**Typhoon Merbok**
**17 September, 2022**
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PRJ- 3737

# PRELIMINARY VIRTUAL RECONNAISSANCE REPORT (PVRR)


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# PREFACE

The National Science Foundation (NSF) awarded an EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network (see https://www.steer.network for more details). StEER was renewed through a second award (CMMI 2103550) to further enhance its operational model and develop new capabilities for more efficient and impactful post-event reconnaissance. StEER builds societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities. StEER achieves this vision by: (1) deepening structural engineers' capacity for post-event reconnaissance by promoting community-driven standards, best practices, and training, as well as their understanding of the effect of natural hazards on society; (2) coordination leveraging its distributed network of members and partners for early, efficient and impactful responses to disasters; and (3) collaboration that broadly engages communities of research, practice and policy to accelerate learning from disasters.

Under the banner of the Natural Hazards Engineering Research Infrastructure (NHERI) CONVERGE node, StEER works closely with the wider Extreme Events Reconnaissance consortium to promote interdisciplinary disaster reconnaissance and research. The consortium includes the Geotechnical Extreme Events Reconnaissance (GEER) Association and the networks for Interdisciplinary Science and Engineering Extreme Events Research (ISEEER), Nearshore Extreme Event Reconnaissance (NEER), Operations and Systems Engineering Extreme Events Research (OSEEER), Social Science Extreme Events Research (SSEER), and Sustainable Material Management Extreme Events Reconnaissance (SUMMEER), as well as the NHERI RAPID equipment facility, the NHERI Network Coordination Office (NCO), and NHERI DesignSafe CI, curation site for all StEER products.

While the StEER network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Southeast Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER is currently expanding its network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as cross-cutting areas of Assessment Technologies and Data Standards, led by the following individuals:

- **Tracy Kijewski-Correa (PI),** University of Notre Dame, serves as StEER Director responsible for overseeing the design and operationalization of the network and representing StEER in the NHERI Converge Leadership Corps.
- **Khalid Mosalam (co-PI),** University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, serving as primary liaison to the Earthquake Engineering community.
- **David O. Prevatt (co-PI),** University of Florida, serves as StEER Associate Director for Wind Hazards, serving as primary liaison to the Wind Engineering community.
- **Ian Robertson (co-PI),** University of Hawai'i at Manoa, serves as StEER Associate Director for Coastal Hazards, serving as a primary liaison to the coastal engineering community and ensuring a robust capacity for multi-hazard assessments.
- **David Roueche (co-PI),** Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data suitable for re-use by the community.

This core leadership team works closely with StEER Research Associates, Data Librarians and its Student Administrator in event responses, in consultation with its Advisory Boards for Coastal, Seismic and Wind Hazards.

# ATTRIBUTION GUIDANCE

## Reference to PVRR Analyses, Discussions or Recommendations

Reference to the analyses, discussions or recommendations within this report should be cited using the full citation information and DOI from DesignSafe (these are available at https://www.steer.network/products).

## Citing Images from this PVRR

Images in this report are taken from public sources. Each figure caption specifies the source; re-use of the image should cite that source directly. Note that public sources might still have copyright issues and depending on the use case, the user may need to secure additional permissions/rights from the original copyright owner.

## ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. CMMI 2103550. Any opinions, findings, and conclusions or recommendations expressed in this material are those of StEER and do not necessarily reflect the views of the National Science Foundation. All authors and editors listed on the cover page participate as volunteer professionals. Thus, any opinions, findings, and conclusions or recommendations expressed herein are those of the individual contributors and do not necessarily reflect the views of their employer or other institutions and organizations with which they affiliate.

Special thanks also go to our Student Administrator, Ella Gerczak, for monitoring outage/access and restoration data used in this report.

The sharing of videos, damage reports and briefings via Slack by the entire NHERI community was tremendously helpful and much appreciated. StEER recognizes the efforts of the DesignSafe CI team who continuously supported and responded to StEER's emerging needs.


For a full listing of all StEER products (briefings, reports and datasets) please visit the StEER website: https://www.steer.network/products

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# Common Terms & Acronyms

| Acronym | General Terms | Brief Description |
|---|---|---|
| -- | DesignSafe | Data Repository |
| -- | DesignSafe-CI | Academic Organization within NHERI |
| ASCE | American Society of Civil Engineers | Professional Organization |
| BOCA | Building Officials and Code Administrators | Code Body |
| CC-BY | Creative Commons Attribution License | Code/Standard |
| CESMD | Center for Engineering Strong Motion Data | Federal/State Agency |
| CI | Cyberinfrastructure | Research Asset |
| CLPE | Critical Load Path Elements | StEER Term |
| CMU | Concrete Masonry Unit | Building Material |
| DOI | Digital Object Identifier | Common Term |
| EF | Enhanced Fujita | Intensity Measure |
| EF | Equipment Facility | Academic Organization within NHERI |
| FAA | Federal Aviation Administration | Federal Agency |
| FAQ | Frequently Asked Questions | Common Term |
| FEMA | Federal Emergency Management Agency | Federal Agency |
| GEER | Geotechnical Extreme Events Reconnaissance | Academic Organization within NHERI |
| GSA | Government Services Administration | Federal Agency |
| IBC | International Building Code | Code/Standard |
| ICC | International Code Council | Code Body |
| IRC | International Residential Code | Code/Standard |
| ISEEER | Interdisciplinary Science and Engineering Extreme Events Research | Academic Organization within NHERI |
| NBC | National Building Code | Code/Standard |
| NEER | Nearshore Extreme Event Reconnaissance | Academic Organization within NHERI |
| NHERI | Natural Hazards Engineering Research Infrastructure | Academic Organization within NHERI |
| NIST | National Institute of Standards and Technology | Federal Agency |

| | | |
|---|---|---|
| NOAA | National Oceanic and Atmospheric Administration | Federal Agency |
| NSF | National Science Foundation | Federal Agency |
| NWS | National Weather Service | Federal Agency |
| OSEEER | Operations and Systems Engineering Extreme Events Research | Academic Organization within NHERI |
| PEER | Pacific Earthquake Engineering Research center | Academic Organization Focusing on Earthquake Hazard |
| RAPID | RAPID Grant | Funding Mechanism |
| RAPID-EF | RAPID Experimental Facility | Academic Organization within NHERI |
| SPC | Storm Prediction Center | Federal Agency |
| SSEER | Social Science Extreme Events Research | Academic Organization within NHERI |
| StEER | Structural Extreme Events Reconnaissance network | Academic Organization within NHERI |
| SUMMEER | SUstainable Material Management Extreme Events Reconnaissance | Academic Organization within NHERI |
| UNDRR | United Nations Office for Disaster Risk Reduction | International Organization |
| USGS | United States Geological Survey | Federal Agency |

# EXECUTIVE SUMMARY

Typhoon Merbok struck Western Alaska on September 17, 2022, producing hurricane-force winds, higher than normal tidal ranges, and storm surges of up to 10 feet above mean high water. This event caused wind damage as well as severe riverine and coastal flooding, affecting about 21,000 people in approximately 40 cities and villages along an approximately 1,300-mile-long section of the Western and Northwestern Alaska coastline. The storm impacted Western Alaska with wind gusts as high as 91 mph and historic high water surge levels of 10.5 feet above low-tide level in Nome, the highest since a major storm in 1974. The storm formed in a region where typhoons do not typically form due to colder ocean temperatures in September, however ocean waters in the region were the warmest on record (for this time of year), going back 100 years.

Typhoon Merbok brought flash flooding and erosion and impacted critical infrastructure, such as roads, airports, power infrastructure, etc. Five communities, including Hooper Bay (population 1,375), Scammon Bay (population 600), Golovin (population 175), Newtok (population 209), and Nome (population 3,699), were severely impacted by the storm. Coastal erosion was the primary hazard causing significant damage to airport runways, berms, roadway embankments, and bridge abutments. The section of the 70 mile long Nome-Council highway that runs along barrier islands separating Safety Sound from Norton Sound was heavily damaged, with up to 10 miles of the highway totally destroyed. Shaktoolik's protective berm, which was constructed recently to protect the community from the sea, was eroded significantly by the storm. Hooper Bay lost to coastal erosion a significant amount of the rows of natural dunes. Several airports experienced erosion (Scammon Bay airport), damaged runway lights (Chevak and Shaktoolik airport) and malfunction of FAA weather equipment (Unalakleet, Nunapitchuk, White Mountain, Chevac, Golovin, and Hooper Bay). Local subsistence infrastructure including hunting and fishing camps, boats, vehicles and equipment were damaged or destroyed by the storm, particularly near Nome and Chevak, and power outages threatened frozen subsistence foods stored for the winter.

