ARCTIC
VOL. 57, NO. 4 (DECEMBER 2004) P. 336–346

An Arctic Disaster and its Policy Implications

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(*Received 21 October 2002; accepted in revised form 10 March 2003*)

ABSTRACT. The purpose of the research reported here is to help the community in Barrow, Alaska, clarify its vulnerability to extreme weather events, and devise better-informed policies for reducing that vulnerability and adapting to climate variability and change. We examine the worst disaster on record there—a storm that struck on 3 October 1963—from different disciplinary perspectives and in the context of other severe storms. The major policy responses to date have been a beach nourishment program, a feasibility study of additional means of erosion control, and an emergency management plan. Additional possible responses have been identified in the community's cumulative experience of these storms, but have not yet been fully explored or implemented. Meanwhile, given inherent uncertainties, it is clear that sound policies will allow for corrective action if and when expectations based on the best available knowledge and information turn out to be mistaken. It is also clear that the people of Barrow are in the best position to understand the evolving situation and to decide what to do about it.

Key words: policy, disaster, extreme events, adaptation, climate change, Barrow, North Slope

RÉSUMÉ. Les travaux de recherche que l'on présente ici ont pour but d'aider la collectivité de Barrow (Alaska) à définir son degré de vulnérabilité à des conditions climatiques extrêmes, et à créer des politiques plus éclairées qui réduiraient cette vulnérabilité et favoriseraient l'adaptation à la variabilité et au changement climatiques. On examine le pire désastre jamais enregistré à cet endroit, soit une tempête qui fit rage le 3 octobre 1963, et ce, sous l'angle de différentes disciplines et dans le contexte d'autres grandes tempêtes. Jusqu'à présent, les politiques majeures d'intervention se sont résumées à un programme de recharge de plage, à une étude de faisabilité portant sur des mesures supplémentaires de lutte contre l'érosion et à un plan de gestion des situations d'urgence. L'expérience cumulative de la collectivité relative à ces tempêtes a permis de dégager d'autres interventions possibles, sans qu'elles aient toutefois été explorées à fond ou concrétisées. Entre-temps, vu les incertitudes inhérentes à ce genre de choses, il est évident que des politiques bien pensées permettront l'application de mesures correctives si et quand les prédictions fondées sur les toutes dernières connaissances et informations disponibles s'avèrent erronées. Il est en outre évident que les habitants de Barrow sont les mieux placés pour comprendre comment la situation évolue et pour décider des mesures à prendre.

Mots clés: politique, désastre, événement météorologique extrême, adaptation, changement climatique, Barrow, versant Nord

Traduit pour la revue *Arctic* par Nésida Loyer.

INTRODUCTION

On Thursday, 3 October 1963, an intense storm struck Barrow, Alaska, with little warning, causing more damage there than any other storm in historical records or living memory. The storm was an Arctic disaster, but it is also an opportunity for research to help the community in Barrow clarify its vulnerability to future storms and devise policies better informed by the community's own experience and the scientific knowledge available. In particular, this storm, in the context of other storms, provides a basis for projecting where and how life and limb might be threatened, property damaged, and the coast eroded and flooded by extreme weather events in the future. The community might factor such impact information into plans for reducing its vulnerability and for adapting to climate variability and change. This article reports results from ongoing research to clarify the policy implications of the 1963 storm in the larger context of Barrow's past and future.

This research is part of a project to integrate scientific knowledge from a variety of disciplines with local knowledge and to make that knowledge useful to people in Barrow and on the North Slope. For scientists with similar aspirations, this article may be useful as an example of research on the human dimensions of the Arctic, including human responses to climate variability and change. The approach taken here is based on the policy sciences (Lasswell, 1971) and draws upon natural hazards and disaster research over the last three decades (Mileti, 1999; Tierney et al., 2001).

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THE DISASTER

The 1963 storm was "unique in its violence and consequences" (Schafer, 1966:374). The low-pressure system (or depression) that produced the strong winds, erosion, and flooding in Barrow originated along the Arctic front over Siberia, around 145.6˚E, late on 1 October 1963. Over the next 24 hours, it traversed Siberia to the coast of the East Siberian Sea and continued northward on a track typical for such systems. However, shortly after 9:00 p.m. (all times Alaska Standard Time) on 2 October, the storm turned eastward and commenced a rapid deepening, reaching an estimated central low pressure of 976 millibars at 11:00 a.m. on 3 October, while located in the Beaufort Sea north of Barrow (Schafer, 1966). At this time, the winds had already shifted from southerly to westerly and were reaching 40 mph, with gusts up to 60 mph recorded at Barrow (Schafer, 1966). The depression continued to intensify as it traveled eastward, and the winds at Barrow turned west-northwesterly. The strongest winds at Barrow were reported between 1:00 and 3:00 p.m., with gusts possibly as high as 75 or 80 mph (Rock, 1963; Hume and Schalk, 1967). The highest official observation from the National Weather Service was 55 mph, for wind sustained for one minute. These extreme winds were reinforced by a strong Aleutian high to the south with a central pressure of 1030 millibars. Between 3:00 and 4:00 p.m., wind strength at Barrow started to diminish, but the low-pressure system continued eastward and may have reached its peak intensity in the Canadian Archipelago early on 4 October. (Reports differ on the later stages of the system.) As the cold sector of the depression passed over Barrow, it produced a blizzard over the next few days. Unofficially, the storm probably remains the most severe in Barrow's records and in the memories of residents. Guy Okakok (1963), then the *Tundra Times* correspondent in Barrow, wrote: "I am 60 years old now…and I have never seen the winds as strong as we had that day on October 3. High winds and high water everywhere."

