble Point.

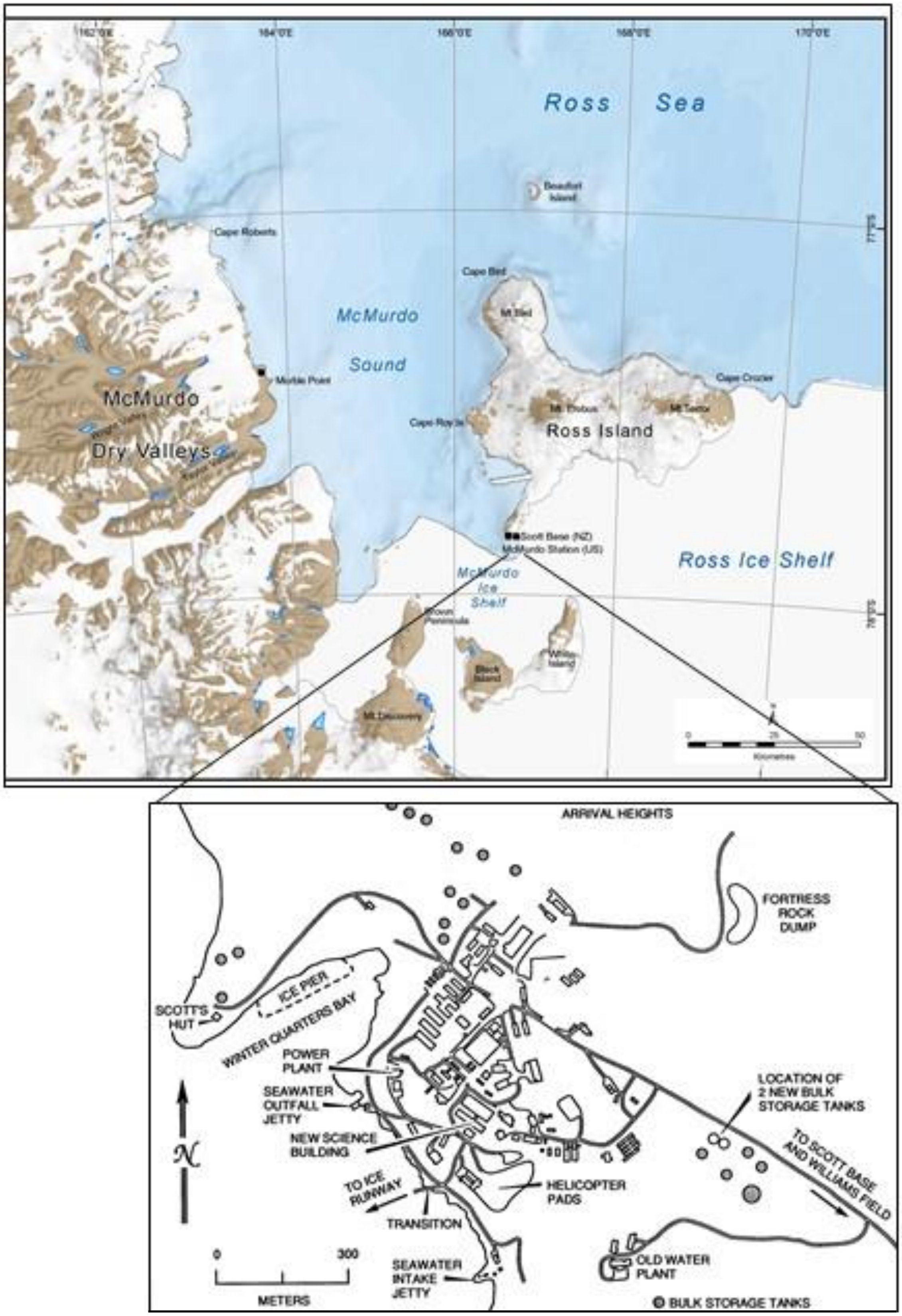

Figure 2-1. Map of McMurdo Area with Map of McMurdo Station in 1990

Since 1972, an ice pier has been used for the annual resupply and refueling vessels to transfer cargo; this operation continues today. The ice pier consists of a matrix of steel cable over the ice surface that is subsequently flooded with water. Repeated frozen water layering results in thickness sufficient to support operations and cargo. Each season before use, approximately 15 cm (6 in) of fines are spread over the top of the ice pier to provide a working surface and insulation against solar heating. This material is then scraped off at the end of each year for reuse. Periodically, the ice pier deteriorates and becomes separated from the shoreline and is then towed out to sea for disposal (following procedures approved through a permit issued by the United States Environmental Protection Agency), to be replaced by the construction of a new ice pier.

Two important remote facilities were located near McMurdo Station. Marble Point, located approximately 90 km (55 mi) from McMurdo Station near the MDV, served as a helicopter fueling area and logistic support area for science projects. Marble Point was constructed to comprise three modular wood buildings and four fuel bladders, and was staffed by two workers during the austral summer. All waste from Marble Point was contained and returned to McMurdo Station. Approximately 33 km (21 mi) southwest of McMurdo Station, BITF was established in 1985 as the satellite communication (SATCOM) link for all primary, off-continent communications. BITF was developed to include housing for a small austral summer staff and an antenna to send and receive communication signals.

2.2.2 Improvements to McMurdo Area

Numerous improvements to McMurdo Station infrastructure and support resources have been completed since the early 1990s. These efforts were necessary to meet the changing needs of scientific research, replace old facilities, improve operational efficiencies, and enhance environmental stewardship. Potential environmental impacts from each of these planned improvements were assessed and appropriate mitigation measures were designed and implemented during construction and operation. Additionally, projects were monitored during implementation to ensure that mitigations were appropriate and effective. The following discussion highlights key improvements to illustrate the gains in efficiency and environmental stewardship and identifies the EIA document that assessed potential impacts. Table C-1 in Appendix C provides a more comprehensive list of EIA reviews conducted between 1990 and 2018.

The Albert P. Crary Science and Engineering Center (Crary Laboratory; NSF 1988, 1992a), the Science Support Center (SSC), (NSF 1999), and the Long Duration Balloon facility (LDB; NSF 1994a, 2004a, 2007a, 2014a) are three important science-support facilities that were constructed and have been in operation since the early 1990s. These facilities consolidated and improved or expanded science-support capabilities. The Eklund Biological Laboratory and Thiel Earth Science Center were demolished and removed from McMurdo Station and replaced by the Crary Laboratory, which provided expanded space (4320 m^2 [46,500 ft^2]), aquaria facilities, and modern laboratories. The SSC replaced the USAP Garage that was constructed in 1958, expanding available space and consolidating activities from the Mechanical Equipment Center (MEC) and Field Safety Training Program. The LDB facility is located on the McMurdo Ice Shelf and includes eight buildings, providing dedicated facilities for 60-100 staff in support of NASA balloon launches and subsequent communications and control, tracking, and data processing activities.

Improvements in the storage and distribution of fuel have been a long-term effort at McMurdo Station (NSF 1992b, 1997a, 2000a, 2004b, 2006a, 2007b, 2007c, 2008a, 2009a, 2011a, 2012). Bulk fuel storage increased between 1990 and 2018 to 14 above-ground tanks that have a combined capacity of 50 million L (13.2 million gal). This represented a 47% increase in fuel storage capacity at McMurdo Station. In addition, environmental protection during fuel off-load from vessels at the ice pier was reviewed and has been improved (NSF 2006b). The upgrades removed most small, single-walled tanks and consolidated fuel into new, larger tanks with leak detection, improved piping and hoses, and secondary containment. These improvements reduced the need for annual refueling (depending on annual usage rates) and the potential for spills. In addition, all day tanks throughout McMurdo Station now have secondary containment and are inspected as part of a spill prevention plan. Similar upgrades have been completed at Marble Point (NSF 1991a, 1994b, 1995a, 2004c, 2007d, 2013a), resulting in a bulk fuel capacity of approximately 567,000 L (150,000 gal) in six steel tanks.

Wastewater treatment has been improved since 1990 (NSF 1995b). The Wastewater Treatment Plant (WWTP) now uses extended aeration technology and treated effluent is disinfected with ultraviolet light before it is discharged into McMurdo Sound. The WWTP reduced pollutant discharge by approximately 85%, consistent with United States regulatory levels. Wastewater treatment residues (e.g., biosolids) are digested, dewatered, containerized, and retrograded to the United States for disposal as non-hazardous solid waste. Additionally, a sewer system now connects plumbed buildings to the WWTP, and the floor drainage wastewater from the VMF is conveyed to an oil/water separator system before introduction into the sewer system. Oil from the wastewater is accumulated, containerized, and retrograded as hazardous waste, while the remaining water is discharged with sanitary wastewater. These improvements in wastewater processes and capabilities have reduced the toxicity of releases. Saline effluents (e.g., aquarium seawater, brine from potable water production, and unprocessed seawater) are conveyed in piping that bypasses the WWTP and is discharged into McMurdo Sound.

Electricity is now provided by five, efficient, diesel-electric generators (NSF 2004d). Two 1,500 kW generators and one 1,300 kW generator are in the station's power plant. Two additional 1,500 kW generators at the water plant are used when other units are taken offline for maintenance or when unanticipated power outages occur. All five McMurdo Station generators are regularly used, including the two located in the water plant, and all five are cycled to maintain an equal number of operational hours.

The power plant is equipped with a waste-heat collection system. Under average load levels, approximately 2270 kW of heat is produced and used to heat selected buildings, saving an estimated 935,000 L (247,001 gal) of fuel annually. Wind turbines cooperatively operated by Antarctica New Zealand (ANZ) and the USAP supply electrical power to a grid operated jointly by the USAP and ANZ. The turbines are at a site overlooking ANZ's Scott Base, approximately 3 km (1.9 mi) from McMurdo Station. Each wind turbine can generate up to 330 kW. Annually, the wind turbines produce approximately 22% of total Ross Island power.

Heat for buildings not included in the waste-heat system is provided primarily by petroleum-fueled furnaces. Fuel is provided to these buildings from small aboveground tanks (i.e., day tanks) that are filled approximately once a week, either by a tank truck or via a direct pipeline connection to bulk fuel storage tanks. The use of more efficient generators, alternative energy sources (e.g., wind turbines), and waste heat has reduced fuel use compared to 1990.

Since 1990, no major improvements have been made to the fresh water production system at McMurdo Station. Minor improvements include using low-flow toilets, implementing water conservation practices, and educating the McMurdo Station population on the need for water conservation. However, fresh water production remains at approximately 277,000 L/day (74,000 gal/day), resulting in approximately 39,357,000 L/yr (10,370,000 gal/yr), and water storage capacity remains at 760,000 L (200,000 gal).

Environmental protection efforts focus on minimizing and managing waste at McMurdo Station and outlying facilities. Since 1990, waste minimization and recycling efforts have reduced the amount of waste produced (NSF 1990). On average, approximately 873,120 kg (1,824,900 lb) of non-hazardous solid waste is generated annually, which is a 61% reduction from the quantity of waste produced in 1990. Typically, 60% of the non-hazardous solid waste transported out of McMurdo Station is recycled. Approximately 230,920 kg (515,710 lb) of hazardous waste was generated and removed annually between 2014 and 2018. This volume is 66% greater than the volume from 30 years ago, attributable to changes in research and hazardous waste handling procedures. Since the 1990s, hazardous waste handling and packaging has improved to reduce potential releases to the environment. In addition, per the United States implementation of the Protocol, all hazardous waste started to be packaged, shipped, and removed from McMurdo Station for disposal in the United States within 15 months of generation. To improve efficiency and limit the release of waste, waste handling was consolidated (NSF 1996, 1997b) and processed (to the maximum extent possible) in enclosed buildings. The USAP also established procedures for demolishing buildings (NSF 1997c, 2014b) that minimize releases to the environment by highlighting waste management and minimization actions.

Fines have been and continue to be excavated for building foundations and road maintenance. To minimize disturbance, the USAP developed a management process to identify specific harvest areas. These defined areas and fines harvesting methods were reviewed to minimize environmental impacts (NSF 2003, 2004e, 2007e, 2010, 2011b, 2014c). Between 2005 and 2016, NSF attempted to thermally treat soils contaminated with hydrocarbons (NSF 2005a, 2013b, 2015b). Treatments resulted in some success and the ability to re-use treated fines. However, at the end of 2016, thermal treatment was discontinued due to cost and inconsistent results.

Aircraft fuel-use efficiency has been improved since 1990 by replacing C-5s and C-141s with C-17 aircraft and using improved engines and propellers on LC-130s. From 1990 through 2002, the USAP used a seasonal sea-ice runway (on the sea ice immediately adjacent to McMurdo Station). Williams Field skiway (on the ice shelf) has been in continuous operation since the early 1960s. Since the ice shelf is in continual motion toward McMurdo Sound, Williams Field has been moved multiple times as it approached the ice edge (NSF 1994c, 1995c, 2009b, 2018a). Beginning in 2002 and continuing through 2017, the Pegasus blue ice runway was used in combination with Williams Field and/or the annual sea ice runway. The USAP stopped using the sea ice runway in 2015. Phoenix Runway (Phoenix), a new, packed-snow airfield was constructed in 2016 (NSF 2015c). Fixed-wing aircraft began using Phoenix in 2017, and operations at Pegasus ceased at that time (NSF 2017).

In 2007, the USAP began using overland traverses to provide logistical support and fuel to Amundsen-Scott South Pole Station (NSF 2004f, 2008b), BITF (NSF 2005b) and Marble Point. Transporting fuel to South Pole via traverse each year used 40% less fuel than would be used if delivered by aircraft alone. As of 2018, the USAP transports fuel to Marble Point via traverse at the beginning of the austral summer season and operates three traverses to South Pole Station throughout the season. The South Pole traverse is also used to remove waste from South Pole at a substantive fuel savings compared to using aircraft.

The USAP developed processes and evaluated the environmental impacts of routine field operations, including:

- Camp construction, operation, and closure (NSF 2008c)
- Deployment and management of fuel caches (NSF 1997d)

- Remotely deployed equipment use (NSF 2008d)
- Automatic weather station installation, maintenance, and removal (NSF 1995d, 2001a)
- Explosives use (NSF 1995e, 2004g, 2006c)

The development of standard procedures supported environmental protection and resulted in mitigations that were consistently applied. More recently, environmental training and tracking processes were put in place in the USAP to prevent and/or immediately mitigate the occurrence of non-native species in the Antarctic. (Refer to Section 6 for additional discussion on mitigations and environmental stewardship.)

2.2.3 Current Layout of McMurdo Station and Supported Facilities

Changes at McMurdo Station have resulted in a station footprint that is the same size as in 1990, but with some consolidation of similar functional areas (Figure 2-2). As described above, process efficiencies and new capabilities have improved waste handling and fuel use, lowered the risk of fuel spills, and improved wastewater discharge. The discussion below summarizes the current layout of McMurdo Station, BITF, MDV fixed facilities (Marble Point is discussed above), and field camps supported from McMurdo Station. Additional information on current operations at the station and outlying facilities is provided in Section 3.4. Fuller discussions of environmental stewardship mitigations and monitoring are found in Sections 6 and 7, respectively.

As of 2018, McMurdo Station consists of repair and maintenance facilities, dormitories, administrative buildings, a firehouse, a medical clinic, redundant power and water production plants, an ice pier, recreational facilities, warehouses, bulk fuel tanks, and laboratories/research facilities. The station has approximately 63,200 m^2 (680,000 ft^2) of dedicated storage space for materials and supplies in 22 buildings. Eleven lodging facilities are located along the western side of the station and consist largely of two- and three-story dormitories. Additional lodging is located in the station core building (Building 155), along with administrative offices and the dining facility. Air traffic control, weather, and radio communication are co-located in one building, as are the McMurdo Station data center and National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA) Joint Polar Satellite System (JPSS) ground station operations. Other station support facilities are the VMF, a flammables storage building, a building housing both fuel operations and an electrical warehouse, two combination power/water plants, and the WWTP.

McMurdo Station hosts multiple communication systems, including local and off-continent telephone, radio-telephone, high frequency (HF) and very high frequency (VHF) radio, and SATCOM. Most communication facilities are concentrated at the HF Transmit Site (T-Site), which is located on a hillside 170 m (558 ft) above sea level and approximately 1 km (0.6 mi) east of the main station area. T-Site includes a transmitter operations building, satellite receptor radomes, 17 antenna towers, data relay station, and various above-ground power cables and telecommunications lines. T-Site facilities are connected to the McMurdo Station electrical grid. For data transmission, fiber-optic and copper cables connect T-Site to various structures at the station. Additional capabilities and antennas installed since 1990 have been reviewed to identify and minimize environmental impacts (NSF 2000b, 2000c, 2000d, 2000e, 2007f, 2008e). Most recently, construction of a new earth station at T-Site to potentially replace the satellite receptor station (also referred to as an “earth station”) at BITF has been initiated (NSF 2018b).

In 2012, two earth stations began operation at McMurdo Station to receive data transmitted by satellites supporting the NOAA JPSS program. One JPSS receptor is approximately 600 m (1969 ft) north of the station, near the existing NASA McMurdo ground station antenna and the other is approximately 600 m (1969 ft) east of the station, at T-Site. Both receptors operate passively and do not transmit data off the continent.

Aircraft operations and associated service areas for ski-equipped aircraft are based at Williams Field on the McMurdo Ice Shelf, about 11km (7 mi) southeast of McMurdo Station. McMurdo Station is accessible by plane year-round. Wheeled aircraft (e.g., C-17) can land at Phoenix, which is approximately 18 km (11 mi) from McMurdo Station. C-17 landings may occur as frequently as every 4-6 weeks during the austral winter to deliver supplies, science teams, and personnel.

Williams Field and Phoenix operate 24 hours a day during the summer. A maximum of approximately 75-80 staff support flights and operate ground facilities at these airfields. Williams Field handles approximately 75 large aircraft intercontinental flights, while Phoenix handles approximately 52 large aircraft intercontinental flights each year. In addition, approximately 200 large-aircraft intracontinental flights (i.e., round-trips to South Pole Station and to deep field camps) originate at the two airfields each season. A few intercontinental flights during the austral winter land at Phoenix each year. Both airfields handle small, fixed-wing aircraft (e.g., Twin Otter and Basler) throughout the austral summer, and Phoenix handles a few flights during the austral winter.

Bell 212 and AS-350-B2 (A-Star) helicopters support camps in close proximity to McMurdo Station, including sea ice camps, tent camps, and MDV camps. The helicopter landing area, hangar, and maintenance facilities are located south of the Crary Laboratory at McMurdo Station. Table 2-1 lists typical annual flight hours for each type of aircraft operated out of McMurdo.

Table 2-1. Typical Annual Aircraft Support to the USAP

Type of Aircraft	Flight Hours
LC-130/C-130	2,613
C-17	250
B-757	15
A-319	50
Twin Otter/Basler	1,632
Helicopters (all)	1,500

Depending on the intensity of airlift operations, up to 950,000 L (251,000 gal) of fuel per week may be transferred to the airfields and stored in multiple 75,600 L (20,210 gal), double-walled, steel tanks. Diesel fuel for aircraft, equipment, and structures is transferred from McMurdo Station to the airfields via a 25 cm (10 in) diameter flexible hose. The hose is deployed along the runway access road at the beginning of each austral summer and retrieved at the conclusion of seasonal runway operations.

BITF has been upgraded since 1990 and is now composed of multiple, prefabricated buildings, radomes, communications towers, antennas, wind generator turbines, and fuel storage tanks (NSF 1991b, 1997e, 2001b, 2005c). BITF continues to support HF communications with field camps and with United States

Air Force and Air National Guard aircraft operating in the Antarctic interior, and BITF receives recreational television programming for rebroadcast to the USAP facilities in Antarctica. Access to BITF is by helicopter during the austral summer and by traverse during the austral winter. The facility is staffed during the summer and operates in an automated mode in the winter, except when maintenance personnel are needed for emergency repairs.

Marble Point, discussed earlier, remains as an important refueling station for helicopters supporting work in the MDV. Marble Point continues to serve as a helicopter fueling and logistics support area for science projects. Marble Point includes three modular wood buildings and six steel bulk fuel tanks with a capacity of approximately 567,000 L (150,000 gal). Marble Point continues to be staffed by two workers during the austral summer, and all waste continues to be contained and returned to McMurdo Station.

During the austral summer, the USAP typically supports approximately 80 research projects at 60 field camps. The USAP's field camps are categorized by size: major camps, minor camps, tent camps, day-use facilities, and traverse/mobile camps. Camp categories and typical camp resources are presented in Table 2-2. An Initial Environmental Evaluation (IEE; NSF 2008c) evaluated the potential impacts of construction, operation, and closure of field camps and identified mitigation measures.

The USAP's field camps are located in remote areas in a variety of environmental settings (e.g., snow- and ice-covered terrain, dry land, coastal areas, and sea ice) and are supported from McMurdo Station. The size of each camp is designed to meet specific research needs and operational requirements and can range from tent camps occupied solely by researchers to major, semi-permanent facilities composed of multiple, rigid structures and occupied by several dozen personnel, including a camp manager, support personnel, and researchers. The USAP also partners with the Antarctic programs of other nations to share existing or purpose-built camps.

Field camps may be operated for one season or multiple seasons. Upon completion of research and support activities, field camps are decommissioned and removed. In the event a camp is needed for more than one season, it is secured for the austral winter. Wastes generated at outlying facilities are placed in appropriate containers and transported via aircraft, vessel, or overland traverse to a primary USAP station. At some locations, sewage and other domestic liquid wastes are discharged to snow accumulation areas or in intertidal zones, consistent with Protocol requirements. In some instances, non-hazardous waste may be stored in the field over the austral winter in a manner that prevents their release to the environment and prevents damage to the containers when the wastes are removed, typically during the following austral summer season.

The USAP manages seven camps within fixed facility zones in the MDV, Antarctic Specially Managed Area (ASMA) No. 2. Each facility zone has a small laboratory, a kitchen and common area structure, a helicopter landing area, a toilet facility, and sleeping tent sites. These facilities assist in limiting environmental impacts from repeated overnight visits by research teams. All of the USAP activities that occur within the MDV are conducted in accordance with the MDV ASMA Management Plan guidance (Table 4-1 provides weblinks to applicable management plans).

Deep field sites are generally a significant distance from a permanent supply facility and require transportation by ski-equipped aircraft or overland traverse. The types of camps operated at deep field sites are major field camps, minor field camps, and tent camps. In the Antarctic interior, these camps are located on the snow-covered Polar Plateau (in East and West Antarctica), mountains, glaciers, basins, and ice shelves. Major camps may support more than one field research project and/or serve as a logistical support facility. Such camps may include groomed skiways and fuel storage to support fixed-wing aircraft.

Scientific research activities in coastal or sea-ice areas near McMurdo Station are typically conducted from a minor camp, tent camp, or mobile camp. Some research sites on the McMurdo Sound sea ice have mobile huts for day use by personnel based at McMurdo Station. In a normal year, between 10 and 20 camps are established in these settings. A proposed major field camp in a coastal region or on seasonal sea ice would likely require a site-specific environmental impact assessment.

2.3 International Collaborations

International collaborations have been an important part of United States research activities for many years and would continue during the proposed activity. Such collaborations bring together expertise from various national programs and minimize impacts associated with redundant actions and resources. Collaborations involve joint science projects and sharing facilities or logistical resources, such as stations, airfields, cargo and fuel ships, field camps, traverse platforms, and research vessels to avoid duplicated efforts and thereby minimize environmental impact. Below is a description of some international collaborations that illustrate the diversity of United States engagement at McMurdo Station and surrounding areas whose remote facilities are supported from McMurdo Station; however, it is not an exhaustive or complete list.

The United Kingdom and United States have initiated a joint research program (International Thwaites Glacier Collaboration) to improve decadal and longer-term projections of ice loss and sea-level rise originating from Thwaites Glacier. Eight research projects are being conducted from the 2018-2019 season through the 2021-2022 season and are focused on glaciological, geological, and marine science in the Thwaites Glacier and Pine Island Bay area of Antarctica. The United Kingdom and United States are sharing vessels, traverse capabilities, field camps, and aircraft. In addition, South Korea is collaborating with the project through research being conducted on its research vessel and other nations are expected to join the effort.

The United Kingdom and United States conducted research between the 2010-2011 and 2012-2013 seasons to study the oceanographic and glaciological characteristics of the West Antarctic Ice Sheet near Pine Island Glacier. The goal was to understand the interaction of the ocean and ice (heat, mass, and salt fluxes) at the sub-ice shelf interface. Shared resources included aircraft, camps, and traverse capabilities.

New Zealand and the United States have collaborated on an international science project on Roosevelt Island to understand past, present, and future environmental changes in the Ross Sea sector of West Antarctica. The effort supported 27 different events, with over 105 scientists and 40 support staff. An international team that included United States researchers collected approximately 760 m (2493 ft) of ice core, conducted geophysical data logging of the borehole, and measured borehole temperatures during the 2010-2011 and 2011-2012 field seasons. Additional geophysical surveys at nearby sites were conducted during the 2012-2013 field season.

The United States built a field camp and helicopter facility to support collaborative, international research in the Central Trans-Antarctic Mountains (CTAM) near the Beardmore Glacier. Multi-disciplinary, international research teams from the New Zealand, China, and the United States operated out of the camp during the 2010-2011 and 2011-2012 seasons.

The ANtarctic geological DRILLing Programme (ANDRILL) McMurdo Sound Portfolio was a research collaboration with over 150 scientists from New Zealand, Germany, Italy, and the United States. The project investigated the role of Antarctica in global environmental change and implications for future change through stratigraphic drilling of ice-marginal sedimentary basins in Antarctica. The United States provided drilling, aircraft, and other logistical support for the project during the 2005-2006 and 2006-2007 seasons and additional, similar support from the 2007-2008 through 2010-2011 seasons (ANDRILL Coulman High Project).

The Concordiasi program (2008-2010) was a result of a joint initiative by France and the United States for atmospheric science in the Polar Regions. Concordiasi used stratospheric balloons as research platforms to carry instruments for taking in-situ and remote measurements of the atmosphere over the Antarctic region. Concordiasi was similar to the Stratéole-Vorcore project, a previous campaign at McMurdo in 2005, where 27 balloons were launched to permit calibration of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) weather satellites for improved global and regional forecast modeling.

The Antarctica Gamburstev Province (AGAP) project was a large International Polar Year effort to determine the role of the Gamburstev Mountains in the origin and dynamics of the East Antarctic Ice Sheet. Buried under 4 km of ice, the mountain range and associated subglacial aquatic system was studied through aerogeophysical surveys using ice-penetrating radar, gravimeters and magnetic sensors and a network of seismic sensors. This project, conducted in the 2008/2009 field season, involved the United Kingdom, Australia, Canada, China, Germany, Japan and the United States.

In 2007-2008, an international team of scientists and teachers from Sweden, Chile, and the United States participated in a research cruise on the Swedish icebreaker Oden as part of the International Polar Year. While the primary mission of the Oden was to establish the re-supply channel into McMurdo Station, the ship's transit from Chile to the Ross Sea provided an opportunity for collaboration. Nine projects studied ocean characteristics, sea ice, wildlife abundance and distributions, and pollutant presence.

