Report of Investigation 2021-1E Golovin

# COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—GOLOVIN

Richard M. Buzard and Jacquelyn R. Overbeck

Photo from Baldy Hill looking southwest at Golovin during the October 13, 2017, flood. Photo: Toby Anungazuk, Jr.

Published by
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
2021

# COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—GOLOVIN

Richard M. Buzard and Jacquelyn R. Overbeck

Report of Investigation 2021-1E Golovin

State of Alaska
Department of Natural Resources
Division of Geological & Geophysical Surveys

**STATE OF ALASKA**
Mike Dunleavy, Governor

**DEPARTMENT OF NATURAL RESOURCES**
Corri A. Feige, Commissioner

**DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS**
Steve Masterman, State Geologist and Director

Publications produced by the Division of Geological & Geophysical Surveys (DGGS) are available for free download from the DGGS website (dggs.alaska.gov). Publications on hard-copy or digital media can be examined or purchased in the Fairbanks office:

Alaska Division of Geological & Geophysical Surveys
3354 College Rd., Fairbanks, Alaska 99709-3707
Phone: (907) 451-5010 Fax (907) 451-5050
dggspubs@alaska.gov | dggs.alaska.gov

**DGGS publications are also available at:**
Alaska State Library,
Historical Collections & Talking Book Center
395 Whittier Street
Juneau, Alaska 99811

Alaska Resource Library and Information Services (ARLIS)
3150 C Street, Suite 100
Anchorage, Alaska 99503

**Suggested citation:**
Buzard, R.M., Overbeck, J.R., Chriest, Jonathan, Endres, Karen, and Plumb, E.W., 2021, Coastal flood impact assessments for Alaska communities: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2021-1E. https://doi.org/10.14509/30855

# Contents



# Figures



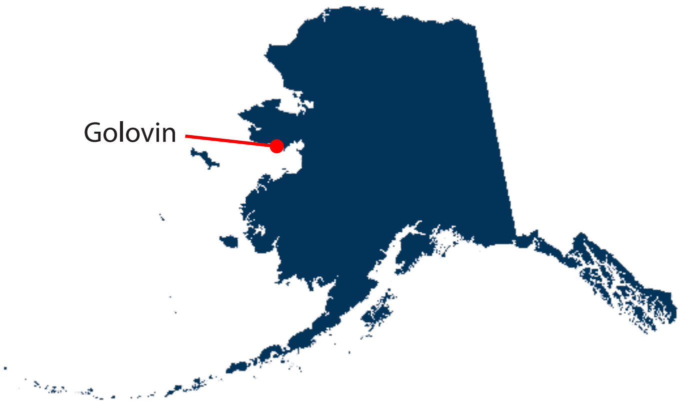
# Tables



# Appendices

# COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—GOLOVIN

Richard M. Buzard and Jacquelyn R. Overbeck




## OVERVIEW

This report is an assessment of the historical flood record and flood impact levels for the community of Golovin, Alaska. Methods used to evaluate historical floods and designate flood impact elevations (minor, moderate, or major; as defined by the National Weather Service) are described in detail in an overview report (Buzard and others, 2021). This community-specific report has three sections: data description, historical flood record, and flood impact categories. Flood and infrastructure heights are relative to the local mean higher high water (MHHW) datum. All estimate uncertainties are reported to the 95 percent confidence interval. Quoted text from the sources used to estimate storm heights can be found in Appendix A, and Appendix B has tables and figures used to determine flood category heights.

## SUMMARY

Flood categories and related infrastructure heights are listed in table 1, and estimated storm heights are listed in table 2. Most infrastructure was not considered subject to wave runup because storms typically do not overtop the natural berm on the south side of the community. In 2006, Antone Street was raised and connected to a man-made berm to prevent flooding from the north side. There is a break in the berm for beach access, which the community fills in for incoming storms. This effort has reduced flood impacts in recent years. If the soil berm had existed during four of the historically major events, these storms may have only caused moderate impacts.

Although historical accounts of coastal flooding date back to 1900, the first declared disaster at Golovin occurred in October 1992 (City of Golovin, 2015). There have been six state or federal disaster declarations for coastal flooding. From 1900 to February 2019, Golovin may have experienced at least 23 significant coastal flood events from storm surge. Of these reported events, we estimated the peak still water elevations of 14 storms. At the time they occurred, these storms caused six minor, one moderate, and seven major flood events. If these storms had occurred with Golovin's current infrastructure (including the berm), they would have resulted in six minor, five moderate, and three major flood events (table 2). The highest recorded storm occurred on October 5, 1913, reaching a still water height of 12 ± 2 ft MHHW. Water may have reached two to four feet higher in areas subject to wave runup.

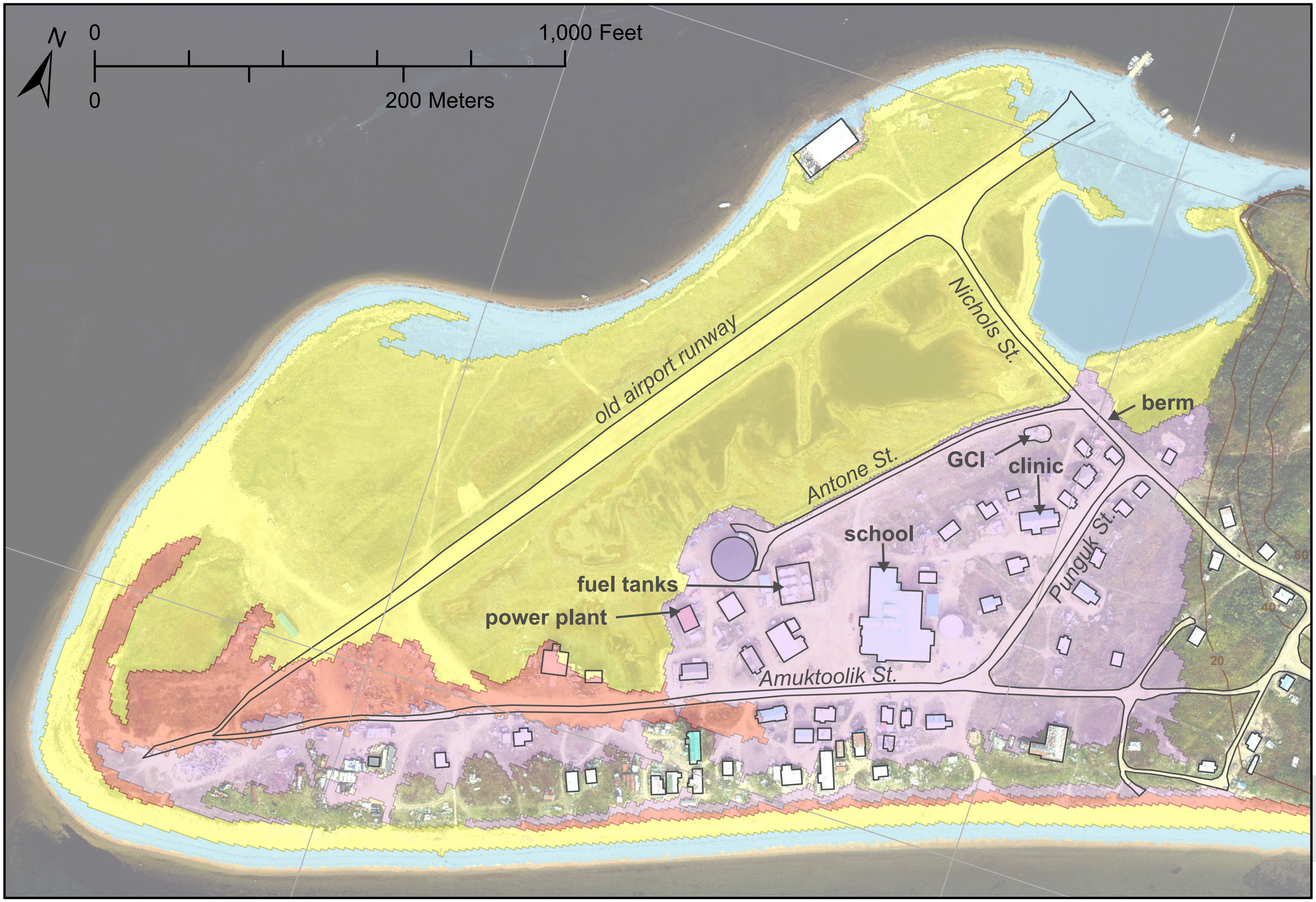
## DATA

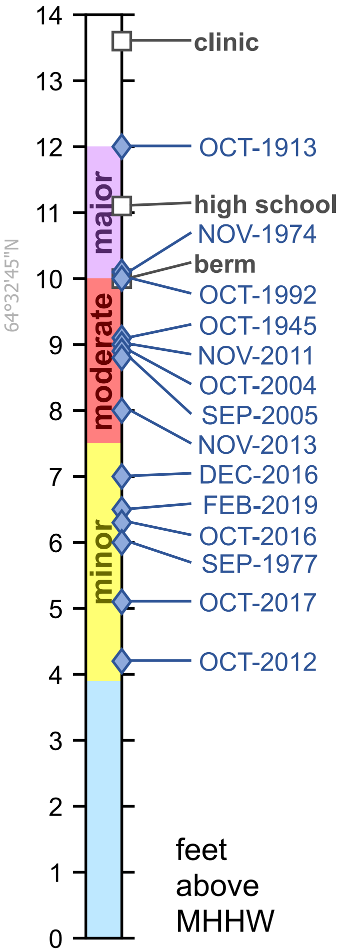
Mapped data were used to interpret flood elevations from historical photographs and accounts. Data that were available and used for the community of Golovin are described in this section.

[1]Alaska Division of Geological & Geophysical Surveys, 3354 College Rd., Fairbanks, Alaska 99709-3707.

# Coastal Flood Impact Map
## Golovin, Alaska

REPORT OF INVESTIGATION 2021-1E
Buzard and others, 2021
GOLOVIN




To calculate height above
MLLW: add 1.7 ft
NAVD88: add 4.6 ft

Projection: NAD 1983 2011 UTM Zone 3N
Orthoimagery available from elevation.alaska.gov
Contours drawn at 20 ft intervals above MHHW
Houses or infrastructure may have moved since DCRA linework was completed

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

*The State of Alaska makes no expressed or implied warranties (including warranties for merchantability and fitness) with respect to the character, functions, or capabilities of the electronic data or products or their appropriateness for any user's purposes. In no event will the State of Alaska be liable for any incidental, indirect, special, consequential, or other damages suffered by the user or any other person or entity whether from the use of the electronic services or products or any failure thereof or otherwise. In no event will the State of Alaska's liability to the Requestor or anyone else exceed the fee paid for the electronic service or product.*

website: dggs.alaska.gov

**Major Flooding** is defined to have extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary.

**Moderate Flooding** is defined to have some inundation of structures and roads near the water. Some evacuations of people and/or transfer of property to higher elevations may be necessary.