These winds caused a storm surge (or rise in sea level) and extensive wave action. The fetch, or open water to the point where the sea was 50% covered by ice, was around 350 miles—extending about 150 miles farther north than the average for this time of year (although variability across years is very high in this region). The sea level started to rise at around 5:00 a.m. on 3 October, and the surge reached almost 10 feet (Schafer, 1966) sometime between 3:00 and 4:00 that afternoon. The storm surge may have been as high as 12 feet (Hume and Schalk, 1967). The unusual height of the surge was due primarily to the long duration of the strong northwesterly winds, but the rapid movement of the low-pressure system also contributed (Kowalik, 1984). As it traversed the Chukchi Sea, the system traveled at an average speed of around 44 mph, which is close to the speed of the surge itself. Hence there could have been a resonance effect, in which the system and the surge reinforced each other. Even a 40% ice cover may have had only minimal impact on the size of the surge (Kowalik, 1984), although sea ice at greater concentrations is known to damp the generation of wind-driven waves. The extent to which the more compact ice below the storm had a moderating effect on the surge is unknown. However, the large fetch certainly allowed the formation of waves that could have reached as high as 15 feet (Anon., 1963b).

The storm surge and wave action from the October 1963 storm caused erosion and flooding of the coastal environment. A study that compared estimated sediment transport during the storm surge to the accumulated transport over the years 1948 to 1962 concluded that the storm "moved over 200,000 cubic yards of sediments, which is equivalent to 20 years' normal transport" (Hume and Schalk, 1967:86). The resulting coastline changes included shoreline retreat, with a steepening and increase in the elevation of the beaches. The bluffs on the southern edge of Barrow retreated as much as 10 feet during this storm, exposing large ice masses that subsequently melted, causing some further shoreline collapse (Hume and Schalk, 1967). In the Arctic, climate warming leads to thawing of the permafrost, which destabilizes the coastline and makes it more vulnerable to both normal and storm-induced sediment transport.

Because of the coastal geography, flooding from the storm surge and waves was more extensive several miles northeast of Barrow in the area around the Naval Arctic Research Laboratory (NARL), which included the camp that serviced the nearby Distant Early Warning (DEW) line (See Fig. 1). "Near the Camp, the water flowed over the beach and down the back slope into the Camp area. A temporary lake was created which had an elevation of 9.2 feet above sea level. The lake extended about 3/4 of a mile inland directly behind the Camp" (Hume and Schalk, 1967:96). Water depth generally ranged from one to three feet in this temporary lake, which linked up with Elson Lagoon farther to the northeast (See lower inset, Fig. 1). Most of the spit surrounding the lagoon from NARL to Point Barrow and Plover Point was under water. "Areas near the village [of Barrow] were not flooded as badly because the beaches there are backed by higher tundra" (Hume and Schalk, 1967:96).

There was little warning to help the community respond to these impacts. "The great storm that staggered Barrow on October 3 happened so suddenly that even the weather bureau did not have an idea that it was coming. There was no warning, which meant, the people of Barrow had to do some quick thinking to save themselves during the onslaught" (Rock, 1963). The Weather Bureau in Barrow did not expect the storm because poor radio propagation had prevented it from receiving the normal weather reports from Soviet Siberia for several days (Anon., 1963c). Remarkably, there were no deaths and only one serious injury. The injury occurred when "The wind hit a pile of sheet metal [pieces] and they took off like kites. One of them slammed into Lawrence Ahmouak [now spelled