This **Preliminary Virtual Reconnaissance Report (PVRR)** is the primary product of the Level 1 response to Typhoon Merbok, intended to (i) provide an overview of Typhoon Merbok, particularly relating to flooding and storm surge impact on the built environment, (ii) overview the regulatory environment and construction practices in the affected area, (iii) synthesize preliminary reports of damage to buildings and other infrastructure, and provide recommendations for continued study of this event by StEER and the wider engineering reconnaissance community.

# 1. Introduction

Typhoon Merbok struck Western Alaska on September 17, 2022 producing hurricane-force winds, higher than normal tidal ranges, and storm surges of up to 10 feet above mean high water. This event caused wind damage as well as severe riverine and coastal flooding, affecting about 21,000 people from approximately 40 cities (**Figure 1.1**) and villages along an approximately 1,300-mile-long section of the Western and Northwestern Alaska coastline. Merbok caused extensive damage to local highway infrastructure, including a several hundred foot breach of a barrier island, and the Nome-Council Highway erosion, coastal road embankment loss, and pavement loss.


**Figure 1.1**: Typhoon Merbok impact area (as of 9/19/2022), State of Alaska Department of Transportation and Public Facilities (source: Alaska DOT & PF 2022)

The affected area contains a number of widely dispersed small towns and indigenous Alaska Native villages, primarily located along the coastline or rivers. The largest town in the region is Bethel (population 6,538), which is inland along the Kuskokwim River; the next largest are Nome (3,699) and Kotzebue (3,102), both along the coast. The few local roads and highways in the affected areas are not connected to Alaska's main highway network, meaning that the only access to the area from the state's main population centers, Anchorage and Fairbanks, is via boat or plane.

## 1.1. Societal Impact

Typhoon Merbok brought an intense storm with peak wind gusts of 91 mph observed at Cape Romanzof and 67 mph at Nome (NWS 2022a). The water levels in Nome peaked at 10.52 feet above low-tide level, the highest storm water surge recorded since a major storm in 1974 (Rick Thoman 2022c). The recovery of Western Alaska will be challenging due to the remoteness of the affected area and its lack of road access. According to the state's informal preliminary survey, 40 towns and villages experienced damage, stretching from the Bering Strait region in the north to the mouth of the Kuskokwim River in the south — some 1,300 miles of coastline (Zachariah Huges 2022a).

Merbok affected about 21,000 people living along the coast of Western Alaska. At least five communities, including Hooper Bay (population 1,375), Scammon Bay (population of 600), Golovin (population of 175), Newtok (population of 209), and Nome (population of 3,699), were severely impacted by the storm. The population data reported herein is based on the 2020 Decennial Census (USCSB 2022)

Local officials reported damage to 69 homes and 28 other structures (NOAA Incident News 2022) as of September 20; damage assessments were still being conducted with the number of damaged buildings likely to rise. The typhoon-induced surge knocked an unoccupied home off its foundation in Nome that floated along the Snake River (**Figure 1.2a**). On Friday, 16th September the rising water level forced many residents in Golovin to evacuate from their homes and shelter at a school or in three buildings on a hillside. About 250 residents of Hooper Bay took shelter in Hooper Bay school (Thiessen and Gecker 2022). Five days after the storm, 22 Hooper Bay residents remained displaced due to damage to their homes (Will McCarthy 2022a).

Typhoon Merbok brought flash flooding and erosion, and impacted critical infrastructures, such as airports, roads, power infrastructure, and hospitals. Storm surge flooded the Kotlik, Nunam Iqua, and Chevak airports. Stormwater submerged portions of Newtok, Golovin, Bethel, and Napaskiak airports. Debris, logs, and gravel from erosion severely impacted the Hooper Bay, Scammon Bay, Nome, and Shaktoolik airports. East front street in Nome had missing pavement after the surge came inland on the morning of Saturday, 17th September, and debris flooded the Seppala road (Alaska DOT & PF 2022). Storm surge washed away half of the gravel delivered in the past month in Nunam Iqua for road maintenance. Shaktoolik protective berm made of gravel, sand and driftwood, was washed away endangering the community's fresh water supply which was inundated with saltwater (Alaska Public Media 2022). An estimated 1,000 gallons of petroleum products spillage along the Chevak's beach was reported by the U.S. coast guard

(Zachariah Hughes 2022c).

The typhoon caused substantial damage to most of the fishing fleet in Chevak. Storm water flooded several structures and vehicles in Napakiak (Alaska Public Media 2022). The storm left Chevak residents without drinking water for 3 days. A gallon of water at Chevak was selling for $11.00 at Chevan Company Corporate Store (Emily Schwing 2022a). As of 20th September, half of Chevak was still without water supply. Most of the people in Hooper Bay, Chevak, Newtok, Tununak, and Toksook were in need of water and food (Berman et al. 2022). High water levels were observed near the AVEC power plants in Kotlik and Chevak. However, these power plants are elevated on pilings and don't appear to be damaged.

(a) (b)

**Figure 1.2:** (a) Building washed against the Snake River Bridge, Nome (source: Alaska DOT & PF 2022) and (b) surging water flooded several structures and vehicles in Napakiak on Saturday, September 17, 2022 (source : Alaska Public Media 2022)

Media reports indicate concern amongst local residents about the ability to gather and access foods traditionally gathered/harvested and relied upon in these areas. Most affected communities are Alaska Native communities; such losses have tremendous cultural impacts in addition to economic impacts. Alaska Natives have a traditional practice of supporting themselves through foods and materials available locally, and many other Alaskans have adopted some of these subsistence practices. In many of the remote areas affected by the storm, obtaining food locally through fishing, hunting and gathering is an economic necessity due to the high cost of food brought in from outside. As a result many members of communities rely on subsistence harvesting of fish and game for direct family use. Local subsistence

infrastructure including hunting and fishing camps, boats, vehicles and equipment were damaged or destroyed by the storm, particularly near Nome (Zachariah Huges 2022b; Davis Hovey 2022) and Chevak (population of 951), and power outages threatened frozen subsistence foods stored for the winter (Emily Schwing 2022b). Within the coastal community of Chevak, the loss of more than 90 boats, needed for fishing and access to areas for hunting, is a considerable setback for the community (Alaska Public Media 2022).

Other resources, such as telecommunication, were impacted in Chevak, Elim, Golovin, Hooper Bay, Newtok, White Mountain, Shatoolik, Stebbins, St. George, and Unalakleet. Internet service was also out in Emmonak, Greyling, and Kwigllingok, but was quickly restored (Zacharia et al. 2022).

### 1.2. Loss of Life and Injuries

There are no reported injuries or deaths from Typhoon Merbok in Alaska. However, the Association of Village Council Presidents (AVCP) reports that at least 13 families are still displaced in Chevak as of October 2, 2022 (Zachariah Hughes 2022c).

### 1.3. Official Response

On Thursday, September 15, 2022 the National Weather Service (NWS), Fairbanks, AK issued a series of warnings (NWS 2022b). NWS predicted unprecedented sea levels rise of 3-8 feet above normal high tides near Bering Strait coast, 8-11 feet near Nome, 9-13 feet Govolin, 12-18 feet Elim to Koyuk, 8-12 feet from Shaktoolik to Stebbins, and 3-8 feet from St. Michael to Hooper Bay (**Figure 1.3**).

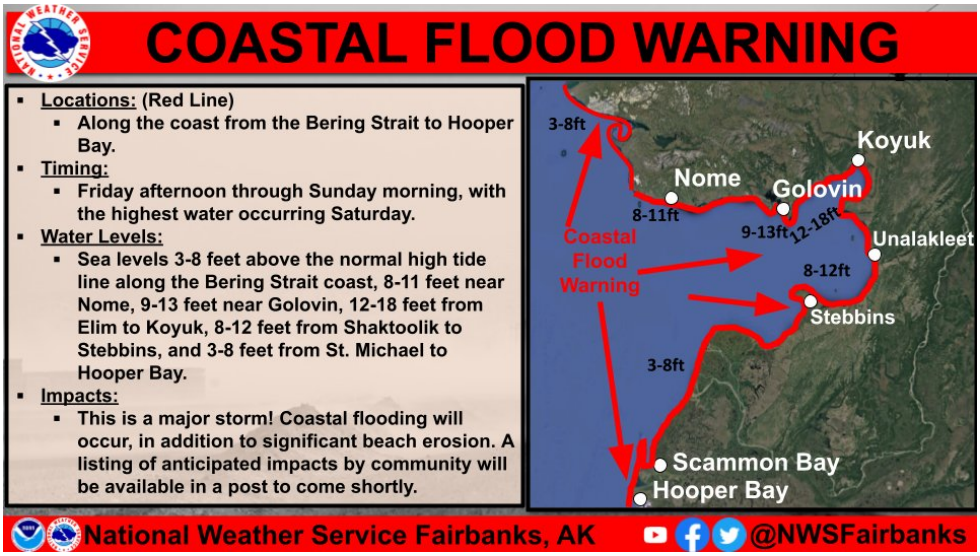


**Figure 1.3**: Typhoon Merbok coastal flood warning (NWS 2022b)

The NWS, Fairbanks, AK also issued a warning for high winds up to 90 mph along the coast of Western Alaska in areas such as Savoonga, Diomede, and the Bering Strait (**Figure 1.4**)