The long-term, successful collaboration in ice core research at Vostok Station among Russia, France, and the United States (with support based from McMurdo Station) resulted in major advancements in understanding the climate history of the Earth over the past 420,000 years. In 1996, during the later years of ice coring, the discovery of the subglacial Lake Vostok, underscored the value of this collaboration and heightened interest in subglacial lakes in the broader Scientific Committee on Antarctic Research (SCAR) community. Subsequent interest in subglacial lake environments resulted in broad community involvement in the development of the SCAR *Code of Conduct for the Exploration and Research of Subglacial Aquatic Environments* (SCAR 2011).

In the 1990s, scientists from the United Kingdom, Australia, Germany, Italy, New Zealand, and the United States conducted a joint research program to recover and analyze cores from sedimentary strata beneath the sea floor in the Ross Sea, about 12-14 km (7.5-8.7 mi) east of Cape Roberts. The team drilled three sedimentary cores and recovered about 1500 m (4921 ft) of core material.

The Dry Valleys Drilling Project (DVDP) was conducted from 1971 through 1976 as a predominately international project among scientists from New Zealand, Japan, and the United States. The project drilled 14 holes in the MDV (at Lake Vanda, Don Juan Pond, Lake Vida, Lake Fryxell, Lake Bonney, New

Harbor, Marble Point, Lake Leon, and North Fork), on Ross Island (at Cape Evans, Cape Royds, and Cape Barne), in McMurdo Sound, and on the Walcott Glacier. The areas investigated have a series of independent analyses of Antarctic geochronology, paleoclimatology, and paleomagnetism. Other projects in the MDV that affiliated with DVDP involved extensive geochemical studies of soils, geothermal measurements in boreholes, a hydrogeological program in the boreholes and lakes, lake geochemistry, and a feasibility study for an earthquake seismology program.

Cape Hallett Station was a joint New Zealand and United States station built in 1956-1957 that had living spaces, a balloon-inflation building, geomagnetic huts, an aurora observation tower, and a landing area. The station was converted to a summer-only facility after the 1964 winter and was closed in 1973. Human impacts on the penguin colony were substantive, and the station was demolished and cleaned up between 1984 and 1986. However, several huts, fuel stores, a 378,541 L (100,000 gal) fuel tank, and debris remained. In 2001, a joint United States and New Zealand team carried out an environmental site assessment, which led to a multi-year remediation project for the station site and surrounding area. Several expeditions removed remaining buildings and the fuel storage tank. Removal of the station was completed in February 2010, with assistance from the Italian Antarctic program and the use of the supply ship Marine Vessel Italica.

The United States engages in collaborative efforts to manage Antarctic Specially Protected Areas (ASPAs) and ASMAs. Collaboration and coordination of activities routinely occurs at Arrival Heights, Cape Royds, and Cape Bird. Also, there is research coordination and information exchange within the MDV ASMA Management Group, which includes members and participants from New Zealand, Italy, China, Korea, the United Kingdom, SCAR, Antarctic and Southern Ocean Coalition, the International Association of Antarctica Tour Operators, and the United States (current chair). The ASMA website (http://www.mcmurdodryvalleys.aq/) provides another venue for international coordination. Below is a summary of some of the specific research and logistical field collaborations between the United States and other parties.

The United States has long-standing and annual agreements with several Council of Managers of National Antarctic Programs (COMNAP) members for cooperative logistics support. The longest United States agreement in the McMurdo Station area is with New Zealand. Resource collaborations include airport facilities and passenger/cargo processing in Christchurch, New Zealand, flights between Christchurch and Antarctica, airport facilities in Antarctica, helicopters, vessels (including a resupply vessel, fuel tanker, and icebreaker), joint on-ice search and rescue, medical and medical evacuation support, logistics support personnel, the Ross Island wind energy combined grid, and other cooperative agreements. Resource collaborations between the United States and New Zealand allows for smaller footprints of both McMurdo Station and Scott Base, collectively reducing the impacts to Ross Island and the surrounding area. New Zealand is currently considering options for redeveloping Scott Base and intends to submit a draft CEE to the Committee for Environment Protection (CEP) in early 2019. As Scott Base redevelopment plans move forward, opportunities for further collaboration would develop.

Other logistics agreements related to the activities of McMurdo Station have been made with Australia, China, Italy, Korea, France, and the United Kingdom, mostly involving the transport of people and fuel among various sites in Antarctica. These agreements serve to reduce redundancy and improve efficiency, which results in a reduced cumulative impact to the Antarctic environment.

Table 2-2. Typical Field Camp Characteristics in the USAP

Facility/Resource (approximate number/year)	Annual Population (person - days)	Fuel Consumption (L)	Resources[1]
Major Field Camps ***(up to 40 persons/day)***			
Research or support camps (typically 6/year)[2]	500 – 2000	50,000 – 200,000	Structures (≤ 15), generators, heavy equipment, vehicles, snowmobiles, all-terrain vehicles (ATVs), and bulk fuel storage and distribution devices (tanks, bladders)
Minor Field Camps ***(up to 15 persons/day)***			
Research or support camps (typically 12/year)[3]	100 – 600	10,000 – 50,000	Structures (≤ 5), generators, vehicles, snowmobiles, and ATVs
Tent Camps (*up to 10 persons/day)*			
Research camps (typically 40/year)	2 – 400	1000 – 10,000	Tents, generators, vehicles, snowmobiles, and ATVs

(1) Source: Environmental document *Construct and Operate New or Modified USAP Field Camps* (NSF 2008c).

(2) Major camps typically operated by the USAP each year include Lake Bonney and Lake Hoare in the MDV and Western Antarctic Ice Sheet (WAIS) Divide and Central Trans-Antarctic Mountains (CTAM) deep field camps.

(3) Common minor camps operated by the USAP include Bull Pass, F6, Lake Fryxell, Lower Erebus Hut, Mount Newall, and New Harbor.

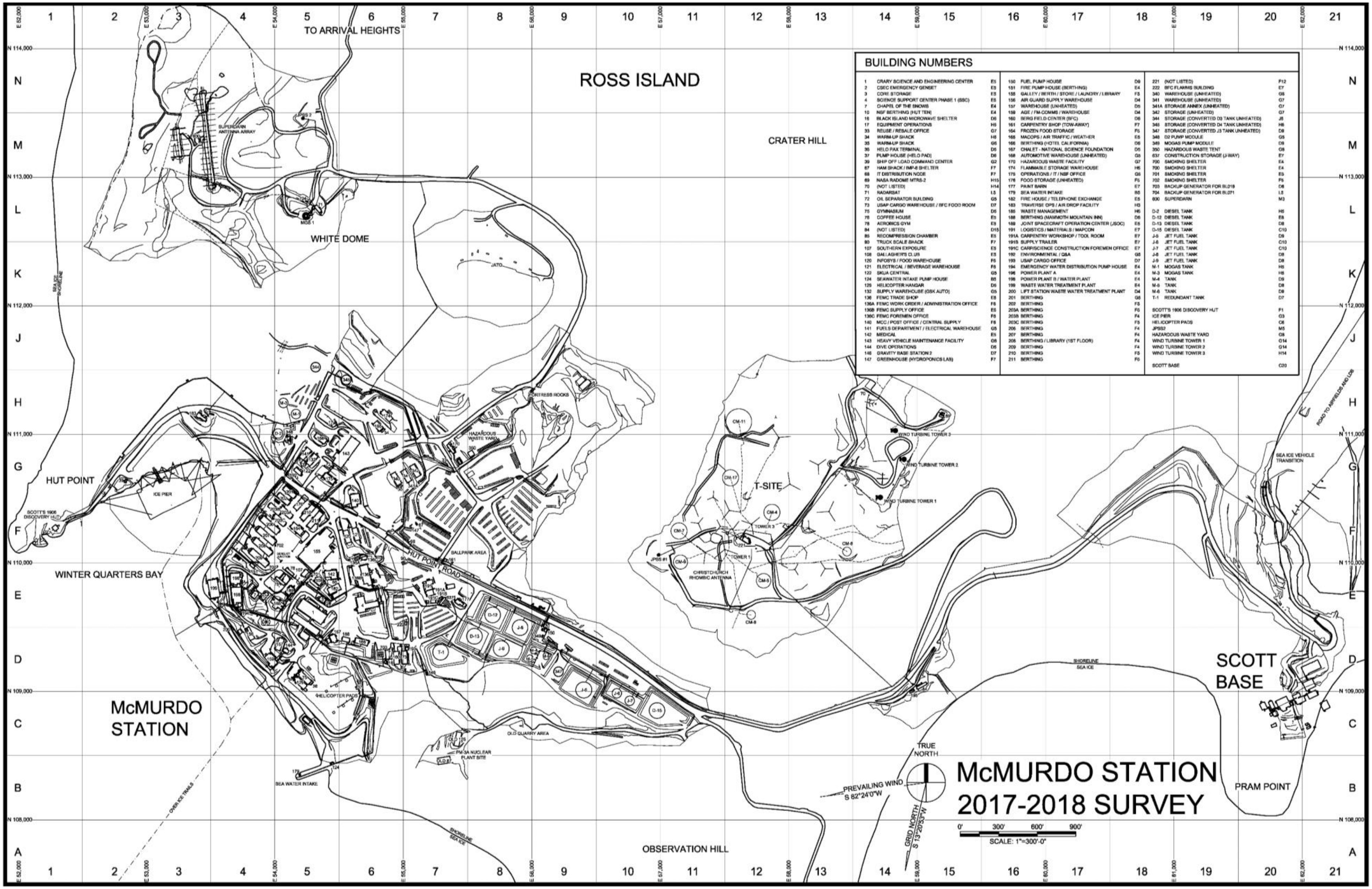

Figure 2-2. McMurdo Station Existing Facilities in 2018

3. Proposed Activity and Alternatives

3.1 Introduction

The proposed activity would implement modernization projects under the McMurdo Master Plan (including AIMS projects) while continuing the USAP's research activities and support operations (Alternative A). The following sections describe the three elements of the proposed activity.

Modernization projects incorporate three phases: construction, operation, and closure (decommissioning and demolition/removal). Similarly, continuing operations would be modified as necessary as modernization projects replace existing facilities and capabilities, until the final closure of McMurdo Station sometime in the future (as presented in Section 8).

The construction phase for the AIMS subset of McMurdo Master Plan activities would start in late 2019 and continue through approximately 2026 (a minimum of eight years). The construction phase for remaining McMurdo Master Plan projects would start in 2027 and continue through approximately 2033 (a minimum of seven years). Note that the construction schedule for modernization projects may be delayed or extended beyond the planned schedule, dependent on weather, material procurements, and other factors. However, for the purposes of this impact assessment, the above schedule is used. Overall, the combined construction phase for modernization projects would be approximately 15-20 years. If the schedule is extended, impacts would be similar, though the intensity would be reduced as the duration increases.

The proposed projects are sequenced to enable ongoing scientific and operational activities during construction, the USAP considered the timing and sequencing of the proposed projects. Additional considerations that influenced work phasing included logistical challenges with delivering project materials via resupply vessel, limited laydown and storage space at McMurdo Station, a finite quantity of worker lodging, reduced airlift schedule during mid-summer, and seasonal weather variations. New or replacement facilities would be built before existing buildings are vacated and demolished. Some existing facilities would be demolished prior to construction, if the facility is located in the footprint of proposed replacement buildings, in areas requiring access to construction sites, or in the way of equipment needed for construction.

3.2 Implement AIMS Projects under the McMurdo Master Plan

Implementing AIMS would provide increased flexibility to meet changing research requirements and improve support efficiency. Seven projects have been identified as part of AIMS, including construction and operation of the Vehicle Equipment Operations Center (VEOC), one lodging building, Central Services, Emergency Operations, Field Science Support, Industrial Trades Building, and associated utility improvements. Functions that are currently located in 25 buildings would be consolidated into eight buildings (Figure 3-1). Most buildings would be connected to the station's existing heat recovery loop, and combined heat and power systems are being considered for buildings where connecting to the main loop is impractical. In addition, utilities and drainage would be improved as part of the AIMS project. Approximately 20 buildings would be demolished during the construction phase of the AIMS project. Table 3-1 includes the estimated amount of demolition debris that would be generated. Each action under AIMS is summarized below. Potential impact sources resulting from implementing each phase (construction and operation) are described in Section 3.2.2.

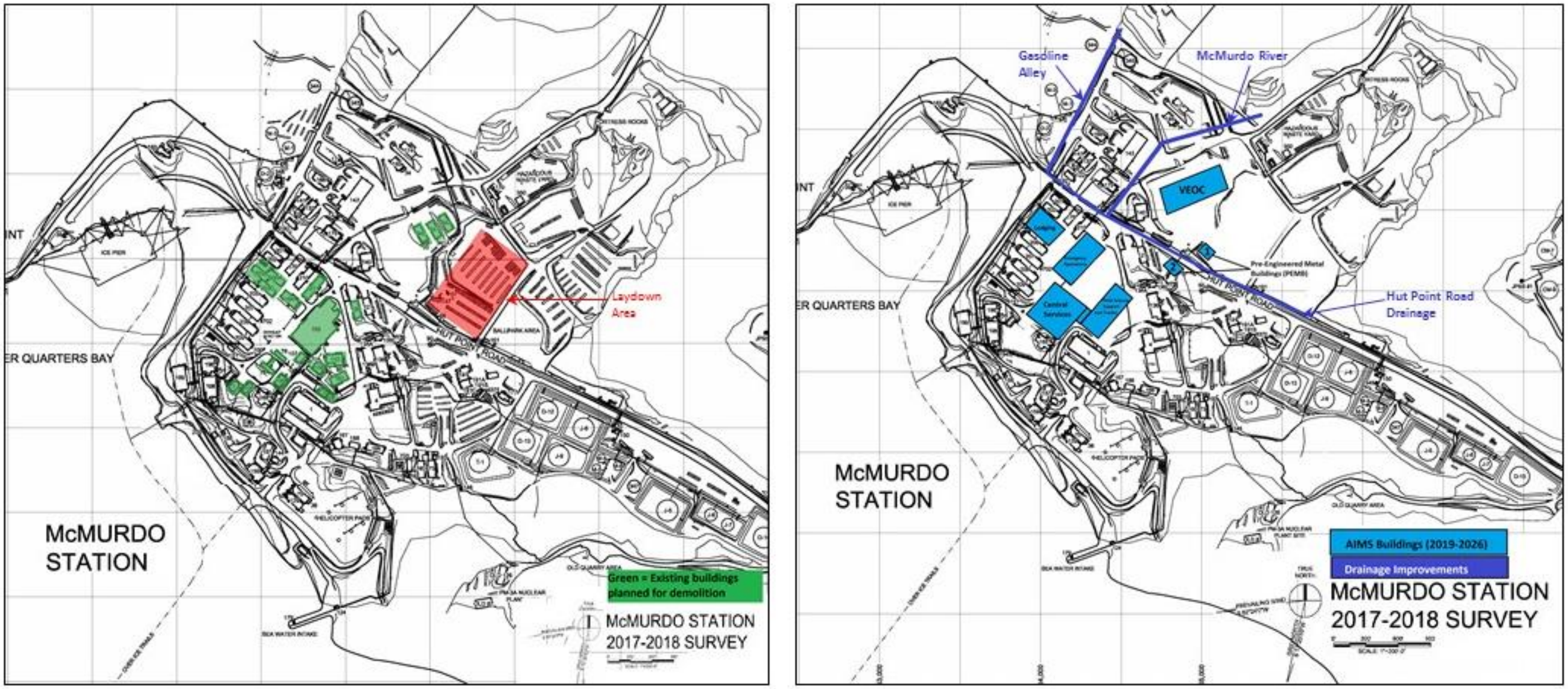

Figure 3-1. McMurdo Station Current Layout and Planned Demolitions

Left: Demolitions (green highlighted buildings) with laydown area marked in red. Right: future state (estimate 2026), post-AIMS modernization activities (light blue buildings are new builds; white buildings are existing; dark blue lines are planned drainage improvements). Note: additional building demolitions or modifications that would occur during modernization under Master Plans are not included.

3.2.1 Summary Description of AIMS Projects

The VEOC would centralize the USAP's vehicle maintenance and repair activities and replace aging structures currently located across McMurdo Station (Figure 3-1). It would serve as the maintenance and operations facility for all McMurdo-based USAP equipment and vehicles by integrating maintenance functions of the current MEC, aerospace ground equipment (AGE), traverse operations, and fleet operations. The VEOC would be a 5388 m^2 (58,000 ft^2), split-level building with a wash bay, five heavy vehicle bays, and one light vehicle bay. The work area would include racks, workbenches, vehicle and welding exhaust systems, lubrication supply and return, pneumatic or hydraulic lifts, and cranes. Administrative offices and storage (1,115 m^2 [12,000 ft^2]) for small parts and equipment would be in a mezzanine level above ground-floor tool and machine rooms. The VEOC building would be connected to existing station utility services through a new utility main. In addition, two 371 m^2 (4000 ft^2) pre-engineered metal buildings (PEMB) may be constructed adjacent to the VEOC. One PEMB would serve as a temporary cold storage warehouse until new, permanent cold storage is available; after which this PEMB would be used for parts storage. The other PEMB would serve as unheated parts storage for VEOC. The approximate construction phase for VEOC and the PEMBs would be between November 2020 and June 2022. Three cold-storage warehouses would be demolished (Buildings 340, 341, and 342) and explosives would be required to prepare the site for footings.

The Lodging #1 building would increase energy efficiency and reduce maintenance requirements compared to the existing housing it would replace. The building would be located adjacent to existing dorms (Figure 3-1). The building would be a three-story structure with up to 285 beds (both single and double occupancy rooms). Dorm-style bathrooms (showers and toilets) and recreational/social lounges would be included, along with other support spaces, such as storage and janitorial space. The project would include mechanical, electrical, plumbing, communications, and fire protection systems that would extend to the McMurdo Station main utility trunk lines and heat recovery loop. The approximate construction phase would be between September 2021 and August 2023.

The Central Services and associated warehouse building would be located adjacent to the current Building 155 and would centralize existing operations by consolidating administrative and station support functions. Central Services would include collaboration and small group spaces, a contemplative space, and social gathering areas. Specifically, Central Services would contain dining, food warehousing (dry, frozen, and refrigerated), commodity warehousing, and a multi-purpose lecture space. In addition, Central Services would contain the primary mission operations center for the station, which includes field and intercontinental communications, the fixed-wing aircraft service provider, air traffic control, and Fire Department dispatch. Secondary Information Technology and Communications (IT&C) infrastructure in Central Services would provide strategic redundancy and emergency backup capabilities to primary IT&C capabilities that would be housed in the IT&C primary operating facility (currently under construction). The Central Services building would be a two-story, 17-18 m (55-60 ft) tall, with an overall area of 12,151 m^2 (130,792 ft^2). The warehouse area within the Central Services building would be a high-bay structure that would accommodate frozen food, dry goods, and general commodities, and would include a small waste processing area. The approximate construction phase would be between January 2021 and January 2023. Central Services would consolidate capabilities from four existing buildings that would be demolished, including the aerobics gym (Building 076), Southern Exposure (Building 107), Coffee House (Building 078), and the Joint Spacecraft Operations Center (Building 189).

The new 4902 m^2 (52,767 ft^2) Emergency Operations Center would include a firehouse, medical clinic, and a multi-use area. The new Firehouse would include a protected staging area for emergency vehicles and berthing and a day room for firefighters on shift, administration areas, a training room, specialized capabilities for storing and servicing emergency breathing equipment, and storage for campus fire extinguisher stock and bunker gear. The Medical Clinic would feature administrative offices, exam rooms, a hyperbaric chamber for treating carbon monoxide poisoning and decompression illness, a dental exam and procedure space, and berthing rooms for patients requiring separation from the general population. The Emergency Operations Center would replace the existing Firehouse (Building 142), Medical Clinic (Building 182), and social area (Building 108). The approximate construction phase would be between January 2022 and May 2023, and three buildings (Buildings 155, 164, and 211) would require prior demolition.

The Field Science Support facility would be located across the road from the existing Crary Laboratory (Building 001) and next to the proposed Central Services building (Figure 3-1). Science field gear, field communications gear, and field mechanical gear would be issued from this facility. Field Science Support would replace the Berg Field Center (Building 160), Science Cargo (Building 073), and Antarctic Terminal Operations (Building 140). The building would be 4986 m^2 (53,664 ft^2), with an overall height of 14-15 m (45-50 ft) and would include training space, classrooms, administrative space, and staging areas for science, communications, and mechanical field gear. The approximate construction phase would be between January 2024 and December 2026.

The new 3731 m^2 (40,157 ft^2) Industrial Trades Building would be located next to the proposed Field Science Support facility, consolidating all light industrial trades within a single facility and replacing the trade shop (Building 136) and carpenter shop (Building 191) plus several smaller, ancillary support administration and storage buildings. The term "light industrial trades" refers to trades that primarily maintain station facilities, assemble minor scientific equipment, and perform minor fabrication or repair of scientific components. Shops would include carpentry, sheet metal, plumbing, electrical, field camp alternative energy equipment maintenance, and others. The building would also have warehousing space for the trades. A minimum of five existing structures (Buildings 182, 142/085, 108, 002, and 003) must be demolished before construction of this facility can begin. Demolition and construction would occur between January 2024 and December 2025.

Utilities improvements under AIMS (power distribution, communications, sanitary sewer system, water storage, fire protection, cable plant) would include new construction and enhancements to existing infrastructure. Additionally, utilidors and drainage would be improved throughout McMurdo Station. Utilities improvements would include installing underground, concrete utilidors; precast bulkheads and end walls; and aboveground racks, stanchions, structural bracing, and supports. Cleanouts, hydrants, fire pumps, pressure gauges, transmitters, and valves are included in this work. Switchgear, transformers, termination cabinets, pad-mounted switches, cabling (including aerial, above ground, and below ground), cable tray, conductors, emergency generators, heat trace cabling, and all other appurtenances also are included. Utilities and requisite conveyance would include fuel, combined potable and fire-suppression water, sanitary sewer, hydronic supply and return, electricity, and communications (fiber optic cable and copper wire), as well as the insulated piping apparatus. Construction and improvements would occur throughout the AIMS construction phase. As part of construction, redundant utility pathways would be created around the station using existing and new utilidors, providing redundant service to user facilities along the route from a minimum of two directions, thus reducing service disruptions. Existing structures would be connected via fiber and copper cables to the new outside plant pathway, and the existing hub-and-spoke network would be disconnected.

During construction, temporary electrical grid modifications would be installed to ensure that power remains for downstream users as existing feeders are demolished and replaced with new feeders and medium voltage cabling. This work would include temporary re-routing of existing overhead power lines; removal and relocation of power poles; temporary modifications to existing electrical feeders; and removals, additions, and modifications to electrical circuits and transformers. An area of approximately 929 m^2 (10,000 ft^2) within the existing, previously developed station footprint would be disturbed (i.e., excavated, graded, or otherwise displaced) during these actions.

Existing major drainages would be improved, including Gasoline Alley, Scott Base Road, and McMurdo River (Figure 3-1). Redesigned drainages would take advantage of their existing placement but would include new slopes, contours, rock check dams, and culvert systems to better control and contain melt water, reduce suspended sediment, and prevent road washouts. Drainages would also channel melt water away from buildings and toward Winter Quarters Bay. The construction phase would be ongoing and performed sequentially throughout AIMS (2020-2026). Approximately 3252 m^2 (35,000 ft^2) of surface area within the existing, previously developed station footprint would be disturbed during drainage improvements.

McMurdo Station's water supply is stored in four, 189,500 L (50,000 gal) tanks, which are insufficient to ensure a reliable quantity for both fire protection and potable use. An additional 246,051 L (65,000 gal) water tank would be constructed outside the existing power plant to hold required fire suppression water for the station, ensuring that all buildings have robust and reliable fire protection. A new pump house would be constructed and would contain a diesel-driven, 5678 L/min (1500 gal/min), high-capacity pump to meet fire suppression and distribution pressure needs. The pump house would also contain smaller pumps and equipment to recirculate warmed water in the new tank, in existing tanks, and in a water loop connecting all storage tanks. For redundancy, the existing, electric, 3785 L/min (1000 gal/min) fire pump in Building 194 would be replaced by an electric 5678 L/min (1500 gal/min) pump. This modification would provide redundant pumping capacity and power diversification to allow full-capacity fire suppression in the event of an emergency.

In addition, utilidors would be upgraded to interconnect the new water tank, new pump house, emergency water distribution pump house (Building 194) and power plant/water plant (Building 198), and existing utilidors. Upgrades would include the vertical pipe and horizontal C-channel supports needed to support above-ground, high-density polyethylene piping. This utilidor piping would contain conduits for combined potable and fire suppression water, electrical cabling, heat trace, and communications wiring. The approximate construction phase for the water tank and associated piping would be between November 2020 and February 2022.

3.2.2 General Aspects of AIMS Construction and Operation Phases

The construction phase for AIMS would start in late 2019 and continue through approximately 2026. The construction of modernization projects would require the steps described below. Table 3-1 provides levels of potential impact sources by construction year.

Site Preparation. Immediately before demolition, existing structures would be vacated and utilities to these structures isolated. Any materials stored outside but within the perimeter of the construction zone would be removed. The construction team would then demolish the buildings and branch utilities. Demolition would include removing footers, which may require limited blasting to loosen the footers from encasement in the Antarctic soil. After demolishing a structure, site soils would be inspected for contamination (from building use) and remediated as needed (Section 6, Mitigation Measures). Demolition waste would be sorted, segregated, and containerized according to the USAP's standards in order to facilitate future recovery and recycling and to minimize disposal costs. Containers of debris would enter the USAP's waste stream to be recorded and manifested for shipment to the United States for processing or disposal. Laydown space would be needed to unpack, organize, and deliver construction material. The laydown space would be approximately 15,250 m^2 (107,639 ft^2; Figure 3-1).

Fill and Fines Generation and Harvesting. Fill and fines required for construction would be acquired on-site (Table 3-1) and would be excavated from existing harvest areas. Native aggregate would be processed using a small, horizontal-impact-shaft rock crusher (purchased for modernization activities). Once fines are sieved to the required size and certified for use on building foundations, they would be placed and compacted as necessary (depending on results of soil density testing) to establish the required strength and grade for construction. When activities cause excessive soil disturbance, dust mitigation would be provided using a water truck and hoses (Section 6, Mitigation Measures).

Table 3-1. Anticipated Impact Sources of AIMS Construction Phase

Impact Source	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Average number of workers	135	189	139	111	40	59	38
Vehicle/equipment use (in hours)	6480	9720	11,880	9720	5400	3240	3240
Vehicle/equipment fuel use (L/gal)	98,040 / 25,900	147,180 / 38,880	179,880 / 47,520	1471800 / 38,880	81,765 / 21,600	49,060 / 12,960	49,100 / 12,960
Area disturbed (m^2/ft^2)	16,000 / 172,000	4830 / 51,990	19,320 / 207,980	11,334 / 121,998	9290 / 100,000	9290 / 100,000	0
New building space (m^2/ft^2)	7500 / 81,000	2420 / 26,000	9660 / 103,990	5667 / 60,999	4830 / 51,990	4830 / 51,990	0
Fill needed (m^3/yd^3)	35,935 / 47,000	15,290 / 20,000	11,470 / 15,000	3820 / 5000	7645 / 10,000	2295 / 3000	0
Excavated soil (m^3/yd^3)	13,750 / 18,000	3820 / 5000	3820 / 5000	2293 / 3000	15,290 / 20,000	765 / 1000	0
Solid (demolition) waste generated (kg/lb)	128,650 / 283,620	37,470 / 82,605	49,400 / 108,920	243,500 / 536,820	88,225 / 194,500	88,225 / 194,500	0
Hazardous waste generated	0	Lead paint	Lead Paint/ Asbestos	Lead Paint/ Asbestos	Lead Paint/ Asbestos	0	0
Number of buildings demolished	3	4	3	4	3	0	0

Blasting Operations. Blasting would be required to level construction sites, excavate foundation areas, and prepare road crossings for buried utility lines. Depending on existing conditions, blasting may be minimal (e.g., leveling the Emergency Operations site) or extensive (e.g., VEOC site preparation). Substantive blasting would also be required to loosen materials in order to install new, buried utilidors. Approximately 225 kg (500 lb) of explosives would be used annually to free up frozen areas as part of site work and preparation. An estimated 15,875 kg (35,000 lb) would be required to prepare the VEOC site. Once blasting (if needed) is completed, the site would be leveled, graded, and compacted to meet building construction requirements.