**Minor Flooding** is defined to have minimal or no property damage, but possibly some public threat.


*This work is part of the Digital Coast Fellowship project: Bringing Alaska to the Digital Coast. The analysis was paid for by the National Oceanic and Atmospheric Administration Office for Coastal Management, and the State of Alaska.*

**Table 1.** Summary of infrastructure heights and flood categories. Infrastructure that may be subject to wave runup is indicated. Purple = major, red = moderate, yellow = minor. Gray represents infrastructure not expected to be impacted by coastal flooding.

| | Elevation Feature | Elevation (ft MHHW) | Vertical Uncertainty (ft) | Subject to Wave Runup |
|---|---|---|---|---|
| Other | Airstrip | 31.0 | 5.0 | |
| | Evacuation area | 80.0 | 5.0 | |
| | Wastewater facility | 60.0 | 5.0 | |
| Major | *Clinic first floor | 13.6 | 0.5 | |
| | Dexter Roadhouse beach side | 13.0 | 1.0 | |
| | Highest recorded storm (still water) | 12.0 | 2.0 | |
| | *Recommended building height | 12.0 | 0.5 | |
| | *High school front door sill | 11.1 | 0.5 | |
| | Drinking water | 10.5 | 0.7 | |
| | Several buildings | 10.5 | 0.7 | |
| | Fuel tanks | 10.1 | 0.3 | |
| | **Major (minimum berm height)** | **10.0** | **1.0** | |
| Moderate | Lowest residences | 8.8 | 1.2 | |
| | Roads in town | 7.5 | 0.7 | |
| | **Moderate** | **7.5** | **0.7** | |
| Minor | Lowest building | 7.0 | 0.3 | |
| | Beach property | 3.9 | 0.7 | |
| | **Minor** | **3.9** | **0.7** | |

*U.S. Army Corps of Engineers (1994)

**Table 2.** Summary of estimated historical storm heights. Flood categories are included for reference: purple = major, red = moderate, yellow = minor. The categories are based on current infrastructure conditions, not the conditions when the storm occurred.

**Estimated Storms**

| Storm | Elevation (ft MHHW) | Vertical Uncertainty (ft) |
|---|---|---|
| 1913-OCT-05 | 12.0 | 2.0 |
| 1974-NOV-10 | 10.1 | 0.9 |
| 1992-OCT-05 | 10.0 | 0.9 |
| 1945-OCT-28 | 9.1 | 1.4 |
| 2011-NOV-08 | 9.0 | 2.0 |
| 2004-OCT-19 | 8.9 | 1.1 |
| 2005-SEP-22 | 8.8 | 0.8 |
| 2013-NOV-09 | 8.0 | 3.0 |
| 2016-DEC-30 | 7.0 | 1.2 |
| 2019-FEB-11 | 6.5 | 1.2 |
| 2016-OCT-29 | 6.3 | 0.7 |
| 1977-SEP-12 | 6.0 | 2.0 |
| 2017-OCT-13 | 5.1 | 0.7 |
| 2012-OCT-05 | 4.2 | 1.3 |

**Not Estimated Storms**

| Storm | Elevation (ft MHHW) | Vertical Uncertainty (ft) |
|---|---|---|
| 1900-SEP-12 | — | — |
| 1946-OCT-25 | — | — |
| 1960-OCT-02 | — | — |
| 1970-AUG | — | — |
| 2002-OCT-08 | — | — |
| 2003-SEP | — | — |
| 2003-NOV-01 | — | — |
| 2008-JAN | — | — |
| 2009-NOV-11 | — | — |

## Digital Elevation Models and Orthoimagery

Two digital elevation models were available for Golovin (table 3). A digital surface model (DSM) and orthoimagery were collected in 2015 (Overbeck and others, 2017). In 2013, a lidar bare-earth digital elevation model (DEM) was collected (Southerland and Kinsman, 2014). Both elevation models were used to analyze historical flood heights.

**Table 3.** Specifications of elevation models available for Golovin.

| | Photogrammetric DSM | Lidar DEM |
|---|---|---|
| Collection date | 8/23/2015 | 9/5/2013 |
| Elevation type | Surface | Bare earth |
| Ground sample distance | 0.20 m | 1.00 m |
| Vertical accuracy | 0.19 m | 0.21 m |
| Vertical datum | NAVD88 (GEOID12B) | NAVD88 (GEOID12A) |

## First Floor and High Water Mark Survey

The U. S. Army Corps of Engineers (USACE) performed a survey of first floor elevations and high water mark estimates using a temporary benchmark (TBM) survey in 1994 (USACE, 1994). The TBM survey benchmark USLM monument 3651 on Baldy Hill was used as the local datum to which elevations were measured. Subsequently, the TBM benchmark was measured using Global Navigation Satellite System (GNSS) surveys that have been shared via the NOAA National Geodetic Survey (NGS) Online Positioning User Service (NGS, 2019). This allows the USACE (1994) survey to be referenced relative to the DSM and DEM. The first shared GNSS occupation of the benchmark was on July 27, 2013; The benchmark was considered "Most reliable; expected to hold position well." We used this GNSS observation to convert the TBM survey into the current tidal datum (table 4). Since the USACE (1994) survey was reported in decimal feet, but the survey methods were not published and features may have changed over time, a conservative uncertainty of 0.5 ft was assigned.

## Tidal Datum

Water level data were collected using a Solinst pressure transducer between July and October 2012 and corrected for atmospheric pressure with measurements from the local airport (Overbeck and others, 2015). Local tidal datums were calculated from these measurements using the Tidal Datum Tool of John Oswald and Associates, LLC (2019).

# FLOOD IMPACT CATEGORIES

Flood impact categories are used by the National Weather Service to define and communicate flood risk to the public. The categories are designated as minor, moderate, and major. A flood advisory is issued when a storm is forecast to cause minor flooding, while a flood warning is issued for moderate or major flooding. Definitions of minor, moderate, and major flooding are provided below followed by the information used to establish the elevation thresholds for each category at Golovin. Elevation thresholds and locations mentioned in the narrative below have been mapped using the DEM (map sheet Golovin, previous page).

**Minor Flooding:** Minimal or no property damage, but possibly some public threat.

**Moderate Flooding:** Some inundation of structures and roads near the water. Some evacuations of people and/or transfer of property to higher elevations may be necessary.

**Major Flooding:** Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary.

Golovin has a unique situation compared to other communities in western Alaska. Golovin residents build a barrier to block storm surge from flooding the lower part of the community. This temporary berm is built on Nichols Street, between Antone Street and the beginning slope of Baldy Hill. On July 14, 2018, DGGS surveyed the existing portions of the temporary berm, averaging 11.9 ± 0.9 ft MHHW. With the berm barrier in place, the elevation model indicated that flood waters could only reach Punguk Street and begin flooding the lower part of the community after exceeding 10.0 ft MHHW.

**Table 4.** USACE (1994) TBM survey of first floor and high water mark heights relative to the school (assigned a height of 100.0 ft), converted to meters above the North American Vertical Datum of 1988 (NAVD88) and feet above MHHW using the USLM monument 3651.

| | TBM (ft) | ft MHHW | m NAVD88 |
|---|---|---|---|
| USLM monument 3651 at the cemetery | 174.4 | 85.5 | 27.47 |
| First floor of the elementary school | 103.5 | 14.6 | 5.85 |
| First floor of the clinic | 102.5 | 13.6 | 5.55 |
| Recommended building elevation | 100.9 | 12.0 | 5.06 |
| Front door sill of the new high school | 100.0 | 11.1 | 4.79 |
| Typical top of the berm around the fuel storage tanks | 99.8 | 10.9 | 4.73 |
| First floor of Post Office | 99.7 | 10.8 | 4.70 |
| High water mark at Maggie Olson's shed | 99.6 | 10.7 | 4.67 |
| 1992 flood (of record), approximated level | 98.9 | 10.0 | 4.45 |
| First floor of the washeteria | 98.0 | 9.1 | 4.18 |

**Table 5.** Tidal datum for Golovin referenced to ft MHHW and m NAVD88.

| Tidal Datum | Abbreviation | ft MHHW | m NAVD88 |
|---|---|---|---|
| Mean Higher High Water | MHHW | 0.00 | 1.41 |
| Mean High Water | MHW | -0.08 | 1.39 |
| Mean Tide Level | MTL | -0.81 | 1.17 |
| Mean Sea Level | MSL | -0.74 | 1.19 |
| Mean Low Water | MLW | -1.55 | 0.94 |
| Mean Lower Low Water | MLLW | -1.73 | 0.89 |
| North American Vertical Datum of 1988 | NAVD88 | -4.64 | 0.00 |

## Other features

**Evacuation center: N/A**

Flooding of an evacuation center would represent major flooding. In Golovin, residents can evacuate to buildings at higher ground from the main spit, up Nichols Street which leads to buildings around 80 ft MHHW.

**Airstrip: N/A**

Loss of access to the airstrip would signify moderate flooding, and a fully flooded airstrip would represent a major flood. The active airstrip in Golovin is well above where coastal flooding could reach. The active airstrip in Golovin is at least 31 ft MHHW, well above where coastal flooding could reach.

**Wastewater facility: N/A**

Flooding of the wastewater facility would represent major flooding. Golovin's sewage lagoon is above 60 ft MHHW, safe from coastal flooding.

## Major flooding: 10 ± 1 ft MHHW

**Fuel tanks: 10.1 ± 0.3 ft MHHW**

The tank farm was fenced and had a short elevated barrier. The base of the barrier was 10.1 ± 0.3 ft MHHW and the top was 12.0 ± 0.3 ft MHHW, measured via GNSS in 2019.

**Several buildings (flooded 1 or more ft): 10.5 ± 0.7 ft MHHW**

The heights of all residential, public, and commercial buildings (as identified by DCCED, 2004) on the spit were analyzed. The maximum ground height under each of the 50 buildings ranged between 6.8 and 13.4 ft MHHW. If the berm did not prevent flooding, 10 buildings (20 percent) would have water underneath them at 8.5 ft MHHW, and 23 buildings (46 percent) at 10.5 ft MHHW. The first floor elevation of the buildings was unknown, but most buildings did not appear to be built higher than 2 to 3 ft off the ground. It was estimated that at 10.5 ft MHHW, 20 percent of buildings could have 2 to 4 ft of water underneath, which would likely have flooded several first floors.

**Drinking water source: 10.5 ± 0.7 ft MHHW**

Four water tanks were identified, two of which were on the spit. The larger water tank near the tank farm and power plant would be reached by a flood of 10.5 ± 0.7 ft MHHW. The smaller water tank near the school was on ground 8.5 ± 0.7 ft MHHW, but would be protected from up to 10.0 ft MHHW of flooding by the berm. There was not enough information to determine at what height flooding would begin to impact these structures. No reports indicated storm impacts to drinking water.

## Moderate flooding: 7.5 ± 0.7 ft MHHW (10.0 ft MHHW with berm)

**Access way to larger parts of town: 7.5 ± 0.7 ft MHHW**

Flood water would begin to cut off access in the lower area of the city after reaching 7.5 ± 0.7 ft MHHW at Punguk Street if the berm was not built.