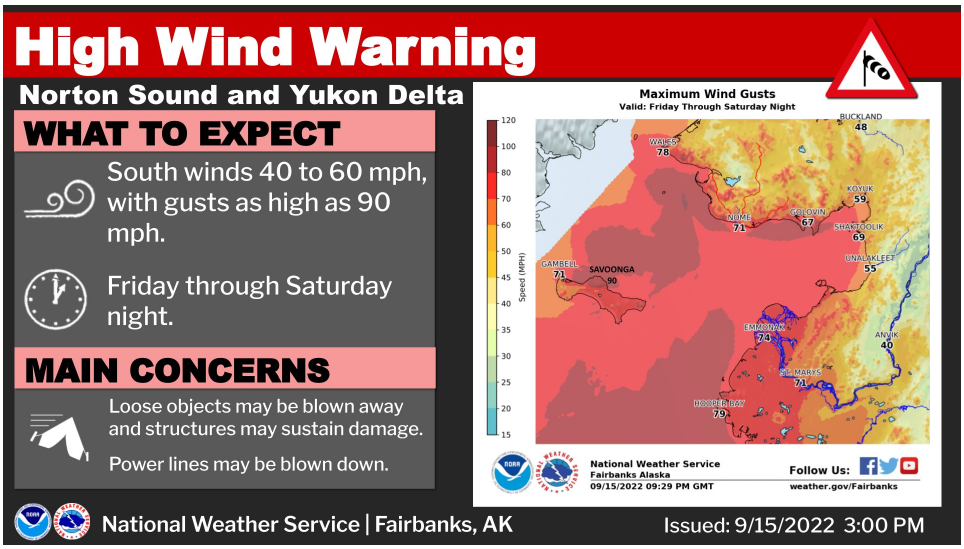


**Figure 1.4**: Typhoon Merbok high wind warning (NWS 2022c)

The Office of the Governor, AK, issued a state disaster declaration for the storm on Saturday, 17 September 2022, at 9 am. The state disaster declaration ensured local and tribal governments, state agencies, and non-governmental partners with authority and funding to conduct any necessary life, health, and safety steps (Office of Governor MIKE DUNLEAVY 2022). A federal disaster declaration allowed support for the damage assessment and recovery of communities affected by the storm in Western Alaska. Following the Governor's state disaster declaration, Alaska Division of Homeland Security and Emergency Management initiated emergency response preparedness level 3 operations involving multiple state, federal, non-profit, private-sector, regional tribal, and native corporations to support local community incident commands responding to Merbok storm impacts (SEOC Alaska 2022).

The Red Cross declared a level 4 disaster in Western Alaska to raise funds for the state's recovery. The organization deployed more than 60 volunteers from across the country via air travel to impacted parts of Alaska. The volunteers flew out of Nome and Bethel, helping in assessing the damage to infrastructure. Efforts were made to secure emergency supplies, such as tarps, coolers, vacuum sealers, window film, insulation, sealing foam, and heater meals, then deliver them to the community members impacted by the storm (Red Cross).

The State is making an effort to arrange resources for home repairs before the winter. On September 23, 2022, the Department of Homeland and Emergency Management announced the State of Alaska Individual Assistance (IA) program for individuals impacted by Typhoon Mebrok. This is a two part program that includes Individual and Family Grants (IFG) and

Temporary Housing Grants (THG). IA will provide financial assistance to impacted individuals who experienced serious losses not covered by their insurance or other financial resources or means. Affected individuals can apply for grants starting on September 26th through November 17th 2022 (Alaska DHS&EM 2022).

On September 23, 2022 the Department of the Interior announced that the Bureau of Indian Affairs (BIA) will start distributing $2.6 million to support the needs of 45 Alaska Native villages affected by Merbok. These funds are intended to provide critical resources for Alaska Native communities prior to winter's arrival, including immediate aid for food, water and other essential supplies (DOI 2022).

On October 6, 2022 The U.S. Department of Transportation's Federal Highway Administration (FHWA) awarded $9 million in 'quick release' Emergency Relief (ER) funds to offset costs of emergency repairs of bridges and roads damaged by widespread flooding (FHWA 2022).

### 1.4. Report Scope

StEER activated a Level 1 response with a Virtual Assessment Structural Team (VAST) formed on September 20, 2022 to evaluate this event. The decision was informed by majority consensus across three decision-making mechanisms: (i) percentile score satisfying StEER's response activation criteria based on hazard, exposure, and feasibility, (ii) output of a prototype predictive model, and (iii) consultation with StEER wind and coastal advisory board members. The details of the response activation memo can be found here.

This **Preliminary Virtual Reconnaissance Report (PVRR)** is the primary product of the Level 1 response to Typhoon Merbok, intended to:

1. provide an overview of Typhoon Merbok, particularly relating to flooding and storm surge impact on the built environment,
2. overview the regulatory environment and construction practices in the affected area,
3. synthesize preliminary reports of damage to buildings and other infrastructure,
4. provide recommendations for continued study of this event by StEER and the wider engineering reconnaissance community.

## 2. Hazard Characteristics

### 2.1. Meteorological Background

The Japan Meteorological Association began tracking a low-pressure system and on September 12, 2022, the system reached 35 knots sustained winds and was subsequently named Merbok. JMA considered the storm "expired" on September 15, 2022. Between September 12th through 15th it reached a minimum pressure of 965 hPa and maximum wind speed of 70 knots (80.5 mph) (Kitamoto Asanobu 2022). Its progression, as monitored by JMA, is shown in **Figure 2.1**.

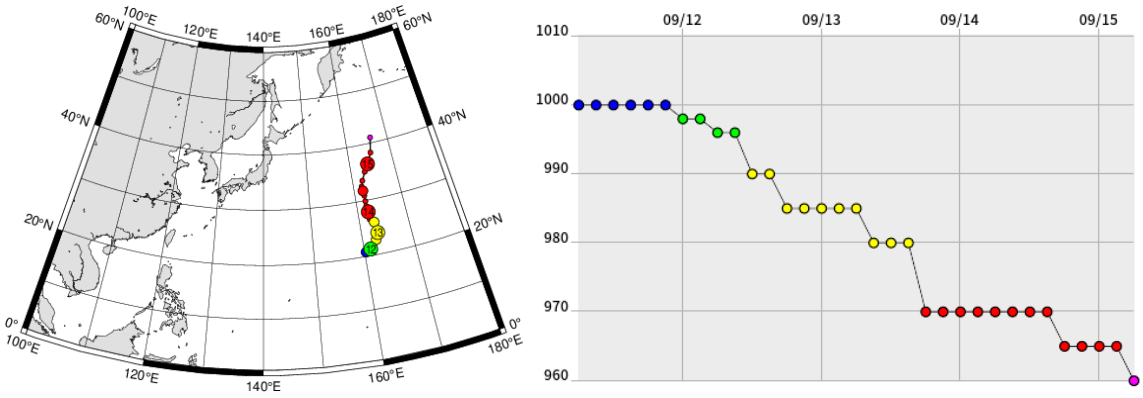


**Figure 2.1**: Merbok track and central pressure as documented by JMA (source:Kitamoto Asanobu 2022)

Post Typhoon Merbok reached Alaska on September 17, 2022. While considered the remnants of Merbok, meteorologically, the U.S. National Weather service offices in Anchorage and Fairbanks were forecasting a very strong storm as early as September 13, 2022 to impact the coast (NWS Fairbanks on Twitter), calling for significant flooding threat and wind gusts up to 90 mph. Offshore wave heights were expected to reach 54 ft, bringing potentially 8 ft of high water into the coast (Bill Chappell 2022). The NWS coastal flooding and high wind warnings were previously shown in **Figure 1.3** and **Figure 1.4**, respectively (Section 1.3 of this report). **Figures 2.2** and **2.3** show weather forecasts on September 16 for high wave height and wind speeds on September 17, respectively.