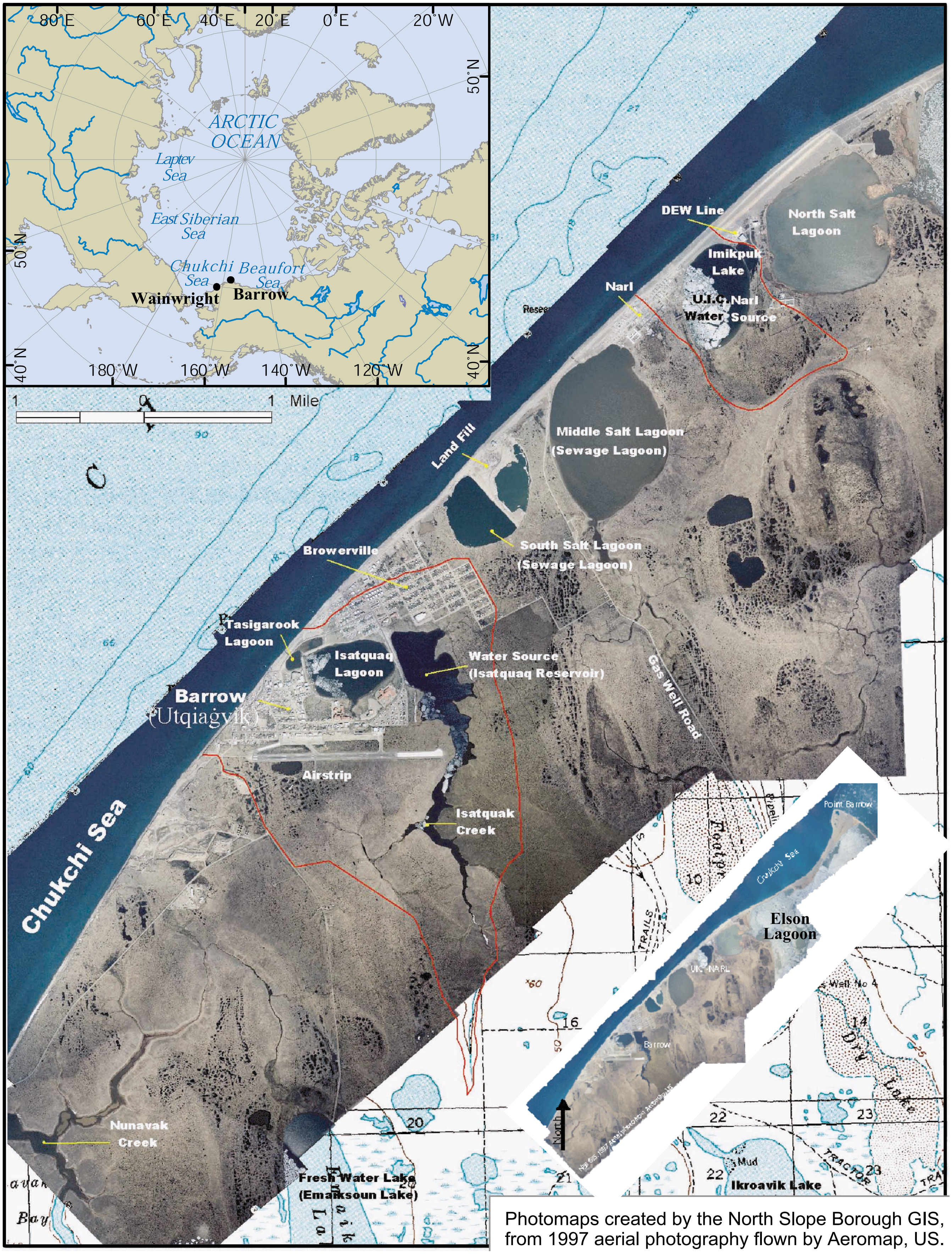

FIG. 1. Photomap of Barrow, Alaska, 1997.

"Ahmaogak"] and knocked him unconscious…. He was the only casualty among some 1350 people living in Barrow" (Rock, 1963) and was later treated and released (Anon., 1963b).

Nevertheless, Guy Okakok reported several close calls, including his own family's. The details illuminate human behavior during disasters (Tierney et al., 2001) and can inform policy responses intended to reduce threats to life and limb from extreme weather events. Like the Weather Bureau, Okakok (1963) did not expect the storm. "Early that morning, October 3, when we woke up around 6:30 a.m., the weather wasn't too bad. After we had our breakfast, my wife and I went [to work] across the lagoon fighting through and against the wind." They left several children at home. But the storm had picked up by 9:00 a.m., when "a neighbor noticed the door of the house opening, then shutting quickly as high seas pounded against the house. The neighbor, realizing somebody must be in the house, waited for a break in the storm, then ran over and found the children…wanting to come out, but afraid to leave" (Anon., 1963d). While they were at work in the local hospital, Okakok (1963) reported, his wife "came running to tell me that they could see big waves splashing over buildings. I didn't say a word to anyone. I went out and started to run toward my home. My children were in the house." After crossing back over the frozen lagoon, which already had water on it, he asked about his children and was told they were safe at Betty Kignak's house.

Okakok struggled over to his house, where big waves had been splashing against the north wall, to sack up the children's clothes. "While I was collecting the clothes, a wave came through the door. All at once the water was up to my knees. As soon as the water dropped, I opened the inside door…. Before I could let go my hands from our doorknob, [a] second strong wave came in and pushed me to the stoves. The house was now half full of water. I couldn't wait any longer and I walked through the water and went out. I couldn't do anything, so I watched. While I was watching, a great strong wave came over and knocked down my walls. Stoves, fuel, food, and clothes scattered all over. What I could save, I saved, but [I] lost the children's clothes, food, range and heater." Okakok (1963) reported other close calls as well: "If Leo Kaleak had waited two more minutes when he tried to reach the house which stood on the highest ground, he said, he would have been washed out to sea. Visibility was very bad in the storm, and he almost got lost. Also Claire Okpeaha, 70 years old, was knocked down by a wave, and he was rolled over and over in the water. His grandson saw him and grabbed him just in time as he was being carried out to sea. He then dragged his grandfather into the house."

Okakok was given shelter, hot coffee, and dry clothes at Betty Kignak's house. There he heard by radio that a Caterpillar and another heavy vehicle would be sent over to rescue people from Browerville and take them to the main part of town. After the Okakok family was rescued, they were given supper at the school, a place to stay overnight at the Presbyterian church, and clothes. Other storm victims were also treated kindly by their neighbors, government officials, and private organizations, including the Red Cross. "When the storm abated, about 200 Eskimos were left homeless. Except for three families that were housed in a church, all of the storm victims were quickly taken in by relatives and friends" (Rock, 1963). Okakok (1963) reported: "I will never forget those people who had done so much for us."

Less was recorded about immediate threats to life and limb northeast of Barrow, at NARL and at the construction camp, where flooding was most extensive. The Laboratory's monthly progress report for October, quoted by Hume and Schalk (1967:94–95), noted that electric power was shut off before the peak of the storm to prevent fire. During the peak in mid-afternoon, "All women and children were evacuated from the Camp to the DEW line site. Most of the damage in the area occurred at this time. The force of the current through the camp was so strong that only Cats could safely be driven through the streets." Even so, a Weasel and a D-4 Caterpillar were sunk trying to rescue a wolf, two wolverines, and three foxes who drowned early in the peak period. Evacuation to Barrow was blocked after a timber bridge washed out and other parts of the coastal road were badly eroded.