**Lowest residences (flooded 0 to 1 ft): 8.8 ± 1.2 ft MHHW**

The lowest residences were in the low section of the spit protected by the temporary berm. The lowest residence had a maximum ground height of 6.8 ± 0.7 ft MHHW. Nine residences were on ground between 6.8 and 8.5 ft MHHW, all in the same area around Punguk Street. Information was not found to determine the height of these residences above the ground, so a conservative estimate of 2 ± 1 ft was assigned. This placed the lowest residences being flooded at 8.8 ± 1.2 ft MHHW.

### Minor Flooding: 3.9 ± 0.7 ft MHHW

**Beach property: 3.9 ± 0.7 ft MHHW**

Loading equipment was on the beach road (abandoned airstrip) at 3.9 ± 0.7 ft MHHW (fig. B2). These would have to be moved if a storm were to reach this height, so this was used as the beach property height.

**Lowest building: 7.0 ± 0.3 ft MHHW**

All actively used buildings were either built on the highest ridge of the spit or are behind the berm. The lowest active building was the GCI satellite dish facility. The ground height measured with GNSS was 7.0 ± 0.3 ft MHHW.

**Access road threatened: 7.5 ± 0.7 ft MHHW**

Nichols Street was the access road to reach the beach, and averaged 7.5 ± 0.7 ft MHHW using the DSM (fig. B1).

## HISTORICAL FLOOD RECORD

The historical flood record for Golovin, Alaska, is listed here from the earliest recorded storm to the most recent (up to February 2019). The sources used in evaluating each storm are listed, along with a brief summary of the relevant information found within. This historical information is used to estimate the flood height where possible. This storm record depends on information that is available to the public. As a consequence, it is possible that storm and flood events have occurred that are not reported here. For the direct quotations from each source that were used to evaluate these storms, see Appendix B.

### 1900-SEP-12 | No water level estimate

| Reference | Source information used to estimate water height |
|---|---|
| City of Golovin and URS (2008) | None |

This storm had the fastest wind speed of all known storms (City of Golovin and URS, 2008), and caused “flooding of 3 m” in Nome (Mason and others, 1996). It caused the loss of homes and life in the Norton Sound region. There were no specific impacts cited for Golovin, so the height of this storm could not be estimated.

### 1913-OCT-05 | 12 ± 2 ft MHHW

| Reference | Source information used to estimate water height |
|---|---|
| City of Golovin and URS (2008) | Water reached Dexter building |
| City of Golovin (2015) | Water reached Dexter building |
| USACE (1994) | Water reached Dexter building |

This storm was titled the “Worst Flood Event” for Golovin by USACE (1994). It was mentioned in many sources, but only the hazard mitigation plans and USACE (1994) discussed impacts to Golovin. The date was incorrectly listed as November 5, 1913, in Mason and others (1996).

Water reached the walls of the Dexter Building, but residents were able to keep it from flooding by caulking the building. From measurements using the DEM, the ground height of the building was between 10.6 and 13.1 ft MHHW, averaging 11.8 ft MHHW (standard deviation = 0.6 ft). From the source description, it appeared that the area east of the building was being subjected to direct wave action: "Large wave[s]" were traveling between the building and higher ground (City of Golovin and URS, 2008). The path of highest ground between the building and the hill ranged between 12.4 and 13.4 ft MHHW.

This storm estimate required differentiating wave-runup height from still-water height. Still water may have reached at least 10.8 ft MHHW to begin flooding the lower area of the Dexter building. This area was also subjected to wave runup. The area between the building and the hill was considered the maximum possible still-water height (13.4 ft MHHW). Still water at this location was estimated to have reached 12 ± 2 ft MHHW (table 6).

**Table 6.** Flood parameters used to estimate the October 5, 1913, storm. Uncertainty was calculated using the upper-lower bounds method.

| Feature | Water at Dexter building |
|---|---|
| Feature represents | Highest water |
| Water level type | Still water |
| Estimate of height (ft MHHW) | 10.8 to 13.4 |
| Elevation model error (ft) | 0.7 |
| Lower bound (ft MHHW) | 10.1 |
| Upper bound (ft MHHW) | 14.1 |
| **Mean and uncertainty (ft MHHW)** | **12 ± 2** |

**1945-OCT-28 | 9.1 ± 1.4 ft MHHW**

| Reference | Source information used to estimate storm height |
|---|---|
| USACE (1994) | A building at the current school location was washed away |
| City of Golovin and URS (2008) | A building at the current school location was washed away |
| City of Golovin (2015) | (Same as 2008 hazard mitigation plan) |
| Wise and others (1981) | None (storm is described, but Golovin not cited) |

The 1945 storm washed away a building where the high school is currently located (City of Golovin and URS, 2008). The ground under the school was estimated to be 8.5 ± 0.6 ft MHHW at the 95 percent confidence interval (fig. 1). Water reached at least this height, but may have been higher because there was enough water to move the structure. In an aerial orthoimage from 1950, a few buildings were built in the flood-prone lower part of the spit where the school now sits. Additional buildings were on the high ridge on the south side. Water above 9.8 ft MHHW would begin to reach the buildings on the ridge, and since impacts to multiple buildings were not reported, this was considered the maximum possible flood height. The storm was estimated to have reached 9.1 ± 1.4 ft MHHW (table 7).

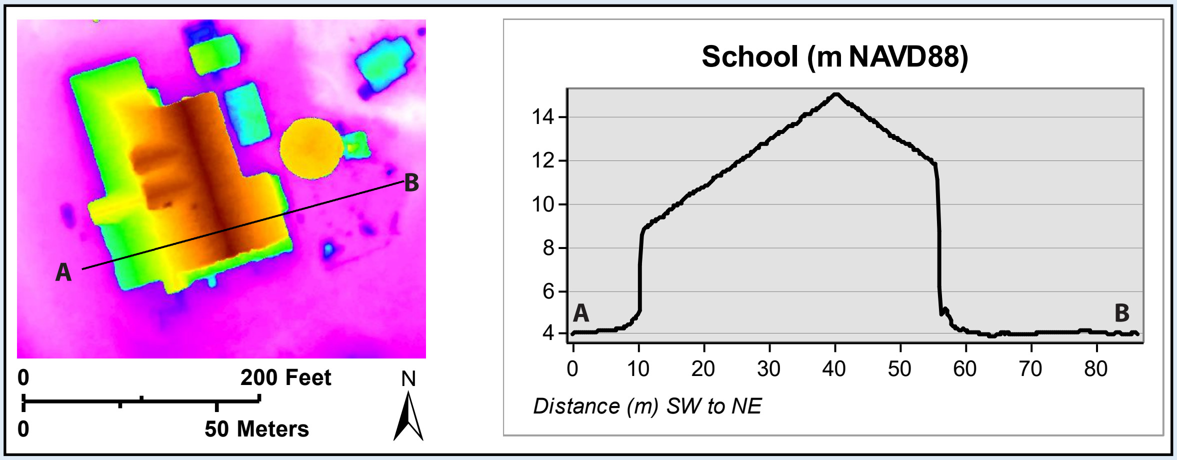



**Figure 1.** (Left) School elevation heat map (pink is low elevation and brown is high) with black profile line drawn across bare earth, the building, and the playground basketball court just east of the building. (Right) Elevation profile showing ground height around 4 m NAVD88 (8.5 ft MHHW).

**Table 7.** Flood parameters used to estimate the October 28, 1945 storm. Uncertainty was calculated using the upper-lower bounds method.

| Feature | Water washing away building |
|---|---|
| Feature represents | Highest water |
| Water level type | Still water |
| Estimate of height (ft MHHW) | 8.5 to 9.8 |
| Elevation model error (ft) | 0.7 |
| Lower bound (ft MHHW) | 7.7 |
| Upper bound (ft MHHW) | 10.5 |
| **Mean and uncertainty (ft MHHW)** | **9.1 ± 1.4** |

## 1946-OCT-25 | No water level estimate

| Reference | Source information used to estimate storm height |
|---|---|
| City of Golovin and URS (2008) | None |
| City of Golovin (2015) | None |
| Wise and others (1981) | None (storm is described, but Golovin not cited) |

There was no specific information about this storm other than it damaged buildings in the Norton Sound region (City of Golovin and URS, 2008). The storm was described by Wise and others (1981) as causing the highest flooding seen in Nome (since the record began in 1898), but did not cite Golovin as impacted. If the storm did affect Golovin, no sources provided information to help determine its impact.

**1960-OCT-02 | No water level estimate**

| Reference | Source information used to estimate storm height |
|---|---|
| U.S. Department of Commerce Weather Bureau (1960) | None |

This storm caused damage in Unalakleet and Nome, and the U.S. Department of Commerce Weather Bureau (1960) explained that "…unreported damage doubtlessly occurred…" in the Golovin area, but specific impacts were not cited so the storm could not be estimated.

**1970-AUG | No water level estimate**

| Reference | Source information used to estimate storm height |
|---|---|
| USACE [1975?] | None |

The flood data report collected by USACE [1975?] indicated that a storm in August of 1970 may have caused flooding in Golovin. However, the report was not clear as to whether the stated impacts pertained to this storm or another, so an estimate could not be made without further clarification.

**1974-NOV-10 | 10.1 ± 0.9 ft MHHW**

| Reference | Source information used to estimate storm height |
|---|---|
| Wise and others (1981) | None |
| Mason and others (1996) | None |
| City of Golovin and URS (2008) | Storm surge reached up to 12 ft mean lower low water (MLLW) in Norton Sound |
| Chapman and others (2009) | Storm surge model |
| Fathauer (1978) | None |
| USACE (1994) | Storm was less severe than 1992 |
| USACE [1975?] | "No water in village"; Ice pileup near school, buildings near airport and some homes flooded |

The November 1974 storm is known as one of the most destructive storms in western Alaska. While mentioned in many sources, few described impacts in Golovin. Aerial imagery was acquired in August 1974, showing that all buildings were constructed on the south berm or the hillside, except the fish processing plant north of the old airport runway. The flood report collected by USACE [1975?] claimed there was "no water in the village," possibly indicating that water did not run up over the beach and into the community. Flooding of homes and buildings near the airport did occur (USACE [1975?]).

A written flood survey from USACE [1975?] stated, "Ice piled up at the base of school." The current school was built in the mid-2000s. The previous school was identified as the cluster of buildings situated on the berm on the southern coast of the community (Northwest Planning and Grants Development, 2004). The largest building was assumed the schoolhouse, and it was still present in the aerial image from August 1974. Using the 2014 DEM, the average elevation on the beach in front of this building was 10.1 ± 0.9 ft MHHW (table 8).

