

Mapping the McMurdo Station sewage plume

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We investigated the spatial distribution and movement of the sewage plume from McMurdo Station, Antarctica. We also examined ocean currents to determine their effect on the movement of the plume. Samples of seawater were obtained and analyzed for coliform bacteria, high densities of which were found along the circa-1-kilometer shoreline of McMurdo Station and the plume extended 200 - 300 meters seaward. Relocating the outfall from a surface configuration to the subsurface had little influence on the distribution of the plume, which sometimes reached the seawater intake station 400 meters to the south. Ocean current measurements in the study area confirmed that although the prevailing advection was to the north and away from the intake area, episodic reversals of flow at some current-meter stations coincided with pulses of sewage that moved into the intake.

The spatial distribution of the McMurdo Station sewage plume was determined by sampling the water column for coliform densities. Samples were collected within the plume and at pristine control locations, miles away from the sewage plume, during three different periods. Coliform numbers were determined using membrane filtration techniques. All of the methods used are widely accepted and are described in the American Public Health Association 1989. Current Patterns were also determined in the study area using InterOcean S4 current meters. These highly sensitive electronic meters were able to detect currents as weak as 0.1 centimeters per second.

The sample periods coincided with three different configurations of the McMurdo Station sewage outfall. During the initial sampling period (17 to 28 October 1991), the outfall was located fifty feet from the shore and submerged in seventeen feet of water during low tide. At that time, 23 sample sites as well as the seawater intake were tested. Water samples were collected just below the ice and at the bottom of the water column. During the second sampling period, 20 to 29 November 1991, the outfall was relocated to the surface, as it had been during the 1990-1991 season. This arrangement was needed to allow the addition of twenty feet of pipe to the subsurface outfall. Samples were collected from 17 sites and the seawater intake. The final sampling period (16 to 18 December 1991) occurred after the outfall pipe had been extended an additional twenty feet, with the discharge end of the pipe in thirty-eight feet of water during low tide. Samples were collected at 18 locations as well as the seawater intake. The information in figure 1 demonstrates that the sewage plume occupied an area that encompassed the entire

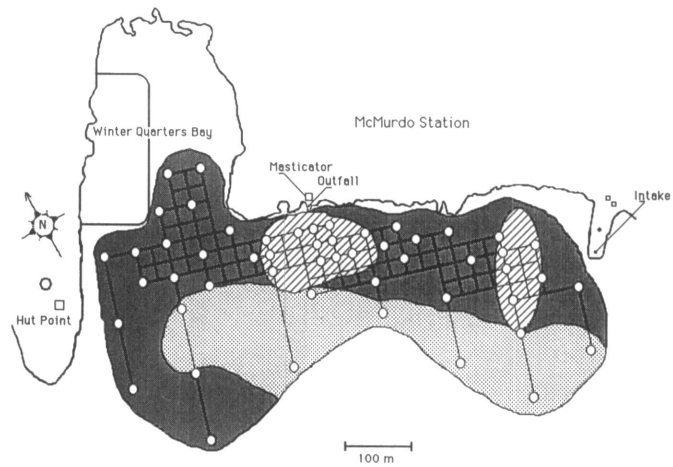


Figure 1. Representative map of coliform bacterial densities near McMurdo Station, Antarctica. The sampling grid is represented by lines overlying the sewage plume, and sampling locations are shown as circles on the grid. Coliform densities are indicated as areas that are stippled (<math>< 100/100</math> milliliters), shaded ($100-1,000/100$ milliliters), and crosshatched ($> 1,000/100$ milliliters).

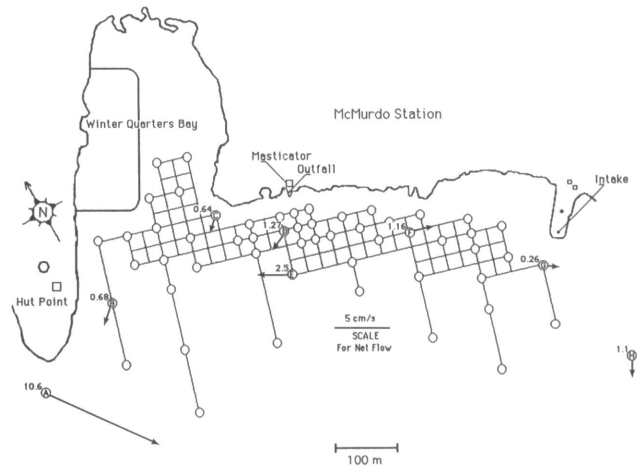


Figure 2. Map of the McMurdo Station vicinity showing the location of current-meter measurement stations. Arrows indicate the direction and magnitude of the net motion of the currents. Numbers indicate the current speed (in centimeters per second). A 5-centimeter-per-second bar is shown.

region from the intake jetty to Hut Point and extended at least 200 to 300 meters seaward, with some localized areas of higher sewage pollution. Samples taken from most of the stations indicated that the sewage was relatively well mixed (vertically) in the water column. On all occasions, the coliforms were detected in the desalination intake water. Their numbers ranged from a high of 523 per 100 to a low of 7 per 100, with an average count over the entire sample period of 187 coliforms per 100 milliliters. The large fluctuations in coliform numbers isolated from the intake station probably resulted from occasional current reversals, discussed below, rather than the outfall configuration. These periodic southern currents likely carried parcels of sewage toward the source-water intake. Repeated sampling at other locations also demonstrated the periodic movement of more concentrated pulses of sewage within the study area.