Perhaps because flooding was more extensive at the camp than in the village, property damage to government installations was greater, although estimates varied in the immediate aftermath of the storm. As repairs were being made later, Hume and Schalk (1967:96–97) reported that actual costs were close to estimates of $3 million in damages to government installations and $250 000 to the village. In addition to the coastal road damage mentioned above, they listed as "major damage" to the camp "contamination of the water supply [in Fresh Lake northeast of the camp], destruction of 70 per cent of the [NARL] airstrip, and loss of six buildings, two with scientific equipment. Supplies and stores were floated away and damaged by salt water…. In addition, the foundations of almost all the buildings were eroded, a process which usually resulted in structural damage. Three buildings, one a large quonset [serving as a gymnasium], were actually floated away. In all likelihood, more buildings would have been rafted if the water level had remained high for a greater period of time." Imikpuk Lake, the fresh water source between NARL and the DEW Line, was contaminated by salt water and sewage, as well as by fuel oil (Anon., 1963e).

The main losses in the village, according to Hume and Schalk (1967:97), were "32 homes, 15 of which were totally destroyed; 250,000 gallons of fuel; and three small airplanes." One of the earliest accounts reported "Total damage…over $1 million; with most of this occurring to private persons, the native Co-op Store, Central Construction Co., Wien Alaska Airlines, Golden Valley Electric, and federal property" (Anon., 1963f). A few weeks later, another account (Anon., 1963h) claimed that "more than

$600,000 in private property was lost at Barrow" during the storm. Various accounts filled in specific details. The storm damaged or destroyed numerous skin and wood boats, three generators recently landed from the Bureau of Indian Affairs supply ship *North Star*, and a 200-foot radio tower, brought down when two houses crashed into the guy wires supporting it. "About 1000 barrels [of fuel oil] were lost when the waves crashed into piles of drums and scattered them helter skelter. Some of them washed out to sea.... Huge oil tanks were ruptured by the force of the waves and they spewed their contents into the streets and into a fresh water lake used by Barrow for water" (Rock, 1963). This probably occurred where Isatquaq Lagoon is now located (Fig. 1).

Citizens and officials alike improvised responses to the emergency, focusing first on taking care of storm victims. But their efforts were hampered by fire danger, damaged infrastructure, and the blizzard that followed the storm. While Okakok waited in Kignak's house, he heard by radio that "they needed able-bodied men to watch over people. They were urged not to smoke, even near the lagoon. The man on the radio said that big tanks had broken and were pouring oil all over the place" (Okakok, 1963). Flooding limited evacuation between Browerville and the main part of town to heavy vehicles; the road from NARL to town was impassable. The airfield under construction in Barrow was pressed into emergency service after the airfield at NARL became unusable and was shut down. Another early report affirmed that "the immediate work of caring for displaced persons is the first job being handled by officials. Even this work is being hampered by continued winds gusting to 40 mph, with snow. Visibility in the area is poor, and no air traffic could get into or leave Barrow on Sunday" (Anon., 1963b).

However, one plane did reach Barrow on Friday, the day after the storm. It was a single-engine plane piloted by Wien Alaska Airlines' Ed Parsons on a mission to restore communications for all transpolar flights. On Saturday, an Air Force cargo plane brought the first relief: blankets for several homeless families. A Wien DC-3 also brought freight. Relief officials arriving by air that day "represented the Red Cross and state civil defense, the Bureau of Indian Affairs, Corps of Engineers and Golden Valley Electric Co-op of Fairbanks" (Anon., 1963b). The co-op sought to restore electric power to the village. The state and the airline sought to expedite compaction of the new airfield to bring in needed freight. Within a few weeks, an American Red Cross representative announced hopes "to have 26 storm-destroyed or damaged homes at Barrow rebuilt and repaired before December 1" (Anon., 1963g). The Red Cross expected to prefabricate some replacement homes and package them for air delivery, at a total cost of $100 000. At about the same time, the Small Business Administration announced that it had "declared Barrow a disaster area for the purpose of making low-interest loans available to restore homes and businesses damaged or destroyed in the October 3 storm" (Anon., 1963h).

The available reports on the restoration of utilities are scanty. Just after the storm, it was reported that another lake near Imikpuk Lake was "expected to freeze to the bottom shortly, as the middle of winter approaches. It will be possible for people to get ice [for water] from this lake, but the contaminated lake will be out of commission for several years" (Anon., 1963e). Within two months after the storm, Golden Valley Electric restored electric power using several generators, including one from the Native co-op store. By that time, the new distribution system for electric power was all but completed (Anon., 1963j, k). Surviving fuel oil reserves in Barrow were estimated to be enough to last for four or five months. Fuel oil losses prompted the Navy to expedite a project, already approved by Congress, to drill a natural gas well for Barrow village in the nearby national petroleum reserve (Anon., 1963i). The first deliveries of natural gas from the well were made in December 1964 (Anon., 1965).

THE LARGER CONTEXT

To clarify Barrow's vulnerability, we consider the 1963 storm in the larger context of other storms in the region over the decades. Barrow's vulnerability depends on the frequency and intensity of storms that track near Barrow, the direction and duration of their winds at Barrow, and the location and concentration of sea ice. Its vulnerability also depends on the people, property, and other things of value at risk (Pielke, 1997), including archaeological sites.