USACE [1975?] found that facilities on the north side of the village near the airport were flooded. These facilities were identified in the 1975 aerial imagery, and the bare earth elevation below them was measured using the 2014 DEM. The three buildings in this area were on ground under 6 ft MHHW. The report also explained that homes were flooded. The lowest homes were on the west edge of Baldy Hill, north of the Dexter roadhouse. The ground underneath them averaged 7.0 ± 1.0 ft MHHW. USACE [1975?] reported there was "4 ft of water," which may have been around the fish plant or around these homes, suggesting flooding near 10 to 11 ft MHHW.

The most reliable estimate of the maximum still water height came from the ice brought up to the school. Water reaching this height would also cause the other observed impacts, including 4 ft of water at the fish plant area, flooding of some homes, and no water overtopping the berm to flood the main strip of buildings (ice pileup from the storm may have prevented runup; USACE [1975?]). Therefore, the November 1974 storm was estimated to have reached 10.1 ± 0.9 ft MHHW. This was 1.0 ft lower than the modeled estimate by Chapman and others (2009).

**Table 8.** Flood parameters used to estimate the November 10, 1974 storm. Uncertainty was calculated using the root-sum-of-squares (RSS) error.

| Feature | Ice in front of school |
|---|---|
| Feature represents | Highest water |
| Water level type | Still water |
| Estimate of height (ft MHHW) | 10.1 |
| Uncertainty of estimate (ft) | 0.6 |
| Elevation model error (ft) | 0.7 |
| **Mean and uncertainty (ft MHHW)** | **10.1 ± 0.9** |

| 1977-SEP-12 \| 6 ± 2 ft MHHW | |
|---|---|
| **Reference** | **Source information used to estimate storm height** |
| Wise and others (1981) | Runway flooded |
| Fathauer (1978) | Runway flooded |
| Mason and others (1996) | No damage (possibly referring to Nome), and runway flooded at Golovin |

This storm resulted in flooding of the now-abandoned runway (Wise and others, 1981). The extent of flooding was not specified. In the DEM, the abandoned runway was between 3.2 and 10.8 ft MHHW (fig. 2). The runway may have been higher in 1977 when it was being maintained, and gravel could have been sourced from it for other projects after it was decommissioned. Half of the runway would be flooded at 4.2 ft MHHW, and water would have reached the community at 7.5 ft MHHW. No sources described flooding in the city, so it was assumed that water did not reach above 7.5 ft MHHW. The 1977 event was estimated to have reached 6 ± 2 ft MHHW (table 9).

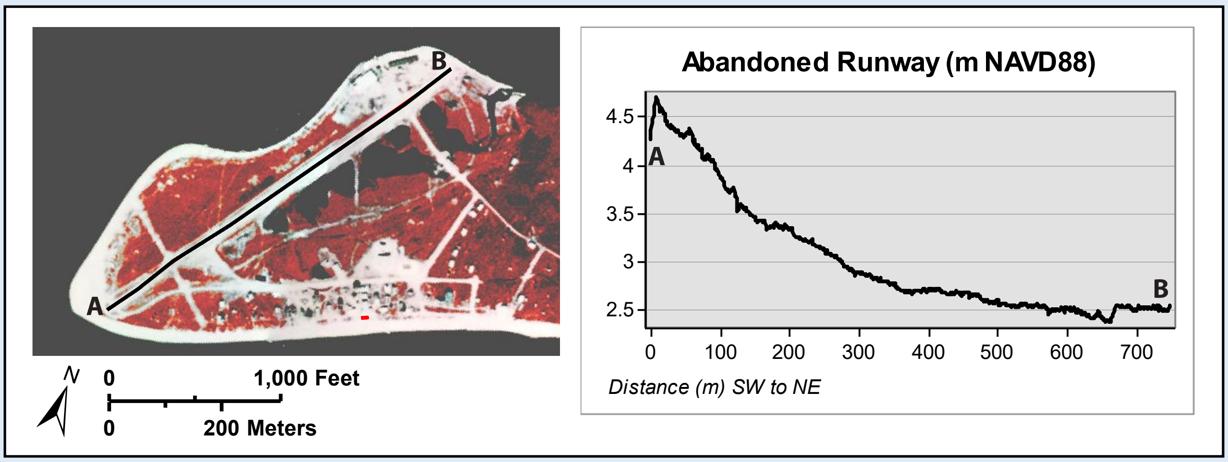



**Figure 2.** (Left) Color-infrared image showing the extent of the runway in 1980, with black line drawn where elevation was extracted from DSM. (Right) Elevation profile of the abandoned runway used to estimate the 1977 storm.

**Table 9.** Flood parameters used to estimate the September 12, 1977 storm. Uncertainty was calculated using the upper-lower bounds method.

| Feature | Water on airstrip |
|---|---|
| Feature represents | Highest water |
| Water level type | Still water |
| Estimate of height (ft MHHW) | 4.2 to 7.5 |
| Elevation model error (ft) | 0.7 |
| Lower bound (ft MHHW) | 3.5 |
| Upper bound (ft MHHW) | 8.2 |
| **Mean and uncertainty (ft MHHW)** | **6 ± 2** |

**1992-OCT-05 | 10.0 ± 0.9 ft MHHW**

| Reference | Source information used to estimate storm height |
|---|---|
| USACE (1994) | Surveyed height of flood |
| USACE (2007) | This was a "major erosion event" similar to October 2004 and September 2005. |
| USACE (2017) | None |
| City of Golovin (2015) | Copy of USACE (1994) |
| City of Golovin and URS (2008) | None |
| DCCED (2004) | Identified as the "1992 Highwater Floodline" [sic] |

This storm was considered the "Flood of Record" by USACE (1994). The flood height was marked by a high water sign which was later removed. It measured approximately 3.5 ft above ground on a utility pole near the church, across from the tank farm, on the southwest corner of Amuktoolik and Punguk Street. From the USACE (1994) survey conversions, the 1992 flood was estimated to have reached 10.0 ± 0.5 ft MHHW (table 4). No specific impacts were reported for the event; the only other quantifiable evidence was the high water mark at Maggie Olson's shed (10.7 ± 0.5 ft MHHW). The reported level of 10.0 ft MHHW was considered the flood height, and the difference (0.7 ft) was used as the interpretation uncertainty. The total uncertainty was the root-sum-squared (RSS) tolerance of the interpretation and measurement uncertainties. The estimated height of the 1992 storm was 10.0 ± 0.9 ft MHHW.

*Note: The Alaska Department of Community, Commerce, and Economic Development (DCCED) (2004) map reported this height as 7.967 ft "based upon this maps vertical control" (National Geodetic Vertical Datum of 1929). The vertical datum of the DCCED contours was 2.015 ft below MHHW (i.e., the 0 mark on the DCCED map was -2.015 ft MHHW, or -0.28 ft MLLW). The mapped high water line on the DCCED (2004) map is approximately 10.0 ft MHHW.*

**2002-OCT-08 | No water level estimate**

| Reference | Source information used to estimate storm height |
|---|---|
| City of Golovin and URS (2008) | None |

This storm was only mentioned in City of Golovin and URS (2008): "Winds in the region were recorded as high as 45 miles per hour and some areas experienced a high tide of 14 feet." There was no high water event in the water level record at the Nome tide gauge in October 2002. A high tide of 14 ft MLLW (the lowest possible reference datum) would have been 12 ft MHHW in Golovin, higher than almost any estimated storm reached. Given that no other information was found to describe impacts in Golovin, this height seemed unlikely, and the storm could not be estimated.

### 2003-SEP | No water level estimate

| Reference | Source information used to estimate storm height |
|---|---|
| USACE (2007) | This was a "major erosion event" on par with October 1992, October 2004, and September 2005. |

The only mention of the September 2003 storm came from USACE (2007). It was described as a "major erosion event" similar to 1992, 2004, and 2005. The report provided one photo attributed to the 2003 storm, but the metadata showed that the photo was taken September 23, 2005 at 8:36 am, the morning after the peak of the 2005 storm. There was also no high water event in the water level record at Nome in September 2003. There was not enough evidence to measure the 2003 storm, or verify that it occurred.

### 2003-NOV-01 | No water level estimate

| Reference | Source information used to estimate storm height |
|---|---|
| City of Golovin (2015) | None |

The disaster declaration list in City of Golovin (2015) cited this event, but no information specific to Golovin was provided. Two separate storms each reached 6 ft MLLW in the water level record at Nome. There was not enough information to estimate this storm for Golovin.

### 2004-OCT-19 | 8.9 ± 1.1 ft MHHW

| Reference | Source information used to estimate storm height |
|---|---|
| USACE (2007) | This was a "major erosion event" on par with October 1992, September 2003, and September 2005. |
| City of Golovin and URS (2008) | High tide of 10.5 ft |
| City of Golovin (2015) | The storm was "similar, but less severe" than the 2005 flood. The storm damaged the washeteria, power plant, and clinic, which were all "in the process of construction." Three photos were provided. |
| Community Photos | http://maps.dggs.alaska.gov/photodb/#show=12&search=Golovin%202004%20October |

The 2004 storm was considered "similar, but less severe" than the 2005 event (City of Golovin, 2015). The highest tide was 8.8 ft MHHW, 0.2 ft higher than the tide reported for 2005 (City of Golovin, 2008). The Nome tide gauge recorded that the 2004 flood reached 0.2 ft higher than the 2005 storm peak water level. The 2004 storm peak was observed at Nome at 4:00 pm Alaska Daylight Time (Chapman and others, 2009).

The storm reached three structures that were under construction at the time (City of Golovin and URS, 2008). An aerial image from July 8, 2004 showed that all three buildings had been built, so it was unclear how exactly the storm impacted them. Assuming that water reaching the ground height at these locations could damage construction materials, the ground heights were used to estimate the minimum height. Using the delineated building footprint from the DCCED map (2004) and the 2013 DEM, ground heights were measured under the washeteria, power plant, and clinic (table 10).

The new washeteria was the highest structure, and water would have to reach 11.0 ± 0.8 ft MHHW to reach all three locations.

The three photos provided by City of Golovin (2015) appeared to have been taken the morning after peak flooding. Flood waters still covered lower areas around Punguk Street, the northeast side of the tank farm was surrounded by water, and ponded water remained under the power plant. These observations suggested that flood waters reached similar heights as the 2005 event (8.8 ± 0.3 ft MHHW).

Ultimately, all sources agreed that waters were between 7.3 and 8.9 ft MHHW except the washeteria measurement of 11.0 ft MHHW. Water reaching 11.0 ft MHHW would have been unprecedented compared to other recent storms. Given that the flood was considered less impactful than the 2005 event, it was determined that the washeteria estimate was not reliable. From the remaining estimates, the mean ground height at the power plant and the clinic was used to determine that the 2004 storm reached 8.9 ± 1.1 ft MHHW.