Construction Phase 1. Typically, each building would be constructed in two phases. The first phase would usually begin after material delivery via vessel (January-February) and continue until April/May, when work would be suspended for the winter and resume again the following season. Phase 1 for each building would involve

1. completing exterior utility runs to the structure;
2. placing the structural foundation, which may include geofoam, precast slab panels, precast walls, retaining walls, and selected exterior features, including concrete stairs, railings, and grates; and
3. erecting the structural steel framework for the building shell, including steel columns, roof beams, and girders.

Construction Phase 2. Construction Phase 2 would commence in September and follow the general sequence below, with staggered starts and overlapping work among new buildings to maximize productivity

1. Building structure, including roof frame, exterior walls and bay doors, stairs, and precast floor panels;
2. Building envelope, including structural insulated roof and siding panels, roof panels, hatches, windows, louvers, sealant, and exterior painting;
3. Interior work, including rough and finish carpentry; installation of data, communications, and electrical wiring; installation of mechanical systems (heating, ventilation, and air conditioning, and plumbing);
4. Furniture, fixtures, and equipment; and
5. Startup and final commissioning, as the final step of the construction phase, which would energizing, testing, and operating mechanical, electrical, air temperature control, ventilation, life safety, and similar building systems.

AIMS projects would become operational in different years until all work is completed in approximately 2026. Once completed, operational improvements are anticipated. Centralization of station facilities would reduce fuel use, lower vehicle operation hours, reduce power and heat requirements, lower air emissions, and require fewer workers. These potential gains are summarized below, discussed as part of continuing operations during and after the construction phase in Section 3.4.2. When complete, each individual building would not rely on equipment or systems from other facilities to be functional.

The most substantial operational efficiencies would derive from consolidating the station's physical footprint into new, modern buildings. Modern building materials and mechanical systems would result in a 35% reduction in station fuel consumption due to a 20% decrease in building square footage, increased insulation, better surface area/volume ratios, and increased use of heat recovery systems. A 20% decrease in the number of ground vehicles is also anticipated due to consolidating and centralizing station resources, since this would result in less driving between buildings.

The number of science-support personnel (e.g., logistics, operations, science-support staff) would be 12% fewer than current staff levels. Building, power, and mechanical system maintenance staffing would decline by 40% compared to current levels due to consolidated mechanical systems, modern maintenance methods, and work planning that uses a computerized maintenance management system. Science and aviation personnel are expected to remain at current levels.

Facilities maintenance material budgets would be reduced by 34%. The station footprint, which was optimized using snow accumulation modeling, would require less road maintenance, snow removal, and drainage maintenance. Moving inventory inside into modern, high-density, high-bay warehouses co-located with work centers would improve efficiency on many levels.

3.3 Implement McMurdo Master Plan

Implementing McMurdo Master Plan projects would provide the flexibility needed to meet changing research requirements and would improve support efficiency. Because the support requirements of future Antarctic research are not completely known, McMurdo Master Plan projects are not as well defined as AIMS projects described in Section 3.2. The USAP EIA process would be conducted prior to implementation of any future Master Plan projects to determine if the analysis in this CEE adequately assesses the environmental impacts. Generally, overall science needs and funding would influence the timing of these projects. Unless otherwise noted, it is anticipated that the majority of these projects would be implemented sometime after AIMS construction is completed.

The McMurdo Master Plan includes up to 11 projects involving the construction and operation of replacement and/or upgraded facilities and infrastructure for helicopter operations, waste processing, the Crary Laboratory, dive services, hazardous waste processing, fuel operations, power grid upgrades, and aircraft runway facilities. Additionally, existing unused buildings would be demolished as part of McMurdo Master Plan projects. Each action under the McMurdo Master Plan is summarized below. Potential impact sources that would result from implementing each phase (construction and operation) are described in Section 3.3.2.

3.3.1 Summary Description of McMurdo Master Plan Projects

A new, approximately 1858 m^2 (20,000 ft^2) helicopter hangar and passenger terminal would be built in a new, yet to be determined location to replace the existing facility. The new facility and helicopter flight patterns require further study to determine a final location. The 1.5 story hangar would take up most of the new facility, while the one-story administrative space would occupy approximately 279 m^2 (3000 ft^2).

A new 279 m^2 (3000 ft^2) waste processing facility would be built to increase waste handling, sorting, and packaging efficiency and to reduce the distance waste must travel from generation points. The waste processing facility would be a one-story structure, and its proposed location would be in the northwestern quadrant of McMurdo Station. Overall project design and funding would determine construction timing. The facility would replace several current buildings at the station, including the Waste Management office (Building 170) and the waste sorting building (Building 185).

Renovating the Crary Laboratory would provide new or remodeled labs, office spaces, sample freezers, aquarium facilities, administrative spaces, storage areas, supply areas, and an IT&C data room. A new, 465 m^2 (5005 ft^2) lower-level addition would house new mechanical, electrical, fire protection, direct digital control, and IT upgrades.

A new 93 m^2 (1000 ft^2) Dive Services facility would provide better access and storage space for equipment. It would feature shelving space, fresh-water showers to rinse gear, and warm storage space.

Siting has not yet been determined. It would replace the existing Dive Services facility (Building 144) and would be located south of the new Central Services building.

A new 279 m^2 (3000 ft^2) hazardous waste processing facility and a 743 m^2 (7998 ft^2) fuels processing unit would be located in the northwest quadrant of the station and away from inhabited structures, in compliance with physical safety standards. It would feature the mechanical, electrical, and architectural controls necessary to safely process, store, package, and ship hazardous waste. The hazardous waste processing facility would replace current buildings, including Hazardous Waste Storage (Building HAZ03).

Two additional lodging buildings (#2 and #3) would be constructed. The buildings would be located in proximity to Lodging #1 and would be similar to the proposed Lodging #1 building. Each would be three-story structures with up to 285 beds in both single and double occupancy rooms, dorm-style bathrooms (showers and toilets), and recreational/social lounges. The buildings would include mechanical, electrical, plumbing, communications, and fire protection systems that would extend to the main utility trunk lines and heat recovery loop.

Expanded and updated fuel distribution infrastructure would be co-located with utilities corridors for shared routing, support, and heating. Additional fuel piping would support new construction and reduce vehicular fuel deliveries to day tanks, provide usage metering, and replace existing, aging infrastructure. Proposed fuel distribution infrastructure upgrades would be added between 2020 and 2026.

Power grid upgrades would simplify maintenance and increase reliability by changing the medium voltage distribution system from overhead power lines to ground-based lines. Routing would coincide with other utilities where possible to minimize the amount of utilidor infrastructure required on station and reduce the possibility of accidental disruption. A ground-based infrastructure would increase maintenance and operation efficiencies and enhance reliability by eliminating the wind risk currently faced by a pole-mounted infrastructure. Locations to be upgraded would be determined by the need for power of a new facility. Temporary feeders would be required to keep downstream facilities energized during the upgrade but, ultimately these upgrades (including pad-mounted transformers), would result in a new, more reliable power grid. Upgrades would be implemented from 2020 through 2026.

A new distributed combined heat power (CHP) generation with an alternative energy technology system may be installed in some buildings. The CHP system would provide power to the building rather than relying only on a local grid, therefore improving energy efficiency by more fully integrating heat recovery with power generators to supply power. Other proposed facilities in the McMurdo Master Plan would be designed to accommodate future CHP systems.

Smart grid technologies would be used to automate the power distribution grid and integrate power sources, distribution, and loads throughout McMurdo Station. Smart grid technologies would encompass the CHP, central energy plant, wind-farm power, and potential photovoltaic power, as well as future power generation and storage technologies. Excess energy from all sources, including the CHP and wind turbines, would be used to create a balance of energy between heating and power needs.

An expanded and new heat recovery loop would be co-located with other utility lines and/or vaults. The heat recovery loop would capture heat from power generation and use it to provide radiant heat to station buildings. This loop would be extended to new facilities as they are constructed. The work would be implemented between 2020 and 2026.

Replacing runway support facilities would create a single airfield complex at McMurdo Station. The primary goal of the single airfield concept is to enhance operational efficiency by reducing the cost and redundancy of facilities located across multiple airfields during the austral summer. Twenty-seven (27) buildings, totaling 1471 m^2 (15,834 ft^2), would be replaced with 14 buildings, totaling 1821 m^2 (19,600 ft^2; Table 3-2).

Table 3-2. Replacement Airfield-Support Buildings

User	# of Buildings	m^2 (ft^2)
Air National Guard	3	557 (6000)
AGE/Cargo/Fixed Wing	4	399 (4300)
Space and Naval Warfare Systems Command	1	139 (1500)
Fleet Operations	2	130 (1400)
Aircraft Rescue and Firefighting	1	149 (1600)
Passenger Terminal	1	149 (1600)
Kitchen/eating and toilet facilities	2	297 (3200)
Total	**14**	**1820 (19,600)**

3.3.2 General Aspects of McMurdo Master Plan Project Construction and Operation

The construction phase for most of the McMurdo Master Plan projects would start in 2027 and continue through approximately 2033. Construction steps for McMurdo Master Plan projects are similar to the phases described in Section 3.2 for AIMS. Table 3-3 provides potential impact sources by construction year.

Table 3-3. Anticipated Impact Sources of the McMurdo Master Plan Projects Construction Phase

Impact Source	2026-27	2027-28	2028-29	2029-30	2030-31	2031-32	2032-33
Average number of workers	30	25	21	15	15	15	18
Vehicle/equipment use (in hours)	3240	1,250	2,650	2,500	2,500	2,500	2,800
Vehicle/equipment fuel use (L/gal)	47,100 / 12,440	13,100 / 3460	24,400 / 6450	23,500 / 6210	23,500 / 6210	23,500 / 6210	24,800 / 6550
Area disturbed (m^2/ft^2)	2140 / 23,0002,	6000 / 64,580	5250 / 56,510	500 / 5380	18,000 / 193,750	18,000 / 193,750	22,000 / 236,810
New building space (m^2/ft^2)	23,000 / 247,570	500 / 5380	372 / 4000	0	560 / 6000	560 / 6000	650 / 7000
Fill needed (m^3/yd^3)	12,250 / 16,020	1250 / 1635	3200 / 4185	0	0	0	0
Excavated soil (m^3/yd^3)	8000 / 10,460	850 / 1110	1250 / 1635	0	0	0	0
Solid waste generated (kg/lb)	37,875 / 83,500	49,895 / 110,000	7030 / 15,500	5670 / 12,500	68,040 / 150,000	68,040 / 150,000	81650 / 180,000
Number of buildings demolished	0	0	1	0	5	5	7

Operational improvements from implementing McMurdo Master Plan projects would be similar to those discussed for AIMS projects (e.g., fuel efficiency, lower air emissions, reduced power and heat requirements, fewer vehicle operation hours, and fewer workers). However, quantifying the operational gain is not currently possible because the designs are under development. Therefore, for the purposes of environmental impact analysis, current methods and levels of operations (excluding Master Plan improvements) are used to bound potential environmental impacts from continuing operations, as described in Section 3.4.

3.4 Continued Operation of McMurdo Area Activities and Facilities

During implementation of modernization projects, it is anticipated that operational and research activities at McMurdo Station (and outlying facilities supported by the station) would continue at their current tempo (Section 2.2.3). Facilities and activities not modified by the proposed activity would continue to generate impacts similar to current levels. Those activities would also continue at similar levels once projects in the proposed activity are operational. Impacts from existing McMurdo area facilities would ultimately combine with those from the proposed activity.

Section 3.4.1 presents key potential impact sources of existing operations and activities at McMurdo Station and its outlying areas from the last five years in order to establish a baseline of impacts from ongoing operations. Potential impact sources of continuing operations and facilities during construction and post-construction at McMurdo Station and its outlying areas are presented in Section 3.4.2.

3.4.1 McMurdo Station Facilities and Operations (Baseline Conditions)

It is anticipated that baseline levels would remain relatively constant throughout the implementation of the proposed action, as well as once projects are operational. In some cases, efficiencies gained through implementing the proposed activity may extend to existing facilities. Table 3-4 provides key impact sources of McMurdo Station operations averaged over the past five years.

The developed, previously disturbed footprint of McMurdo Station encompasses approximately 2.5 km^2 (1 mi^2). Outlying areas supported by McMurdo Station cover an additional estimated 1.1 km^2 (0.4 mi^2). Ongoing operational and research activities are confined to these disturbed areas. When it is determined necessary to establish new facilities or camps in undisturbed areas, the USAP prepares an EIA in accordance with its environmental stewardship program to evaluate potential environmental impacts.

Population, vehicle use, fuel and water consumption, land disturbance, waste generation, and other impact sources summarized in Table 3-4 are regularly occurring activities in the McMurdo area. These impact sources are highest during the austral summer and are considerably reduced during the winter. Overall, there is wide variation in staffing, fuel and water consumption, and emissions in the McMurdo Station area throughout the year based on the character, intensity, and extent of ongoing operations and research.

As applicable, activities involving disturbance or other impacts are conducted in accordance with established USAP procedures. In particular, non-hazardous solid waste and hazardous waste generated through station operations and research activities are characterized, segregated, packaged, and shipped off-continent for disposal at appropriate facilities, in accordance with applicable laws and regulations. To the extent possible, land disturbance is limited to existing boundaries of McMurdo Station and outlying facilities. The USAP implements the EIA process and prepares the appropriate EIA documentation, per Annex I of the Protocol and in accordance with the ACA and its implementing regulations set forth in 45 C.F.R.§ 641, to evaluate potential environmental impacts when projects outside the boundaries of

McMurdo Station and its outlying facilities are proposed. Mitigation measures are routinely incorporated into proposed USAP activities to eliminate or minimize impacts on the Antarctic environment.

Table 3-4. Key Impact Sources of McMurdo Station Operations, Averaged Over Previous Five Years

<table>
<tr><th>Impact Source (annual)</th><th colspan="2">McMurdo Station</th><th colspan="2">Outlying Facilities[1]</th><th colspan="2">Total</th></tr>
<tr><td>Annual population</td><td colspan="2">974</td><td colspan="2">460 (total for season)</td><td colspan="2">1434</td></tr>
<tr><td rowspan="5">Fuel use (L/gal)</td><td>Power, heat, water</td><td>5,201,400 / 1,374,065</td><td>Deep field camps</td><td>58,270 / 15,395</td><td colspan="2" rowspan="5">12,338,410 / 3,259,465</td></tr>
<tr><td>Vehicles / equipment</td><td>1,043,600 / 275,690</td><td>MDV and tent camps</td><td>49,290 / 13020</td></tr>
<tr><td rowspan="3">Aircraft</td><td rowspan="3">5,401,800 / 1,427,005</td><td>Traverse</td><td>536,640 / 141,765</td></tr>
<tr><td>BITF and Marble Point</td><td>47,410 / 12,525</td></tr>
<tr></tr>
<tr><td rowspan="2">Area disturbed (km²/mi²)</td><td colspan="2" rowspan="2">0.2 / 0.08</td><td>Fixed facilities</td><td>0.18 / 0.07</td><td>Fixed facilities</td><td>0.38 / 0.15</td></tr>
<tr><td>Seasonal camps</td><td>0.95 / 0.37</td><td>Seasonal camps</td><td>0.95 / 0.37</td></tr>
<tr><td>Total building space (m²/ft²)</td><td colspan="2">58,000 / 624,307</td><td colspan="2">1045 / 11,248
(fixed facilities only)</td><td colspan="2">59,045 / 635,555</td></tr>
<tr><td>Fill used/yr (m³/yd³)</td><td colspan="2">3060 / 4000</td><td colspan="2">0</td><td colspan="2">3060 4000</td></tr>
<tr><td>Water generated annually (L/gal)</td><td colspan="2">39,257,000 / 10,370,000</td><td colspan="2">Not Applicable</td><td colspan="2">39,257,000 / 10,370,000</td></tr>
<tr><td>Wastewater released annually (L/gal)</td><td colspan="2">26,385,160 / 6,970,220</td><td colspan="2">122,480 / 32,355</td><td colspan="2">26,507,640 / 7,002,580</td></tr>
<tr><td>Waste generated (including demolition waste; kg/lb)</td><td colspan="2">853,760 / 1,882,215</td><td colspan="2">19,360 / 42,680</td><td colspan="2">873,120 / 1,924,895</td></tr>
<tr><td>Hazardous waste generated (kg/lb)</td><td colspan="2">222,765 / 491,110</td><td colspan="2">11,155 / 24,600</td><td colspan="2">233,920 / 515,710</td></tr>
</table>

[1] Outlying facilities include Marble Point, BITF, MDV fixed facilities, and field camps support by McMurdo Station.

3.4.2 McMurdo Station Facilities and Operations (During Construction and Post-Construction)

As shown in Tables 3.1 and 3.3, modernization activities at McMurdo Station would reduce the number of buildings in the station footprint. This would contribute to gains in resource and operational efficiency, as there would be fewer individual buildings to heat and less need for vehicle trips between buildings. Labor efficiencies would also accrue, since functions would be consolidated among fewer structures, and outdoor storage of materials and supplies would be reduced by at least 35%, and up to 90%.

Table 3-5 presents the potential impact sources of continuing McMurdo Station operations and facilities during construction and post-construction periods. Estimated fuel consumption is shown on Figure 3-2. Although several potential impact sources (e.g., fuel use, fill and cut material, and solid waste) would increase during the construction period, several others (e.g., water and wastewater generation and staffing) would remain similar to or be lower than baseline levels. Once the proposed activity is completed, impact sources would generally remain at or below current levels (particularly staffing and fuel use) as a result of efficiencies gained.

Table 3-5. Anticipated Impact Sources of Continuing McMurdo Station Operations and Facilities During Construction and Post-construction[1]

Impact Source	Pre-construction	AIMS (construction + continuing operations)		McMurdo Master Plan (construction + continuing operations)		Post-construction
		Average	Min-Max	Average	Min-Max	
Number of personnel (Science and Science Support)	976	1,078	1014 - 1165	996	991 - 1006	840
Vehicle/equipment use (in hours)	Not available	7097	3240 - 11,880	2490 +	1250 - 3240	~2490
Fuel use – power, heat, and water generation (L)	5,201,400	5,491,170	4,292,280 - 6,199,050	4,292,280	4,292,280	3,432,925
Vehicle and equipment fuel use (L)	1,043,600	1,340,290	1,092,700 - 1,223,480	1,069,300	1,056,700 - 1,090,700	834,880
Aircraft fuel use (L)	5,401,800	5,401,800	5,401,800	5,401,800	5,401,800	5,401,800
Traverse and outlying facility fuel use (L)	691,610	691,610	691,610	691,610	691,610	691,610
Total fuel use (L)	12,338,410	12,924,870	11,478,410 - 13,383,470	11,502,400	11,442,390 - 11,476,390	10,408,625
Water use – five-year average ($L*10^3$)	39,257	43,355	40,060 - 46855	40,060	39860 - 40460	34,390
Fill needed (m^3)	3060	12,745	3060 - 38,995	8630	1250 - 12,250	3060
Wastewater generated – McMurdo (five-year average; $L*10^3$)	26,385	29,140	27,410 - 31490	26,920	26,785 - 27190	23,111
Wastewater generated – outlying facilities (five-year average; L)	122,480	122,480	122,480	122,480	122,480	122,480
Solid waste (kg; includes demolition waste)	853,760	944,540	873,120 - 1,116,620	899,215	859,430 - 935,410	873,120
Outlying facilities solid waste (kg)	19,360	19,360	19,360	19,360	19,360	19,360
Total solid waste (kg)	873,120	963,900	892,480 - 1,135,980	918,575	878,790 - 954,770	892,480
Hazardous waste generated (kg)	233,920	233,920	233,920	233,920	233,920	233,920

[1] Imperial (English) units not provided for better readability.

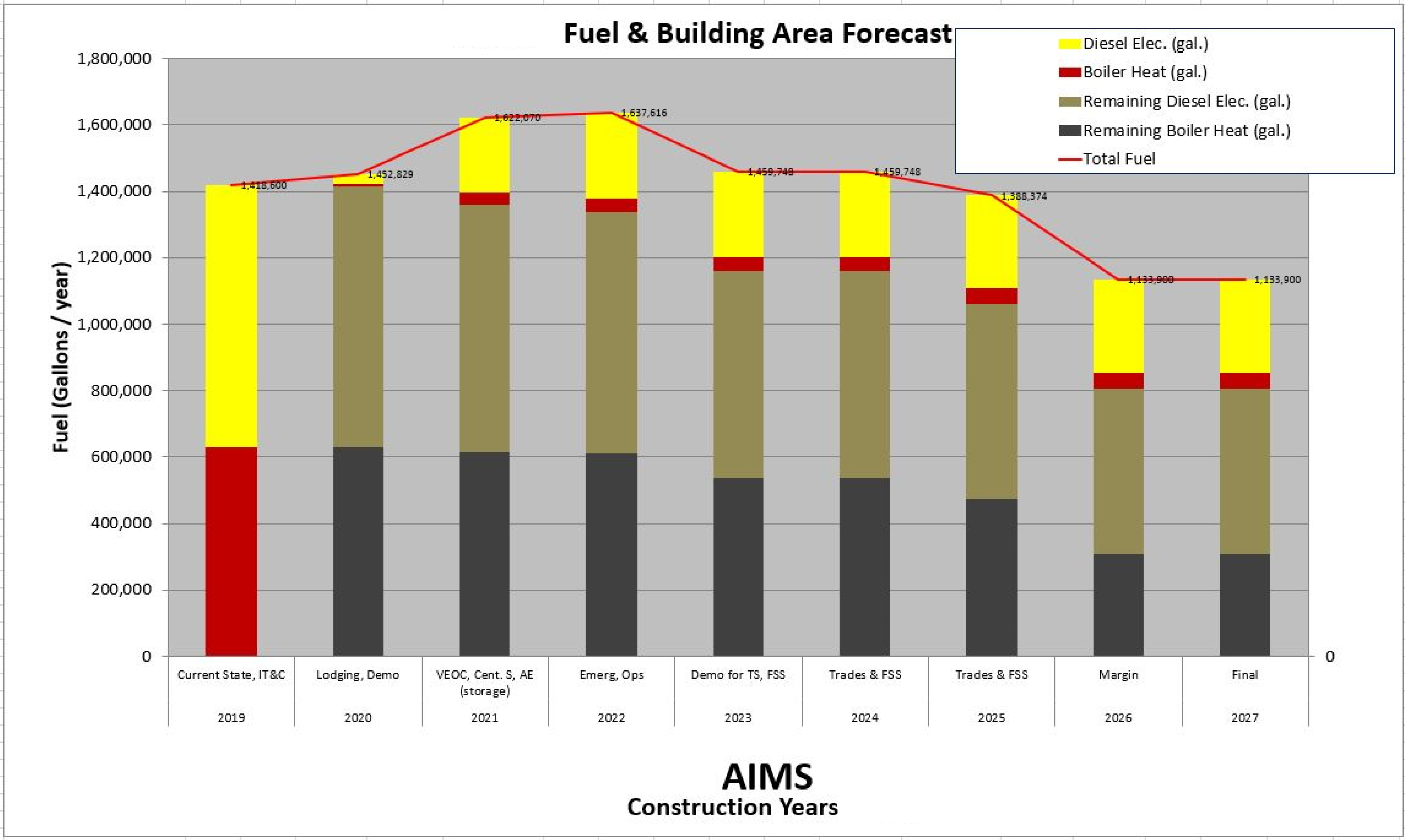

Figure 3-2. AIMS Energy Consumption by Construction Year

3.5 Closure and Demolition of McMurdo Station Facilities

The *Guidelines for Environmental Impact Assessment in Antarctica* (ATS 2016a) advise that decommissioning a facility or resource should be considered if the facility or resource has reached the end of its service life or is no longer needed after a proposed activity is completed. The potential decommissioning of McMurdo Station, if it were to occur, is discussed further in Section 8 of this CEE. However, the United States has conducted scientific and educational programs in Antarctica continuously since 1956 and is dedicated to continuing the USAP as a matter of national policy to foster international cooperation in science and education. In addition, as the largest national facility in Antarctica, McMurdo Station is a major research and resupply resource for the USAP and is likely to continue operations for the foreseeable future.

3.6 Alternatives Considered

The proposed activity to implement AIMS and McMurdo Master Plan projects while continuing the USAP's research activities and support operations is defined as Alternative A in this CEE. One other alternative was evaluated.

3.6.1 Alternative B: No Action/Maintain Current Level of Activity

In Alternative B, current infrastructure and facilities at McMurdo Station and its outlying areas, represented by the baseline conditions described in Section 2, would continue to be used and maintained or replaced when no longer functional. Applicable environmental reviews would be conducted for each action, consistent with the USAP EIA process.

In this alternative, McMurdo Station would continue operations and science-support activities. However, as station systems deteriorate or fail, these operations and activities could decrease, risking the health and safety of personnel and increasing risk to the environment. Aging facilities would likely be replaced if adequate resources are available. Facility improvements needed to support evolving science requirements may be delayed or unachievable. The McMurdo Master Plan actions, which are designed to enhance energy efficiency on station, may be significantly compromised or not implemented. While the USAP would continue to function, the scale of science conducted would likely be reduced, particularly with respect to new research projects. Maintenance and upkeep requirements would continue to increase and logistical support would be less efficient and likely become increasingly more expensive in the long term.

3.6.2 Alternatives Considered but Not Carried Forward

The USAP considered a number of options and alternatives related to the function, location, size, design, configuration, and other characteristics of facilities that would be built as part of AIMS in Alternative A. Building designs and locations were constrained by existing site conditions and footprint at McMurdo Station. As examples, alternative configurations for VEOC, Lodging, and Central Services were considered. These configurations included different numbers of floors (e.g., two- versus three-stories), building location, building size, building orientation on the site, and construction materials. In addition, alternative construction schedules were considered. In general, these alternatives were not carried forward due to higher cost, lower efficiency gain, or the construction schedule would result in lost capabilities for at least one season.

4. Initial Environmental Reference/Affected Environment

4.1 Introduction

The initial environmental state (i.e., existing conditions) of the McMurdo Station area, where the proposed activity would be implemented, includes locations on Ross Island, in McMurdo Sound, on the Ross Ice Shelf, in the MDV, and at deep field sites supported by McMurdo Station.

4.2 McMurdo Station and Ross Island

McMurdo Station is located on Ross Island, along the shoreline of McMurdo Sound and at the southern tip of the Hut Point Peninsula, which is the southernmost area of solid ground in Antarctica accessible by ship. The station is within Environment S of the Environmental Domains Analysis (Morgan et al. 2007) and in Antarctic Conservation Biogeographic Region 9 (Terauds et al. 2012). The developed, previously disturbed footprint of McMurdo Station encompasses approximately 2.5 km^2 (1 mi^2). The station and its surrounding area are characterized as “heavily disturbed” (Geochemical and Environmental Research Group [GERG], 2003).