The storms or low-pressure systems of interest often form in favorable regions along the Arctic front (See Fig. 2). These regions are evident in Siberia in summer and persist into the autumn (e.g., Serreze et al., 2001). From Siberia, low-pressure systems tend to migrate through the Laptev, East Siberian, and Chukchi seas and then northward into the Arctic Ocean, rather than eastward into the eastern Chukchi or Beaufort seas (Serreze et al., 1993). In general, the eastern Chukchi and western Beaufort seas, where the 1963 storm reached maximum intensity, are a region of low frequency and intensity for low-pressure systems compared to other regions of the Arctic. Keegan (1958), in one of the earliest climatologies for the Arctic, noted a pronounced minimum of low-pressure systems in this region, while LeDrew (1983, 1985), in climatologies for the winters and summers of 1975 and 1976, found that depressions off the North Slope coast are very rare.

In the Chukchi-Beaufort region over the last 50 years, there has been a small but statistically significant increase in the intensity of summer storms as gauged by the depth of the central low pressure (Lynch et al., 2004). The trend in the frequency of low-pressure systems is not significant; nor is it linear, according to the convergent results of researchers using different methods (Maslanik et al., 1996; Walsh et al., 1996; Lynch et al., 2004). In the record of high-wind events in the Chukchi-Beaufort region from 1945 to the present, the frequency of storms was relatively

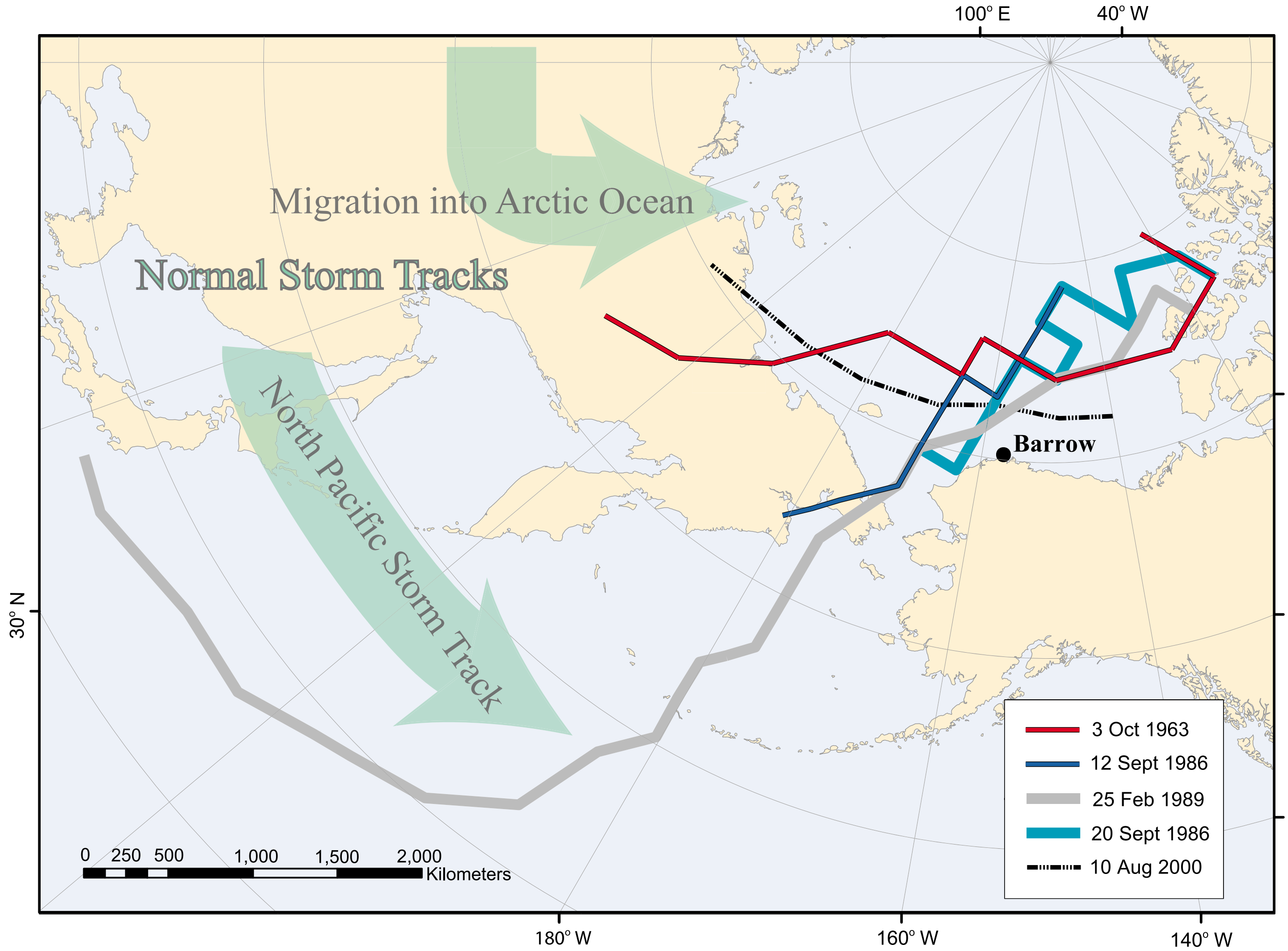

FIG. 2. Normal and selected storm tracks near Barrow.

low from the late 1960s through the mid 1980s, though higher before and after that period (Lynch at al., 2004). This pattern is consistent with the dramatic shift toward low-pressure systems over the central Arctic Basin observed in the late 1980s, resulting from the shift of a large-scale air mass to the North Pacific (Walsh et al., 1996; Cullather and Lynch, 2003).