**Table 10.** Flood parameters used to estimate the October 19, 2004 storm. The washeteria measurement was considered too high given other observations, and was not used for the final calculation. Uncertainty was calculated using the root-mean-sum-of-squares error of the clinic and power plant uncertainties. The values used for the final mean and uncertainty are in the last row.

| Feature | Clinic | Washeteria | Power Plant |
|---|---|---|---|
| Feature represents | Lowest water | Lowest water | Lowest water |
| Water level type | Still water | Still water | Still water |
| Minimum ground height (ft MHHW) | 8.9 | 11.0 | 7.3 |
| Mean ground height (ft MHHW) | 9.9 | 11.5 | 7.8 |
| Uncertainty of estimate (ft) | 0.7 | 0.3 | 0.5 |
| Elevation model error (ft) | 0.7 | 0.7 | 0.7 |
| Min. estimate uncertainty (ft) | 0.7 | 0.7 | 0.7 |
| Mean estimate uncertainty (ft) | 1.0 | 0.8 | 0.9 |
| **Mean and uncertainty (ft MHHW)** | | **8.9 ± 1.1** | |

| 2005-SEP-22 \| 8.8 ± 0.8 ft MHHW | |
|---|---|
| **Reference** | **Source information used to estimate storm height** |
| USACE (2017) | "Floodwaters damaged the power plant, school, and GCI building in 2005." |
| USACE (2007) | This was a "major erosion event" on par with October 1992, September 2003, and October 2004. [1 image of Golovin flooded by 2005 storm] |
| City of Golovin and URS (2008) | "This storm was a declared federal and state disaster. The storm lasted two days and high tides in the area reached 10.3 feet with winds at 56 miles per hour. The City of Golovin experienced severe flooding and erosion." |
| City of Golovin (2015) | "A severe fall storm in September 2005 caused the tides to run 7 to 9 feet higher than normal levels. This storm produced severe flooding with seawater flooding the lower village streets and structures, including the school, tank farm, and many of the buildings along Amuktoolik and Punguk Streets.... Roads were covered in 3 feet of water, fuel tanks were floating and the lower village was completely inundated with flood water" |
| Community Photos | http://maps.dggs.alaska.gov/photodb/#show=12&search=Golovin%202005%20September |

Many sources were used to interpret the elevation of the 2005 storm. USACE (2017) explained that floodwaters damaged the power plant, school, and GCI building. The degree of "damage" was not specified, so the minimum height required to reach these structures was measured. The bare-earth DEM did not appear to adequately represent the school area, so the DSM was used. The ground under the school was 8.5 ± 0.6 ft MHHW (fig. 1). The school's front doorsill height was 11.1 ± 0.5 ft MHHW, measured by USACE (1994), but this only served as a maximum possible value because no reports indicated that the school was flooded. City of Golovin (2015) provided photos of flooding around the power plant; the building itself was elevated above the flood water, while the gas tank nearby was in standing water. The elevation model showed a road elevated around the power plant (approximately 12 ft MHHW) that had not existed in the 2005 photos. The ground under the power plant measured 7.8 ± 0.3 ft MHHW from a 2019 DGGS GNSS survey. It was estimated from the photo that there was at most 1 ± 0.5 ft of water above the ground level, placing the estimated water height at 8.8 ± 0.6 ft MHHW. The GCI building location was identified by Mikulski (2009), and the ground height averaged 8.9 ± 0.9 ft MHHW based on the DEM.

The City of Golovin (2015) stated that roads were covered with 3 ft of water. It was assumed this meant roads in town (Amuktoolik and Punguk streets) and the estimate was ± 1 ft. The elevation profile of these streets varied between 7.2 and 11.8 ft MHHW (fig. 3). Assuming water reached up to but not above 3 ft deep, the water height would have been 10 ± 1 ft MHHW.

The City of Golovin (2015) stated that the storm was "7 to 9 feet above normal levels," but the meaning of "normal levels" was not specified. If they meant mean high water, this would bring the estimate to 7 to 9 ft MHHW. The City of Golovin and URS (2008) stated that tides reached 10.3 ft, and it was assumed this meant above MLLW as this datum was traditionally used for tide forecasts. In the current tidal datum, this would be 8.6 ft MHHW. No information was found for the tidal datum used in 2005. The estimated height used decimal ft, but the measurement method was not specified. Given the precision of the reported height, but the uncertainty of the source of the measurement, this estimate was considered to be 8.6 ± 1.0 ft MHHW.

From photos of flooding, the ground under the clinic (ranging from 9.1 to 11.4 ft MHHW) was dry, whereas the building to its southwest (maximum ground height 7.5 ft MHHW) was in water. All buildings to the northeast of the clinic that appeared dry in photos had a minimum ground height above the clinic. The red building in water northeast of the clinic had a maximum ground height of 8.5 ± 0.7 ft MHHW.

Estimates of maximum water height ranged between 8 and 10 ft MHHW (table 11). Estimates of minimum or instantaneous water heights were between 8.5 and 8.8 ft MHHW. The mean estimate of all values was used. The 2005 storm was estimated to have reached 8.8 ± 0.8 ft MHHW.

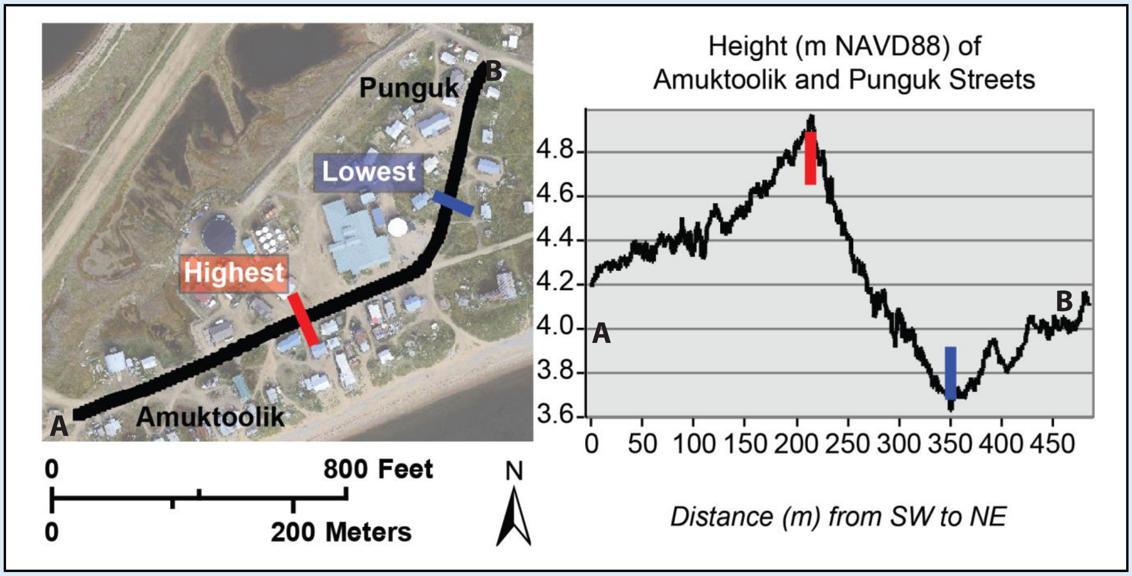



**Figure 3.** Elevations at Amuktoolik and Punguk streets, which were covered by 3 ft of water during the September 22, 2005, flood. (Left) Black profile line drawn on Amuktoolik and Punguk streets, which intersect southeast of the school. (Right) Elevation profile in m NAVD88, showing that Amuktoolik Street has a peak height south of the tank farm, and Punguk Street has the lowest point east of the school.

**Table 11.** Flood parameters used to estimate the September 23, 2005 storm. The total uncertainty of each estimate was calculated using the RSS error. The uncertainty of the final estimate used the root-mean-sum-of-squares error of the total uncertainties.

| Feature | School | Power plant | GCI building | 3 feet of water on road | "7 to 9 feet above normal levels" | 10.3 foot tide | Clinic ground height | Red building ground height |
|---|---|---|---|---|---|---|---|---|
| Feature represents | Min. water height | Instant. water height | Min. water height | Max. water height | Max. water height | Max. water height | Max. water height | Min. water height |
| Water level type | Still water | Still water | Still water | Still water | Still water | Still water | Still water | Still water |
| Height (ft MHHW) | 8.5 | 7.8 ground + 1.0 water | 8.9 | 10.0 | 8.0 | 8.6 | 9.1 | 8.5 |
| Uncertainty of estimate (ft) | 0.1 | 0.3 ground + 0.5 water | 0.6 | 1.0 | 1.0 | 1.0 | n/a | n/a |
| Uncertainty of height measurement (ft) | 0.6 | n/a | 0.6 | 0.6 | n/a | n/a | 0.7 | 0.7 |
| Total uncertainty (ft) | 0.6 | 0.6 | 0.9 | 1.0 | 1.0 | 1.0 | 0.7 | 0.7 |
| **Mean and uncertainty (ft MHHW)** | | | | **8.8 ± 0.8** | | | | |

| 2008-JAN \| No water level estimate | |
|---|---|
| **Reference** | **Source information used to estimate storm height** |
| City of Golovin and URS (2008) | None |

The wind from this storm tore a roof from a home, but there were no reports of flooding in the 2008 hazard mitigation plan. Kinsman and DeRaps (2012) cited the City of Golovin and URS (2008) when claiming that this storm caused "severe flooding." There was not enough evidence to determine whether this flood occurred or how high it reached.

| 2009-NOV-11 \| No water level estimate | |
|---|---|
| **Reference** | **Source information used to estimate storm height** |
| USACE (2017) | City was protected from flooding by Antone Street |
| City of Golovin (2015) | [Quoting USACE 2010 Floodplain information, same as USACE 2017] |

This event was mentioned in the USACE floodplain information document, but the month was not specified. It may have been the November 11, 2009, storm that also flooded Nunam Iqua. Antone Street (fig. 4) was raised in 2006 and blocked the flood from causing damage (USACE, 2017). A height of 7.5 ft MHHW would have been required to begin flooding into the community by the clinic, with water entering via Nichols Street. While the flood likely did not go higher than this, there was not enough information to determine how high it reached.