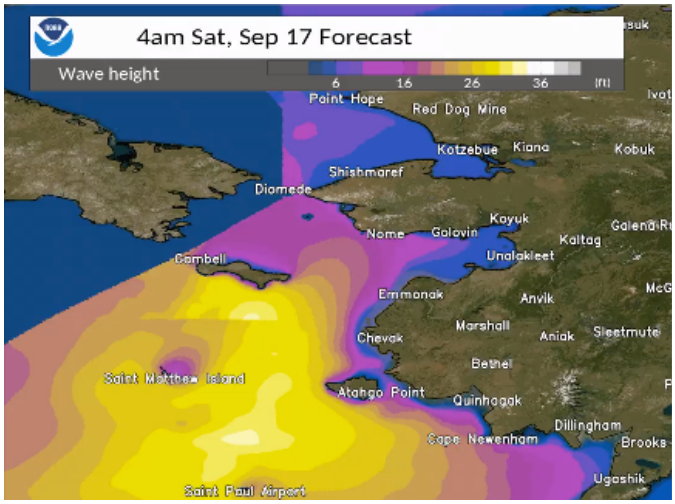


**Figure 2.2**: September 16, 2022 wave height forecast for early morning September 17, 2022 (source: NWS 2022d)

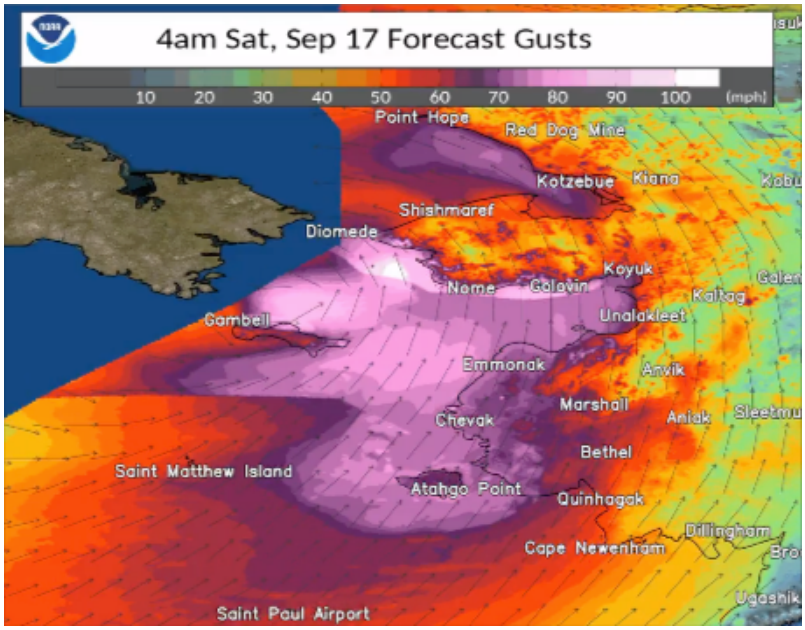


**Figure 2.3**: September 16, 2022 wind gusts forecast for early morning September 17,2022 (source: NWS 2022e)

Merbok made landfall on the coast of Western Alaska on September 17, 2022. The storm impacted Western Alaska with wind gusts as high as 90 mph and historic high water surge levels of 10.5 feet in Nome, the highest sincea major storm in 1974.

**Figure 2.4** shows satellite imagery of post-typhoon Merbok as it reached Alaska. Low-pressure systems with such high wind speeds are considered rare within the Bering Sea during September. Typhoon Merbok formed in a region where typhoons do not typically form due to colder ocean temperatures, however ocean waters in the region were the warmest on record (for this time of year), going back 100 years (Rick Thoman 2022a), as shown in **Figure 2.5**. It is highly likely that Merbok was able to form as a result of climate change and rising ocean temperatures.

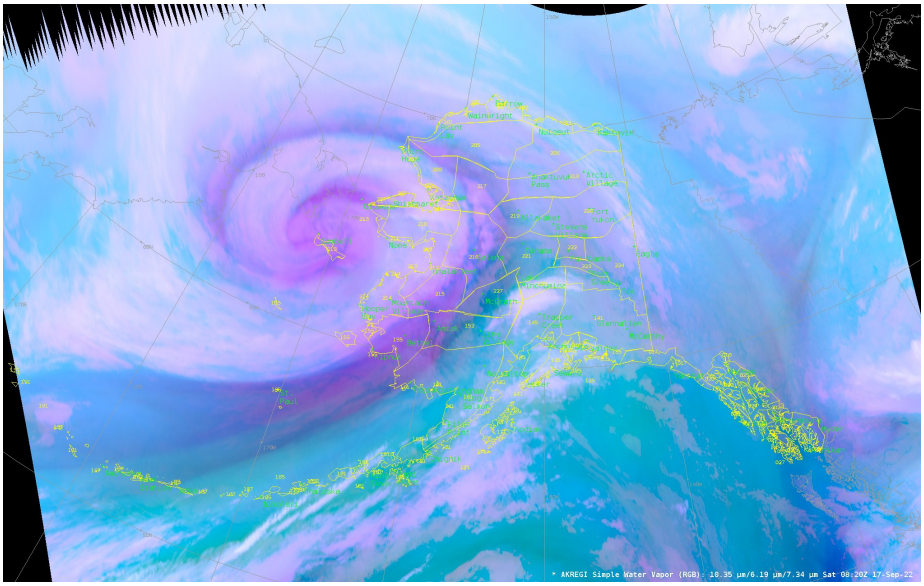

**Figure 2.4**: Satellite imagery of low-pressure system (Merbok) reaching Alaska September 17, 2022 (source: NWS 2022f)

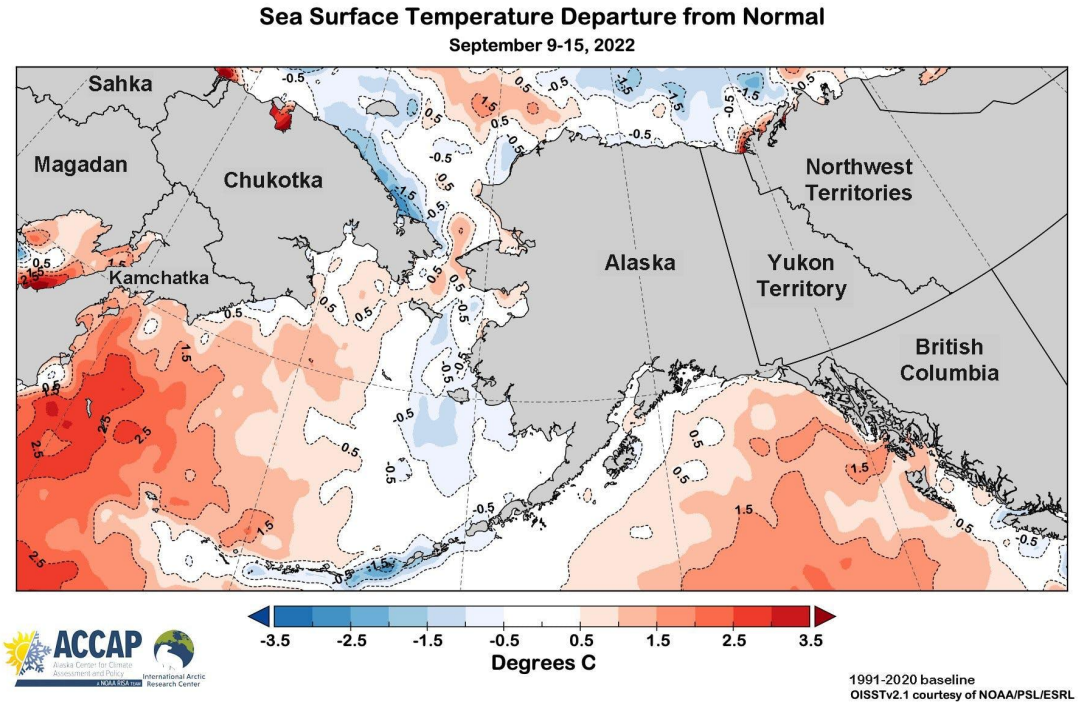


**Figure 2.5**: Sea surface temperatures September 9-14 (source: Rick Thoman 2022a)

While Typhoon Merbok was no longer at typhoon strength when it reached Alaska, warmer than normal ocean waters sustained some of the storm's strength.

## 2.2. Wind Field

Surface level winds due to post-tropical Merbok were expected to reach at least 58 mph (50 knots) as shown in **Figure 2.6**. Peak wind gusts of 91 mph were observed at Cape Romanzof (NWS 2022a) and 67 mph at Nome. A buoy, 310 nautical miles north of Adak, AK also measured maximum gusts of 75 mph (65 knots) (**Figure 2.7**).