4.2.1 Environmental Resources

Terrain at Ross Island consists of high ridges and sloping hills of barren volcanic rock, frozen soil with permafrost, and snow and ice fields. Soils are composed of weathered volcanic cinders and granular rock with little, if any, organic material (Campbell and Claridge 1987). Permeable soils consist of gravel with sand and silts. Land areas are generally ice-free during the austral summer. Surface materials in and around McMurdo Station have been heavily disturbed by human activity.

Annual mean temperature at McMurdo Station is −18°C (0°F), while temperatures may reach 8°C (46°F) in summer and −50°C (−58°F) in winter. Average wind speed is 22 km/hr (14 mph/12 knots), with peak wind gusts around 72 km/hr (45 mph/39 knots) in the summer and 126 km/hr (78 mph/68 knots) in the austral winter. Recorded winds have exceeded 185 km/hr (115 mph or 100 knots; BRP 2012). Winds are predominantly from the east because the local terrain channels them around Ross Island.

Precipitation occurs only as snowfall, with an average rate of 18 cm (7.2 in) of water equivalent annually (Monaghan et al. 2005). Ice fog is common throughout the year and sometimes reduces visibility to zero. The extent of snow- and ice-free areas is variable and dependent on ambient temperatures.

McMurdo Station is adjacent to McMurdo Sound, which is an embayment of the Ross Sea. Tides follow a 13-day cycle, with daily variations in water surface elevation ranging from about 0.1-1 m (0.3-3 ft; Robinson et al. 2010). Directions and speed of currents vary widely along the Ross Island coast. Seawater in McMurdo Sound is saline (34-35 parts per thousand) and cold, approximately −2° C (28.4° F). There is little vertical variation in temperature and salinity in spring, but some stratification occurs in summer (Barry and Dayton 1988). Additional detail on the marine environment in McMurdo Sound is described in Section 4.5.

Most snowfall at the station sublimates or melts during the summer. Snowmelt runoff is channeled through a network of diversion ditches, culverts, pipes, and plastic lining that reduces erosion and controls soil and sediment transport. The snowmelt runoff drainage area is approximately 5.1 km^2 (2 mi^2) and includes portions of glaciers adjacent to the station that may thaw and contribute to runoff. Runoff ultimately flows into Winter Quarters Bay and McMurdo Sound from four primary discharge points.

4.2.2 Ecological Resources

Biota occurring on land surfaces at Ross Island may include algae, fungi, lichen, mosses, and small invertebrates. The presence of wildlife in these areas varies depending on the region and may include seal colonies, penguin colonies, and/or seabird nesting sites. Table C-2 provides a list of species found in the McMurdo Station area. Sensitive habitats, including floral or faunal communities, are present on numerous islands and coastal regions in Antarctica. Many such areas have been designated as ASPAs or ASMAs, as discussed in Section 4.6.

Six plant associations, including lichens, mosses, and algae, have been documented on Ross Island (Longton 1973). The most widespread vegetation type is a community of turf- and cushion-forming mosses found in habitats ranging from dry cinder slopes to areas adjacent to meltwater streams (Skotnicki et al. 1999). These communities are usually sparsely developed, with plant coverage ranging between 5% and 85%. Algal communities occupy wet areas around streams, and small communities of crustaceous lichens occupy exposed rock (Longton 1973, 1985). Cryptoendolithic species (those that colonize the empty spaces or pores inside a rock) of lichens, algae, and fungi are the dominant plants and microorganisms in the MDV (Longton 1985).

Dominant terrestrial fauna on Ross Island consists of protozoans, insects, and mites. At least 140 invertebrate species have been documented in substrate and vegetation on the island (Somme 1985; Block 1984). However, these species are unlikely to occur in the immediate vicinity of McMurdo Station due to the lack of undisturbed habitat. Soils in and around penguin colonies on Ross Island contain a high level of organic matter, which can support invertebrate communities. However, the abundance and diversity of such communities are limited by the excessive accumulation of nutrients (Sinclair 2001; Porazinska et al. 2002).

Emperor (*Aptenodytes forsteri*) and Adélie (*Pygoscelis adeliae*) penguins breed in the southern Ross Sea region. Adélie penguin breeding colonies, which are established in September and October, generally occur on ice-free coastal areas accessible from the ocean. Adélie penguins require open water to feed and can dive to a depth of 170 m (558 ft). ASPA No. 121, Cape Royds is home to the southernmost Adélie penguin colony in the Ross Sea, although these penguin's frequent other areas in the region later in the summer as the sea-ice edge retreats (ATS 2014a). Foraging distance from the colony increases as the season progresses (Ainley et al. 2004).

The southernmost emperor penguin colony is located in ASPA No. 124, Cape Crozier on Ross Island. These penguins are dependent on annual fast ice that does not break out until after the year's chicks have fledged, which occurs in late December. Foraging locations, depths, and diet of emperor penguins and Weddell seals overlap, but seasonal differences in their use of resources enable the species to coexist (Burns and Kooyman 2001).

The largest south polar skua (*Catharacta maccormicki*) colony in Antarctica is located at Cape Crozier on Ross Island, hosting over 1000 nesting pairs and representing approximately 15.7% of the global population of the species (Ainley et al. 1990; Harris et al. 2017). Four important areas with nesting south polar skuas have been identified on Ross Island, including Cape Crozier, Cape Bird (two sites), and Rocky Point (Harris et al. 2015). South polar skuas are opportunistic scavengers and predators; they often nest near other seabird colonies and forage on the remains of adult Adélie penguins and chicks. Refuse from McMurdo Station was a component of the south polar skua diet (for all Ross Island colonies) until waste management practices at McMurdo Station changed in 1992 (Mund and Miller 1995).

4.3 McMurdo Dry Valleys (MDV)

The MDV region, located in Environment S of the Environmental Domains Analysis (Morgan et al. 2007) and in Antarctic Conservation Biogeographic Region 9 (Terauds et al. 2012) is the subject of numerous USAP scientific research projects supported by McMurdo Station. A description of the environment in the MDV region is included in the environmental document *Initial Environmental Evaluation/Environmental Assessment (IEE/EA): Continuation of McMurdo Dry Valley LTER Program (MCM4): Increased Connectivity in a Polar Desert Resulting from Climate Warming* (NSF, 2011c).

4.3.1 Environmental Resources

Encompassing approximately 15,000 km^2 (5792 mi^2), the MDV region represents the largest relatively ice-free area on the Antarctic continent and the largest ASMA in Antarctica. MDV ASMA No. 2 contains ecosystems that encompass mountain ranges, glaciers, ice-covered lakes, ephemeral streams, and hyper-arid soils. ASPA Nos. 123, 131, 138, 154, and 172 are within MDV ASMA No. 2.

The MDV is a cold desert ecosystem. Weather patterns in the MDV region are strongly influenced by the region's location between the Transantarctic Mountains and the Ross Sea coast. The region is generally dominated by a strong, boundary-layer temperature inversion (cold air below, warm air above) during calm conditions (Doran et al. 2002). Strong katabatic winds descending from the Polar Plateau frequently disrupt this inversion, resulting in extremely arid conditions (Doran et al. 2002). Katabatic winds and seasonal water flow are the main drivers for moving material across the landscape (Sabacká et al. 2012; Michaud et al. 2012).

Glaciers that flow into the MDV are fundamental to the hydrology and biology of ecosystems in the area because they are the only significant source of water for valley streams and lakes (Doran et al. 2008). Glacier melt-off during the 6 to 12-week flow season is limited by snow cover, which increases the albedo of the ice surface; an accumulation of a few centimeters of snow can largely eliminate glacial melt (Fountain et al. 1999, Fountain et al. 2010). During the summer, glacial meltwater flows along well-established streambeds into closed basin lakes (Gooseff et al. 2002). Hydrologic inputs into MDV lakes are primarily from stream flow while lacking outflow; outputs are limited to sublimation and evaporation (Doran et al. 2008).

4.3.2 Ecological Resources

In the MDV, microorganisms and fauna are found in soil, rocks, and water. The microscopic soil nematode (*Scottnema lindsayae*) is the apex organism of the MDV soil ecosystem. Tardigrades, rotifers, collembola, and mites can also be found in this arid ecosystem. Additionally, cryptoendolithic microorganism communities of bacteria, fungi, and algae live within surface pore spaces of ice-free, weathering sandstone (Siebert et al. 1996).

Vertebrates and vascular plant species are not present in the MDV. However, numerous microbiological species may be found. Colonies of moss, algae, and cyanobacteria occur, primarily in wet areas and streams. Lakes within the MDV support abundant, widespread growths of benthic cyanobacteria-dominated mats, which influence overall lake geochemistry.

4.4 Deep Field Sites

Deep field sites are generally a significant distance from any permanent supply facility and require transportation by ski-equipped aircraft or overland traverse. The types of camps operated at deep field sites are major field camps, minor field camps, and tent camps. The locations of these camps in the Antarctic interior include the snow-covered Polar Plateau (in East and West Antarctica), the Transantarctic Mountains, glaciers, basins, and ice shelves.

4.4.1 Environmental Resources

The interior of the Antarctic continent includes the snow-covered Polar Plateau (in East and West Antarctica), mountains, glaciers, and basins. There are also numerous mountain peaks and ridges not covered with snow or ice (nunataks), and deep field camps are often established on or near these exposed features. The weather on most of the elevated Polar Plateau is characterized by relatively low wind speed. However, strong katabatic winds can occur as the result of dense, cooler air blowing down from the ice sheet toward lower elevations at the edge of the continent.

4.4.2 Ecological Resources

Snow- and ice-covered areas in the Antarctic interior are generally devoid of flora or fauna.

4.5 McMurdo Sound and the Ross Sea

4.5.1 Environmental Resources

McMurdo Sound is a deep body of water within the waters of the Ross Sea, stretching 10 km (6 mi) west of McMurdo Station with depths reaching 900 m (2952 ft; Murray 2014). During spring and summer, the McMurdo Sound region is characterized by stable, fast sea ice (ice anchored to land). This ice occurs in the southern part of the McMurdo Sound and in a 15-20 km (9-12 mi) wide strip along the western coast to Granite Harbor. Depending on location or time of year, certain areas in McMurdo Sound may contain either sea ice or open water.

Islands and coastal areas in the McMurdo Sound region may be snow-covered or ice-free and may contain mountainous peninsulas, rocky islets, spurs, nunataks, and glaciers. Shorelines may include pebble-covered beaches subject to coastal marine processes.

Weather in the McMurdo Sound region is dominated by the cold polar climate with a strong seasonal cycle. Storms, including major blizzards with blowing and drifting snow, may be more frequent and severe in autumn and spring. Most parts of the Ross Sea region experience surface temperatures that fall to below -40°C (-40°F) in winter, with temperatures above 0°C (32°F) achieved only at the height of summer, usually in ice-free areas (Waterhouse 2001). Temperatures on the sea ice are characterized by lower mean and minimum temperatures resulting from frequent, surface-based inversions.

The relative humidity around the Ross Sea coast is typically 60%-70% which, at low temperatures, represents a very small amount of water in the atmosphere. Over the Ross Ice Shelf, annual precipitation is generally below 20 cm (7.8 in water equivalent), with slightly more falling over the mountains to the west (Waterhouse 2001).

The McMurdo Ice Shelf is a portion of ice shelf bounded by McMurdo Sound and Ross Island on the north and Minna Bluff (a rocky promontory) on the south. The floating glacier system that occupies the southern part of McMurdo Sound is an unusual and complex feature composed of different ice masses. The eastern part of the McMurdo Ice Shelf is formed from snow accumulating on ice flowing westward between Ross and White Islands from the Ross Ice Shelf and is contributed to by the Aurora and Terror Glaciers on Ross Island. Much of this ice is removed by melting (up to 3 m/year) at its base.

The southern McMurdo Ice Shelf is located between Black and White Islands, Minna Bluff, and Brown Peninsula. There, surface accumulation, ablation, and basal freezing are possible. There is little distributary flow from the Ross Ice Shelf between Black and White Islands. In the west, the Koettlitz Glacier flows down from the Royal Society Range and out to McMurdo Sound (Hatherton 1990).

The central portion of the McMurdo Ice Shelf, between the Dailey Islands and Black Island, is likely to be formed from frozen sea water. This central zone protrudes farthest into the sound because it is thickest and clearly marked by moraine patterns on the surface. Ice in the central zone is formed in tide cracks along the shores of Brown Peninsula, Mount Discovery, Bratina Island, and Black Island; in the water column; on the sea floor (known as "anchor ice") beneath the ice shelf; or directly on the bottom of the shelf. Fresh or brackish water drains off the ice shelf through holes or cracks and subsequently freezes, which may also contribute to ice in the area.

Prevailing southerly winds that are low in moisture and warmed slightly by descending Mount Discovery, probably accelerate ablation in this area and elongate meltwater features downwind. Ice velocity and thickness here are much less than on the Ross Ice Shelf. Along the 9-20 m (30-65 ft) thick ice front, speeds range from 100-1700 m (328-5577 ft) per year in the east to only 5-10 m (16-33 ft) per year in the west.

The Transantarctic Mountains turn prevailing easterly winds from open areas of the Ross Ice Shelf to the north and along the western side of the Ross Ice Shelf and Ross Sea so that the prevailing winds (barrier winds) are from the south (O'Connor et al. 1994). The predominant wind direction at Marble Point is from the southeast and south-southeast. There is little change in wind direction throughout the year.

Phoenix Airfield and Williams Field are located on the McMurdo Ice Shelf approximately 18 km (11 mi) and 11 km (7 mi) from McMurdo Station, respectively. Both are accessed by a snow roadway. The airfields experience thin but permanent and complete snow cover, underlain by a contiguous mass of glacial ice. Seasonal melting may occur. The ice shelf in this area is approximately 30 m (98 ft) thick.

4.5.2 Ecological Resources

4.5.2.1 General

The Ross Sea, including McMurdo Sound, is one of the most biologically productive regions of the Southern Ocean and includes a variety of benthic communities, marine mammals, penguins, fish, and invertebrates. Table C-2 in Appendix C summarizes the fauna occurring in the vicinity of McMurdo Station, in the McMurdo Sound region. Microalgal production follows a predictable pattern in the Ross Sea, with diatoms dominating early in the season. Pelagic zooplankton found in the Ross Sea region includes protozoa, larval and juvenile stages of copepods, herbivorous adult copepods, krill, mollusks, and larvae of benthic marine invertebrates (Hopkins 1987; Bhaud et al. 1999). Zooplankton in the Ross Sea region are also characterized by low biodiversity and diurnal and seasonal migrations (Mackintosh 1973).

4.5.2.2 Marine Benthic Communities

Rich and diverse communities of plants and animals, many of which are unique to Antarctica, live on the sea floor in the Ross Sea region. Benthic species include sponges, sea stars, and nudibranchs (Brueggeman 1998). Many of these species are circumpolar and extremely long-lived (Arntz et al. 1994; Dayton 2013). Sponge species include *Mycale acerata*, *Rosella racovitzae*, *R. nuda*, and *Scolymastra* *joubini*. Sea star species include *Perknaster fuscus antarcticus*, *Acodontaster conspicuous*, and *Odontaster validus*. *Austrodoris mcmurdensis* is a species of nudibranch found in waters around Ross Island. Generally, sponges are a food source for some species of sea star and nudibranch, while some sea stars also feed on one another in addition to organic material in sediments (Dayton et al. 1974). Abundant infaunal organisms include the amphipod *Heterophoxus videns* and a tanaid crustacean, *Nototanais dimorphus* (Oliver and Slattery 1985). Organic matter inputs are a significant driver of benthic organism densities, with suspension feeders found in shallower water and the amount of detritus feeders increasing with depth (Barry et al. 2004).

Subtidal ecosystems in Antarctica have extremely high diversity and levels of endemism (i.e., organisms unique to a defined geographic location). With the possible exception of decapod crustaceans (shrimps, crabs, and crayfish) and cirripeds (barnacles), species diversity in nearly all major groups of Antarctic marine invertebrates is at least 50%-100% higher than in the Arctic and is comparable to temperate or even tropical environments (White 1984; Arntz et al. 1997). Levels of endemism in the major groups of Antarctica's marine benthic fauna range from 50%-90% of all species present, indicating a long period of isolation and independent evolution. One unusual feature of such specialization is that only a few groups account for much of the diversity, as they have a high degree of dominance.

Soft sediments dominate the sea floor of the Ross Sea region. Sampling of the seabed throughout Granite Harbor and McMurdo Sound identified, with a few exceptions, muddy sand and relatively sparse macrofauna (Barrett et al. 1983). In shallower, soft-sediment areas of McMurdo Sound, total biomass is generally lower than in areas with hard substrates dominated by sponge communities; although the sponge spicule mat and its associated abundant macrofauna sometimes occurs on consolidated soft sediment as well as on rock. However, infaunal abundance in soft sediments may be extremely high, particularly in eastern McMurdo Sound, where densities of over 155,000 individuals/m^2 have been recorded (Dayton and Oliver 1977). In contrast, densities were much lower in the western portion of McMurdo Sound, with a total number of only 10,036 individuals/m^2 in New Harbor. This difference has been attributed to oligotrophic conditions in the western portion of McMurdo Sound, caused by nutrient-impoverished water flowing north from under the Ross Ice Shelf.

4.5.2.3 Marine Mammals

Marine mammals are the largest marine organisms present in McMurdo Sound. These include pinnipeds (seals) and cetaceans (whales).

Pinnipeds

Three pinniped species are known to occur in McMurdo Sound: Weddell, crabeater, and leopard seals. These species are discussed below.

<u>Weddell Seal *(Leptonychotes weddellii)*</u>

Weddell seals are the most common species of seal observed in McMurdo Sound, and they are generally associated with inshore fast ice throughout the summer. Weddell seals feed mainly on Antarctic silverfish (*Pleuragramma antarctica*) and *Trematomus* ice fish (Burns et al. 1998) and typically dive to depths of 100-600 m (328-1969 ft; Sterling 1969). Weddell seals are capable of diving beneath stable, contiguous sea ice, staying underwater for more than an hour, and swimming up to 300 m (984 ft) from an access hole. They actively maintain breathing and access holes by reaming the ice with their incisors. They may also maintain surface access by using perennial cracks in the ice. Weddell seals vocalize underwater and can produce a wide range of calls associated with a number of behaviors.

Weddell seals do not migrate, but most of the McMurdo Sound population disperses to the north during the austral winter. Some adult seals remain in the McMurdo Sound region during the winter, including at an isolated colony at White Island (ASPA No. 137). Breeding season occurs in October, with a one year gestation period. Pupping occurs on the sea ice and begins in mid-October. Nursing extends for approximately 45 days, at which time the pups are weaned. A second influx of the main population typically occurs in November along sea ice cracks from the Koettlitz Glacier northward. Concentrations of over 200 adults have been observed near the Strand Moraines, south of New Harbor, in November (Ross et al. 1982). A few Weddell seals breed at the Cape Bernacchi tide crack and Marble Point. The population breeding within Erebus Bay most recently numbered 917 females, and the population has stayed relatively stable, with annual variation due to temporary immigration (Cameron and Siniff 2004; Rotella et al. 2012).

Leopard Seal *(Hydrurga leptonyx)*

Leopard seals typically haul out on ice floes for breeding and pupping. Leopard seals feed only in the water, and their diet consists primarily of penguins and krill. Leopard seals can swim long distances under ice and seek out breathing holes created by Weddell seals, which are often found in the fast ice of McMurdo Sound. Leopard seals generally prefer to remain in pack ice and areas of open water, such as at the sea-ice edge.

Crabeater Seal *(Lobodon carcinophaga)*

Crabeater seals feed primarily on krill and move south into the Ross Sea and McMurdo Sound during the summer months. Crabeater seals are also found in pack ice (concentrated areas of drifting ice).

Cetaceans

The species of cetaceans known to occur in the McMurdo Sound area belong to two taxonomic groups: odontocetes (toothed cetaceans, such as the killer whale) and mysticetes (baleen whales, such as the minke). These species are discussed below.

Killer Whale *(Orcinus orca)*

Killer whales are cosmopolitan and globally abundant. They can be seen from equatorial regions to polar pack-ice. Killer whales are most common at high latitudes, especially in cooler areas where productivity is high, such as the Ross Sea and McMurdo Sound region.

The animals are segregated socially, genetically and ecologically into three distinct groups: residents, transients, and offshore animals. Resident groups feed exclusively on fish, whereas transients feed exclusively on marine mammals. Less is known about offshore killer whales, and their feeding habits are not strictly defined. Killer whale movements generally appear to follow the distribution of prey (Pitman and Ensor 2003).

In the McMurdo area, killer whales prowl the edge of fast ice for prey. They can also be observed at pack ice edges and sometimes in dense pack ice. They will venture for short distances under fast ice while hunting at the ice edge.

Antarctic Minke Whale *(Balaenoptera bonaerensis)*

Minke whales have a cosmopolitan distribution that spans ice-free latitudes (Stewart and Leatherwood 1985). Minke whales find and exploit small and transient concentrations of prey (including fish and invertebrates) as well as more stable concentrations that attract multi-species assemblages of large predators. Minke whales are relatively solitary and are usually seen individually or in groups of two or three, although they can occur in large aggregations of up to 100 at high latitudes where food resources are concentrated (Perrin and Brownell 2002).

In Antarctica, the minke whale is usually sighted near the ice edge, either singly or in pairs. It feeds primarily on krill, may dive up to twenty minutes, and could be encountered in pack ice areas in McMurdo Sound.

4.5.2.4 Fish

Numerous fish occupy the waters of McMurdo Sound. The most abundant species belong to the notothenioid group, which have adapted to cold water temperatures. Generally, most of these species are found from near the surface to depths of up to 700 m (2297 ft), although one species, the Antarctic toothfish (*Dissostichus mawsoni*), can be found at depths of up to 1600 m (5249 ft). Most species, such as the DeVries's snailfish (*Paraliparis devriesi*) and the sharp-spined notothen (*Trematomus pennellii*), live on the seafloor.

4.5.2.5 Avifauna

Two species of penguin, the Adélie penguin and the emperor penguin, and one species of skua, the south polar skua are found in McMurdo Sound.

Adélie Penguins

Adélie penguins are found throughout the Ross Sea region. Breeding colonies are established in September to October, typically on ice-free coastal areas accessible from the ocean. The Adélie colony known to be the farthest south in the Ross Sea/McMurdo Sound region is at Cape Royds (ATS 2014a), although these penguins will frequent other areas in McMurdo Sound later in the summer as the sea ice edge retreats. The Adélie requires open water to feed and can dive down to a maximum depth of 170 m (558 ft).

Emperor Penguins

Emperor penguins are also found throughout the Ross Sea region and generally within the limits of pack ice. Emperors breed on stable fast ice near open water, and colonies are established in March and early April. The farthest south emperor penguin colony in the Southern Ross Sea is located at Cape Crozier (ATS 2014b). Emperor penguins may visit other areas in McMurdo Sound in the spring to late summer, as the sea ice edge retreats. Emperor penguins feed on fish, squid, and crustaceans and typically dive to depths of 100 m for a period of 5-6 minutes.

South Polar Skua

In the McMurdo region the south polar skua arrives in late October or early November and nests on high, rocky areas and in loose colonies associated with penguin colonies. South polar skuas are opportunistic scavengers and predators, often nesting near other seabird colonies and foraging on the remains of adult Adélie penguins and chicks (Mund and Miller 1995). South polar skuas are highly philopatric, return to the same nest site each year, and are highly likely to retain mates in successive years (Ainley et al. 1990).

4.5.2.6 Sea Ice Communities

Sea ice in McMurdo Sound forms annually as early as late March. In most years, the sea ice breaks up naturally for a brief period in the austral summer and subsequently reforms the following winter. In other years the sea ice may not break up and may accumulate.

The period of productivity in McMurdo Sound begins early in the austral summer and continues with the annual breakup of the sea ice. An important component of annual primary production is the microalgae that grow in association with the sea ice (Horner et al. 1992). The sea ice provides a growth substratum and refugium for a complex microbial community consisting primarily of microalgae, bacterium, protozoa, and small metazoa. Additionally, sea ice provides habitat for other animals, such as penguins and seals.

4.6 Protected Areas and Other Sites of International Significance

Numerous areas in the McMurdo region have been designated ASPAs or Historic Sites and Monuments (HSM) to safeguard outstanding environmental, scientific, historic, aesthetic, or wilderness values or to protect ongoing or planned scientific research. Similarly, an area in Antarctica where research, logistics, and/or tourism activities are being conducted (or may be conducted in the future may) be designated as an ASMA to assist in the planning and coordination of activities, avoid possible conflicts, improve cooperation between Antarctic Treaty parties, and/or minimize environmental impacts (ATS 2016b).

Five HSMs are present at or next to McMurdo Station: No. 18, Scott's Discovery Hut (also designated as ASPA No. 158); No. 19, George Vince's Cross; No. 20, Observation Hill Cross; No. 54, a bust of Richard E. Byrd; and No. 85, a plaque commemorating the PM-3A Nuclear Power Plant. In addition, one ASMA and 20 ASPAs are in the McMurdo area. As previously noted, ASMA No. 2 encompasses the MDV and represents the largest protected area in Antarctica. In addition to containing the largest relatively ice-free area on the continent, ASMA No. 2 includes unusual microhabitats and biological communities and special geological features and minerals. The MDV represent a nearly pristine environment, largely undisturbed and uncontaminated by humans. Five ASPAs are located in ASMA No. 2, and 10 ASPAs are located on Ross Island. Characteristics of these areas are summarized in Table 4-1.

There are 27 Important Bird Areas (IBAs) in the Ross Sea region, which represents 13% of all IBAs in Antarctica. Of these, 11 are located in Northern Victoria Land, four in the Wood Bay/Terra Nova Bay area, five in or close to the MDV in Southern Victoria Land, four on Ross Island, and the remaining three are on islands in the southern Ross Sea. The IBAs of Southern Victoria Land all qualify on the basis of their populations of South Polar skuas, while those on Ross Island qualify on the basis of penguin and skua populations. IBA ANT187, Cape Crozier, in particular, has one of the largest populations of Adélie penguins in Antarctica, with approximately 272,000 breeding pairs present in 2012 (Lyver et al. 2014). IBAs ANT173, Cape Wadworth and ANT176, Cape Washington host the two largest Emperor penguin colonies in Antarctica, with approximately 25,000 and 17,000 breeding pairs, respectively.