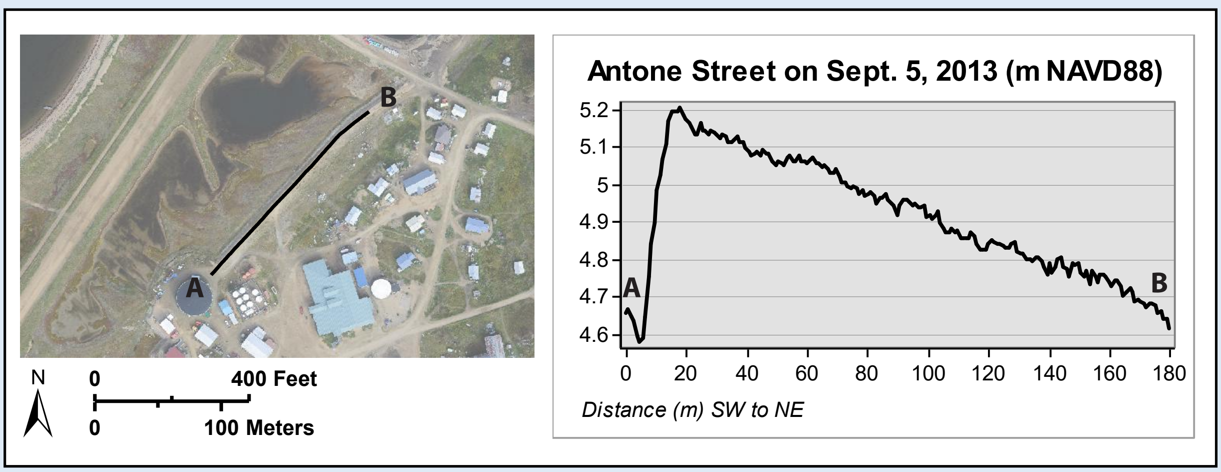



**Figure 4.** Elevation profile of Antone Street from the water tank (**A**) to the temporary berm (**B**) showed that the street rose abruptly near the water tank and sloped down gradually to the northeast.

| 2011-NOV-08 \| 9 ± 2 ft MHHW | |
|---|---|
| **Reference** | **Source information used to estimate storm height** |
| Kinsman and DeRaps (2012) | GPS survey of storm debris |
| City of Golovin (2015) | None |
| Overbeck and others (2015) | Antone Street protected against flooding |
| Community Photos | maps.dggs.alaska.gov/ photodb/#show=12&search=Golovin%202011%20 November |

The 2015 hazard mitigation plan stated that "water level peaked at 7.4 feet" above MLW (5.8 ft MHHW). This claim was far below observed flooding. Photos from the community showed that the berm on Nichols Street was not built, and thus did not prevent flooding. Kinsman and DeRaps (2012) traveled to Golovin soon after the storm to map the flood extent, and worked directly with the community to evaluate flood extent estimates. They found that the still water level reached 4.3 ± 0.6 m NAVD88 (GEOID09), which was 9.1 ± 2.0 ft MHHW. Wave setup reached up to 4.3 ft higher, but not in a populated area. When projecting 9.1 ft MHHW onto the DSM, the horizontal extent of flooding matched very closely with the extent delineated by Kinsman and DeRaps (2012; fig. 5). The 2011 storm was estimated to have reached 9 ± 2 ft MHHW. Water reached similar levels in Nome, where the tide gauge recorded 8.4 ft MHHW.

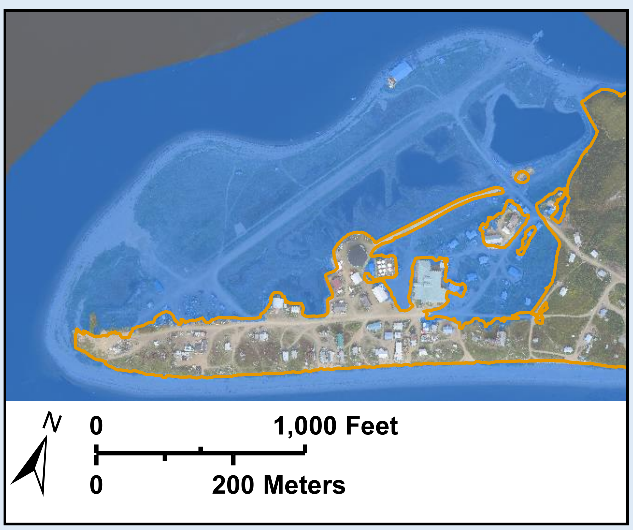



**Figure 5.** Flood extent for the November, 2011, storm. The orange line is the flood extent determined by Kinsman and DeRaps (2012). The blue layer is the bathtub flood level for 9.1 ft MHHW using a hydrologically connected DEM. Floodwaters reached the lower part of town through a narrow channel on the northeast side.

**2012-OCT-05 | 4.2 ± 1.3 ft MHHW**

| Reference | Source information used to estimate storm height |
|---|---|
| Division of Homeland Security & Emergency Management (2013) | None |
| FAA Cameras | Shows before and after photos of erosion caused by storm |

The only source that mentioned this storm was the 2013 Alaska State Hazard Mitigation Plan (Division of Homeland Security & Emergency Management, 2013). Images from the Golovin FAA camera downloaded at the time of the event showed the abandoned airstrip partially submerged at the peak of the flood (fig. 6). Using the DEM, this section of airstrip measured 3.7 ± 0.4 ft MHHW. It was estimated that water did not exceed 1 ft above the airstrip, thus this storm reached 4.2 ± 1.3 ft MHHW (table 12).

**Figure 6.** Photographs taken by FAA camera looking north over abandoned airstrip toward abandoned fish processing plant during the October 5, 2012, storm. The section of airstrip in view was completely visible in the top image (white arrows), but fully inundated in the lower image.

**Table 12.** Flood parameters used to estimate the October 5, 2012 storm. Uncertainty was calculated using the upper-lower bounds method.

| Feature | Water on airstrip |
|---|---|
| Feature represents | Highest water |
| Water level type | Still water |
| Estimate of height (ft MHHW) | 3.7 to 4.7 |
| Elevation model error (ft) | 0.7 |
| Uncertainty of estimate (ft) | 0.4 |
| Total uncertainty (ft) | 0.8 |
| Lower bound (ft MHHW) | 2.9 |
| Upper bound (ft MHHW) | 5.5 |
| **Mean and uncertainty (ft MHHW)** | **4.2 ± 1.3** |

## 2013-NOV-09 | 8.0 ± 3.0 ft MHHW

| Reference | Source information used to estimate storm height |
|---|---|
| Overbeck and others (2015) | Written account and photo from community |
| Alaska Department of Environmental Conservation (2015) | Before and after photos of erosion caused by storm |
| Community Photos | maps.dggs.alaska.gov/photodb/#show=12&search=Golovin%202013%20November |

This storm was actually a series of four storms and resulted in a federal disaster declaration. Overbeck and others (2015) summarized the local impacts: "The localized response was to build a temporary berm of unconsolidated materials … The berm performed adequately to diminish flooding of the Golovin spit." Antone Street was raised in 2006 to serve as a permanent berm to prevent flooding, and the temporary berm built for this storm appeared to match or exceed the height of Antone Street. Some overwash occurred on Antone Street, but the written account indicated that no significant amount of flood waters overtopped the berm.

The lidar DEM collected two months before this event served as the best dataset for estimating the height of Antone Street just prior to the event. From the water tank to the telecom site where the temporary berm began, Antone Street ranged from 10.5 to 12.4 ft MHHW (fig. 4). Given that no significant overtopping occurred, the lowest height of Antone Street served as a maximum possible still water height (the observed overwash being a result of runup). Uncertainty of the interpretation of water height in the photos was considered 1.0 ft, leading to a total uncertainty of 1.2 ft for the measurement.

The Nome tide gauge recorded the 2013 flood reaching 6.1 ft MHHW at its peak. Given observed similarities between this gauge and flooding in Golovin, 6.1 ft MHHW was used as the lowest possible flood height, with an uncertainty of 1.0 ft. Using the upper-lower bounds method, the 2013 storm was estimated to have reached 8 ± 3 ft MHHW (table 13).

**Table 13.** Flood parameters used to estimate the November 9, 2013 storm. Uncertainty was calculated using the upper-lower bounds method.

| Feature | Nome tide gauge | Minimum height of Antone St. |
|---|---|---|
| Feature represents | Lowest water | Highest water |
| Water level type | Still water | Still water |
| Estimate of height (ft MHHW) | 6.1 | 10.5 |
| Elevation model error (ft) | n/a | 0.7 |
| Uncertainty of estimate (ft) | 1.0 | 1.0 |
| Total uncertainty | 1.0 | 1.2 |
| Lower bound (ft MHHW) | 5.1 | 9.3 |
| Upper bound (ft MHHW) | 7.1 | 11.7 |
| **Mean and uncertainty (ft MHHW)** | **8.0 ± 3.0** | |

## 2016-OCT-29 | 6.3 ± 0.7 ft MHHW

| Reference | Source information used to estimate storm height |
|---|---|
| Overbeck (2017) | Storm estimated using photographs from community and elevation model |

Overbeck (2017) estimated water levels for this storm. Still water level was 6.3 ± 0.7 ft MHHW. Wave runup was 7.1 ± 0.8 ft MHHW.

## 2016-DEC-30 | 7.0 ± 1.2 ft MHHW

| Reference | Source information used to estimate water height |
|---|---|
| Local reporting | Written account |
| Alaska Climate Research Center (2019) | Considered minor flooding |
| Overbeck (2017) | Storm height estimate using photos and DEM |

This was "the highest [storm] in over a year" (Toby Anungazuk, Jr., written commun., October 13, 2017). This observation suggested the December 2016 storm reached higher than the October 2016 event (still water height of 6.3 ± 0.7 ft MHHW). Overbeck (2017) used photos of flooding and the 2015 DSM to estimate a minimum still water height of 6.5 ± 0.7 ft MHHW. The statewide climate summary for December 2016 stated, "Minor flooding was reported at Golovin and Shaktoolik…." It was assumed flooding did not surpass 7.5 ± 0.7 ft MHHW, where it would begin to cause more impacts than were reported (see Flood Impact Categories section). These bounds placed the estimate at 7.0 ± 1.2 ft MHHW (table 14).

**Table 14.** Flood parameters used to estimate the December 30, 2016 storm. Uncertainty was calculated using the upper-lower bounds method.

| Source data used | Overbeck (2017) | Minor flooding |
|---|---|---|
| Water feature | Minimum height | Maximum height |
| Water level type | Still water | Still water |
| Estimate of height (ft MHHW) | 6.5 | 7.5 |
| Elevation model error (ft) | 0.7 | 0.7 |
| Lower bound (ft) | 5.8 | 6.8 |
| Upper bound (ft) | 7.2 | 8.2 |
| **Mean and uncertainty (ft MHHW)** | **7.0 ± 1.2** | |

**2017-OCT-13 | 5.1 ± 0.7 ft MHHW**

| Reference | Source information used to estimate storm height |
|---|---|
| Community Photos | maps.dggs.alaska.gov/photodb/#show=12&search=Golovin%202017%20October |

Five photos were taken the morning after the storm peak, and a written description mentioned that the tide was receding and water may have covered three quarters of the abandoned runway (Toby Anungazuk, Jr., written commun., October 13, 2017). The photos were taken after water levels had receded, so instantaneous water level estimates would underestimate the maximum height. A high water wrack line left on Nichols Street was the best proxy for the peak height. Using the average height of this section of Nichols Street, the storm estimate was 5.1 ± 0.7 ft MHHW.

**2019-FEB-11 | 6.5 ± 1.2 ft MHHW**

| Reference | Source information used to estimate storm height |
|---|---|
| Community Photos | maps.dggs.alaska.gov/photodb/#show=12&search=Golovin%202019%20February |

Four photos from the storm were provided (Toby Anungazuk, Jr., written commun., February 2019). Water pooled up to one side of the berm and covered Nichols Street near the lagoon fence. The water level appeared to be the highest water level the storm reached; local accounts did not indicate that it reached significantly higher. The flood heights were estimated using the DEM. Modifications have occurred around the berm area, so the ground height of Nichols Street was measured instead, yielding a maximum height of 6.5 ft MHHW in the flooded area. This instantaneous water level may not represent the maximum water height, but local observations did not indicate that it reached much higher, so it was assigned an uncertainty of 1.0 ft. Using the RSS of the assigned uncertainty and the DEM, the storm estimate was 6.5 ± 1.2 ft MHHW.