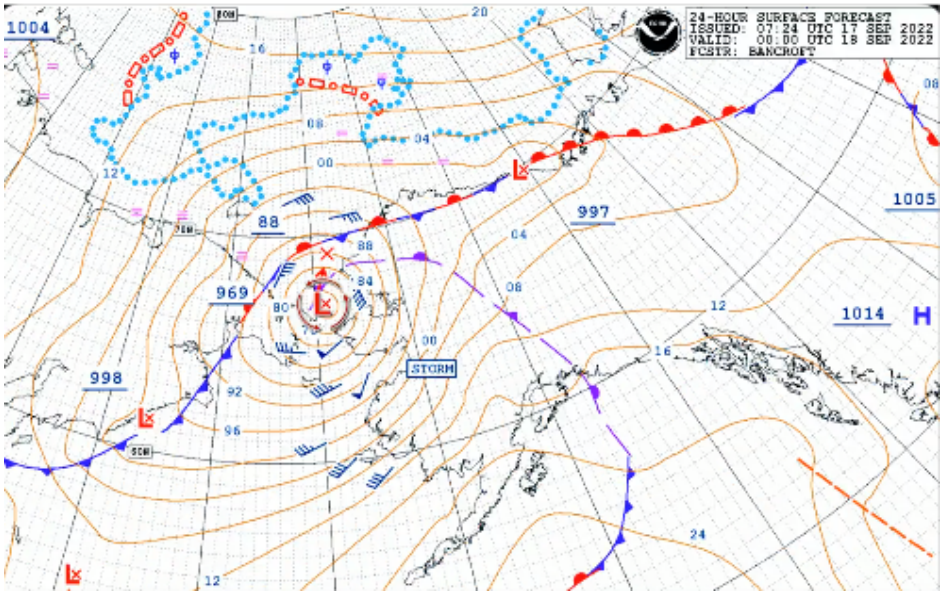


**Figure 2.6**: Surface level wind, pressure, and front locations (source: NWS 2022g)

Reports on Merbok commonly compared the event to the 2011 Bering Sea Superstorm, which occured in November of 2011 and resulted in 89 mph wind gusts (Doug O'Harra 2022). The September 17, 2022 event did not exceed this record.

## 2.3. Storm Surge and Coastal Flooding

Post-Tropical Cyclone Merbok was primarily a storm-surge event, bringing high water levels ashore. Forecasts on September 16th were predicting 10 to 13 feet water level above high tide for the evening of September 17th (NWS Fairbanks). A buoy, 310 nautical mile north of Adak, AK, measured wave heights of more than 50 ft (**Figures 2.8** and **2.9**), while a tide gauge in Nome, AK measured an 11-foot tide height (**Figure 2.10**).