These storm patterns interact with sea-ice cover to affect the severity of storm impacts on the coastal environment. Light-ice years are associated with more low-pressure activity in the East Siberian Sea (Rogers, 1978). The question is whether the location and concentration of the sea-ice cover influence the tracks of storms in this region, or vice versa. The sea-ice cover does not appear to influence strongly either the intensity or the tracks of deep low-pressure systems in the western Arctic (Maslanik et al., 1996; Lynch et al., 2002). Rather, the low-pressure systems influence the sea-ice cover. Increased low-pressure activity north of Siberia since the late 1980s has exposed the marginal ice zone to more frequent warm southerly wind events as the warm sectors of the cyclones pass over the ice. This exposure has had the effect of enhancing both ice melt and northward retreat of the ice pack. Thus the extension of the storm track through the Chukchi and Beaufort seas is associated with strong ice retreat in this region (e.g., Maslanik et al., 1999). The sea-ice retreat can be expected to magnify the impact of summer and autumn storms, which have increased in intensity and, since the late 1980s, in frequency.

In this context, the October 1963 storm was highly unusual, although the large fetch can be considered an expected consequence of the storm track, for reasons outlined above. This low-pressure system formed along the Arctic frontal zone over Siberia and traveled northeastward to the East Siberian Sea. At this point, rather than tracking northward into the central Arctic Ocean as is typical for such systems, the depression turned in a more eastward direction, steered and strengthened by the jet stream, into the Chukchi Sea and thence to the Beaufort Sea. What was most unusual about this system, however, was not its track or intensity, but its warm core, more typical of mid-latitude ocean regions. No other example of an intense, warm-cored system has been found in the meteorological record of this part of the Arctic. The storms of record are all cold-cored. Warm-cored systems are more likely to develop explosively and to draw energy from the open water below.

At least 30 storms have produced high winds at Barrow since October 1963. Remarkably, no fatalities or serious injuries have been attributed to any of them. However, some of these storms are more notable than others in terms of their intensity, impacts, and human responses.

- 12 and 20 September 1986: The first of these storms from the southwest had peak and sustained winds of 56 and 38 mph, respectively, but the second storm was even stronger, with peak and sustained winds of 65 and 49 mph. Contemporary reports placed the ice out over 200 miles. They emphasized the loss of House Mound 59, an archaeological site with human remains, from erosion of bluffs at the southern edge of Barrow, which also left George Leavitt's house "suspended perilously over a 35 foot drop into the ocean." Estimated damage to roads and structures in Barrow and Wainwright, a smaller village southwest of Barrow, was over $7.5 million (Anon., 1986).
- 25 February 1989: This storm hit from the southwest when the ice was in, with peak and sustained winds of 73 and 55 mph, respectively, and reported gusts close to 100 mph. There were reports of "piled shore ice up to eight feet in height [and 100 feet inland] blocking roads and pushed up dangerously close to buildings, snapped telephone poles, damaged roofs, broken windows and various other types of structural damage." The wind knocked a house under construction off its foundation, flipped over one airplane, and damaged several others. An early estimate of total damage to the North Slope Borough, including both private and public property, was over $500 000 (Anon., 1989).
- 10 August 2000: This storm hit from the west when the ice was out, with peak and sustained winds of 75 and 55 mph, respectively, equivalent to the October 1963 storm but not as long-lasting. The major loss, at $7 million, was the dredge *Qayuuttaq*. The storm ripped it from its anchors and washed it ashore, flooding it and damaging its starboard hull (USACE, 2001:5). About 35 private homes and four public housing units sustained roof and siding damage. Waves washed out a gravel seawall and a culvert crossing at Middle Salt Lagoon and damaged the road along the coast once again. The initial total damage estimate was about $7.7 million (Ahmaogak, 2000).

For comparison, the estimated damage from the October 1963 storm ($3.25 million in 1963 dollars) is roughly equivalent to $19 million in 2000 dollars. However, the actual damage from each storm is unclear because of unresolved questions about what was included in or excluded from each estimate. Additional factors complicate comparison of damages and their significance. For example, the federal government, not the villagers, sustained most of the damage in the 1963 storm. For the August 2000 storm, insurance covered $6 million of the $7 million in damage to the dredge, and $830 000 was later added to the initial estimate to cover the cost of replacing the gravel seawall (Neakok, 2000).

Despite the decline in damages since October 1963, later storms appear to have prompted more efforts by the community to reduce its vulnerability. In particular, the September 1986 storms drew attention to effects of coastal erosion in Barrow and Wainwright. As a result, the North Slope Borough commissioned studies that came together in a report entitled "Mitigation Alternatives for Coastal Erosion" (BTS/LCMF, 1989). This report, released two months after the February 1989 storm, led to approval of a beach nourishment program, which included the custom-designed dredge *Qayuuttaq*, in the summer of 1992. The dredge lifted material from the sea floor and deposited it on the beach, in Wainwright in 1995 and in Barrow beginning in 1996. The August 2000 storm terminated those operations, as noted above. The damaged dredge was towed to Seattle for repairs, but put up for sale instead.