During October to December 1991, currents were measured at eight locations near the shoreline adjacent to McMurdo Station in

conjunction with the collection and measurement of coliform bacteria presumably released from the McMurdo Station wastewater outfall. Measurements continued for periods of 9 to 75 days. Preliminary analyses indicate several features of currents in the near-shore environment at McMurdo Station, including periodic flow patterns related to daily tidal changes, net transport, and episodic flow reversals in some areas. These features have important implications for the advection of the sewage plume from the McMurdo Station sewage outfall.

The general patterns of advection are shown in figure 2, which also shows station locations and a current vector that is indicative of the direction and magnitude of each net flow. This vector indicates the average direction and rate of the flow at each station during the measurement period but does not indicate any variation in flow, although at some stations, the variation was considerable. This flow pattern, which involves a strong southward flow near Hut Point and a small counterclockwise gyre in Winter Quarters Bay reaching at least as far south as the outfall station, is probably typical, as documented in other studies (e.g., Raytheon report circa 1983). Near the sea-ice transition (station F) the net flow was slow and toward the southeast, along the coast. This station may be southeast of the gyre mentioned above,

or advection may be related to its shallow depth. The net flow near the jetty was very sluggish, with somewhat higher speeds toward the south at station H.

The most important implication of this preliminary analysis of the data on advection in the vicinity of the outfall is that although the flow generally carries the sewage plume offshore and toward the west (away from the intake area), there are episodes of current reversal when the plume may be advected toward the intake pipe. We plan to undertake continuing studies to consolidate our understanding of the distribution and movement of sewage from McMurdo Station in the antarctic marine environment.

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References

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The *Bahia Paraiso* spill in Arthur Harbor, Anvers Island

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Enroute to resupply an Argentine antarctic base, the *Bahia Paraiso* ran aground on 28 January 1989, approximately 2 kilometers from Palmer Station, an U.S. antarctic research station. The *Bahia Paraiso* had just completed a sight-seeing visit to the station and was exiting Arthur Harbor when the accident occurred. The vessel contained a cargo of diesel fuel arctic (DFA), jet fuel, gasoline, and compressed gas cylinders totaling more than 250,000 gallons. A 30-foot tear in the ship's hull began to discharge petroleum into the waters of the surrounding bays almost immediately. Within 4 days of the accident 100 square kilometers of sea surface was covered by an oil slick and an estimated 600,000 liters of diesel fuel arctic (DFA) had been released.

The first evidence of ecological damage was observed in the intertidal zone. Invertebrate mortality, mostly dead and moribund limpets, was observed as early as 1 February, with thousands of dead individuals being observed by 4 February (Kennicutt et al. 1990). Comparative qualitative evidence suggested as much as 50 percent of the littoral population perished within a 2 kilometer radius of the wreck. Limpet mortality was heaviest in coves that retained oiled waters or were persistently replenished with oil due to the prevailing winds (Stockton, personal communica-

tion.). Well-drained intertidal pools more distant from the spill were less affected.

The earliest evidence of lethal exposure of sea birds was noted on 1 February when dead, oiled Adélie penguins and blue-eyed shags were found in Biscoe Bay adjacent to Palmer Station (Fraser personal communication). The mortality rate during the spill was less than 300 individuals over a 3-week period, with 89 percent being penguins and shags. The actual rate may have been higher due to an underestimate of mortality caused by the severe weather conditions, the efficiency of scavengers and predators, and the abandonment of breeding colonies. A breeding failure—caused by natural factors—among shags and south polar skuas coincided with the spill.

In response to the grounding of the *Bahia Paraiso* a series of intertidal, subtidal, and bay sampling sites were established to determine the fate and effect of the released petroleum (figure). Tissue, sediment, and water samples were collected over a 6-week period after the spill and standard stations were established for reoccupation in subsequent years. Hydrocarbon analyses confirmed that macroalgae, limpets, and beaches were repeatedly stained with diesel fuel and the greatest contamination was in intertidal areas (Kennicutt et al. 1991a and b). Intertidal limpets were "oiled" over a 6- to 7-week period. Two weeks after the first spillage PAH contamination was reduced by a factor of three to five. After 6 to 7 weeks contamination was nearly an order of magnitude lower than during the most intense "oiling" (Kennicutt et al. 1991a). Sediments and cobble beaches in the intertidal were contaminated over a period of several weeks and took anywhere from days to weeks to be cleansed.

The diesel fuel rapidly evaporated, was diluted with seawater, and much of the residue was flushed from the immediate area by wave and current action. Several factors contributed to limiting the impact of the spill including the volatility of the released product, the relatively small volume of material released, the