## ACKNOWLEDGMENTS

This work was funded in part by the National Oceanic & Atmospheric Administration Office of Coastal Management through the Digital Coast Fellowship, and by the State of Alaska. Significant contributions to this work have been made by the Chinik Eskimo Community, specifically by Toby Anungazuk, Jr. Toby has been the primary source of photos and descriptions of flooding at Golovin and correspondence regarding flood events in recent years.

## REFERENCES

Alaska Climate Research Center, 2019, Alaska statewide climate summary—December 2016: The Alaska Climate Research Center [website]: found at http://akclimate.org/Summary/Statewide/2016/Dec

Alaska Department of Community, Commerce, and Economic Development (DCCED), 2004, Community profiles—Golovin: Division of Community and Regional Affairs [website]: found at https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/CommunityProfileMaps.aspx

Alaska Department of Environmental Conservation, 2015, Detailed action plan—Golovin fish processing plant waste erosion assessment & review (WEAR): Alaska Department of Environmental Conservation, 5 p.

Buzard, R.M., Overbeck, J.R., Chriest, Jonathan, Endres, K.L., and Plumb, E.W., 2021, Coastal flood impact assessments for Alaska communities: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2021-1. https://doi.org/10.14509/30573

Chapman, R.S., Kim, S.-C., and Mark, D.J., 2009, Storm-induced water level prediction study for the western coast of Alaska: U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory, 92 p.

City of Golovin, 2015, City of Golovin hazard mitigation plan: The City of Golovin Hazard Mitigation Planning Team, 183 p.

City of Golovin and URS, 2008, The city of Golovin multi-hazard mitigation plan: The city of Golovin Hazard Mitigation Planning Team, 96 p.

Division of Homeland Security & Emergency Management, 2013, State of Alaska hazard mitigation plan 2013: Department of Military and Veterans Affairs, 569 p.

Fathauer, T.F., 1978, A forecast procedure for coastal floods in Alaska: NOAA Technical Memorandum NWS AR-23, 32 p.

John Oswald and Associates, LLC, 2019, Tidal datum tool: Tidal datum tool [website]: found at https://www.tidaldatumtool.com

Kinsman, N.E.M., and DeRaps, M.R., 2012, Coastal hazard field investigations in response to the November 2011 Bering Sea storm, Norton Sound, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2012-2 v. 1.1, 51 p., 1 sheet. http://dggs.alaska.gov/pubs/id/24484

Mason, O.K., Salmon, D.K., and Ludwig, S.L., 1996, The periodicity of storm surges in the Bering Sea from 1898 to 1993, based on newspaper accounts: Climate Change, v. 34, p. 109–123.

Mikulski, Pearl, of Kawerak, Inc., for the Chinik Eskimo Community, the City of Golovin, and the Bering Strait Development Council, 2009, Golovin local economic development plan 2009–2013: Kawerak, Inc., 77 p.

National Geodetic Survey, 2019, Shared Solution: Online positioning user service [website]: found at https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBDJ67

Northwest Planning and Grants Development, 2004, A local economic development plan for Golovin 2004–2009, 45 p.

Overbeck, J.R., Kinsman, N.E.M., and Misra, Debasmita, 2015, Coastal vulnerability of a populated arctic spit—A case study of Golovin, Alaska, USA: Shore & Beach, v. 83, no. 4, p. 35–47.

Overbeck, J.R., Hendricks, M.D., and Kinsman, N.E.M., 2017, Photogrammetric digital surface models and orthoimagery for the continuous coastline, Wales to Platinum, Alaska: Alaska Division of Geological & Geophysical Surveys: Raw Data File 2017-8, 21 p.

Overbeck, J.R., 2017, Storm water level feature extraction from digital elevation models using intra-storm photographs: Alaska Division of Geological & Geophysical Surveys Report of Investigations 2017-6, 10 p. http://dggs.alaska.gov/pubs/id/29730

Southerland, L.E., and Kinsman, N.E.M., 2014, Lidar data for the community of Golovin, Alaska: Alaska Division of Geological & Geophysical Surveys Raw-Data File 2014-20, 27 p. http://dggs.alaska.gov/pubs/id/29127

U.S. Army Corps of Engineers, [1975?], Flood data–Golovin, Alaska: U.S. Army Corps of Engineers Alaska District, 1 p.

———1994, High Water Elevation Identification–Golovin: Alaska District Corps of Engineers–Flood Plain Management Services, 4 p.

———2007, Erosion information paper–Golovin, Alaska: Alaska Baseline Erosion Assessment, 4 p.

———2017, Alaska Floodplain Management flood hazard data–Golovin: USACE Civil Works Branch, 1 p.

U.S. Department of Commerce Weather Bureau, 1960, Storm data—October 1960: Storm data and unusual weather phenomena, v. 2, no. 10, p. 117–123.

Wise, J.L., Comiskey, A.L., and Becker, Richard, Jr., 1981, Storm surge climatology and forecasting in Alaska: Anchorage, AK, Arctic Environmental Information and Data Center University of Alaska, 108 p.

# APPENDIX A: STORM-RELATED ACCOUNTS

There were many written reports that contained information pertaining to storm-driven flooding in Golovin. Reports may be difficult to find in the future as their online linked location may change. This appendix provides the exact relevant text from each source used in this report to preserve the information. Any added commentary or summary information is enclosed by brackets.

### U.S. Army Corps of Engineers, 2017, Alaska Floodplain Management flood hazard data–Golovin: USACE Civil Works Branch, 1 p.

[Exact text from relevant sections:]

Flood of Record: 2005

Floodplain Notes: …1992 flood… intersection of Amuktoolik Street and Punguk Street… Floodwaters damaged the power plant, school, and GCI building in 2005. The road to the city drinking water tank was elevated in 2006, and protected the main infrastructure during the 2009 event.

### U.S. Army Corps of Engineers, 2007, Erosion information paper–Golovin, Alaska: Alaska Baseline Erosion Assessment, 4 p.

[Exact text from relevant sections:]

Description of Erosion Problem: … four major erosion events… October 1992… September 2003… October 2004… September 2005…. Community areas at lower elevations, including the old runway, are periodically flooded.

Potential Damages: … damages from erosion include downtown roads…, an abandoned fish plant, the old Golovin dump, and several downtown house pads….

[2 images of flooding on September 23, 2005; one was incorrectly labeled as 2003]

### U.S. Army Corps of Engineers, 1994, High Water Elevation Identification–Golovin: Alaska District Corps of Engineers–Flood Plain Management Services, 4 p.

[Exact text from relevant sections:]

Flood potential is rated as high, due primarily to storm surges and wind-driven waves. Most of the homes lie outside the area subject to flooding. A new airstrip has been constructed northeast of the village which is out of the flood hazard area. Storm conditions can cause wave run-up into town from the south and also high water from storm surges can flood the village from the west.

Historical Record of High Water:

The highest flood occurred in October of 1992 just before freeze-up. The water was said to have come all the way up into town due to an intense storm in Norton Sound. A high water mark was pointed out by Maggie Olson at the corner of the shed in front of the old store. Debris from wave run-up still could be seen at this location. Another large storm occurred in the fall of 1993, but according to Maggie Olson, it was not as severe as 1992's storm. Storms which caused flooding also occurred in 1974 and 1945, but these were even less severe. The 1945 storm was reported to have washed away a building near where the high school is at the present. According to Maggie Olson, a village elder named Maude Moses used to tell of a flood which occurred in 1913 which was the worst of all. Water was high enough that residents were inside of the Dexter building caulking the walls to keep the water out. The high water level for this flood was not determined.

Actions Taken:

One High Water Elevation (HWE) sign was placed at the elevation of the 1992 flood, the flood of record. This elevation is based on a six inch to one foot depth of water on the road in front of the new high school reported by Bobby Amarok. It should be noted that this elevation represents a storm surge coming up and over the beach from the south and into the village. It was compared to the high water mark at the shed near Maggie Olson's store. The two elevations are very close. High water can enter the village from the west over the old airstrip without overtopping the beach to the south. Such a storm surge from the west could cause a high water level somewhat less than the HWE sign indicates. The point of measurement for the 1992 flood level is the water symbol on the HWE sign.

The HWE sign is on a power pole on the southwest corner of the intersection of Amuktoolik street and Punguk street, in front of the building site for the new church. It is across the street from the fuel tank farm. The sign is about 3.5 feet above the ground.

[Temporary benchmark survey data provided in table 4]

### City of Golovin, 2015, City of Golovin hazard mitigation plan: The City of Golovin Hazard Mitigation Planning Team, 183 p.

[Exact text from relevant sections:]

Flood – History: The community has experienced major erosion events in 1992, 2003, 2004, and 2005. … The 2004 and 2005 events occurred during major storm events…. A severe fall storm in September 2005 caused the tides to run 7 to 9 feet higher than normal levels. This storm produced severe flooding with seawater flooding the lower village streets and structures, including the school, tank farm, and many of the buildings along Amuktoolik and Punguk Streets…. Roads were covered in 3 feet of water, fuel tanks were floating and the lower village was completely inundated with flood water…. A similar, but less severe flood occurred during the Bering Sea Storm of October 2004.

According to the U.S. Army Corps of Engineers (COE), the "flood of record" was recorded at 98.9 feet in October 1992. During this flood, a High Water Elevation (HWE) sign was placed on a utility pole on the southwest corner of the intersection on Amuktoolik Street and Punguk Street. The HWE sign is 3.5 feet above ground in front of a new church building site and across the street from the City Fuel Tank Farm.

COE records also indicate that a storm in 1945 washed away a building where the high school is currently located. The worst flood occurred in October 1913 according to COE records. Village elder, Maude Moses recalled that residents had to caulk the walls of the Dexter Building to keep water from getting inside....

[Excerpts from Kinsman and DeRaps, 2012 regarding the 2011 storm]

[List of Disaster Declarations which have specific storm dates]

Table 5-5 Historic Flood Events and impacts

11/5/2013 – High Winds, and Storm Surge [not Golovin-specific information]

11/8/2011 – Coastal Flood: At Golovin, the coastal flooding began approximately 0300AKST on the 9th and continued until 1400 AKST on the 10th. It is estimated that the water levels peaked at 7.4 feet above the normal mean low water levels at 1900AKST on the 9th. In Golovin, many of the downtown areas were flooded and the phone company facility was submerged. Water flooded many home [sic] in the downtown area. Ice driven by the storm surge moved into a campsite 6 miles northeast of Golovin on the lagoon side of the village and destroyed 4 cabins and damaged fish racks.

9/22/2005 – Storm Surge/Tide … Golovin AWOS wind gusts as high was 57 knots (66mph)

10/19/2004 – Storm Surge/Tide … Damages to the washeteria, the drain field, new power plant and new clinic (all were in the process of new construction). The high ocean water lifted up several three [sic] old and unused fuel tanks along with two Connex trailers and floated them away. The school's septic system was rendered unusable….