North Slope Borough Mayor George N. Ahmaogok, Sr. (2001) cited the August 2000 storm in a letter expressing support for a feasibility study proposed by the U.S. Army Corps of Engineers. Now approved by the federal government and underway, the study as proposed includes beach nourishment, elevation of the coastal road, and "hardening" of the seaward side of the road with a concrete mattress revetment. In his letter, the Mayor wrote: "The study is a critical step in determining the protection of enormous capital infrastructure essential to the health and safety of residents of Barrow. The recent storm last August attests to the urgency to provide coastal storm damage protection for our community." The capital infrastructure includes an underground utility corridor heavily insulated from permafrost, which contains water, sewage, and some power lines, as well as communication facilities. This "utilidor" began service to Barrow residents in 1984, at a cost of $270 million (USACE, 2001:3–4); recent additions have employed a less expensive direct bury technology. Modernization on a more modest scale was already underway in 1963 at the insistence of Barrow residents (Anon., 1963a), but accelerated after incorporation of the North Slope Borough in July 1972 (Hess, 1993). The number of people in Barrow has more than tripled since 1963, to almost 5000. Thus more people and more property are exposed to extreme weather events now than in 1963.

The October 1963 storm has been cited in support of major programs to address the erosion problem. For example, a key document in the approval of the beach nourishment program noted that "insufficient information is available to determine the occurrence intervals for storms similar to those in 1954, 1963 and 1986…. However, we feel the probability of another occurrence in the next 25-30 years is very high." These storms were later described as "the three most notable episodes of bluff erosion" (BTS/LCMF, 1989:I, 3). The proposal for a feasibility study also cites the 1963 storm in connection with erosion rates (USACE, 2001:5). However, the formal emergency management plan developed by Emergency Response Institute International, Inc. (2000) for the North Slope Borough does not attempt to harvest the experience of human impacts and responses from the 1963 storm or other extreme weather events on the North Slope. It does clarify formal authorities and responsibilities for emergency management based on a template designed for any community. On the basis of information presently available, it appears that the policy implications of the 1963 storm and subsequent storms in Barrow have not been exhausted.

POLICY IMPLICATIONS

Given the diversity of storms and their impacts on Barrow in the past, and the probability of additional climate changes, policies to reduce Barrow's vulnerability cannot anticipate in sufficient detail all the possible impacts of major storms in the future. This means that improvisations like those observed in the 1963 storm are necessary and inevitable in emergency responses to the next disaster, that resilience is necessary to minimize disruptions and expedite recovery from the unanticipated impacts of a disaster, and that flexibility is necessary to incorporate what is learned from each disaster and thus reduce vulnerability over the long term. For such purposes, policy planning can be improved by harvesting additional experience gained from big storms in Barrow on a continuous basis.

For emergency responses, an earlier warning of the impending storm is an important priority. An earlier warning would reduce threats to life and limb by alerting families like the Okakoks to stay together, or by giving them more time to get together and find shelter on high ground before evacuation routes are blocked. The 1963 storm suggests that children, the elderly, and perhaps other especially vulnerable people need the care of family and friends who are better able to find safety and improvise when necessary. An earlier warning would provide more time to secure sheet metal, plywood, and similar materials before they are picked up by winds and turned into potentially lethal flying objects. It would also provide more time for the Borough's Department of Municipal Services to construct temporary gravel seawalls that would reduce threats to public safety and critical infrastructure from erosion and flooding. In the 20 September 1986 storm at least, heavy equipment operators were ordered off the beach before the temporary construction job was completed because it became too dangerous.

Planning might anticipate disruptions that have hampered emergency operations or recovery from storms in the past and target vulnerable areas as priorities for mitigation. For example, the 10 August 2000 storm, like earlier storms, once again washed out sections of the coastal road, hampering emergency operations until temporary repairs restored traffic the next day. Redundancies, reserves, and other proven methods for coping with uncertainties might be employed more explicitly and broadly. Redundancies in October 1963 included an alternative to the coastal road for evacuation from NARL, heavy equipment to back up cars as means of transportation, a partially completed airfield to back up the damaged airfield at NARL, and multiple generators and sources of fresh water. Reserves of fuel oil were sufficient to provide winter heat for several months, even though much fuel oil was lost. Since October 1963, safety valves have been installed on natural gas pipelines—including those buried ten feet inland from the coastal road—to shut off the flow of gas automatically if a line breaks. The valves reduce danger to emergency operations and leave other parts of the distribution system intact. A similar concept might be developed for the utilidor. At present, two of the lift stations at low points in the gravity-fed sewer system are exposed to erosion along the coast. If these stations were breached during a storm, the whole utilidor could be flooded up to the height of the storm surge and waves. If they were retrofitted with bulkheads and backups, however, the damage might be limited and service more quickly restored.

Some additional possibilities for reducing vulnerability over the long term have been suggested by community members but not yet fully explored or implemented. These include planning and zoning to prevent further development in coastal areas vulnerable to erosion and flooding. This possibility was considered along with the beach nourishment program in the summer of 1992, and may or may not have been part of the policy approved at that time; sources available differ on this point. In either case, however, a planning and zoning policy has not been fully implemented. The Borough's new veterinary clinic, for example, was built in 1998 in an area of Browerville that had been flooded in October 1963. A planning and zoning policy could help the community "roll back," removing community infrastructure from vulnerable areas along the coast and relocating or building new infrastructure inland, to reduce its vulnerability a step at time, at a pace and locations to be determined by extreme weather events in the future. Also suggested in the summer of 1992 was a possible means of reducing the costs of beach nourishment, by mining gravel from the barrier islands east of Barrow and trucking it across Elson Lagoon in winter, when the lagoon's shallow waters are frozen solid to the ground. Other possibilities suggested by community members, and still pending, include location of a proposed new hospital outside the flood plain; construction of a new road inland from the coast that would provide an alternative evacuation route from NARL; and design of a new $35 million Global Climate Change Research facility at NARL to withstand a flood of the magnitude experienced in October 1963. Similar possibilities for long-term reductions in vulnerability to extreme weather events will arise in the normal course of community development. Planning and action need not be limited to programs focused on erosion control.