Table 4-1. ASPAs and ASMAs in the McMurdo Area

No.	Name	Area (km^2/mi^2)	Description
105	Beaufort Island, McMurdo Sound, Ross Sea	22.4 / 8.6	The island contains substantial avifauna and it is one of the most important breeding areas in the region and a significant area of extensive vegetation. https://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=10&lang=e
106	Cape Hallett, Northern Victoria Land, Ross Sea	0.53 / 0.20	The site possesses outstanding aesthetic values, with its combination of prolific plant and avian (South polar skua and Adélie penguin) biological resources. https://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=11&lang=e
116	New College Valley, Caughley Beach, Cape Bird, Ross Island	0.34 / 0.13	The site of the most extensive and luxuriant stands of moss, algae, and lichens in southern Victoria Land. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=21&lang=e
121	Cape Royds	0.6 / 0.2	The area supports the most southerly established Adélie penguin colony known. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=26&lang=e
122	Arrival Heights, Hut Point Peninsula, Ross Island	0.7 / 0.3	The ASPA was designated as a natural and electromagnetically quiet site, offering ideal conditions for the installation of sensitive instruments for recording data associated with upper atmosphere research programs. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=27&lang=e
123	Barwick and Balham Valleys, Southern Victoria Land	418 / 161	The site is one of the least disturbed and contaminated of the MDV of Victoria Land. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=28&lang=e
124	Cape Crozier	72 / 28	The area supports rich bird and mammal fauna, as well as microfauna and microflora, and the ecosystem depends on a substantial mixing of marine and terrestrial elements of outstanding scientific interest. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=29&lang=e
131	Canada Glacier, Lake Fryxell, Taylor Valley, Victoria Land	1.5 / 0.6	The site contains some of the richest plant growth (bryophytes and algae) in the MDV. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=36&lang=e

Table 4-1. ASPAs and ASMAs in the McMurdo Area

No.	Name	Area (km^2/mi^2)	Description
137	North-West White Island, McMurdo Sound	142 / 54.8	This locality contains an unusual breeding population of Weddell seals that has been physically isolated from other populations. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=42&lang=e
138	Linnaeus Terrace, Asgard Range, Victoria Land	0.8 / 0.3	The site is one of the richest locations of unique cryptoendolithic communities that colonize the Beacon Sandstone. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=43&lang=e
154	Botany Bay, Cape Geology, Victoria Land	2.1 / 0.8	This site is an extremely rich botanical refuge for such a high latitude location. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=58&lang=e
155	Cape Evans, Ross Island	0.06 / 0.023	The site is one of the principal sites of the Heroic Age of Antarctic exploration; it contains historic structures and relics pertaining to this era. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=59&lang=e
156	Lewis Bay, Mount Erebus, Ross Island	14.4 / 5.56	Site of an Air New Zealand aircraft crash on 28 November 1979 into the northern slope of Mount Erebus. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=60&lang=e
157	Backdoor Bay, Cape Royds, Ross Island	0.04 / 0.015	The area is of significant historic value. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=61&lang=e
158	Hut Point, Ross Island	N/A	The hut was built during the National Antarctic (Discovery) Expedition in 1901-1904, and used again by other expeditions in 1907-1909, 1910-1913, and 1914-1917. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=62&lang=e
165	Edmonson Point, Wood Bay, Ross Sea	5.5 / 2.1	The site contains one of the most outstanding terrestrial and freshwater ecosystems in northern Victoria Land. https://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=69&lang=e
172	Lower Taylor Glacier and Blood Falls, Taylor Valley, McMurdo Dry Valleys, Victoria Land	436 / 168	The site is designated for its unique physical properties and unusual microbial ecology and geochemistry. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=165&lang=e

Table 4-1. ASPAs and ASMAs in the McMurdo Area

No.	Name	Area (km^2/mi^2)	Description
173	Cape Washington and Silverfish Bay, Terra Nova Bay, Ross Sea	286 / 110	The site contains one of the largest emperor penguin colonies in Antarctica and has extensive volcanic rock exposures originating from the nearby active volcano, Mount Melbourne. https://www.ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=175&lang=e
175	High Altitude Geothermal sites of the Ross Sea region	0.265 / 0.102	High altitude geothermal sites with unique biological communities. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=2&id=177&lang=e
ASMA 2	McMurdo Dry Valleys, Southern Victoria Land	17945 / 6928	Largest relatively ice-free region in Antarctica with important scientific and wilderness value. https://ats.aq/devPH/apa/ep_protected_detail.aspx?type=3&id=75&lang=e

4.7 Prediction of Future Environmental Reference in the Absence of Proposed Activity

In the event the proposed activity is not implemented, the USAP's operations and research would continue at their current level of activity, using existing resources and facilities, as represented by Alternative B (No Action). Therefore, the initial environmental state, as described above, would continue unchanged.

5. Identification and Prediction of Impacts

5.1 Introduction

This section discusses impacts on the affected environment that would potentially result from the implementation of Alternative A, the proposed activity for continuation and modernization of McMurdo Station area activities. In addition, potential impacts associated with Alternative B, No Action – Maintain Current Level of Activity are also discussed. Alternatives Considered but not Carried Forward (e.g., location, size, configuration options of Alternative A) were evaluated, and ultimately rejected by NSF for a variety of reasons, including cost, greater environmental impact, logistical challenges, and/or the potential to impact research, health and safety, and ongoing station operations. The discussion of impacts addresses

- methods and sources of data used to identify, quantify, and evaluate the potential impacts of the proposed activity (Section 5.2);
- aspects of the proposed activities that could impact the Antarctic environment (e.g., physical disturbances, hazardous materials, wastes, release to the environment, non-native species, noise; Section 5.3);
- continuation of existing McMurdo facility operations, research support, and area activities (Section 5.4);
- unavoidable and cumulative impacts (Sections 5.5 and 5.6); and
- proposed activity impacts summary (Section 5.7).

5.2 Methodology and Data Sources

Data used to project the nature and extent of impacts from the proposed activity were derived primarily from the AIMS Execution Plan and secondarily from the McMurdo Master Plan (NSF 2015a). Methods used to evaluate potential environmental and operational impacts are consistent with strategies used to evaluate program-wide and project-specific activities for EIAs (as listed in Table C-1 in Appendix C).

Initial environmental conditions described in Section 4 are the existing conditions at McMurdo Station (and at remote locations supported by McMurdo Station), including physical resources (e.g., facilities), environmental resources (e.g., geology, water), and ecological resources and ecosystems. The USAP conducts comprehensive monitoring routinely and uses a variety of data to assess impacts from land use, air quality, hazardous material use and storage, waste management, and releases that affect these existing conditions.

The assessment of potential environmental impacts described below assumes that mitigation measures (i.e., measures to reduce or avoid impacts on the environment) described in Section 6 would be implemented as part of the proposed activity, when applicable. Impacts were estimated based on impacts identified for similar types of projects and activities assessed in previous IEE documents and other USAP evaluations (e.g., monitoring information, EIA audits, and site reviews). If feasible, additional measures may be developed that would further reduce environmental impacts.

The impact assessment assumes that AIMS construction would be completed in approximately eight years and McMurdo Master Plan construction would be completed approximately seven years after the completion of AIMS construction. However, it is possible that operational, logistical, funding, or weather-related factors may extend construction phases; thus, the entire construction phase of modernization projects would be approximately 15-20 years. Lengthening the duration of construction would change the duration of impacts but not the extent, intensity, and probability of impacts. Therefore, impacts associated with an extended schedule would be consistent with the findings described in this CEE.

5.3 Impacts from McMurdo Station Modernization

Impacts from construction of modernization projects would temporarily increase many impacts above those experienced during ongoing operations (Section 2.2.3 for a summary of ongoing operations). Alternative A construction phase is fully discussed in Sections 3 and Table 3-1 through Table 3-5. Air emission calculations are provided in Appendix C (Tables C-3, C-4, C-5, and C-6).

5.3.1 Building Demolition and Construction

Building demolition would generate a number of impacts, including air emissions (from equipment and vehicle use), waste, fugitive dust, hazardous materials (e.g., lead paint, asbestos), physical disturbance of surrounding soils, and noise. The quantity of construction- and demolition-related debris generated each year during the construction phase of the proposed activity would range between 5670 kg (12,500 lb) and 243,500 kg (536,820 lb) and average 73,360 kg (161,730 lb), as shown in Table 3-1 and Table 3-3. For comparison, operating McMurdo Station and outlying facilities generates approximately 873,120 kg (1,924,895 lb) of solid waste annually. Waste created from demolition and construction activities would represent an expected annual increase of between 0.6% and 28% (averaging 8%). Therefore, implementing the proposed activity would increase the amount of waste to be handled annually at McMurdo Station during the period that demolition activities are occurring. Demolition wastes that cannot be retrograded within same season would be securely packaged for shipment as soon as transport is available.

Hazardous waste (e.g., lead paint, asbestos) would be generated during construction and may include contaminated debris or soils discovered during demolition. This waste would be packaged and removed from Antarctica for disposal within 15 months, per ACA requirement and as part of existing hazardous waste handling processes (additional discussion in Section 6, Mitigation Measures). Current planning and investigations suggest that the amount of hazardous waste generated during demolition would represent a small percentage compared to current volumes generated from continuing operations.

Buried materials frozen in place or residues from past activities may be present at some demolition sites. Depending on site conditions, removal may result in a greater impact than leaving the materials in place. In these instances, remedial actions would be determined following an environmental review and concurrence by USAP officials. These decisions and related impacts would be documented using the USAP's standard tracking processes.

Following completion of AIMS and McMurdo Master Plan project demolitions, disturbed areas would be regraded to the approximate original contour or prepared for new construction, reducing the potential for long-term impacts if residual contamination remains below the soil surface.

Ambient noise would increase during proposed demolition and construction activities during normal work hours. Noise would be periodic and concentrated at work sites, and might be slightly more intense than typical station operations. Noise abatement procedures and personal protective equipment would be used to protect workers. The nearest known nesting birds (skuas) are near Arrival Heights and over 440 m (1444 ft) from the nearest proposed construction activity location (fines excavation area). Noise levels from construction would be less than 93 decibels at the nesting location, which is the sound level where a temporary shift in the auditory threshold may occur in birds. The nearest seal haul out area is approximately 180 m (591 ft) to the nearest proposed construction area (pump house and water tank). NOAA has identified 100 decibels as the in-air acoustic threshold for behavioral disruption of pinnipeds. Noise levels from McMurdo Station construction would be less than 88 decibels at the nearest seal haul out location since noise levels from construction equipment within McMurdo Station would be less than 106 decibels. Therefore, disturbance to wildlife would be minimal.

Demolishing existing facilities and constructing new facilities at McMurdo Station would not further degrade the wilderness value or aesthetics of Ross Island, since construction would occur within the existing footprint of the station. The reduced number of structures and redesigned arrangement of the station would improve visual sightlines from McMurdo Sound (NSF 2015a) and improve station aesthetics.

5.3.2 Site Preparation, Fill, and Fines

Between 1250 m^3 (1635 yd^3) and 35,935 m^3 (47,000 yd^3), with an average of approximately 10,690 m^3 (13,980 yd^3) of fines would be harvested each year for nine years during the 15-20 year construction phase of modernization projects. This is approximately 3.5 times more than the 3060 m^3 (4000 yd^3) of fines used each year for existing operations. Numerous locations at McMurdo Station would be disturbed for soil (fines) excavation, grading, and/or filling due to building demolition and construction, utilidor installation, and roadway and drainage improvements. Additional fines excavated to support construction would be harvested in accordance with the IEE that assesses fines collection from existing locations within the current, previously-disturbed footprint of the station (NSF 2011b, 2014c).

5.3.3 Drainage Improvements

Generally, proposed drainage improvement projects would slow the runoff of melted snow and minimize or eliminate scouring and erosion of drainage channels. Some of suspended, contaminated sediments would be collected in catchment basins, thus reducing contaminants entering Winter Quarters Bay. For these reasons, implementing the proposed activities would be expected to have no adverse, and some beneficial, long-term impacts on earth surfaces at McMurdo Station and the discharge of meltwater runoff into McMurdo Sound.

5.3.4 Blasting and Explosives Use

Explosives would be used to quarry fill and fine materials, level construction sites, excavate foundation areas, and prepare road crossings for buried utility lines. Approximately 225 kg (500 lb) of explosives would be used annually to free up frozen areas as part of site work. Approximately 15,875 kg (35,000 lb) would be used to prepare the site for the new VEOC building. Explosives use would generate emissions of explosive by-products. The size and number of detonations would be kept to a minimum and planned to ensure that safety and environmental guidelines are followed. The nearest bird nest is over 440 m (1444 ft) from the nearest proposed explosives use location (fines excavation area). Noise levels at nesting locations would be below the 93 decibel threshold for birds (Section 5.3.1). The nearest seal haul out area is approximately 180 m (591 ft) from the nearest proposed explosives use area (northeast of the existing WWTP). The largest charge would be approximately 1.4 kg (3 lb). The charges would be placed in drilled holes in the rock and fill material, which would confine the noise level from the blasts. Noise levels would potentially exceed the NOAA behavioral seal disturbance threshold of 100 decibels within 500 m (1640 ft) of the detonation location. Therefore, blasting would cease if seals are hauled out within 500 m (1640 ft) of the blast site to ensure their behavior is not affected (Section 6). Mitigating measures (Section 6) would be used to control airborne releases.

5.3.5 Import of Material

During the construction phase, building material would be shipped to McMurdo Station, thus increasing the amount of cargo received annually. No additional vessel shipments are anticipated (i.e., there would still be only one resupply vessel per year). Antarctic Treaty Parties are concerned about the introduction of non-native species (e.g., insects, plant material, microbes) to Antarctica. The potential for introducing non-native species would increase during modernization activities because of the increase in material received at McMurdo Station. The USAP would continue to implement protective actions and educational programs to prevent the importation and transport of non-native species (Section 6.2.5). Mitigation measures would reduce the likelihood of non-native species impacts from the proposed activity.

5.3.6 Vehicle Use

Impacts from vehicle and heavy equipment use during the proposed activity would primarily involve exhaust emissions from fuel consumption (Table 3-1 and Table 3-3). During the construction phase, an average of approximately 66,560 L (17,590 gal) of fuel would be used by vehicles for construction. This represents an average 6.4% annual increase in fuel use (within a range of 1.3%-17.2%) compared to operations between 2014 and 2018. When construction is completed, the number of vehicles used is anticipated to reduce by 20%, which would result in a comparable reduction in annual vehicle fuel use.

5.4 Impacts from Continuing Existing McMurdo Area Activities and Operating Existing Facilities

In general, impacts from continued operations of McMurdo Station during construction of modernization projects would be the same as current operations, as described in Section 3.4.1. Once AIMS projects are completed, operational improvements and efficiencies are anticipated for the USAP. Centralization of station facilities would reduce fuel use, lower vehicle operation hours, reduce power and heat requirements, lower air emissions (Appendix C, Tables C-3, C-4, C-5, and C-6), and require fewer workers. These potential gains are highlighted below and in Section 3.4.2. Potential impact sources from continuing operations at McMurdo Station during construction and after all AIMS and McMurdo Master Plan projects are complete are enumerated in Table 3-5.

Under Alternative B (No Action), the USAP's operations would continue at the current level of activity, using existing resources and facilities, and impacts would be equivalent to or greater than the impacts described below.

5.4.1 Building Use

Impacts from using existing buildings at McMurdo Station would primarily involve waste generation and the release of airborne emissions from the combustion of fuel for heating. Once modernization projects are completed, the support staff population would be reduced and 20% less building space would be used to support science. The number of support personnel (e.g., logistics, operations, science-support staff) would be 12% lower than current staff levels and 40% fewer personnel would be required to maintain facilities. Science and aviation personnel are expected to remain at current population levels. Therefore, the ratio of scientists to support staff likely would increase and the total maximum overnight population at McMurdo Station would likely be reduced.

5.4.2 Helicopter and Fixed Wing Operations

It is anticipated that aircraft flight operations after construction of modernization projects would continue at the same level as in the past five years (2013-2018). This would include approximately 6000 hours of flight time (Table 3-1) and the transfer and use of approximately 5,401,800 L (1,427,005 gal) of aviation fuel each year (Table 3-4). After modernization projects are completed, helicopter ground support would be improved by a new passenger terminal and hanger, the latter of which would have updated and expanded maintenance capabilities. Similarly, implementing the single-airfield concept, which would include replacing 27 buildings totaling 1471 m^2 (15,834 ft^2) with 14 buildings totaling 1821 m^2 (19,600 ft^2; Table 3-2), would reduce the cost of airfield ground operations.

5.4.3 Traverse Operations

Traverse operations would continue at the current level during modernization project construction and after construction is completed. Therefore, no changes to existing physical disturbances and impacts from continuing traverses are expected. Each year, three to four traverses would continue to be conducted to Amundsen-Scott South Pole Station. In addition, refueling traverses to BITF and Marble Point and science traverses to deep-field science locations would continue. Approximately 536,640 L (141,765 gal) of fuel would be consumed each year for the USAP traverses. Traverses to Amundsen-Scott South Pole Station may result in multiple, small wastewater releases each year. However, incinerator toilets have minimized the wastewater volume released during traverses.

5.4.4 Vessel and Ice Pier Operations

Support vessel and ice pier operations would continue at current levels and use the same logistical resources. Each year, one resupply vessel and one fuel vessel would resupply McMurdo Station. No additional resupply or fuel vessels are anticipated to support AIMS and McMurdo Master Plan project construction.

5.4.5 Support Facility Operations

Support facility operations at BITF and the Marble Point refueling facility are not expected to be affected by Modernization activities. These facilities would continue to house a small number of staff to support helicopter fueling (Marble Point) and communications connectivity (BITF).

5.4.6 Field Camp Operations

Field camp construction, operation, and closure would continue at current levels (Section 3.4.1 and Table 3-4) during and after construction of AIMS and McMurdo Master Plan projects (Alternative A). This would include maintaining current practices to minimize the impacts of field camp activities consistent with guidelines set forth in the IEE, *Construct and Operate New or Modified USAP Field Camps* (NSF 2008c). These practices include utilizing camp infrastructure appropriate to the level of support required and incorporating mitigation measures to minimize physical disturbances; preventing releases of fuel, waste, and other materials; and ensuring that wastewater discharged in snow- and ice-covered areas is isolated from the surrounding environment.

Each year, approximately 60 tent and minor camps plus two or three major deep field camps would be constructed, operated, and closed. This would result in approximately 0.95 km^2 (0.37 mi^2) of temporary surface disturbances. Most camps would be on ice- and snow-covered areas, which would recover in one to three years. Tent camps on rock areas would require more time to recover, but efforts to minimize the footprint of these camps would continue to be exercised.

Fixed facilities would continue to be used in the MDV to constrain and minimize the spread of impacts. The ASMA Management Plan and ASMA-specific environmental stewardship training provide additional guidance on minimizing impacts from fixed facilities.

Continued operations at field camps are not expected to change the types or quantities of hazardous waste (11,155 m^3 [24,600 yd^3]) or solid wastes (19,360 kg [42,680 lb]) generated. Similarly, wastewater releases would remain similar to current annual levels of 122,480 L (32,355 gal).

5.4.7 Water and Wastewater Operations

Wastewater generated and water use at McMurdo Station would increase from current annual levels (26,385,160 L [6,970,220 gal] of wastewater and 39,257,000 L [10,370,000 gal] of water) during the construction phase of Alternative A, but would decrease after construction is completed. Variations in volume are driven by population increases during construction and decreases after construction is completed (Table 3-5). The WWTP would continue to use primary and secondary treatment by extended aeration and effluent disinfection with ultraviolet light.

AIMS and McMurdo Master Plan projects (Alternative A) would replace portions of the existing sanitary sewer system. Co-locating new sewer lines with other utilities in proposed utilidors would facilitate access and maintenance. In addition, replacing the current system with a gravity-based system would minimize or eliminate the need for sewer pumping stations, further minimizing maintenance requirements. Therefore, the proposed activity would have beneficial long-term impacts on wastewater conveyance and treatment at McMurdo Station.

5.4.8 Power Operations

The proposed activities at McMurdo Station would result in the removal of outdated structures, a smaller heated building area, construction of better-insulated and more-efficient buildings, installation of CHP units, upgrades to the power grid (smart grid systems), expansion of electrical generation from wind power, expanded use of solar technologies, and consolidation of functions into a more efficient layout and smaller developed footprint. These actions would improve fuel and energy efficiency, resulting in an approximate 35% reduction in diesel fuel consumption compared to current conditions (Table 3-5).

5.4.9 Solid Waste Operations

After completion of the construction phase of the proposed activity, the types and quantities of non-hazardous solid waste generated annually at McMurdo Station and field camps by ongoing science and operations are expected to remain similar to current levels and produce similar amounts: 873,120 kg (1,924,900 lb; Table 3-4 and Table 3-5). Since the proposed activity would include a new, non-hazardous solid waste processing facility at McMurdo Station, waste management processes would improve due to modernized capabilities (e.g., greater efficiency and fewer releases to the environment).

5.4.10 Hazardous Waste Operations

The new hazardous waste processing facility at McMurdo Station would have a positive impact on the future management of hazardous waste. Following completion of the construction phase of the proposed activity, the nature and intensity of operations that generate hazardous waste are expected to remain similar to those existing previously and produce amounts similar to or less than the current level of hazardous waste, at 233,920 kg (515,710 lb) per year.

5.4.11 Fuel Use and Storage

Once the construction phases of modernization projects are complete, continued operations would require approximately 10,408,625 L (2,749,670 gal) of fuel, which is approximately 16% less than is currently required, at 12,338,410 L (3,259,465 gal). Fuel use reduction is associated with reduced power and heat generation for buildings and fewer ground vehicles. No changes to fuel storage or fueling processes for buildings, aircraft, or ground-based vehicles are anticipated under the proposed activity, and secondary containment procedures would continue to be used to prevent unintended releases to the environment.

The USAP reviewed the carbon emission sources of all its buildings in Antarctica for 2005 through 2010. The total greenhouse gas emissions from McMurdo area facilities and activities for the first three years were approximately 19,500 metric tons/year of carbon dioxide equivalents (CO_{2-e}). Once modernization projects are completed, reduced fuel use would result in a further reduction to approximately 16,300 metric tons/year of CO_{2-e}.

5.4.12 Hazardous Material Storage and Use

Consistent with current operations, varying quantities and types of hazardous materials would be used and stored at McMurdo Station and at field camps. These materials include oils, lubricants, solvents, propane, compressed gases, and liquid fuels. The types and quantities of these hazardous materials would be consistent with the nature and extent of the current inventory of hazardous materials.

Following completion of AIMS and McMurdo Master Plan projects, a number of structures at McMurdo Station would be removed or consolidated, resulting in a corresponding consolidation and reduction of hazardous materials. Additionally, the vehicle and equipment fleet would be reduced, which would result in decreased, required quantities of vehicle-related fuel, oil, and other hazardous materials.

5.4.13 Explosives Use

The use of explosives to support maintenance projects and scientific research at field sites would continue similar to current levels. At certain locations, detonation of explosives would release combustion by-products and would generate fugitive dust. Emissions are temporary and not expected to affect local air quality.

5.4.14 Fines and Fill

After completion of modernization projects, quarrying fines and fill materials would continue at McMurdo Station to support roadway and ice pier maintenance and similar projects. Approximately 3060 m^3 (4000 yd^3) of fines would continue to be harvested each year for continued station operations. Fines would be collected from established harvest areas following environmental protection guidelines to minimize fugitive dust, fuel use, and area disturbed.

5.4.15 Materials Storage and Use

Consistent with current operations, varying quantities of materials would be used and stored at McMurdo Station and at field camps. At McMurdo Station, these materials are typically stored in outdoor cargo lines or inside warehouses, requiring transport to work sites when needed. Modernization projects would consolidate and modernize warehouses at McMurdo Station, reducing the need to transport these materials to their intended work sites and therefore reducing vehicle fuel consumption. Following modernization improvements, outdoor storage of materials and supplies would be reduced by at least 35%, and up to 90%, reducing the potential for releases to the environment.

5.4.16 Vehicle Use

Vehicles and equipment would continue to be used for cargo transport and overland traverses to support existing operations and scientific research. Once modernization projects are completed, the number of vehicles needed would be expected to decrease by 20% due to increased centralization and building integration. Similarly, spills from vehicle failures (e.g., hose breaks) likely would decline due to a modernization of the vehicle fleet and an overall reduction in use.

5.4.17 Science Support

The USAP would maintain the current level of scientific, operational, and logistical activities under Alternative A of the proposed activity. Once construction is completed, the proposed activity at McMurdo Station would create consolidated work centers dedicated to science support, thereby yielding increased efficiency. In addition, improvements to Crary Laboratory would enhance the laboratory, aquaria, and office spaces used by scientists.

5.5 Unavoidable Impacts

Unavoidable impacts are those that are inherent to the proposed activities and that cannot be fully mitigated or eliminated if the action is completed. The proposed modernization projects involve replacing or upgrading existing facilities; they do not involve expanding the resources used in Antarctica and would not result in impacts that are substantively new or different than those already occurring. The USAP is committed to making these improvements to better serve new and continuing research and enhance stewardship of the Antarctic.

Unavoidable impacts directly resulting from implementing the proposed activity include physical disturbance of surfaces (fines) in the McMurdo Station facility zone, releases to the environment, releases of fuel-combustion by-products from equipment operation, and noise.

5.6 Cumulative Impacts

5.6.1 Introduction

Potential cumulative impacts of the proposed activity (Alternative A), in conjunction with other past, present, and (reasonably) foreseeable future actions can result from individually minor but collectively significant actions expected to occur in a similar location during a similar time period. The analysis of cumulative impacts incorporates all actions that would occur during the lifespan of modernization activities in Alternative A, including the construction phase and continuing operation phase. Past completed projects contributed to existing conditions.

Activities at McMurdo Station prior to the adoption of the Protocol resulted in more than minor or transitory impacts. However, remediation of contaminated sites, plus closure and removal of former waste disposal areas at McMurdo Station have reduced historic impacts. Continued cleanup of contaminated areas would further reduce impacts from past activities.

Present and ongoing activities conducted by other organizations and individuals near McMurdo Station and areas supported by the station, and within the temporal scope of the proposed activities, include continuing operation of New Zealand's Scott Base, research performed by other national programs in MDV and deep field sites, and vessel and air operations by Non-Governmental Organizations (NGOs) and other national Antarctic programs. Reasonably foreseeable future projects likely to occur include the rebuilding of Scott Base; additionally, construction has been initiated and will continue for several years for the IT&C Primary Operations Facility (POF), and the Ross Island Earth Station (RIES). At T-Site, RIES would supplement the existing earth station at BITF. An approved IEE (NSF 2018b) for this project evaluated potential environmental impacts resulting from its construction and operation. The IT&C POF will support evolving program requirements and serve as the primary NSF data center. It will include control center offices, the network operations center, and relocated NASA and JPSS data centers. An approved IEE (NSF 2018c) evaluated the potential environmental impacts of renovating and expanding the existing SSC to create the IT&C POF.

5.6.2 Impacts of Past, Present, and Reasonably Foreseeable Future Projects

Cumulative impacts would be similar to impacts of the proposed activity. Modernizing and operating Scott Base would yield emissions of airborne pollutants from heating equipment and vehicles, while vessel and aircraft operations by NGOs and other national Antarctic programs would generate emissions, noise, and fuel-combustion by-products. Traverses to the South Pole would also generate noise, physical disturbances, and fuel-combustion by-products from vehicular use. However, these effects would be concentrated in the immediate environment and disturbances would occur within exiting footprints, traverse routes, and vessel/aircraft operating areas. The USAP is expected to continue implementing mitigation measures to minimize any adverse impacts.

5.6.3 Cumulative Impacts of the Proposed Activity

The proposed activity, as described in Section 3, plus the other projects described above would have potentially cumulative impacts, including

- fuel use, air emissions (including dust) and particulate deposition;
- fines and rock harvesting, resulting in a change to the existing land contour;
- waste generation; and
- wastewater releases.

See Section 5.6 for a full description of the cumulative impacts and Section 6 for the mitigation measures proposed for each of these activities.