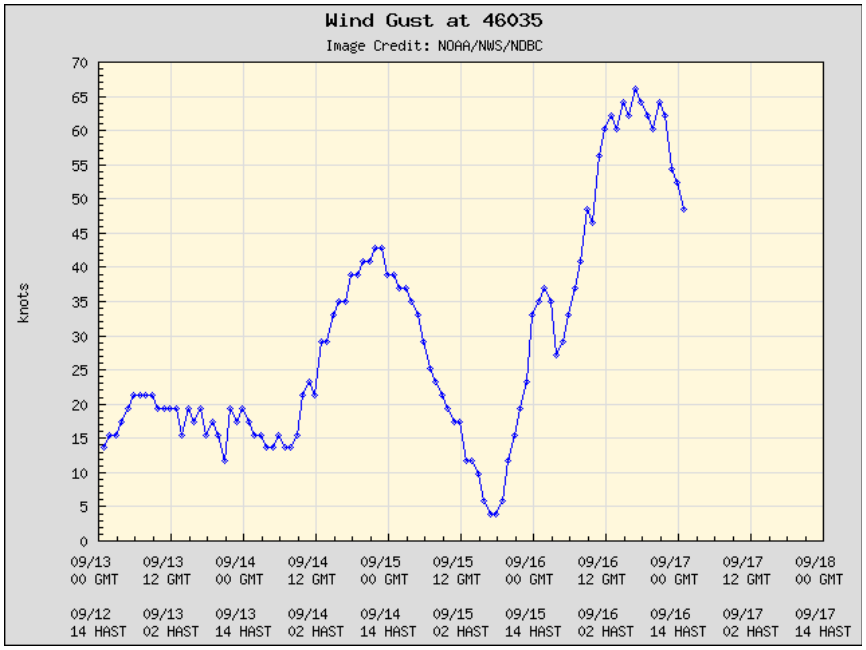


**Figure 2.7**: Buoy 46035 wind speed measurements in knots (source: NWS 2022h)

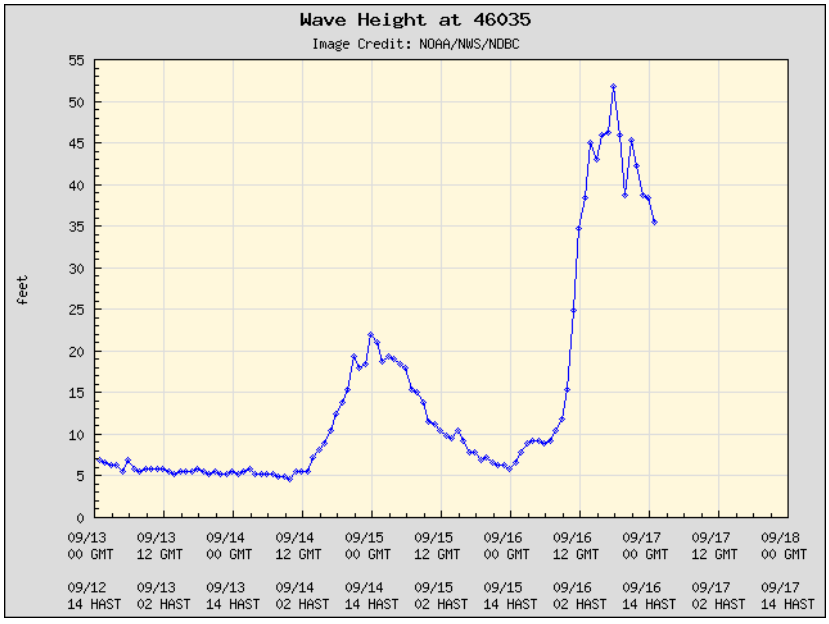


**Figure 2.8**: Buoy 46035 wave height measurements in feet (source: NWS 2022i)

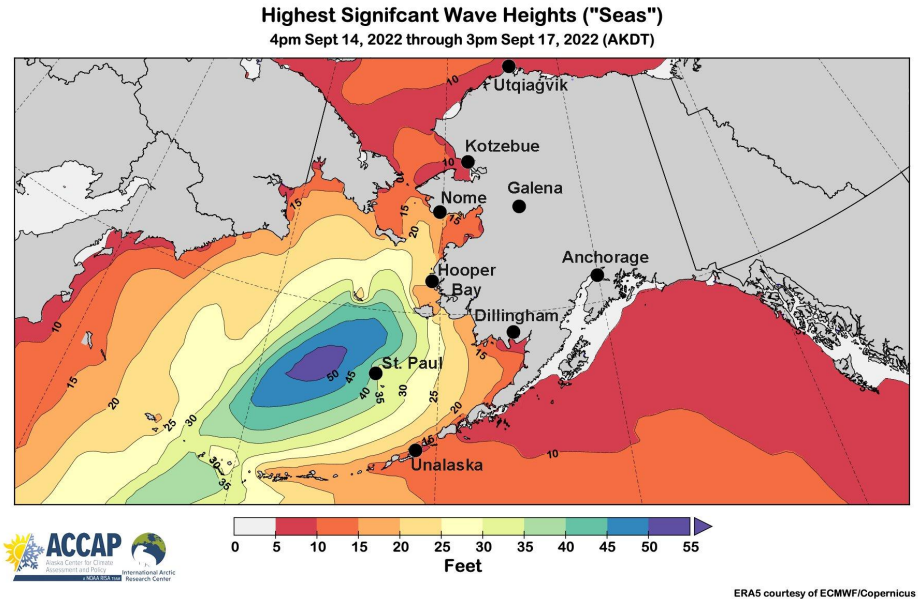


**Figure 2.9**: Maximum significant wave heights (source: Rick Thoman 2022b)

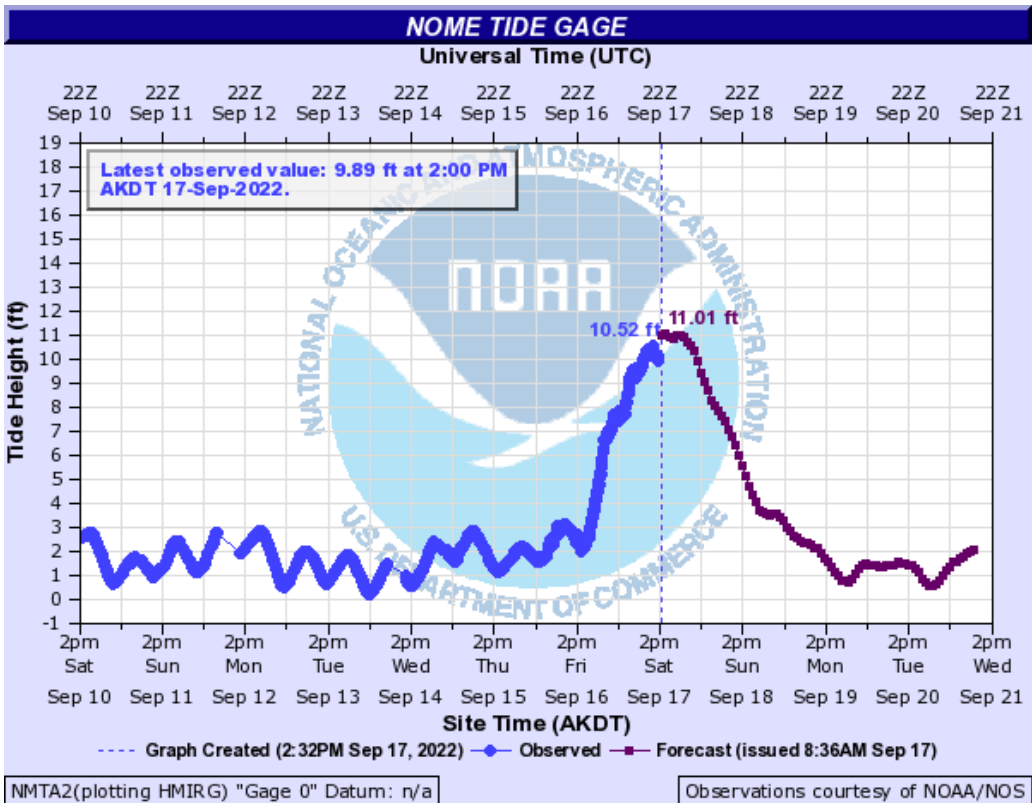


**Figure 2.10**: Tide height measurement in Nome, AK (source: Rick Thoman 2022c)

High water marks reached between 15 to 20 ft in Golovin, over 20 ft in Nome, and between 20 to 25 ft along Shaktoolik, AK (USGS via the Flood Event Viewer). A few locations further north also reported high water marks between 5 to 15 ft. Despite the post-typhoon nature of this storm, the pressure remained just below 970 mbar (as seen in the surface map in **Figure 2.4**) with tropical storm force winds. While the wind from this event did not exceed that of the 2011 Bering Sea Superstorm, these water levels, specifically those recorded in Nome, AK, were the highest recorded since November 1974 (Rick Thoman 2022a). The combination of these meteorological factors along with the lack of sea ice this time of year, which can serve to dampen waves, led to significant flooding along the coastline. As oceans warm due to climate change, the presence of sea ice has diminished. This trend can be expected to continue as oceans continue to warm (Rick Thoman 2022a).

## 3. Local Codes and Construction Practices

Alaska has a statewide building code, as part of the Alaska Administrative Code, that incorporates the International Building Code (IBC) by reference, as well as other model codes for fire, fuel gas, mechanical, and electrical (Alaska Department of Public Safety, Fire and Life Safety). The current version referenced in the state code is the 2012 IBC (Alaska Department of Public Safety, Building Code) adopted in 2017, but an update to the 2021 IBC is in the process of being adopted (Alaska Department of Public Safety, 2022 Building Code Update). Alaska's building code was previously updated in 2012, 2007, 2004, 2001, 1981, 1971, and 1969 (Alaska Department of Public Safety, Building Code).

The state code applies to commercial, institutional, government, and multifamily residential buildings with four or more units; there is no statewide residential code covering single-family homes or smaller multifamily residential buildings. Some jurisdictions, such as Anchorage, adopt local amendments and may have adopted a different version of the IBC than the State (see Anchorage Municipal Code 2020 for an example of Anchorage amendments to adopt the 2018 IBC).

Much of the affected geographic area is located in federal census areas rather than an organized borough, with the northern part of the affected area in the Northwest Arctic and North Slope Boroughs. These boroughs do not have separate building codes, and along with the federal census areas, use the state code.

Buildings in affected areas are primarily single-family wood frame residences not covered by the state building code. Villages and small cities in the region have a modest number of schools, health facilities, government buildings, commercial buildings, and other community buildings. Because the affected area is not connected to the main highway or rail systems in the rest of the state, construction materials must be sourced locally or arrive via marine, river or air transport. Transportation expenses limit the construction types that are economically feasible.

ASCE 7-10 design wind speeds in the affected area were approximately 140-158 mph for Risk Category II and 150-168 mph for Risk Category III, as shown by the maps in **Figure 3.1**. Flood hazard maps are available in the ASCE 7 Hazard Tool only for the largest communities in the region, such as Nome (**Figure 3.2**) and Bethel.