Three decades of research on natural hazards and disasters elsewhere can suggest additional possibilities for reducing vulnerability in Barrow (e.g., Mileti, 1999; Tierney et al., 2001). But experience elsewhere is no substitute for attending to the situation in Barrow, or in other communities on the North Slope, each of which is unique for policy purposes. To exploit the possibilities, whatever their origins, a community generally has a window of opportunity in the immediate aftermath of a disaster (Ungar, 1995). The opportunity typically includes the practical necessity and political will to reconstruct what can be reconstructed, as well as disaster relief and other resources that tend to converge on a devastated community from outside. The window of opportunity is likely to close, however, unless the community is prepared to act quickly under policies already in place when the window opens. In the absence of such policies, the default often is to rebuild damaged structures in the same place, leaving them as vulnerable as before.

CONCLUSIONS

Any specific policy implications of the 1963 disaster in the larger context are necessarily tentative because research is ongoing and because the context in Barrow and the North Slope continues to evolve. Stepping back from the details above, however, we can be relatively confident in three general conclusions.

The scientific conclusion is that profound uncertainties are inherent in the task of reducing Barrow's vulnerability, which arises from unique interactions among many relevant factors, each the focus of a particular scientific specialization. The factors include variability and change in weather and climate, sea-ice cover, the coastline, and the pattern and pace of modernization in Barrow, as well as the individual and collective acts of people in Barrow. Some acts in direct response to environmental factors, like the beach nourishment program, have changed the ocean floor and coastline, with consequences not fully understood. Other acts, like mining the beach for construction materials in earlier decades, have had unintended consequences. Mining probably exposed parts of Barrow's coastline and bluffs to erosion and accelerated erosion rates (Walker, 1991). Significant human acts alone are enough to make this an open, evolving context in which uncertainties cannot be eliminated through scientific research (Oreskes et al., 1994). Thus uncertainties will persist in estimating Barrow's vulnerability and the consequences of any action expected, on the best available knowledge and information, to advance the common interest of the community.

The policy conclusion is that sound policies will go beyond science to include judgments that clarify the community values at stake and construct the relevant context as events unfold. Considered in narrow context, the 1963 disaster demonstrates where and how public safety has been threatened, property damaged, and the coastline eroded and flooded to the maximum extent in Barrow's known past. It therefore clarifies possible areas of vulnerability to storms in the future. Considered in larger context, however, the 1963 disaster is highly unusual. No other storm since 1963 has been nearly so damaging, despite more high-wind events since the mid-1980s and the exposure of more people and property through population growth and modernization. Perhaps present vulnerability is much less than that inferred from the 1963 disaster alone; or perhaps Barrow has just been fortunate. Considered in global context, the significance of the 1963 disaster and subsequent storms in Barrow is unclear. Expectations from global change research are that the frequency and intensity of storms—and their impacts—are increasing. However, the regional pattern over the last several decades partially contradicts those expectations and is much more complicated. Thus, whatever the contribution of global change research, sound policies to reduce vulnerability in Barrow must take into account unique interactions there among the many relevant factors. Sound policies also will allow for corrective action, if and when expectations about the appropriate values and context turn out to have been mistaken (Brunner, 2000).

The governance conclusion is that the people of Barrow are in a better position than anyone else to understand unique interactions in Barrow, to decide on sound policies for Barrow, and to take responsibility for those policy decisions. They understand the community's values better than anyone else. They can decide whether to prepare for a future disaster like the October 1963 storm, the August 2000 storm, or some other scenario. They can evaluate the expected consequences of alternative courses of action according to the best available knowledge and information, local and scientific, and learn from the consequences of the actions taken. Responsibility comes from the fact that they must live with the direct consequences of those actions, good and bad, so long as they reside in Barrow—unlike remote decision makers in Juneau, in Washington, D.C., or in the U.N. Framework Convention on Climate Change. In these respects, Barrow is similar to thousands of other unique communities around the globe that are vulnerable to climate change and variability. Climate change is not an irreducibly global problem (Brunner, 2001).

Compared to many other communities, however, Barrow has a richer array of cultural resources to draw upon. To mitigate the demanding climate of the North Slope, Barrow has access to modern science and technology as represented by the utilidor, the beach nourishment program, and resident and visiting scientists. But Barrow also has access to the traditional knowledge and skills of Native people who have survived for thousands of years in that climate. Rock (1963) saw the value of traditional culture in the October 1963 disaster: "It was a freak storm. It had to be dealt with quick thinking and without panic…. It was a classic example of survival of man in the Arctic." In a broader context, Masks and Songs (1982:7) contrasted "the fragmented perception of the non-Native world in which man is separated from the land" with the Native world in which "we have learned to view the community as a comprehensive whole, whose members include: plants, animals, soil, air, water, cosmos, spirits and man." The implication of this Native view is that "The duty of man is not to change nature, but to adapt himself to Nature" (Masks and Songs, 1982:8).

ACKNOWLEDGEMENTS

Thanks to colleagues Anne Jensen and Glenn Sheehan and the people of Barrow. This research was supported by grant OPP-0100120 from the National Science Foundation.

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