Due to the temporary nature of construction activities and the fact that construction would be restricted to the previously disturbed footprint of McMurdo Station, Alternative A of the proposed action is unlikely to contribute significant adverse cumulative impacts to the environment. Typical construction- and demolition-related impacts (e.g., air and fugitive dust emissions, hazardous and solid waste generation, increased noise, physical disturbance) would be minimized to the extent practicable, as would impacts from future construction projects. The cumulative effects of physical disturbances from Alternative A and other actions would remain localized, and disturbances would mostly occur within the existing station footprint. In addition, mitigation measures (Section 6) would further minimize cumulative impacts.

Cumulative impacts from ongoing operations are likely to occur, but contributions from operations at McMurdo Station would decrease due to operational improvements (e.g., reduced fuel consumption and reduced greenhouse gas emissions, as discussed in Section 5.4.11). Continued USAP operations and the activities of other national Antarctic programs and NGOs are expected to be similar to current levels. Further, coordination with other projects and programs would minimize impacts. Cumulative impacts from Alternative A would not negatively affect the current and future scientific operations undertaken at and near McMurdo Station.

Under Alternative B, the current infrastructure and components of the USAP would continue, and existing conditions would remain the same. The impacts of continuing operations under Alternative B would be larger than those under Alternative A.

5.7 Summary of Impacts

Potential impacts from implementing the proposed activity have been identified and evaluated, consistent with the *Guidelines for Environmental Impact Assessment in Antarctica* (ATS 2016a). Table 5-1 summarizes the criteria used to evaluate the significance of the potential impacts relative to the extent, duration, and intensity of each activity, as well as the probability of their occurrence. Table 5-2 and Table 5-3 summarize potential environmental impacts resulting from the proposed McMurdo Station area modernization activities and continuing operations, respectively. Because current USAP operations would continue during the construction phase of modernization projects, some impacts (e.g., waste generation, use of hazardous materials, accidental releases, noise) may be additive from both components of the proposed activity.

Implementing modernization improvements at McMurdo Station represents a significant commitment of resources over many years and could result in temporary but noticeable environmental impacts. However, the potential benefits of the proposed activity are substantial and long-lasting. Overall, some of the projected impacts from the proposed activity would be more than minor or transitory (e.g., cumulative impacts due to pre-Protocol activities). However, some impacts (e.g., waste generation, wastewater release, air emissions) would be localized, while other impacts would be widely dispersed (e.g., air emissions from aircraft). In addition, application of mitigations would reduce impacts to no more than minor or transitory.

Table 5-1. Criteria for Assessment of Potential Impacts on the Environment

Type of Impact	Criteria		
	Less than Minor or Transitory	***Minor or Transitory***	***More than Minor or Transitory***
	Low	**Medium**	**High**
Extent	Local extent - Impact confined to the site of the activity.	Partial extent - Impact extends to a small area around the site of the activity.	Major extent - Impact extends well beyond the site of the activity.
Duration	Short term - Impact lasts several weeks up to several seasons; short compared to natural processes.	Medium term - Impact lasts more than several years; may or may not be reversible.	Long term - Impact extends beyond activity completion; impact may not be reversible.
Intensity	Minimal impact on natural functions and processes of the environment; impact may not be noticeable to an uninformed observer; reversible.	Impact on natural functions or processes of the environment, but these remain viable with no long-lasting changes; impact is noticeable to an uninformed observer; may or may not be reversible.	Natural functions or processes of the environment impacted or changed over long term; reversibility uncertain; mitigation of impact may be required.
Probability	Impacts possible but unlikely.	Impacts likely.	Impacts certain.

Table 5-2. Impacts of McMurdo Station Modernization (AIMS and McMurdo Master Plan) Activities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Building Demolition	Emit fuel combustion by-products (vehicle & equipment use, electrical power generation)		X							Direct	Limit equipment use to minimum amount necessary; maintain equipment in order.	L	L	L	H
	Generate fugitive dusts		X							Direct	Implement fugitive dust control plan.	L	L	L	L
	Emit by-products from use of explosives		X							Direct	Limit explosive use to minimum amount necessary.	L	L	L	H
	Generate noise	X								Direct	Noise abatement would be performed to protect human safety and health. Demolition noise levels would be below thresholds disruptive to birds or marine mammal environments.	L	M	L	H
	Release fuel or hazardous materials				X	X				Direct	Utilize spill prevention procedures and resources.	L	L	M	L
	Generate waste							X		Direct	Establish waste staging areas and provide sufficient containment.	L	M	L	H
	Regrade land surface		X	X						Direct	Regrade surface to match surrounding contours.	L	L	L	H

Table 5-2. Impacts of McMurdo Station Modernization (AIMS and McMurdo Master Plan) Activities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Building Demolition (continued)	Excavate/reveal previous contamination			X	X			X		Direct	Manage contaminated materials consistent with current procedures.	L	L	M	L
	Remove or relocate historic features								X	Direct	Implement management plan to preserve historical resources.	L	L	L	H
Site Preparation, Fill, and Fines	Physical disturbance (site preparation and site regrading)			X						Direct	Limit disturbance to the existing footprint of McMurdo Station.	L	L	M	H
	Emit fuel combustion by-products (vehicle & equipment use)		X							Direct	Limit equipment use to minimum amount necessary; maintain equipment in order.	L	L	L	H
	Generate fugitive dusts		X							Direct	Implement fugitive dust control plan.	L	L	L	H
	Generate noise	X								Direct	Noise abatement would be performed to protect human safety and health.	L	L	L	H
	Release fuel or hazardous materials				X	X				Direct	Utilize spill prevention procedures and resources.	L	L	M	L

Table 5-2. Impacts of McMurdo Station Modernization (AIMS and McMurdo Master Plan) Activities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Blasting and Explosives Use	Physical disturbance	X		X					X	Direct	Limit explosives use to amount necessary.	L	M	L	H
	Emit by-products from use of explosives		X							Direct	Limit explosive use to minimum amount necessary.	L	L	L	H
	Generate fugitive dusts		X							Direct	Utilize blasting mats to reduce dust.	L	L	L	H
	Generate noise	X								Direct	Noise abatement would be performed to protect human safety and health. Site activity would cease in the event birds entered the work site. Blasting and explosives would not be used in or near marine environments.	L	M	L	H
Import Materials	Transportation of non-native species						X			Indirect	Ship inspections and fumigations; inspect cargo and materials; remove and destroy discovered non-native species.	L	L	L	H

Table 5-2. Impacts of McMurdo Station Modernization (AIMS and McMurdo Master Plan) Activities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	**Decreased air quality**	**Altered land contours and drainage patterns**	**Polluted terrestrial environment**	**Polluted marine environment**	**Introduced non-native species**	**Increased waste management**	**Altered historic or aesthetic resources**			**Extent**	**Duration**	**Intensity**	**Probability**
Building Construction	Emit fuel combustion by-products (vehicle & equipment use, electrical power generation)		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H
	Generate fugitive dusts		**X**							Direct	Implement fugitive dust control plan.	L	L	L	H
	Generate noise	**X**								Direct	Noise abatement would be performed to protect human safety and health	L	M	L	H
	Release fuel or hazardous materials				**X**	**X**				Direct	Utilize spill prevention procedures and resources.	L	L	M	L
	Generate waste							**X**		Direct	Establish waste staging areas and provide sufficient containment.	L	M	L	H
	Alter visual landscape								**X**	Direct	Reduce the number of McMurdo Station structures.	L	L	L	H
Vehicle Use	Emit fuel combustion by-products		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H
	Generate noise	**X**								Direct	Noise abatement would be performed to protect human safety and health	L	L	L	H

Table 5-3. Impacts of Continued Operations of McMurdo Area Activities and Facilities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Building Use	Emit fuel combustion by-products (heating)		**X**							Direct	Expand glycol heat recovery loop.	L	M	L	H
	Emit fuel combustion by-products (vehicles and equipment)		**X**							Direct	Locate warehouses or cargo lines closer to work centers.	L	M	L	H
	Release fuel or hazardous materials				**X**	**X**				Direct	Utilize spill prevention procedures and resources.	L	M	M	L
	Generate wastewater							**X**		Indirect	Improve wastewater conveyance systems to reduce maintenance.	L	M	L	H
Helicopter and Fixed Wing Operations	Emit fuel combustion by-products (aircraft)		**X**							Direct	Limit aircraft use to minimum amount necessary; maintain equipment.	L	L	M	H
	Generate noise	**X**								Direct	Adhere to ASPA or ASMA management plans.	L	L	L	H
	Release fuel or hazardous materials				**X**	**X**				Direct	Utilize spill prevention procedures and resources during refueling.	L	L	M	L

Table 5-3. Impacts of Continued Operations of McMurdo Area Activities and Facilities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Traverse Operations	Emit fuel combustion by-products (vehicle use)		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H
	Generate noise	X								Direct	Routes avoid ASPAs and animal concentrations.	L	L	M	L
	Regrade land surface (snow)			**X**						Direct	Regrade surface to facilitate safe transport of equipment through Shear Zone.	L	L	L	M
Vessel and Ice Pier Operations	Emit fuel combustion by-products (vehicle & equipment use)		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H
	Release fuel or hazardous materials				**X**	**X**				Direct	Utilize spill prevention procedures and resources.	M	L	M	L
Support Facility Operations	Emit fuel combustion by-products (vehicle & equipment use, electrical power generation)		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H
	Release fuel or hazardous materials				**X**	**X**				Direct	Utilize spill prevention procedures and resources.	L	L	M	L
Field Camp Operations	Emit fuel combustion by-products (vehicle & equipment use, heating, electrical power generation)		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H
	Regrade land surface (soil, snow)			**X**						Direct	Limited to skiways for major camps; natural snow drifting removes in one to two seasons.	L	L	L	M

Table 5-3. Impacts of Continued Operations of McMurdo Area Activities and Facilities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Field Camp Operations (continued)	Release fuel or hazardous materials				**X**	**X**				Direct	Utilize spill prevention procedures and resources; buffer between camps and water.	L	L	L	M
	Generate waste							**X**		Direct	Establish waste staging areas and provide sufficient containment.	L	L	L	H
	Discharge wastewater (snow and ice areas)				**X**					Direct	Isolate discharges in deep ice pits.	L	L	L	H
Water and Wastewater Operations	Discharge wastewater (McMurdo Sound)					**X**				Direct	Use primary and secondary treatment and disinfection prior to discharge.	L	M	L	H
Power Operations	Emit fuel combustion by-products (electrical power generation)		**X**							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	M	L	H
Solid Waste Operations	Release waste				**X**					Direct	Establish waste staging areas and provide sufficient containment.	L	L	L	H
	Generate noise	X								Direct	Limited to McMurdo Station area; perform packaging and compaction inside buildings.	L	L	L	H
Hazardous Waste Operations	Release waste				**X**					Direct	Establish waste staging areas and provide sufficient containment.	L	L	L	L
	Generate noise	X								Direct	Limited to McMurdo Station area; perform packaging and compaction inside buildings.	L	L	L	H

Table 5-3. Impacts of Continued Operations of McMurdo Area Activities and Facilities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Fuel Use and Storage	Accidental release of fuel				X	X				Direct	Utilize spill prevention procedures and resources.	L	M	L	H
Hazardous Material Storage and Use	Release hazardous materials				X	X				Direct	Utilize spill prevention procedures and resources.	L	L	L	L
Explosives Use	Physical disturbance	X		X						Direct	Limit explosives use to amount necessary.	L	M	L	H
	Generate fugitive dusts		X							Direct	Utilize blasting mats to reduce dust.	L	L	L	H
	Emit by-products from use of explosives		X							Direct	Limit explosive use to minimum amount necessary.	L	L	L	H
	Generate noise	X								Direct	Noise abatement would be performed to protect human safety and health. Site activity would cease in the event birds entered the work site. Blasting and explosives would not be used in or near marine environments.	L	L	L	H
Fines and Fill	Physical disturbance			X						Direct	Limit disturbance to designated collection areas within the existing footprint of McMurdo Station.	L	M	L	H
	Emit fuel combustion by-products (vehicle & equipment use)		X							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	L	L	H

Table 5-3. Impacts of Continued Operations of McMurdo Area Activities and Facilities

Activity	Environmental Aspect	Potential Environmental Impacts								Type	Preventive or Mitigating Measures	Impact			
		Wildlife disturbance	Decreased air quality	Altered land contours and drainage patterns	Polluted terrestrial environment	Polluted marine environment	Introduced non-native species	Increased waste management	Altered historic or aesthetic resources			Extent	Duration	Intensity	Probability
Fines and Fill (continued)	Generate fugitive dusts		X							Direct	Implement fugitive dust control plan.	L	L	L	H
	Alter visual landscape								X	Direct	Limit disturbance to designated collection areas within the existing footprint of McMurdo Station.	L	H	L	M
Materials Storage and Use	Emit fuel combustion by-products (vehicles and equipment)		X							Direct	Consolidate storage areas to reduce material transport.	L	L	L	H
	Release materials				X					Direct	Utilize spill prevention procedures and resources.	L	L	L	M
Vehicle Use	Emit fuel combustion by-products (vehicles and equipment)		X							Direct	Limit equipment use to minimum amount necessary; maintain equipment.	L	M	L	H
Science Support	None									Indirect	Minimize disruptions or delays to scientific research and support activities through advance planning.	L	L	L	L

6. Mitigation Measures

6.1 Introduction

All USAP projects are reviewed to determine their anticipated environmental impact, with the aim of avoiding, minimizing, and/or mitigating those impacts. Throughout the USAP operations, a series of best management practices and mitigation measures have been developed and integrated into both unique and routine USAP activities, such as demolition, construction, remodeling, scientific drilling, fines recovery, explosives use, remotely deployed equipment recovery, field camp size management, non-native species prevention, spill prevention and response, and waste and wastewater management. Mitigation measures would continue to be integrated into the USAP's actions throughout implementation of the proposed activity. All of the USAP's actions performed in ASMAs and/or ASPAs would also be guided by respective, area-specific management plans.

6.2 Mitigation during McMurdo Infrastructure Modernization Activities

6.2.1 Building Demolition and Construction

Demolition activities identified in the proposed AIMS and McMurdo Master Plan projects would be carried out in accordance with established, routine USAP procedures. Because demolition activities would only occur within the existing footprint of McMurdo Station, there would be no impacts to undisturbed or environmentally sensitive areas. Demolition impacts would be further minimized by staggering the demolition schedule over many years so that waste and emissions do not occur in only one or two years (Table 3-1 and Table 3-3). If not re-developed, demolition sites would be regraded to natural contours as much as feasible. Dust control measures (e.g., water spray) would be implemented at sites where soil disturbance has the potential to generate dust that would migrate in the environment.

At some locations, materials may have become frozen in place, or contamination from past activities may be present. Depending on conditions, removal may cause greater impacts than leaving the materials in place. At proposed project sites where hazardous materials are known or suspected to have been released during previous operations, potentially contaminated soil, snow, or ice would be tested to determine whether removal or on-site clean-up is required. As needed, subsurface contamination would be removed and uncontaminated fill would be used to restore the area to the approximate original contour or a contour that would support activities planned for the location. At sites where subsurface contamination cannot be removed, the material would continue to be managed in place (e.g., encapsulated) in accordance with established USAP measures and procedures and following an environmental review and concurrence by NSF/OPP officials.

Personnel involved with removing facilities identified for demolition would review building plans or inspection reports to determine the potential presence of hazardous substances (e.g., asbestos-containing materials, lead-based paint, petroleum or chemical-contaminated materials). Once NSF approves demolition, asbestos-containing materials and lead-based paint abatement would be conducted beforehand using established protocols, if necessary. The resources required to demolish the facility and remove debris from the continent, such as temporary storage areas and transportation containers, would also be identified.

During construction and demolition, ambient noise is expected to increase. Birds and marine mammals are not expected to be near work areas during the proposed activities. However, the USAP would continue implementing standard procedures to halt project activities when birds enter construction or demolition areas. If seals are hauled out along the shoreline, near the center of McMurdo Station (i.e., near the WWTP or Hut Point Peninsula), blasting activities would cease until the animals have reentered the water. It is expected that noise-generating activities would be limited to work hours, when most of the local McMurdo Station population is awake. Personal protective equipment, such as earplugs or earmuffs, would continue to be used by workers on project sites, as needed.

High winds occur frequently in Antarctica and may be capable of lifting construction materials or debris if these are left unsecured. In addition to being unsightly, windblown materials can be hazardous to wildlife, personnel, and property. To eliminate the risk of windblown objects, materials awaiting installation or removal would be secured and/or contained. Additionally, work would be suspended by the on-site manager if winds become excessive or are forecast to increase rapidly. Any windblown debris would be cleaned up after each high-wind event.

6.2.2 Waste Management

Waste generated during construction, demolition, and operations would continue to be managed to prevent release to the environment and ensure that sufficient resources are available to package the waste for removal from the continent. If delays in retrograding waste occur, the waste would be stored until transport is available to remove it from Antarctica through the current waste management process. Waste management has integrated mitigations that emphasize recycling, segregation, compaction, and prevention of release to the environment. In addition, the USAP procurement process incorporates a review of material to ensure banned substances are not purchased or shipped to McMurdo Station. During procurement, hazardous materials (e.g., chemicals, solvents, or other toxic substances) are reviewed and more environmentally friendly alternatives are substituted whenever possible. Implementing the McMurdo Master Plan projects to build a new hazardous waste facility and improve solid waste capabilities would further improve waste management and increase efficiency at McMurdo Station.

When not in use, hazardous materials would continue to be stored in containment areas, such as berms, sea containers, or lockers to prevent release into the environment. In the event a hazardous material is accidentally released to the environment, corrective action would be taken immediately to stop the release and prevent the material from migrating. To the maximum extent practical, all spilled material and contaminated media would be cleaned up as soon as possible and the resulting residues managed as hazardous waste.

6.2.3 Site Preparation, Fill, and Fines

Demolition and construction activities at McMurdo Station would involve site preparation and the collection and use of soil fines. Excavation of material for road maintenance and building foundations would be minimized by re-using previously excavated fines and limiting excavation areas. Fines would be collected using excavators, front-end loaders, and bulldozers and transported in dump trucks. During excavation, fines would be screened to segregate different sizes of material. The USAP procedures would continue to be followed to limit fugitive dust and to harvest only from established and approved areas.

6.2.4 Explosives

During demolition, explosives would be used to dislodge buried or frozen building components and loosen soils for subsequent installation of underground infrastructure. Explosives would also be used during construction to prepare foundation areas or loosen frozen ground to install culverts. In these instances, blasting would be planned and designed to limit the amount of explosives to the minimum necessary. If seals are hauled out along the shoreline, near the center of McMurdo Station (i.e., near the WWTP or Hut Point Peninsula), blasting would cease until the animals have reentered the water. In addition, blasting mats may be utilized to contain the blast and minimize the amount of noise, prevent flying rocks, and suppress dust.

6.2.5 Importation of Materials

Over the past 10 years, the USAP has enhanced training and prevention measures to mitigate the introduction of non-native species to USAP facilities and the Antarctic environment. Preventive measures include inspecting and cleaning cargo, equipment, and clothing before deployment to Antarctica and before deployment to field sites. Further, the USAP requires the inspection and, if necessary, treatment of imported materials or equipment (e.g., wood, gravel, machinery) to eliminate non-native species. The USAP also decontaminates or removes insects and seed materials that are discovered in raw foods or other materials imported to Antarctica. USAP participants regularly report observations of non-native insects, plants, and/or seeds, which are then isolated, destroyed, and removed from the Antarctic. Records of non-native species are used to identify areas or species of concern and to aid in determining if the species enters the continent through natural processes or as a result of the USAP's operations.

6.2.6 Vehicle Use

Vehicles and heavy equipment would be used for demolition and construction and would release fuel-combustion by-products into the air. Since the proposed activity would occur over multiple years, vehicle emissions would not be concentrated into a short time period and would be roughly equivalent to emissions during normal operations (emission estimates are presented in Table C-4 and Table C-5 in Appendix C). Mitigation to minimize fuel consumption and related emissions would include limiting equipment use to the minimum amount necessary to complete an activity and maintaining equipment in good working order to ensure proper and efficient combustion.

6.2.7 Historic Sites and Monuments

Five HSM are present at or next to McMurdo Station. All HSM would be avoided, with the exception of HSM No. 54 (bust of Richard E. Byrd), which is adjacent to a building scheduled for demolition. The monument would be relocated to a new facility before demolition starts.

6.3 Mitigation Measures During Continuing, Existing McMurdo Area Activities and Operating Existing Facilities

Best management practices and mitigation actions would continue to be implemented during continued USAP operations in the McMurdo area. Mitigation measures applicable to McMurdo Station activities are presented in Table 6-1. Personnel involved with the proposed activities would adhere to management practices, codes of conduct, and other requirements provided in management plans for ASMAs or ASPAs to avoid or minimize impacts on those areas.

6.4 Environmental Reporting and Review

The USAP has established a formal process to gather data in an efficient and consistent manner that addresses all activities at each permanent station and outlying facility in Antarctica. Since 1990, the USAP has engaged in a number of monitoring programs that have evolved, improved, and expanded along with the USAP. Detailed in Section 7, monitoring has included annual measurement, monitoring, and tracking of population, fuel use, aircraft and traverse support, waste generation and disposition, wastewater discharge, annual wastewater characterization, planned releases to the environment, accidental releases (spills), and remotely deployed equipment. These data are used to evaluate trends and identify conditions that may require additional mitigation to limit or manage adverse environmental impacts.

The USAP has also implemented a program to document the extent of environmental disturbances resulting from past and current USAP facilities and the deployment of equipment and materials. Data collected includes locations of airplane helicopter landing sites, field camp sites, sampling activities, and fuel and waste storage facilities or locations.

Table 6-1. Mitigation Measures during Continuing Operations and Activities

Environmental Aspect	Impact Goal	Mitigating Measure	Applicable USAP Operations and Resources																
			Building Use	Aircraft (Helo and Fixed Wing)	Traverse	Vessel and Ice Pier	Support Facilities	Field Camps	Water and Wastewater	Power	Solid Waste	Hazardous Waste	Fuel Use and Storage	Hazardous Material Storage and Use	Explosives Use	Fines and Fill	Use of Materials	Vehicle Use	Science Support
Emit fuel combustion byproducts (heating)	Reduce emissions	Expand glycol heat recovery loop.	X							X									
Emit fuel combustion byproducts (vehicles and equipment)	Reduce emissions	Locate warehouses or cargo lines closer to work centers.	X														X		
		Maintain equipment to operate efficiently.			X													X	
Emit byproducts from use of explosives	Reduce emissions	Prepare blasting plan; limit explosive use to amount necessary.													X	X			
Emit fugitive dust	Reduce emissions	Use blasting mats to reduce dust.													X				
		Implement fugitive dust control plan.	X													X			
Generate noise	Minimize wildlife disturbance	Adhere to ASPA or ASMA management plans.						X											X
Accidental release of fuel	Prevent release	Utilize spill prevention measures during refueling.	X	X	X	X	X	X					X					X	
Accidental release of hazardous materials (non-fuel)	Prevent release	Utilize spill prevention features.	X					X						X					X
		Consolidate material storage (indoor storage).												X					
		Procure only materials needed to adequately support activities.	X					X											X

Table 6-1. Mitigation Measures during Continuing Operations and Activities

Environmental Aspect	Impact Goal	Mitigating Measure	Applicable USAP Operations and Resources																
			Building Use	Aircraft (Helo and Fixed Wing)	Traverse	Vessel and Ice Pier	Support Facilities	Field Camps	Water and Wastewater	Power	Solid Waste	Hazardous Waste	Fuel Use and Storage	Hazardous Material Storage and Use	Explosives Use	Fines and Fill	Use of Materials	Vehicle Use	Science Support
Accidental release of waste	Prevent release	Establish waste staging areas and provide sufficient containment.	X				X	X			X	X							
Regrade land surfaces (soil, snow, ice)	Reduce disturbances	Limit operating/facility zone to only the area needed to support operations or research.					X	X								X			X
Regrade land surfaces (soil)	Reduce disturbances	Reuse recovered material generated during building demolitions, treat fuel-contaminated soil for reuse, and improve drainage around the station to reduce erosion resulting from snowmelt runoff.	X													X			
Release wastewater (marine, snow or ice areas only)	Reduce discharge; reduce maintenance	Containerize or treat wastewater where practical.			X			X											
		Improve conveyance systems.	X						X										
Introduce non-native species	Prevent distribution or cross-contamination	Inspect clothing, materials and equipment; remediate as needed	X	X	X	X	X	X									X		X
Transfer of non-native species	Prevent cross-contamination	Inspect and clean clothing, materials, and equipment between field sites.	X	X	X	X	X	X									X		X

7. Environmental Monitoring

In accordance with Article 5 of Annex I of the Protocol, the USAP conducts a comprehensive monitoring program of key environmental indicators to assess and verify the impacts of activities conducted in Antarctica. Since 2005, the USAP has used the guidance in the *Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica* (COMNAP 2005) to assist in developing robust environmental monitoring. The environmental monitoring program also verifies that projected impacts in EIAs are consistent with actual impacts. Environmental impacts and impact sources that are monitored include land use and disturbance, fuel use, hazardous material use and storage, waste management, and releases to the environment. The monitoring program also confirms if those impacts are localized and do not constitute a major adverse impact on the environment. The USAP regularly conducts on-site reviews of field camp operations and projects to assess the use and efficacy of best management practices (e.g., waste collection and management, spill prevention practices, and environmental impacts to the surrounding environment), as well as compliance with environmental protection requirements.

7.1 Overview of Past Monitoring Studies and Assessments

Historically, environmental monitoring has been performed at the USAP's facilities for the quality of water, air, soil, ice, and snow. Drinking water samples collected annually at McMurdo Station and select field camps are used to determine water safety and to protect the health of the USAP participants. Additionally, annual wastewater samples are collected from the McMurdo Station WWTP effluent to calculate pollutant loadings (e.g., biochemical oxygen demand [BOD], total suspended solids [TSS], ammonia-nitrogen) and determine if contaminants are being discharged to the receiving body.

A long-term, benthic monitoring program was conducted at McMurdo Station between 1988 and 1993 to study changes in benthic communities in response to chemical contaminants and the organic enrichment of sediments, as documented in the resulting Moss Landing Marine Laboratory report (Lenihan and Oliver 1995). An air monitoring program was conducted at McMurdo Station during the 1992-1993 and 1993-1994 austral summers. Those data showed that station operations had a less than minor or transitory impact on local air quality (Lugar 1994). Seasonal air emissions continue to be calculated from fuel use.

A drainage and erosion study was conducted at McMurdo Station in 2008, with the goal of providing recommendations for mitigating drainage-related erosion within the station footprint (CRREL 2014). The study identified areas where erosion was a concern and provided recommendations on soil compaction and drainage design to limit future erosion.

Environmental impacts caused by anthropogenic activities at McMurdo Station were monitored between 1999 and 2012 (Kennicutt et al. 2010; Klein et al. 2012). Researchers determined the extent of physical disturbance at the station (Klein et al. 2008) and analyzed soil to identify the contaminant footprint. A number of physical, chemical, and biological indicators were measured in soils and marine sediments, including contaminant dose (concentrations), toxicological properties, and *in situ* biological responses over short- and long-term time scales. The USAP also monitors and assesses previously disturbed locations at McMurdo Station and/or the McMurdo area through a system that tracks sites of past activity.