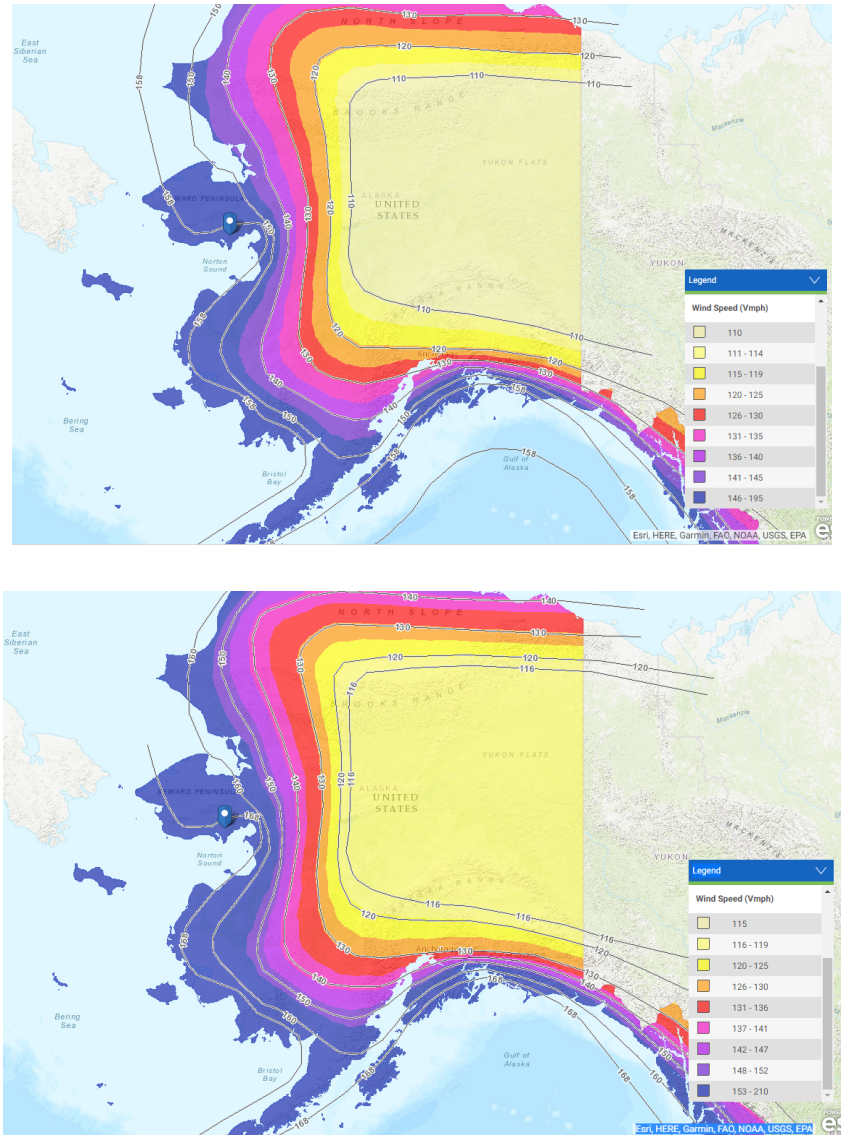


**Figure 3.1**. ASCE 7-10 design wind speeds, Risk Category II (top) and III (bottom) (source: ASCE 7 Hazard Tool)

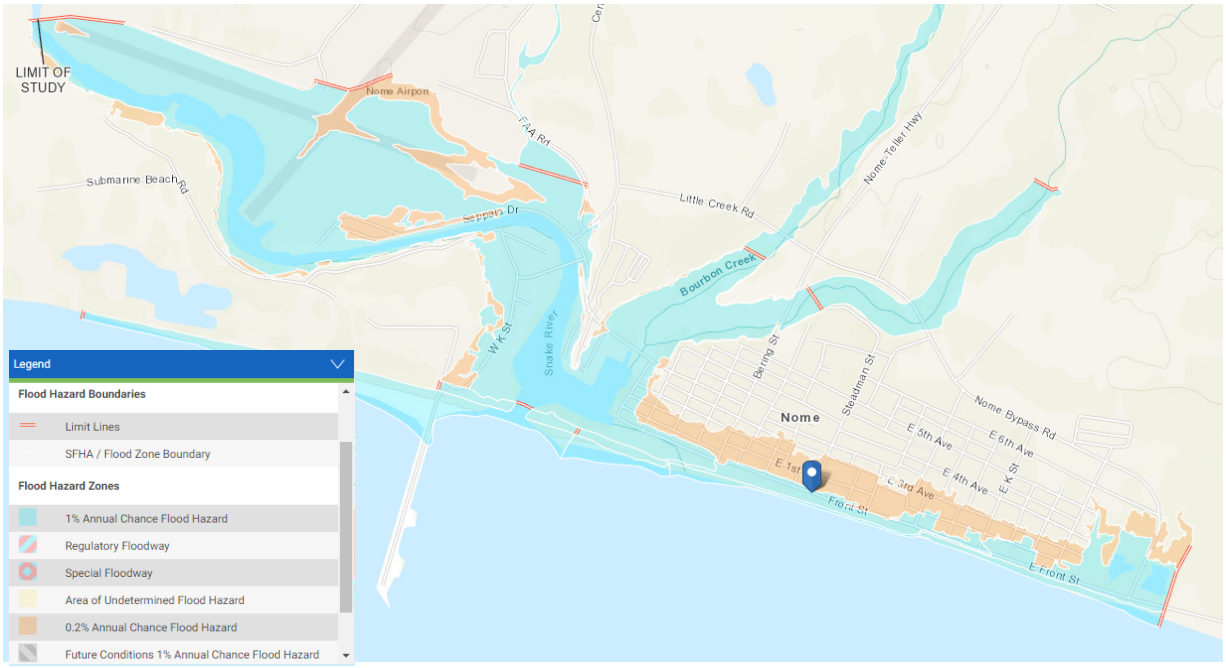


**Figure 3.2**. Mapped flood hazard zones, Nome (source: ASCE 7 Hazard Tool)

## 4. Building Performance

**Tables 4.1** and **4.2** provide a synthesis of the typical performance of buildings in this event, organized by occupancy and geography. The subsections that follow present notable case studies. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe, to access a richer collection of georeferenced visual evidence cataloged by occupancy.

**Table 4.1.** Summary of Building Performance by Occupancy

| | |
|---|---|
| Single-Family Residential Buildings | Local officials reported damage to 69 homes as of September 20, 2022 (NOAA Incident News 2022). The typhoon surge knocked an unoccupied home off its foundation in Nome that floated along the Snake River (Schwing and Baker 2022). Multiple homes in Chevak sustained wind damage to roofs resulting in water intrusion (Emily Schwing 2022e). In Hooper Bay three houses moved off their foundation due to storm surge and multiple others experienced door, window, and roof damage due to high winds (Will McCarthy 2022a; Ervin Chayalkun 2022). Three homes were pulled off their foundation in Golovin and multiple others were flooded and left with sheets of sand, silt and debris (Boots et al. 2022; KTOO 2022; Alaska DHS & EM 2022b). |

| | |
|---|---|
| Multi-Family Residential Buildings | No observations available for this class at the time of this report. |
| Commercial Buildings | Commercial buildings were inundated in downtown Nome (Thiessen and Gecker 2022). Bering Sea Bar & Grill in Nome was destroyed by fire (Frey and Bartosik 2022). |
| Healthcare/Medical Facilities | No observations available for this class at the time of this report. |
| Schools | No observations available for this class at the time of this report. |
| Government Facilities | No observations available for this class at the time of this report. |
| Mobile/Manufactured Homes | No observations available for this class at the time of this report. |
| Critical Facilities | No observations available for this class at the time of this report. |
| Historical Buildings | No observations available for this class at the time of this report. |
| Religious Institutions | No observations available for this class at the time of this report. |

| **Table 4.2.** Summary of Building Performance by Geography | |
|---|---|
| Nome | An unoccupied home was pulled of its foundation and washed away in the Snake River (Schwing and Baker 2022) |
| Golovin | Three homes moved off their foundations and another destroyed in Golovin (Schwing and Baker 2022) |
| Hooper Bay | At least 3 houses moved off their foundations (KTOO 2022) |

## 5. Infrastructure Performance

**Tables 5.1** and **5.2** provide a synthesis of the typical performance of other infrastructure classes during this event, organized by class and geography. The subsections that follow present notable case studies. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe, to access a richer collection of georeferenced visual evidence cataloged by infrastructure class. Interested readers may also consult the Outage/Restoration Database, curated with this report in DesignSafe, for a chronology of disruption/outage/restoration data for power, telecommunication, and transportation networks.

| **Table 5.1.** Summary of Performance by Infrastructure Class |
|---|

| | |
|---|---|
| Power and Telecommunications Infrastructure | Power outages and/or damage to power systems was reported in nine communities including Hooper Bay, Chevak, Emmonak, Mountain Village, Toksook Bay, Holy Cross, Nunapitchuk, Bethel, and Koyuk with most due to storm surge (Alaska Public Media 2022). Chevak lost power for three days, leading to impacts on the water treatment plant and a boil water notice (Emily Schwing 2022a).Telecommunication was impacted in Chevak, Elim, Golovin, Hooper Bay, Newtok, White Mountain, Shatoolik, Stebbins, St. George, and Unalakleet. Internet service was also out in Emmonak, Greyling, and Kwigllingok, but was quickly restored (Zacharia et al. 2022). A radio tower was toppled in Chevak (Emily Schwing 2022d). |
| Airports | Several airports experienced erosion, damage to runway lights and FAA weather equipment. These include erosion to the west end of Scammon Bay airport, broken runway lights, damaged supplemental wind cones and damage of bi-fold snow removal equipment building doors in Chevak airport, and debris accumulation and damaged lights in the west runway of Shaktoolik airport. Moreover, extensive damage to the Automated Weather Operating System (AWOS) was observed in multiple airports including Unalakleet, Nunapitchuk, White Mountain, Chevac, Golovin, and Hooper Bay (Alaska DOT & PF 2022). |
| Roads & Bridges | Extensive damage due to erosion was reported in Nome-Council highway, Nome Front Street, and Shishmaref Landfill Access Road (Alaska DOT&PF 2022). Up to 10 miles of the Nome-Council highway was totally destroyed (Mark Thiessen 2022). Safety Sound bridge on the Nome-Council Road was found to fare well though abutments experienced erosion (Alaska DOT&PF 2022). |
| Port Facilities | United States Army Corps of Engineers (USACE) checked the Port in Nome and found no issues with safe operation (Office of Governor MIKE DUNLEAVY 2022b). |
| Agricultural | Dozens of fishing boats, and hunting and fishing camps were damaged in Chevak. Residents also reported losing fishing nets, drying houses and racks, gas cans, life jackets, and other equipment essential to indigenous subsistence life of Western Alaska (Emily Schwing 2022b; Emily Schwing 2022d). |

### 5.1. Power Outages & Restoration

Power and water systems serving the region's many small cities and villages are typically local facilities without connections to other locations. Alaska Village Electric Cooperative (AVEC),

which serves 58 communities, reported outages and/or damage to power systems on 9/17 in nine communities including Hooper Bay, Chevak, Emmonak, Mountain Village, Toksook Bay, Holy Cross, Nunapitchuk, Bethel, and Koyuk with most due to storm surge (Alaska Public Media 2022). Chevak lost power for three days, leading to impacts on the water treatment plant and a boil water notice (Emily Schwing 2022a).

**Table 5.3.** Extent of Power Outage and Restoration (at time of report release)

| Location | Peak Outage | Restoration Status |
|---|---|---|
| Chevak | Village power completely out for 3 days | Power restored at time of report |
| Hooper Bay, Emmonak, Mountain Village, Toksook Bay, Holy Cross, Nunapitchuk, Bethel, Koyuk | Partial outages reported 9/17 | Power appears restored at time of report |
| Source: Alaska Public Media (2022) | | |

## 5.2. Transportation Disruptions & Restoration

Few roads exist in the affected region, as **Figure 5.1** shows. The portion of the Nome-Council Highway along Safety Sound barrier islands experienced severe damage to the roadbed (bridges were apparently structurally undamaged), which was being regraded and repaired at the time this report was written.