7.2 Monitoring Plan

7.2.1 Current USAP Environmental Monitoring Program

The USAP has a monitoring program which follows guidance in the *Antarctic Environmental Monitoring Handbook: Standard techniques for monitoring in Antarctica* (COMNAP and SCAR 2000) and the *Practical Guidelines for Developing and Designing Environmental Monitoring Programmes in Antarctica* (COMNAP 2005). Data is gathered on all science and operational activities at McMurdo Station, outlying facilities, and field camps in an efficient and consistent manner. The data collected through this process forms the basis of the current monitoring program, which is summarized by season and collates key parameters, including

- population (person-days by location);
- camp use;
- fuel use;
- field fuel caches;
- aircraft and traverse support;
- waste generation and disposition;
- wastewater discharge;
- annual wastewater characterization;
- planned releases to the environment (e.g., research balloons);
- sample sites;
- accidental releases (e.g., spills); and
- the recovery status of remotely deployed equipment.

In addition, the USAP inspects and reports non-native species found in food and cargo to assess and improve pre-shipping procurement and inspection processes.

The USAP has also implemented a program to document the extent of environmental disturbances resulting from past and current USAP facilities and the deployment of equipment and materials. Data is collected on field camp site locations, field sampling activities and locations, field population (person-days by location), and fuel and waste storage facilities. In recent years, the USAP has reviewed its monitoring program with the aim of improving the collection, maintenance, and quality of data. Future improvements to the monitoring program are aimed at developing a relational database to improve the ability of the USAP to identify the impact of all its activities on the Antarctic environment. Over the approximately 10 years of McMurdo Station recapitalization, the USAP monitoring program would need to evolve to cover the full extent of the proposed modernization activities. Appropriate monitoring would be undertaken after modernization activities have been completed to verify that impacts are in line with those assessed in this CEE.

The USAP monitoring program would be divided into three categories: short term monitoring of key parameters related to modernization activities, monitoring of environmental indicators following modernization activities, and annual monitoring of key parameters related to ongoing McMurdo area activities.

7.2.2 Monitoring During Modernization Activities

Key environmental indicators related to McMurdo Station area modernization activities would be monitored for the impacts identified in this CEE. This monitoring effort would be similar to, and integrated into, the current USAP monitoring program. Monitored impacts include disturbance to wildlife, releases to the air (e.g., fugitive dust) and water, noise (disturbance to Antarctic animals), physical disturbance of terrestrial and marine environments, introduction of non-native species, increased waste production, and alteration of historic and aesthetic resources. Monitoring of material procurement processes would include preventing the purchase and transport of banned materials to Antarctica. In addition, all material would be inspected before shipment to ensure that no banned substances are included and to prevent importing non-native species.

Monitoring would occur throughout the extent of each modernization activity, including building demolition; site preparation, fill, and fines; blasting and explosives use; import of material; building construction; and vehicle use.

7.2.3 Monitoring Post Modernization Program Activities and Ongoing Operations

After McMurdo Station modernization activities are completed, The USAP would continue monitoring key environmental indicators. This monitoring would be conducted as part of the overall USAP monitoring program, as discussed in Section 7.2.1.

7.3 Verification of Predicted Impacts of the Proposed Activities

The USAP has historically undertaken a program of field audits to evaluate the environmental impacts of science, operations, and field camps to ensure that the impacts have been correctly identified. The results of these audits have been periodically reported to the CEP in ATCM XL IP8 *Field Project Reviews: Fulfilling Environmental Impact Assessment (EIA) Monitoring Obligations, 2017* and in ATCM XXXVIII IP42 *EIA Field Reviews of Science, Operations, and Camps, 2015*. The USAP would continue to document and systematically evaluate impacts resulting from the proposed activities through a system of on-site audits undertaken during McMurdo Station modernization activities and throughout ongoing operations. The audits would ensure that the actions and mitigation measures detailed in this CEE are being performed as planned, that the impacts have been correctly evaluated, and that corrective actions are initiated as necessary to mitigate increased or unexpected impacts. Audits would focus on specific construction projects during McMurdo Station modernization activities, and reviews of modernization activity impacts would be completed following each construction season throughout the project. The audit program would continue for ongoing USAP activities and operations, focusing on specific science and operational activities to verify that impacts identified through the EIA process are also being performed as planned, that the impacts have been correctly evaluated, and that corrective actions are initiated as necessary to mitigate increased or unexpected impacts.

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8. Decommissioning of United States Antarctic Program Facilities in the McMurdo Area

The *Guidelines for Environmental Impact Assessment in Antarctica* (ATS 2016a) advises that decommissioning existing facilities to a pre-activity state should be considered, where such actions are appropriate. McMurdo Station is a major research and resupply resource for the USAP that is expected to continue operating for the foreseeable future. However, in the event that decommissioning were to occur, dismantling of each building would likely be in reverse of the construction sequence (i.e., it would start with removing building panels or other structural components, progress to removing utility connections and footers, and end with regrading the building site to restore its original condition, to the greatest extent practical). Building demolition has been subject to an IEE and has always been a part of the USAP upgrades and improvements. Therefore, the USAP has extensive experience in minimizing environmental disturbance during demolition.

The full removal of all material and components of McMurdo Station would require a minimum of 10 years, though the actual time would depend on the condition of facilities at the time of decommissioning. The resultant waste materials would be managed to prevent releases to the environment and would be shipped back to the United States via cargo vessel. After decommissioning, land surfaces would be regraded to either resemble pre-disturbance conditions or blended into surrounding contours to the greatest extent possible.

Materials may have become frozen in place or contamination from past activities may be present in some locations. Depending on conditions, removal may cause greater impacts than leaving the materials in place. In these instances, appropriate actions would undergo the USAP EIA process and EIA documentation would be prepared to meet the requirements of Annex I of the Protocol and in accordance with the ACA and its implementing regulations set forth in 45 C.F.R.§ 641.

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9. Gaps in Knowledge and Uncertainties

Uncertainty and unknowns are inherent in the environmental analysis of the proposed activity. The greatest uncertainties and gaps in knowledge relate to methodology, construction conditions, and future science. Impacts described in this CEE account for a range of conditions during facility modernization and the service life of the facility. Therefore, any variations or uncertainties that do not involve major changes are not expected to significantly affect the potential impact sources of activities or alter conclusions. Additionally, if project-specific plans are refined or changed, the USAP EIA process would be implemented and updated or new EIA documentation may be prepared to meet the requirements of Annex I of the Protocol and in accordance with the ACA and its implementing regulations set forth in 45 C.F.R.§ 641.

9.1 Uncertainties in Methodology

While some uncertainty exists with respect to the methods used to estimate certain parameters, potential inaccuracies in the estimates did not affect the conclusions reached from the environmental reviews conducted or the impacts identified by those reviews. Technical information and data related to the proposed activity were derived from details of the action and its estimated impacts, such as waste generation, physical disturbances, fuel consumption, noise, and emissions to the air. Using these data, potential environmental impacts were evaluated relevant to the characteristics of the environmental settings that could be affected. The USAP's project teams provided quantitative estimates developed using generic models based on preliminary design, area of the buildings, number of floors, construction materials, and other factors. Inaccuracies in these estimates are not expected to affect the conclusions derived from this environmental review.

9.2 Uncertainties in Construction and Demolition

Uncertainties may exist with respect to construction, demolition, operations, and impacts that could affect the surrounding environment, such as soil and rock conditions beneath structures to be demolished, including the potential presence of contaminants. Resources needed to house and support temporary construction workers and the adequacy of existing facilities to accommodate personnel and work functions displaced by construction and demolition contribute to uncertain construction conditions, such as adapting project schedules due to logistical considerations (e.g., delays due to weather and/or material delivery). Further, the adequacy of resources to handle, contain, and store demolition debris until it can be retrograded from Antarctica for disposal is unknown, particularly if there are changes to project schedules or to the estimated volume of material generated. However, consistent with current USAP practices, waste would be stored in a manner that prevents inadvertent release to the surrounding environment. In addition, the availability of sealift resources to remove demolition waste according to the estimated removal schedule is an uncertainty that may affect the final completion date of the proposed activity.

Although the general timing of modernization activities has been developed, specific demolition and construction sequences are uncertain at this time. Plans for the proposed activities would include AIMS, a subset of McMurdo Master Plan projects, that are implemented over a period of approximately eight years and remaining McMurdo Master Plan projects that are implemented over approximately the following seven years. However, it is possible that operational, logistical, funding, or weather-related factors may extend construction phases; thus the entire construction phase of modernization projects would be approximately 15-20 years. As a result, some environmental impacts would be spread over time at a lower intensity than those that would result from actions occurring simultaneously or with greater frequency.

9.3 Uncertainties in Future Science

Changes in future science projects, including the potential application of more advanced technologies, also contribute to uncertainty regarding the resources needed to support those projects. While the proposed changes to McMurdo Station science-support infrastructure are intended to be flexible and accommodate a number of changes in the types of research supported, the specific focus of future research projects is unknown. In addition, the nature and extent of future research projects involving international collaboration may affect the facilities or logistical resources that are needed and shared among the USAP and the programs of other Treaty Parties.

10. Conclusions

This CEE identifies impacts potentially resulting from Alternative A (the proposed activity) and Alternative B. The proposed activity would implement modernization projects at McMurdo Station and continue ongoing science and operations at McMurdo Station and the areas it supports. The proposed construction phase for modernization projects is anticipated to occur over a period of approximately 15-20 years.

The proposed activity (modernization and continuing operations) is not anticipated to expand the operating footprint of McMurdo Station or fixed facilities supported by McMurdo Station. Similarly, the proposed activity would not result in impacts that are substantively new or different from those that have already occurred. Impacts from the proposed activity are projected to be localized and either contained and removed from the continent (e.g., solid and hazardous waste) or at a level that the environment is able to absorb the impacts without change at the regional level (e.g., wastewater effluent and air emissions). However, some impacts would result in more than minor or transitory impacts, even with the proposed mitigations. Therefore, some long-term adverse impacts on the Antarctic environment are expected.

The proposed activity would result in substantial improvements in environmental performance, and consistent use of mitigations and monitoring would further minimize impacts. Benefits would include continuing substantive scientific and logistic collaboration with other Antarctic programs and increased potential for enhanced international collaboration as new science and logistical opportunities arise. The major benefits of modernization components of the proposed activity are

- improved capacity for USAP research in concert with continuing international collaborations in scientific and operational activities;
- enhanced safety performance in the USAP;
- increased operational efficiency (12% reduction in support staff and a 40% reduction in maintenance staff);
- increased logistical efficiency (20% reduction in building square footage);
- reduction in outdoor storage (at least a 35% reduction and up to a 90% reduction);
- reduced energy consumption (35% reduction in station fuel consumption and a 20% reduction in vehicle fuel use);
- reduced carbon emissions; and
- reduced long-term environmental impact.

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11. CEE Preparers and Reviewers

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12. Glossary

The glossary contains definitions of unusual words or words that are used in unusual ways in this document. The definitions are not necessarily dictionary based.

Ablation – Erosion of a glacier or ice sheet by sublimation (evaporation of ice to atmospheric water vapor) and wind erosion. Areas of ice ablation are those where the rate of ice removal by sublimation and wind erosion is high enough that a net loss occurs. Ice ablation results in blue ice formations consisting of exposed, blue glacial ice without a normal snow cover.

Antarctic Treaty – The Antarctic Treaty was signed in Washington, DC in 1959 and entered into force in 1961. The Treaty established a legal framework for the area of the earth south of 60°S (which includes all of Antarctica), reserves Antarctica for peaceful purposes, and provides for freedom of scientific investigation. The Treaty does not recognize, dispute, or establish territorial claims and prohibits the assertion of new claims.

Antarctic Treaty Consultative Meeting (ATCM) – Annual meeting of Treaty Parties and representatives of associated organizations to deliberate and adopt measures, decisions, and resolutions regarding the management and use of Antarctica. This term also refers generally to the body comprising the Treaty Parties and associated organizations that participate in the annual meeting.

Antarctic Treaty Secretariat (ATS) – Established on September 1, 2004, the Secretariat of the Antarctic Treaty is responsible for fulfilling the following tasks under the direction of the ATCM

- supporting the annual ATCM and the meeting of the CEP;
- facilitating the exchange of information between the Parties, as required in the Treaty and the Environment Protocol;
- collecting, storing, archiving, and making available documents of the ATCM; and
- providing and disseminating information about the Antarctic Treaty system and Antarctic activities.

Austral – Of or pertaining to southern latitudes. The austral summer is the period, approximately November to February, when temperatures in Antarctica are highest and when most of the USAP activities occur.

Baseline condition(s) – Current, present, or existing state of a resource or area.

Bladder (fuel) – Portable, flexible, synthetic-material fuel tank designed for use at temporary or remote sites. Bladders are shaped like pillows and are laid on the ground, snow, ice, or an impermeable liner, and then filled with fuel.

Bulk storage tank – Large fuel storage tank used to resupply smaller day tanks or to supply large fuel users, such as power plants and aircraft.

Committee for Environmental Protection (CEP) - The Protocol on Environmental Protection to the Antarctic Treaty established the CEP as an expert advisory body to the Antarctic Treaty Consultative Meeting.

Comprehensive Environmental Evaluation (CEE) - As described in Annex I of the Protocol, a CEE is a document prepared to analyze an action that is likely to have more than a minor or transitory environmental impact.

Cumulative impacts – As defined in *Guidelines for Environmental Impact Assessment in Antarctica* (CEP 2016) "a cumulative impact is the combined impact of past, present, and reasonably foreseeable activities." Cumulative impacts may occur over time and space and can be additive or interactive and/or synergistic.

Day tank – Small tank that provides fuel for heating or other needs at an individual building. Day tanks are usually filled several times a week.

Decommissioning – Removal of a structure, vehicle, or piece of equipment from service or use. For the purposes of this CEE, decommissioning of a structure refers to its dismantling (i.e., demolition) and removal from any Antarctic location.

Fines – Rock and soil extracted from geological materials in ice-free areas. Materials are typically screened and stockpiled for use in construction and maintenance applications.

Hazardous materials – Substances that exhibit hazardous characteristics, as defined in 45 C.F.R. § 671.

Ice sheet – Continental masses of glacial ice sometimes covered with surface snow. The Antarctic continent is almost entirely covered by ice sheets moving slowly from areas of snow accumulation to the sea or to areas of ice ablation.

Initial Environmental Evaluation (IEE) – As described in Annex I of the Protocol, unless it has been determined that an activity will have less than a minor or transitory impact, or unless a CEE is being prepared in accordance with Article 3, an Initial Environmental Evaluation shall be prepared. If the IEE indicates that the proposed activity is likely to have no more than a minor or transitory effect on the environment, the activity may proceed with the provision that appropriate monitoring of the actual impact should take place.

International Geophysical Year (IGY) – Cooperative endeavor conducted from July 1, 1957 to December 31, 1958 by world scientists to improve the understanding of the Earth and its environment. Much field activity took place in Antarctica, where 12 nations established 60 research stations.

Jamesway – A prefabricated, insulated canvas building, semicircular in cross-section, with a wooden frame and floor.

Loading (wastewater) – The rate (mass per time) at which a wastewater constituent is discharged. The loading of a constituent is determined by multiplying its concentration in the wastewater (mass per volume) times the wastewater discharge flow rate (volume per time).

***Protocol on Environmental Protection to the Antarctic Treaty* (Protocol)** – The Protocol (ATS 1991) was adopted by the Antarctic Treaty Parties in 1991 to enhance protection of the Antarctic environment. The Protocol designated Antarctica as a natural reserve and set forth environmental protection principles to be applied to all human activities in Antarctica, including both governmental and non-governmental activities.

Remotely deployed equipment (RDE) – Equipment and instruments that are temporarily deployed in the field for research or operational purposes for periods of a few weeks to multiple operating seasons.

Retrograde – As used by the USAP, the transport of any items (e.g., wastes, used equipment, research samples) from Antarctica to the United States or other countries for processing or disposition (e.g., disposal, recycling, analysis).

Sanitary wastewater – For the purposes of this EIA, sanitary wastewater includes all liquid wastes entering sewage collection systems, including those from living quarters, galleys, laboratories, and shops. It does not include hazardous waste streams or industrial chemicals, which are collected separately and either recycled or disposed of in permitted facilities in the United States.

Secondary containment – Facilities (e.g., berms, double walls) that contain the contents of a fuel tank, pipeline, or other container that holds hazardous materials in case of rupture.

Smart grid (SG) technology – Generally refers to computer-based, remote-control sensors, automation, and other systems in a utility distribution infrastructure to monitor its operation, efficiency, maintenance requirements, and other characteristics.

Traverse – In the context of operations in Antarctica, the process of transporting cargo or equipment over snow-covered terrain using tracked vehicles and sleds.

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NSF. 1991a. IEE: Placement of steel fuel storage tanks at Marble Point. OPP93019.

NSF. 1991b. IEE: Black Island Telecommunications Facility upgrade. OPP93028.

NSF. 1992a. IEE: Demolition of building 56, Ecklund Biological Center, McMurdo Station. OPP93085.

NSF. 1992b. IEE: Construction of secondary containment around McMurdo Station's bulk fuel storage tanks. OPP93078.

NSF. 1994a. IEE: Management of long duration, heavy lift balloon flights in Antarctica. Unnumbered.

NSF. 1994b. IEE: Fuel storage upgrade at Marble Point, Antarctica. Unnumbered.

NSF. 1994c. IEE: Construction of a mobile runway facility to support air operations at Williams Field and the sea ice runway McMurdo Station, Antarctica. Unnumbered.

NSF. 1995a. IEE: Amendment 1: fuel storage upgrade at Marble Point, Antarctica. Unnumbered.

NSF. 1995b. IEE: Wastewater treatment plant, McMurdo Station, Antarctica. Unnumbered.

NSF. 1995c. IEE: Amendment 1: construction of a mobile runway facility to support air operations at Williams Field and the sea ice runway McMurdo Station, Antarctica. Unnumbered.

NSF. 1995d. IEE: Installation and maintenance procedures for the Antarctic automatic weather station program. PGAN9501.EAF.

NSF. 1995e. IEE: Continued use of explosives to support operations and scientific research in Antarctica. PGAN9601.

NSF. 1996. IEE: Placing a bulk used oil storage tank in the hazardous waste storage yard McMurdo Station, Antarctica. MCST9703.EAF.

NSF. 1997a. IEE: Improving the bulk fuel storage system at McMurdo Station, Antarctica. MCST9801.EAF.

NSF. 1997b. IEE: Consolidation of facilities in the hazardous waste yard McMurdo Station, Antarctica. MCST9704.EAF.

NSF. 1997c. IEE: Adoption of standard operating procedures for the renovation or decommissioning of United States Antarctic Program facilities. PGAN9701.EAF

NSF. 1997d. IEE: Adoption of standard operating procedures for placement, management, and removal of materials cached at field locations for USAP. PGFC9801.EAF.

NSF. 1997e. ROER: Black Island facility renovations. MCBI9800.R01.

NSF. 1999. IEE: Construction of a new science support center McMurdo Station, Antarctica. MCST0001.EAF.

NSF. 2000a. IEE: Helicopter fuel system upgrade. MCST0002.EAF.

NSF. 2000b. IEE: MTRS-2 antenna installation at T-Site, McMurdo Station, Antarctica. MCST0107.EAF.

NSF. 2000c. IEE: Construction of a replacement telecommunications facility (T Site). MCST0108.EAF.

NSF. 2000d. ROER: Installation of sloping v antenna at T-Site. MCST0100.R03.

NSF. 2000e. ROER: Conical monopole antenna installation (T-Site). MCST0100.R04.

NSF. 2001a. ROER: Removal and reinstallation of automatic weather stations in Antarctica. MCAN0200.RO3.

NSF. 2001b. ROER: Installation of satellite downlink at Black Island. MCBI0100.R01.

NSF. 2003. ROER: Gathering red fines from an area behind the ridgeline to the north east of McMurdo Station. MCST0400.R04.

NSF. 2004a. IEE: LDB facility replacement. MCWF0500.R01.

NSF. 2004b. IEE: Construction of replacement gasoline bulk storage tanks at McMurdo Station, Antarctica. MCST0402.IEE.

NSF. 2004c. IEE: Installation of a new modular fuel-pump building at Marble Point. MCMP0500.R01.

NSF. 2004d. IEE: Diesel engine generator set replacement for continued power generation and establishment of redundant power and water generation capacity at McMurdo Station, Antarctica. MCST0401.IEE.

NSF. 2004e. IEE: Gathering fines adjacent to Fortress Rocks for Maintenance and improvement to the former landfill and waste processing area, McMurdo Station, Antarctica. MCST0500.R02.

NSF. 2004f. CEE: Development and implementation of surface traverse capabilities in Antarctica. SPST0502.CEE.

NSF. 2004g. IEE: Continued use of explosives to support operations and scientific research in Antarctica. PGAN9601.AM1.

NSF. 2005a. IEE: Treatment of fuel-contaminated soil at McMurdo Station, Antarctica. MCST0501.IEE.

NSF. 2005b. IEE: Development and use of alternative overland traverse route system from McMurdo Station to Black Island, Antarctica. MCBI0601.IEE.

NSF. 2005c. IEE: Bandwidth improvement project - installation of communications shelters, antennas, and temporary milvan. MCBI0500.R01.

NSF. 2006a. IEE: Amendment no. 1: construction of replacement gasoline bulk storage tanks. MCST0402.AM1.

NSF. 2006b. IEE: Adoption of contingency plan for fuel offload over sea ice at McMurdo Station. MCST0601.IEE.

NSF. 2006c. IEE: Continued use of explosives to support operations and scientific research in Antarctica. PGAN9601.AM2.

NSF. 2007a. IEE: Conduct long duration balloon (LDB) flights in Antarctica. PGAN0801.IEE.

NSF. 2007b. IEE: Construction of five bulk fuel storage tanks. MCST0701.IEE.

NSF. 2007c. ROER: McMurdo Station helicopter fuel dispensing system upgrades. MCST0700.R04.

NSF. 2007d. IEE: Marble Point helicopter fuel dispensing system upgrades. MCMP0800.R01.

NSF. 2007e. ROER: Continued gathering of fines by McMurdo Station operations. MCST0800.R01.

NSF. 2007f. IEE: Construction and operation of earth station satellite receptors at McMurdo Station, Antarctica to support the NPOESS and EUMETSAT. MCST0702.IEE.

NSF. 2008a. IEE: Amendment no. 1: construction of five bulk fuel storage tanks. MCST0701.IEE.AM1.

NSF. 2008b. IEE: Development and implementation of surface traverse capabilities in Antarctica. SPST0502.CEE.AM1.

NSF. 2008c. IEE: Construct and operate new or modified USAP field camps. PGAN0901.IEE.

NSF. 2008d. ROER: Annual reporting of remotely deployed equipment. PGAN0900.R01.AM1.

NSF. 2008e. IEE: Amendment no. 1: construction and operation of earth station satellite receptors at McMurdo Station, Antarctica to support the NPOESS and EUMETSAT. MCST0702.IEE.AM1.

NSF. 2009a. IEE: Amendment no. 2: construction of replacement gasoline bulk storage tanks. MCST0402.AM2.

NSF. 2009b. IEE: Operate a single airfield facility at McMurdo Station, Antarctica. MCST1001.IEE.

NSF. 2010. IEE: Continued gathering of fines for McMurdo Station Operations. MCST0800 R01 AM1.

NSF. 2011a. IEE: Construction of five bulk fuel storage tanks at McMurdo Station, Antarctica. MCST0701.IEE.AM2.

NSF. 2011b. IEE: Collection of rock fines at McMurdo Station, Antarctica. MCST1201.IEE.

NSF. 2011c. IEE: Continuation of McMurdo Dry Valley LTER program (MCM4): increased connectivity in a polar desert resulting from climate warming. MCDV1201.IEE.

NSF. 2012. IEE: Construction of five bulk fuel storage tanks at McMurdo Station, Antarctica. MCST0701.IEE.AM3.

NSF. 2013a. ROER: Reestablishing the Marble Point fuel line and fueling project. MCDV1400 R04.

NSF. 2013b. IEE: Treatment of fuel-contaminated soil at McMurdo Station, Antarctica. MCST0501.IEE.AM1.

NSF. 2014a. IEE: Relocation of the long duration balloon (LDB) facility in Antarctica. PGAN0801.IEE.AM1.

NSF. 2014b. IEE: Adoption of standard operating procedures for the renovation or decommissioning of United States Antarctic Program facilities. PGAN9701.IEE.AM1.

NSF. 2014c. IEE: collection of rock fines (riprap) at McMurdo Station, Antarctica. MCST1201.IEE.AM1.

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NSF. 2015b. IEE: Treatment of fuel-contaminated soil at McMurdo Station, Antarctica. MCST0501.IEE.AM2.

NSF. 2015c. IEE: Construct alpha airfield facility at McMurdo Station, Antarctica. MCST1601.IEE.

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NSF. 2017. IEE: Establishing Phoenix Airfield town site and closing Pegasus Airfield at McMurdo Station, Antarctica. MCST1601.IEE.AM1.

NSF. 2018a. IEE: Construction, operation, and maintenance of a satellite communications antenna (Ross Island earth station) at McMurdo Station, Antarctica. MCST1801.IEE.

NSF. 2018b. IEE: Relocating Williams Field and cleaning up the current location at McMurdo Station, Antarctica. MCWF1801.IEE.

NSF. 2018c. IEE: Construction of a New Science Support Center McMurdo Station, Antarctica, Amendment No.1, Addition of Information Technology and Communications Primary Operations Facility and Associated Activities. MCST0001.EAF.AM1.

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14. Appendices

Appendix A: Public Scoping

A Notice of Intent was published in the *Federal Register* on August 24, 2016 to announce the beginning of the scoping process to solicit public comments and identify issues to be analyzed in the CEE (NSF 2016a). Public comments were accepted until October 15, 2016. One comment was received via email from a member of the public during the scoping period; issues raised in this comment were outside the scope of the CEE.

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Appendix B: Abbreviations, Acronyms, and Units of Measure

Units of Measure

≤	less than or equal to
%	percent
°C	degrees Celsius
°F	degrees Fahrenheit
cm	centimeter(s)
ft	foot (feet)
ft^2	square foot (feet)
gal	gallon(s)
hr	hour
in	inch(es)
kg	kilogram(s)
km	kilometer(s)
km/hr	kilometers per hour
km^2	square kilometer(s)
kW	kilowatt(s)
L	liter(s)
L/min	liters per min
lb	pound(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mi	mile(s)
mi^2	square mile(s)
min	minute
mph	miles per hour
yd^3	cubic yard(s)

General Abbreviations and Acronyms

ACA	Antarctic Conservation Act
AGE	aerospace ground equipment
AIMS	Antarctic Infrastructure Modernization for Science
ANDRILL	ANtarctic geological DRILLing Programme
ANZ	Antarctica New Zealand
ASC	Antarctic Support Contract
ASMA	Antarctic Specially Managed Area
ASPA	Antarctic Specially Protected Area
ATCM	Antarctic Treaty Consultative Meeting
ATS	Antarctic Treaty Secretariat
ATV	all-terrain vehicle(s)
BITF	Black Island Telecommunications Facility
BOD	biochemical oxygen demand
BRP	Blue Ribbon Panel
CEE	Comprehensive Environmental Evaluation
CEP	Committee for Environmental Protection
C.F.R.	Code of Federal Regulations
CHP	combined heat power
CO_2	carbon dioxide
$CO_{2\text{-}e}$	carbon dioxide equivalent(s)
COMNAP	Council of Managers of National Antarctic Programs
CRREL	Cold Regions Research and Engineering Lab
CTAM	Central Trans-Antarctic Mountains
DVDP	Dry Valley Drilling Project
EDA	Environmental Domains Analysis
e.g.	for example
EIA	environmental impact assessment
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
et al.	and others
GERG	Geochemical and Environmental Research Group
HF	high frequency
HSM	Historic Site and Monument
i.e.	that is
IBA	Important Bird Area
IEE	Initial Environmental Evaluation
IGY	International Geophysical Year
IT&C	Information Technology and Communications
JPSS	Joint Polar Satellite System
LDB	long-duration balloon
LTER	Long-Term Ecological Research
MDV	McMurdo Dry Valleys
MEC	Mechanical Equipment Center
NASA	National Aeronautics and Space Administration
NGO	Non Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OPP	Office of Polar Programs
PEMB	pre-engineered metal buildings
POF	primary operations facility
Protocol	Protocol on Environmental Protection to the Antarctic Treaty
RDE	remotely deployed equipment
RIES	Ross Island Earth Station
ROER	Record of Environmental Review
SATCOM	satellite communications
SCAR	Scientific Committee on Antarctic Research
SG	smart grid
SSC	Science Support Center
T-Site	HF Transmit Site
TSS	total suspended solids
USAP	United States Antarctic Program

U.S.C.	United States Code
VEOC	Vehicle Equipment Operations Center
VHF	very high frequency
VMF	Vehicle Maintenance Facility
WAIS	Western Antarctic Ice Sheet
WWTP	wastewater treatment plant

Appendix C: Supplemental Information

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Table C-1. EIAs for USAP Activities Representative of Programmatic Activities and Facility Construction, General Operations, and Selected Long-Term Research Efforts

Title	Document No.	Year Prepared	Location(s)[1]
Collection of Rock Fines at McMurdo Station, Antarctica	MCST1201.IEE	2011 2014 (Amendment No. 1)	McMurdo Station facilities zone
Construction and Operation of a Super Dual Auroral Radar Network (SuperDARN) Antenna Array at McMurdo Station, Antarctica	MCST1002.IEE	2009	McMurdo Station facilities zone
Construction of Five Bulk Fuel Storage Tanks at McMurdo Station, Antarctica	MCST0701.IEE	2007 2008 (Amendment No. 1) 2009 (Amendment No. 2) 2012 (Amendment No. 3)	McMurdo Station facilities zone
Treatment of Fuel-Contaminated Soil at McMurdo Station, Antarctica	MCST0501.IEE	2005 2013 (Amendment No. 1) 2015 (Amendment No. 2)	McMurdo Station facilities zone
Diesel Engine Generator Set Replacement for Continued Power Generation and Establishment of Redundant Power and Water Generation Capability at McMurdo Station, Antarctica	MCST0401.IEE	2004	McMurdo Station facilities zone
Construction of Replacement Gasoline Bulk Storage Tanks at McMurdo Station, Antarctica	MCST0402.IEE	2004	McMurdo Station facilities zone
T-Site: Construction of a Replacement Telecommunications Facility	MCST0108.EAF	2000	McMurdo Station facilities zone
Maintenance of Wastewater Outfall	MCST9800.R09	1998	McMurdo Station facilities zone
Improving the Bulk Fuel Storage System at McMurdo Station, Antarctica	MCST9801.EAF	1997	McMurdo Station facilities zone
Continuation of Food Waste Management at McMurdo Station, Antarctica	MCST9701.FON	1996	McMurdo Station facilities zone
Wastewater Treatment Plant, McMurdo Station, Antarctica	WWTP.IEE	1995	McMurdo Station facilities zone
Placement of a McMurdo Tracking and Data Relay Satellite (TDRS) Relay System (MTRS) in Antarctica	MCST9510.EAF	1995	McMurdo Station facilities zone
Installation of Reverse Osmosis Water Purification Unit at McMurdo Station	OPP93087	1992	McMurdo Station facilities zone
Proposed Replacement, Operation, and Decommissioning of Ice Wharves at McMurdo Station	OPP93064	1992	McMurdo Station facilities zone

Table C-1. EIAs for USAP Activities Representative of Programmatic Activities and Facility Construction, General Operations, and Selected Long-Term Research Efforts

Title	Document No.	Year Prepared	Location(s)[(1)]
Adoption of Contingency Plan for Fuel Offload Over Sea Ice at McMurdo Station	MCST0601.IEE	2006	McMurdo Station (McMurdo Sound)
Construct Alpha Airfield Facility at McMurdo Station, Antarctica	MCST1601.IEE	2015	McMurdo Station Area (Ross Ice Shelf)
Installation and Use of Waste Water Outfalls at the Long Duration Balloon (LDB) Facility	MCST1500.R02	2014	McMurdo Station Area (Ross Ice Shelf)
Operate a Single Airfield Facility at McMurdo Station, Antarctica	MCST1001.IEE	2009 2014 (Amendment No. 1)	McMurdo Station Area (Ross Ice Shelf)
Installation and Operation of an Infrasonic Array at Windless Bight near McMurdo Station, Antarctica	PGAN0106.EAF	2000	McMurdo Station Area (Ross Ice Shelf)
Continuation of McMurdo Dry Valley LTER Program (MCM4): Increased Connectivity in a Polar Desert Resulting from Climate Warming	MCDV1201.IEE	2011	Garwood, Miers, Taylor, and Wright Valley regions of the MDV
Conduct Typical Marine-based Research in Antarctica	PGAN1002.IEE	2010	Waters surrounding Antarctica (south of 60°S)
Conduct Rock, Soil, Ice, or Sediment Drilling, Coring, and Select Excavation Activities to Support USAP Scientific Research and Logistical Operations	PGAN1001.IEE	2009	Continent-wide
Construct and Operate New or Modified USAP Field Camps	PGAN0901.IEE	2008	Continent-wide
Annual Reporting of Remotely Deployed Equipment (RDE)	PGAN0900.R01	2008	Continent-wide
Conduct Long Duration Balloon (LDB) Flights in Antarctica	PGAN0801.IEE	2007 2014 (Amendment No. 1)	Continent-wide
Development and Implementation of Surface Traverse Capabilities in Antarctica	SPST0502.CEE	2004 2008 (Addendum No. 1)	Continent-wide
Continued Use of Assisted Take Off (ATO) Units in Antarctica	PGAN0109.EAF	2001	Continent-wide
Removal and Reinstallation of Automatic Weather Stations in Antarctica	MCAN0200.RO3	2001	Continent-wide
Adoption of Standard Operating procedures for Placement, Management, and Removal of Materials Cached at Field Locations for the USAP	PGFC9801.EAF	1997	Continent-wide

Table C-1. EIAs for USAP Activities Representative of Programmatic Activities and Facility Construction, General Operations, and Selected Long-Term Research Efforts

Title	Document No.	Year Prepared	Location(s)[(1)]
Adoption of Standard Operating Procedures for the Renovation or Decommissioning of United States Antarctic Program Facilities	PGAN9701.EAF	1997 2014 (Amendment No 1)	Continent-wide
Continued Use of Explosives to Support Operations and Scientific Research in Antarctica	PGAN9601	1995 2004 (Amendment No. 1) 2006 (Amendment No. 2)	Continent-wide
Management of Unreliable and Unsafe Explosives in Antarctica	PGAN9503.EAF	1995	Continent-wide
Installation and Maintenance Procedures for the Antarctic Automatic Weather Station Program	PGAN9501.EAF	1995	Continent-wide
Development of Blue-Ice and Compacted-Snow Runways in Support of The United States Antarctic Program	OPP93103	1993	Continent-wide
Final Supplemental Environmental Impact Statement for the United States Antarctic Program	OPP93033	1991	Continent-wide
Final Environmental Impact Statement for the United States Antarctic Program	(none)	1980	Continent-wide

(1) Generally, activities evaluated in programmatic EIAs are subject to additional environmental review if the proposed activity would vary substantially from that evaluated in the EIA and/or if the activity is proposed to occur in an ASMA, ASPA, or other area with specialized management requirements.

Table C-2. Fauna Occurring in the Vicinity of McMurdo Station

Phylum	Type	Common Name (Scientific Name)
Annelida	Polychaetes, bristle worms, featherduster worms, leeches	15 species
Arthropoda	Amphipods, isopods, shrimp, ostracods, krill, sea spiders	50 species
Brachiopoda	Brachiopods	Brachiopod *(Liothyrella uva antarctica)*
Chordata	Fish	Emerald notothen or Emerald rockcod *(Trematomus bernacchii)*
		Eelpout *(Lycodichthys dearborni)*
		Deepwater notothen or Scaly rockcod *(Trematomus loennbergii)*
		DeVries's snailfish (*Paraliparis devriesi)*
		Eaton's skate (*Bathyraja eatonii)*
		Naked dragonfish (*Gymnodraco acuticeps)*
		Bald notothen or Bald rockcod (*Pagothenia borchgrevinki)*
		Striped notothen, Striped rockcod, or Green rockcod (*Trematomus hansoni)*
		Sharp-spined notothen (*Trematomus pennellii)*
		Antarctic silverfish (*Pleuragramma antarcticum*)
		Antarctic toothfish (*Dissostichus mawsoni)*
	Penguins	Emperor penguin (*Aptenodytes forsteri)*
		Adélie penguin (*Pygoscelis adeliae)*
	Seabirds	Antarctic petrel *(Thalassoica antarctica)*
		Snow petrel *(Pagodroma nivea)*
		South polar skua *(Stercorarius maccormicki)*
		Southern giant petrel *(Macronectes giganteus)*
		Southern fulmar *(Fulmaris glacialoides)*
	Seals	Crabeater seal (*Lobodon carcinophaga)*
		Leopard seal (*Hydrurga leptonyx*)
		Weddell seal (*Leptonychotes weddellii)*
	Whales	Antarctic minke whale (*Balaenoptera bonaerensis)*
		Killer whale or Orca whale (*Orcinus orca)*
Cnidaria	Sea anemones, soft coral, hydroids, jellyfish	26 species
Ctenophora	Comb jellies, ctenophores	3 species
Echinodermata	Seastars, urchins, brittle stars, sea cucumbers, crinoids	32 species
Ectoprocta	Bryozoans	8 species
Mollusca	Gastropods, bivalves, nudibranchs, octopus	22 species
Nemertea	Proboscis worms	Proboscis worm *(Parborlasia corrugatus)*
Porifera	Sponges	33 species

Sources: *Underwater Field Guide to Ross Island & McMurdo Sound, Antarctica* (Brueggeman 1998); *The Marine Ecology of Birds in the Ross Sea, Antarctica* (Ainley et al. 1984)

Table C-3a. Projected Annual Air Emissions from Power-Generation Sources at McMurdo Station (Existing Conditions)

Category	Substance	Amount (kg)[1]
Characteristic Air Pollutants	Sulfur oxides[2]	13,745
	Nitrogen oxides	461,963
	Carbon monoxide	85,737
	Particulate matter	10,720
	Carbon dioxide	9,672,000
	Aldehydes	3318
	Total organic carbon	17,062
Volatile Organic Compounds	Benzene	44
	Xylenes	14
	Toluene	19
	Propylene	122
	Formaldehyde	56
Semi-Volatile Organic Compounds	Acetaldehyde	36
	Naphthalene	4.0
	Anthracene	0.09
	Benz(a)anthracene	0.08
	Chrysene	0.02
	Fluoranthene	0.36
	Fluorene	1.4
	Phenanthrene	1.4
	Pyrene	0.23

(1) Annual air emissions from power generation sources are based on 3,246,400 L (857,608 gal) of fuel used for power generation at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuel.

Table C-3b. Projected Annual Air Emissions from Heating- and Water-Production Sources at McMurdo Station (Existing Conditions)

Category	Substance	Amount (kg)[1]
Characteristic Air Pollutants		
	Sulfur oxides[2]	2701
	Nitrogen oxides	4689
	Carbon monoxide	1172
	Particulate matter	469
	Carbon dioxide	5,192,075
	Total organic carbon	130
	Non-methane total organic carbon	80
	Methane	51
	Nitrous oxide	26
	Polycyclic organic matter	0.8
Metals	Arsenic	0.12
	Antimony	0.00
	Beryllium	0.07
	Cadmium	0.31
	Chromium	1.64
	Cobalt	0.00
	Mercury	0.09
	Manganese	0.40
	Nickel	0.51
	Lead	0.25

Category	Substance	Amount (kg)[1]
Volatile Organic Compounds	Benzene	0.05
	Ethylbenzene	0.01
	Xylenes	0.03
	Toluene	1.45
	1,1,1-trichloroethane	0.06
	Formaldehyde	7.74
Semi-Volatile Organic Compounds	Naphthalene	0.2649
	Acenaphthene	0.0049
	Acenaphthylene	0.0001
	Anthracene	0.0003
	Benz(a)anthracene	0.0009
	Benzo(b,k)fluoranthene	0.0003
	Benzo(g,h,i)perylene	0.0005
	Chrysene	0.0006
	Dibenzo(a,h)anthracene	0.0004
	Dibutylphthalate	0.0000
	Fluoranthene	0.001
	Fluorene	0.001
	Indo(1,2,3-cd)pyrene	0.0005
	Octochloro-dibenzo-dioxin	<0.00001
	Phenanthrene	0.0025
	Phenol	0.0000
	Pyrene	0.0010

(1) Annual air emissions from heating and water production sources are based on 1,955,000 L (516,456 gal) of fuel used for heating and water production at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-3c. Projected Annual Air Emissions from Fuel-Powered Equipment at McMurdo Station and Outlying Facilities (Existing Conditions)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants	Sulfur oxides(2)	5441
	Nitrogen oxides	65,681
	Carbon monoxide	176,950
	Exhaust hydrocarbons	10,638
	Particulate matter	5303
	Carbon dioxide	18,398
	Aldehydes	1312
	Total organic carbon	0.7
	Methane	0.29
	Nitrous oxide	1.3

(1) 1,735,310 L (458,420 gal) of fuel used in equipment, including diesel-powered, gasoline-powered, and propane-powered equipment.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-3d. Projected Annual Air Emissions from Aircraft (Existing Conditions)

Type of Aircraft	Projected Flight Hours (per year)	Fuel Combustion By-products from Normal Operations (kg)				
		Carbon Monoxide	Exhaust Hydrocarbons	Nitrogen Oxides	Particulates	Sulfur Oxides
LC-130/ C-130	2,613	43,040	18,335	69,449	18,893	8,751
C-17	250	4,282	355	120,105	5,806	3,168
B-757	15	218	18	7,146	348	190
A-319	50	856	71	24,021	1,161	634
Twin Otter/Basler	1,632	8,487	3,884	4,209	8,314	578
Helicopters (all)	1,500	8,660	2,775	8,500	1,250	1,200
	Totals	**65,543**	**25,438**	**233,430**	**35,772**	**14,521**

Table C-4a. Projected Annual Air Emissions from Power-Generation Sources at McMurdo Station (Maximum during Modernization Activity)

Category	Substance	Amount (kg)[1]
Characteristic Air Pollutants	Sulfur oxides[2]	15,747
	Nitrogen oxides	529,275
	Carbon monoxide	98,230
	Particulate matter	12,282
	Carbon dioxide	11,081,298
	Aldehydes	3,801
	Total organic carbon	19,549
Volatile Organic Compounds	Benzene	51
	Xylenes	15
	Toluene	22
	Propylene	140
	Formaldehyde	64
Semi-Volatile Organic Compounds	Acetaldehyde	42
	Naphthalene	4.6
	Anthracene	0.10
	Benz(a)anthracene	0.09
	Chrysene	0.02
	Fluoranthene	0.41
	Fluorene	1.6
	Phenanthrene	1.6
	Pyrene	0.26

(1) Annual air emissions from power generation sources are based on 3,719,430 L (982,569 gal) of fuel used for power generation at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuel.

Table C-4b. Projected Annual Air Emissions from Heating- and Water-Production Sources at McMurdo Station (Maximum during Modernization Activity)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants		
	Sulfur oxides(2)	3426
	Nitrogen oxides	5948
	Carbon monoxide	1487
	Particulate matter	595
	Carbon dioxide	6,585,357
	Total organic carbon	165
	Non-methane total organic carbon	101
	Methane	64
	Nitrous oxide	33
	Polycyclic organic matter	1.0
Metals	Arsenic	0.15
	Antimony	0.00
	Beryllium	0.09
	Cadmium	0.40
	Chromium	2.08
	Cobalt	0.00
	Mercury	0.11
	Manganese	0.51
	Nickel	0.65
	Lead	0.32

Category	Substance	Amount (kg)(1)
Volatile Organic Compounds	Benzene	0.06
	Ethylbenzene	0.02
	Xylenes	0.03
	Toluene	1.84
	1,1,1-trichloroethane	0.07
	Formaldehyde	9.81
Semi-Volatile Organic Compounds	Naphthalene	0.3360
	Acenaphthene	0.0063
	Acenaphthylene	0.0001
	Anthracene	0.0004
	Benz(a)anthracene	0.0012
	Benzo(b,k)fluoranthene	0.0004
	Benzo(g,h,i)perylene	0.0007
	Chrysene	0.0007
	Dibenzo(a,h)anthracene	0.0005
	Dibutylphthalate	0.0000
	Fluoranthene	0.0014
	Fluorene	0.0013
	Indo(1,2,3-cd)pyrene	0.0006
	Octochloro-dibenzo-dioxin	<0.0001
	Phenanthrene	0.0031
	Phenol	0.0000
	Pyrene	0.0013

(1) Annual air emissions from heating and water production sources are based on 2,479,620 L (655,046 gal) of fuel used for heating and water production at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-4c. Projected Annual Air Emissions from Fuel-Powered Equipment at McMurdo Station and Outlying Facilities (Maximum during Modernization Activity)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants	Sulfur oxides(2)	6112
	Nitrogen oxides	73,620
	Carbon monoxide	180,261
	Exhaust hydrocarbons	11,365
	Particulate matter	5953
	Carbon dioxide	18,398
	Aldehydes	1458
	Total organic carbon	0.7
	Methane	0.29
	Nitrous oxide	1.3

(1) 1,915,090 L (505,913 gal) of fuel used in equipment, including diesel-powered, gasoline-powered, and propane-powered equipment.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-4d. Projected Annual Air Emissions from Aircraft (Maximum during Modernization Activity)

Type of Aircraft	Projected Flight Hours (per year)	Fuel Combustion By-products from Normal Operations (kg)				
		Carbon Monoxide	Exhaust Hydrocarbons	Nitrogen Oxides	Particulates	Sulfur Oxides
LC-130/ C-130	2,613	43,040	18,335	69,449	18,893	8,751
C-17	250	4,282	355	120,105	5,806	3,168
B-757	15	218	18	7,146	348	190
A-319	50	856	71	24,021	1,161	634
Twin Otter/Basler	1,632	8,487	3,884	4,209	8,314	578
Helicopters (all)	1,500	8,660	2,775	8,500	1,250	1,200
	Totals	**65,543**	**25,438**	**233,430**	**35,772**	**14,521**

Table C-5a. Projected Annual Air Emissions from Power-Generation Sources at McMurdo Station (Average during Modernization Activity)

Category	Substance	Amount (kg)[1]
Characteristic Air Pollutants	Sulfur oxides[2]	12,426
	Nitrogen oxides	417,655
	Carbon monoxide	77,514
	Particulate matter	9691
	Carbon dioxide	8,744,347
	Aldehydes	2999
	Total organic carbon	15,426
Volatile Organic Compounds	Benzene	40
	Xylenes	12
	Toluene	18
	Propylene	111
	Formaldehyde	51
Semi-Volatile Organic Compounds	Acetaldehyde	33
	Naphthalene	3.6
	Anthracene	0.08
	Benz(a)anthracene	0.07
	Chrysene	0.02
	Fluoranthene	0.33
	Fluorene	1.3
	Phenanthrene	1.3
	Pyrene	0.20

(1) Annual air emissions from power generation sources are based on 2,935,034 L (775,353 gal) of fuel used for power generation at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuel.

Table C-5b. Projected Annual Air Emissions from Heating- and Water-Production Sources at McMurdo Station (Average during Modernization Activity)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants		
	Sulfur oxides(2)	2703
	Nitrogen oxides	4693
	Carbon monoxide	1173
	Particulate matter	469
	Carbon dioxide	5,196,560
	Total organic carbon	130
	Non-methane total organic carbon	80
	Methane	51
	Nitrous oxide	26
	Polycyclic organic matter	0.8
Metals	Arsenic	0.12
	Antimony	0.00
	Beryllium	0.07
	Cadmium	0.31
	Chromium	1.64
	Cobalt	0.00
	Mercury	0.09
	Manganese	0.40
	Nickel	0.51
	Lead	0.25
Volatile Organic Compounds	Benzene	0.05
	Ethylbenzene	0.01
	Xylenes	0.03
	Toluene	1.45
	1,1,1-trichloroethane	0.06
	Formaldehyde	7.74
Semi-Volatile Organic Compounds	Naphthalene	0.2652
	Acenaphthene	0.0050
	Acenaphthylene	0.0001
	Anthracene	0.0003
	Benz(a)anthracene	0.0009
	Benzo(b,k)fluoranthene	0.0003
	Benzo(g,h,i)perylene	0.0005
	Chrysene	0.0006
	Dibenzo(a,h)anthracene	0.0004
	Dibutylphthalate	0.0000
	Fluoranthene	0.0011
	Fluorene	0.0010
	Indo(1,2,3-cd)pyrene	0.0005
	Octochloro-dibenzo-dioxin	0.000001
	Phenanthrene	0.0025
	Phenol	0.0000
	Pyrene	0.0010

(1) Annual air emissions from heating and water production sources are based on 1,956,689 L (516,902 gal) of fuel used for heating and water production at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-5c. Projected Annual Air Emissions from Fuel-Powered Equipment at McMurdo Station and Outlying Facilities (Average during Modernization Activity)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants	Sulfur oxides(2)	5663
	Nitrogen oxides	68,304
	Carbon monoxide	178,044
	Exhaust hydrocarbons	10,878
	Particulate matter	5518
	Carbon dioxide	18,398
	Aldehydes	1360
	Total organic carbon	0.7
	Methane	0.29
	Nitrous oxide	1.3

(1) 1,896,404 L (500,976 gal) of fuel used in equipment including diesel-powered, gasoline-powered, and propane-powered equipment.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-5d. Projected Annual Air Emissions from Aircraft (Average during Modernization Activity)

Type of Aircraft	Projected Flight Hours (per year)	Fuel Combustion By-products from Normal Operations (kg)				
		Carbon Monoxide	Exhaust Hydrocarbons	Nitrogen Oxides	Particulates	Sulfur Oxides
LC-130/ C-130	2,613	43,040	18,335	69,449	18,893	8,751
C-17	250	4,282	355	120,105	5,806	3,168
B-757	15	218	18	7,146	348	190
A-319	50	856	71	24,021	1,161	634
Twin Otter/Basler	1,632	8,487	3,884	4,209	8,314	578
Helicopters (all)	1,500	8,660	2,775	8,500	1,250	1,200
	Totals	**65,543**	**25,438**	**233,430**	**35,772**	**14,521**

Table C-6a. Projected Annual Air Emissions from Power-Generation Sources at McMurdo Station (Post-Modernization)

Category	Substance	Amount (kg)[(1)]
Characteristic Air Pollutants	Sulfur oxides[(2)]	8721
	Nitrogen oxides	293,103
	Carbon monoxide	54,398
	Particulate matter	6801
	Carbon dioxide	6,136,628
	Aldehydes	2105
	Total organic carbon	10,826
Volatile Organic Compounds	Benzene	28
	Xylenes	9
	Toluene	12
	Propylene	78
	Formaldehyde	35
Semi-Volatile Organic Compounds	Acetaldehyde	23
	Naphthalene	2.6
	Anthracene	0.06
	Benz(a)anthracene	0.05
	Chrysene	0.01
	Fluoranthene	0.23
	Fluorene	0.09
	Phenanthrene	0.09
	Pyrene	0.14

(1) Annual air emissions from power generation sources are based on 2,059,755 L (544,129 gal) of fuel used for power generation at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuel.

Table C-6b. Projected Annual Air Emissions from Heating- and Water-Production Sources at McMurdo Station (Post-Modernization)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants	Sulfur oxides(2)	1,897
	Nitrogen oxides	3,294
	Carbon monoxide	823
	Particulate matter	329
	Carbon dioxide	3,646,855
	Total organic carbon	92
	Non-methane total organic carbon	56
	Methane	36
	Nitrous oxide	18
	Polycyclic organic matter	0.5
Metals	Arsenic	0.08
	Antimony	0.000
	Beryllium	0.05
	Cadmium	0.22
	Chromium	1.15
	Cobalt	0.00
	Mercury	0.06
	Manganese	0.28
	Nickel	0.36
	Lead	0.18

Category	Substance	Amount (kg)(1)
Volatile Organic Compounds	Benzene	0.03
	Ethylbenzene	0.01
	Xylenes	0.02
	Toluene	1.02
	1,1,1-trichloroethane	0.04
	Formaldehyde	5.43
Semi-Volatile Organic Compounds	Naphthalene	0.1861
	Acenaphthene	0.0035
	Acenaphthylene	0.0000
	Anthracene	0.0002
	Benz(a)anthracene	0.0007
	Benzo(b,k)fluoranthene	0.0002
	Benzo(g,h,i)perylene	0.0004
	Chrysene	0.0004
	Dibenzo(a,h)anthracene	0.0003
	Dibutylphthalate	0.0000
	Fluoranthene	0.0008
	Fluorene	0.0007
	Indo(1,2,3-cd)pyrene	0.0004
	Octochloro-dibenzo-dioxin	<0.0001
	Phenanthrene	0.0017
	Phenol	0.0000
	Pyrene	0.0007

(1) Annual air emissions from heating and water production sources are based on 1,373,170 L (362,753 gal) of fuel used for heating and water production at McMurdo Station.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-6c. Projected Annual Air Emissions from Fuel-Powered Equipment at McMurdo Station and Outlying Facilities (Post-Modernization)

Category	Substance	Amount (kg)(1)
Characteristic Air Pollutants	Sulfur oxides(2)	4,663
	Nitrogen oxides	56,469
	Carbon monoxide	173,107
	Exhaust hydrocarbons	9,794
	Particulate matter	4,550
	Carbon dioxide	18,398
	Aldehydes	1,142
	Total organic carbon	0.7
	Methane	0.29
	Nitrous oxide	1.3

(1) 1,526,490 L (403,255 gal) of fuel used in equipment including diesel-powered, gasoline-powered, and propane-powered equipment.

(2) Sulfur content of fuel may vary each year by fuel type (≤ 0.2%); emission factors and related estimates may not account for the use of lower sulfur fuels.

Table C-6d. Projected Annual Air Emissions from Aircraft (Post-Modernization)

Type of Aircraft	Projected Flight Hours (per year)	Fuel Combustion By-products from Normal Operations (kg)				
		Carbon Monoxide	Exhaust Hydrocarbons	Nitrogen Oxides	Particulates	Sulfur Oxides
LC-130/ C-130	2,613	43,040	18,335	69,449	18,893	8,751
C-17	250	4,282	355	120,105	5,806	3,168
B-757	15	218	18	7,146	348	190
A-319	50	856	71	24,021	1,161	634
Twin Otter/Basler	1,632	8,487	3,884	4,209	8,314	578
Helicopters (all)	1,500	8,660	2,775	8,500	1,250	1,200
	Totals	**65,543**	**25,438**	**233,430**	**35,772**	**14,521**