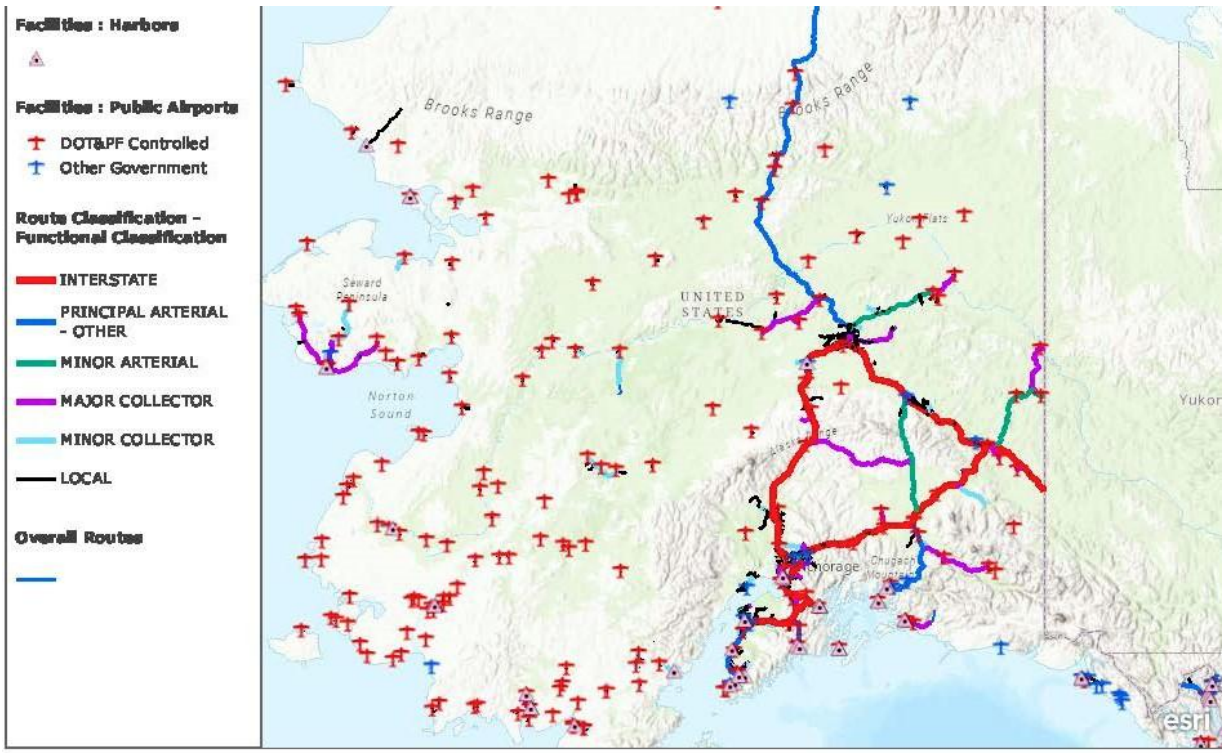


**Figure 5.1:** Alaska highways, airports and harbors (source: [Alaska DOT&PF Roadway Data portal)]

# 6. Geotechnical Performance

This section provides a written synthesis of the geotechnical issues noted during this event. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe, to access a richer collection of georeferenced visual evidence.

The State of Alaska damage assessments indicate a number of communities that experienced significant coastal erosion, including Shaktoolik, Nome, Newtok, Scammon Bay, Tununak, and Elim (Alaska DOT&PF 2022). Absence of sea ice in the Bering Sea resulted in full storm wave pounding the coastline and may have contributed to the extensive erosion (Rick Thoman 2022a). The erosion is further exacerbated by melting permafrost, making the soil more erodible (Yereth Rosen 2022).

Erosion affected airport runways (Scammon Bay), and roadway embankments and bridge abutments of Nome-Council Highway (Alaska DOT&PF 2022). The section of the 70 mile long Nome-Council highway (see **Figure 6.1, 6.2**) that runs along barrier islands separating Safety Sound from Norton Sound was heavily damaged, with up to 10 miles of the highway totally destroyed (Mark Thiessen 2022). Per DOT&PF, crews checked the Safety Sound bridge on the Nome-Council Road and determined the bridge itself (**Figure 6.3**) is intact despite abutment damage. Shaktoolik's protective berm was also significantly eroded, as discussed under coastal protective systems. Severe coastal erosion was also observed in Golovin (**Figure 6.4**) and Elim (**Figure 6.5**).

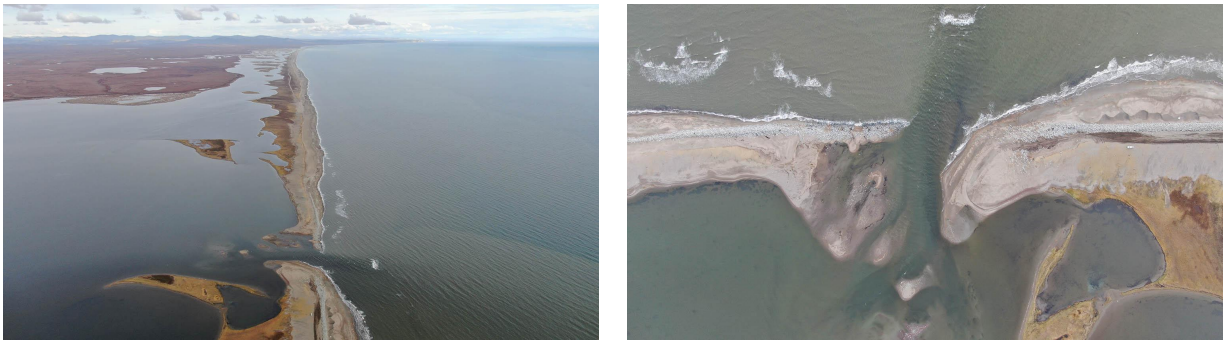

**Figure 6.1**: Significant ocean breach of the Nome-Council Highway (source: Alaska DOT&PF 2022).

**Figure 6.2**: Coastal erosion along Nome-Council Highway (source: Bering Strait School District, Alaska DHS & EM 2022b)

**Figure 6.3**: Bridge on Nome-Council Highway with some apparent abutment damage (source: Alaska DOT&PF 2022)

Erosion caused by storm waves halved the remaining land between Newtok school and the Ningliq River, eroding approximately 40 feet. Newtok is at known risk of flooding and erosion,

and after a decision to relocate 20 years ago, the community is in the process of being moved to a new village site on higher ground at Mertarvik, nine miles down the river on Nelson Island (Emily Schwing 2022c).

**Figure 6.4**: Coastal erosion in Golovin area (source: Alaska DOT&PF 2022)

**Figure 6.5**: Coastal erosion in Elim (source: Alaska DOT&PF 2022)

# 7. Coastal Protective Systems Performance

This section provides a written synthesis of impacts to manmade (levees, seawalls, etc.) and natural coastal protective systems that had potential impact on the performance of the built environment in this event. Readers may consult the imagery compiled in the accompanying Media Repository, curated with this report in DesignSafe, to access a richer collection of georeferenced visual evidence.

The Shaktoolik berm (**Figures 6.6** and **6.7)**, which protected the community from the sea, was eroded significantly by the storm (Stremple and Juneau 2022). The Shaktoolik community of 210 residents, opted against a relocation plan a year ago, estimated to cost $290 million, and opted in favor of a beach-protection berm (Adapt Alaska) constructed with gravel and driftwood at an estimated cost of under $1 million(Yereth Rosen 2022). At the time of writing, United States Army Corps of Engineers (USACE) Engineers were evaluating the Nome Seawall and Shishmaref Bank Protection projects (Office of Governor MIKE DUNLEAVY 2022b).


(a) Before (b) After

**Figure 6.6**: (a) Before and (b) after views of the Shaktoolik berm (source: Stremple and Juneau 2022)

**Figure 6.7**: Remnants of the Shaktoolik berm (source: Bering Strait School District, Alaska DHS & EM 2022b)

Hooper Bay lost to coastal erosion a significant amount of the rows of natural dunes (**Figure 6.8**) that protect the village. According to a local estimate the community lost approximately 300 feet of coastlinecoastaline (Will McCarthy 2022b).

**Figure 6.8**: A partially eroded dune in Hooper bay(source: Will McCarthy 2022b )

## 8. Recommended Response Strategy

Based on the information gathered by the VAST and reported in this Preliminary Virtual Reconnaissance Report (PVRR), StEER offers the following recommendations for future study.

- Alaska lacks a reliable storm surge model. There are only four year-round water-level stations maintained in western and Arctic Alaska by the National Oceanic and Atmospheric Administration. Only two of those stations, located at Nome and Unalakleet (Western Alaska Storm Models), are found in the wide swath of western Alaska hit by the storm. In addition, more than 70% of Alaska's coastal waters remained unmapped as of 2021 (Office of Coastal Survey 2021). Near shore bathymetry information and long-term water level monitoring are paramount for the development of reliable storm surge models.

- Typhoon Merbok was a classic case of large-scale weather models forecasting a potential hazard far in advance (Rick Thoman 2022a) and by September 12 Merbok's storm track was clear (Brian Brettschneider 2022). Preparing for a storm is a massive undertaking and it takes even longer to respond for isolated communities like those in rural Alaska. Unfortunately, communities were not briefed until a day or two days before the storm and there was not enough time for them to fully prepare.

- Coastal flooding and erosion caused by Merbok has increased discourse in multiple communities already known to be at risk (including Newtok, Hooper Bay, Napakiak, Kivalina, and Shaktoolik) regarding vulnerability to future storms and implementing strategies to reduce risk, including relocation, community retreat from low-lying areas, and coastal protection. Future storms will test implemented strategies and provide opportunities to evaluate their performance in Alaska's hazard and climate context.

- As the climate continues to change and ocean waters warm, storm surge impact risks will also change. Instrumentation and locations of interest will need to adapt to encompass more regions, particularly outside of historical storm regions and seasons. While Alaska has historically been subjected to coastal storms, and this one may not have caused significant structural damage, consideration should be given to how this may change in the coming decades.

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