October 1946 – Storm Surge – This was a strong coastal storm that produced a high storm surge and damaged many structures throughout the region.

Storm of 1945 – Storm Surge – This storm washed away at least one building in the City of Golovin and caused severe damage to structures throughout the region.

October 1913 – Storm Surge – This storm produced the worst flood event the City of Golovin has ever experienced. Throughout the region, winds were recorded as high as 60 miles per hour, storm surges as high as 20 feet, and waves reaching 40 feet. Many people in the region were left homeless.

Table 5-7 Severe Weather Events

October 19, 2004 – Coastal Storm Surge … with a high tide of 10.5 feet….

**City of Golovin and URS, 2008, The city of Golovin multi-hazard mitigation plan: The City of Golovin Hazard Mitigation Planning Team, 96 p.**

[Exact text from relevant sections:]

[Flood history: discusses 2005 and 2004 floods, and copies USACE report. Has photos for 2004 event]

[Severe weather history:]

September 12, 1900 – A large fall storm that produced estimated wind speeds up to 75 miles per hour and large waves. Throughout the region, several people were left homeless, some died, and livestock was lost.

October 1913 – This storm produced the worst flood event the City of Golovin has ever experienced. Throughout the region, winds were recorded as high as 60 miles per hour, storm surges as high as 20 feet, and waves reaching 40 feet. Many people in the region were left homeless.

Storm of 1945 – This storm washed away at least one building in the City of Golovin and caused severe damage to structures throughout the region.

October 1946 – This was a strong coastal storm that produced a high storm surge and damaged many structures throughout the region.

Bering Sea Storm of 1974 – In November 1974, three storms simultaneously pounded the region. Storm Surges were recorded at levels reaching 12 feet mean lower low water. Regionally, there was damage to critical facilities and infrastructure and homes were destroyed. Contaminated water was also an issue.

Storm of 1992 – This storm produced the “flood of record” in the City of Golovin.

October 8, 2002 – Winds in the region were recorded as high as 45 miles per hour and some areas experienced a high tide of 14 feet.

October 19, 2004 – This storm was a declared federal and state disaster. Winds in the region were recorded at 59 miles per hour with a high tide of 10.5 feet. The City of Golovin experienced severe flooding and erosion.

September 2005 – This storm was a declared federal and state disaster. The storm lasted two days and high tides in the area reached 10.3 feet with winds at 56 miles per hour. The City of Golovin experienced severe flooding and erosion.

January 2008 – A severe winter storm with winds nearing approximately 60 miles per hour tore the roof off a utility building in the City. Schools and City offices were closed.

**Kinsman, N.E.M., and DeRaps, M.R., 2012, Coastal hazard field investigations in response to the November 2011 Bering Sea storm, Norton Sound, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2012-2 v. 1.1, 51 p., 1 sheet.**

[Exact text from relevant sections:]

[Uses different tidal datum for Golovin]

The earliest documented storm surges in the community date to 1900 and the most severe event on record took place in 1913 (City of Golovin and others, 2008). The record of storm damages specific to the City of Golovin is sparse but includes the loss of a building in 1945 (City of Golovin and others, 2008) and flooding of the old airport in 1977 (Wise and others, 1981).

… severe flooding… in 2004, 2005, 2008, and 2009 (City of Golovin and others, 2008).

[pertaining to Nov 8, 2011 storm] … the measured elevation of the peak water level including astronomical tide (storm tide level) in Golovin was 4.3 ± 0.6 m NAVD88 [GEOID09].

… Antone Street, which was elevated in 2006, helped to reduce the amount of flooding within the town and around the school.

TWL, Total Water Level (surge + tide + setup) – 5.6 ±0.6 m NAVD88(GEOID09)

**Community reporting to Alaska Water Level Watch on 10/13/2017:**

[Exact text from relevant sections:]

Good Morning Denise:

I have attached three pic’s taken from the top of Baldy Hill - from the cliffs to around the Covenant Church.

The tide was already going out when I thought it was bright enough to see, the surge waters covered approximately 3/4's of the Old Golovin Airport. I still need to check better if I can find how far the water covered the old airport - heavy rain made it hard to find how far the water levels went.

The sustained wind was up and down for much of the night, not like in previous years where we had constant strong winds and higher gusts. I believe that that [sic] Dec 31, 2016 storm surge is the highest one in over a year.

Toby

**Wise, J.L., Comiskey, A.L., and Becker, R., Jr., 1981, Storm surge climatology and forecasting in Alaska: Anchorage, AK, Arctic Environmental Information and Data Center University of Alaska, 108 p.**

[Exact text from relevant sections:]

9/12/1977 - Runway flooded at Golovin, minor flooding elsewhere.

**Mason, O.K., Salmon, D.K., and Ludwig, S.L., 1996, The periodicity of storm surges in the Bering Sea from 1898 to 1993, based on newspaper accounts: Climate Change, v. 34, p. 109-123.**

[Exact text from relevant sections:]

1977, Sep. 12 … Intense storm moved ENE at 15 knots, angry seas at Nome, but no damage, runway flooded at Golovin, Solomon Rd. washed out

1900, Sep. 13 – Wind fr. S, Heavy Rain, High breakers, Snake R. bank erosion, flooding of 3m

**U.S. Department of Commerce Weather Bureau, 1960, Storm data—October 1960: Storm data and unusual weather phenomena, v. 2, no. 10, p. 117-123.**

[Exact text from relevant sections:]

…It is quite probable that still stronger winds developed in the exposed coastal areas around Golovin Bay and unreported damage doubtlessly occurred all along the northern shores of Norton Sound.

**Fathauer, T.F., 1978, A forecast procedure for coastal floods in Alaska: NOAA Technical Memorandum NWS AR-23, 32 p.**

[Exact text from relevant sections:]

Seward Peninsula Storm, Sept. 13, 1977. … There was minor wind damage with the storm, and the runway was flooded at Golovin, about 60 miles east of Nome.

**U.S. Army Corps of Engineers, [1975?], Flood data–Golovin, Alaska: U.S. Army Corps of Engineers Alaska District, 1 p.**

[Full source provided here:]

163 02
64 33

FLOOD DATA

1. Village Name: Golovin (Golovnin) Use back if needed
2. Population: 125 ±
3. Type of Hazard: Reputed Storm Surge Flooding
4. Floods of Record and Cause:

| Mo. & Year | % Flooded | Maximum Depth | Cause |
|---|---|---|---|
| Unk. | | Beach & Waterfront | Storm Surge |
| 100 yr. Last Reported | | 1' deep on NE end | SW wind 40k. |
| 1970 Aug | | of Runway | 72 hrs in |
| 1944 Fall | 90 | NONE | Norton Sound |
| | | | Storm driven Wave |

5. Location of high water mark and description:
Came up to within 3 feet of floor of reindeer plant

6. Is high ground available? Yes
Where? Westerly part of village is on
How far from water? a gentle hill ±50'

7. Other information:

8. Coastal:
Is there offshore protection? No
What?
Is Ice erosion a problem? No
Is wave erosion a problem? Not appreciably
Details of above: 1974 Storm No Water in Village

9. Riverine:
Is erosion a problem? N/A
Is Ice a problem?
Details of above

Name Ed.
Title
Organization

Return to:
District Engineer
US Army, Corps of Engineers
Alaska District
Anchorage, Alaska 99510

ATTN: FPMS

Page 1 of 2

Village Chief (or Mayor): Ralph Willoya

ge Status (home rule, 2nd class, traditional, IRA, etc.): 2nd class

Flooding:

Depth of Flood (MAXIMUM): Worst Flood (Fall 1974) 4ft of Water *

Highwater Marks (Describe & Locate): New homes are being located on higher ground at East End of village. Airport is under water at 5ft above M.H.H.W.

Number of Homes Flooded:

Number of Public Facilities and Type Flooded: None

* North side of village (near airport)

No homes that were flooded are currently occupied

Total Damage in $ ?

Cause of Flood (ice jams, stream overflow, wind driven waves, etc.): (WDWs)

Storm with Southerly WDW's Accompanied by ice floes

ge Information:

Population: 103 Number of Homes: 25

Public Facilities:

Access (air, boat, etc): Air, Barge Boat

Economic Activity (substance hunting & fishing, mining, commercial fishing, native arts & crafts, supply point, etc.):

Subsistance Fishing

# APPENDIX B: FLOOD CATEGORY CALCULATION FIGURES

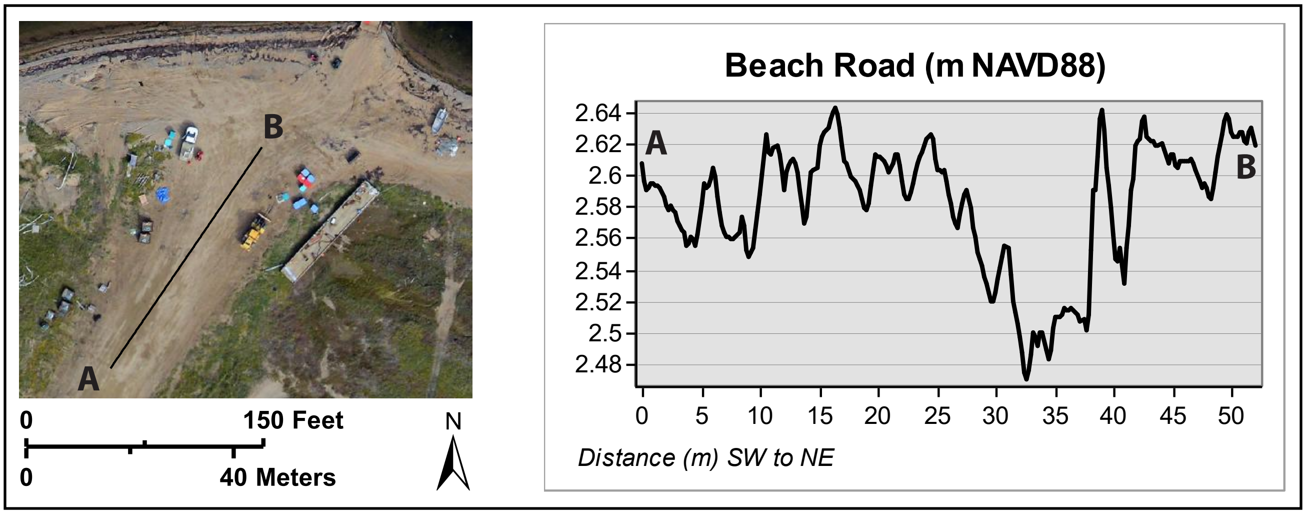



**Figure B1.** (Left) Beach road in recent imagery with black profile to measure ground level. There was a tractor parked on the beach, with several large bins of equipment nearby. (Right) Elevation profile shows the road averaged 2.58 m NAVD88 (standard deviation= 0.04 m).

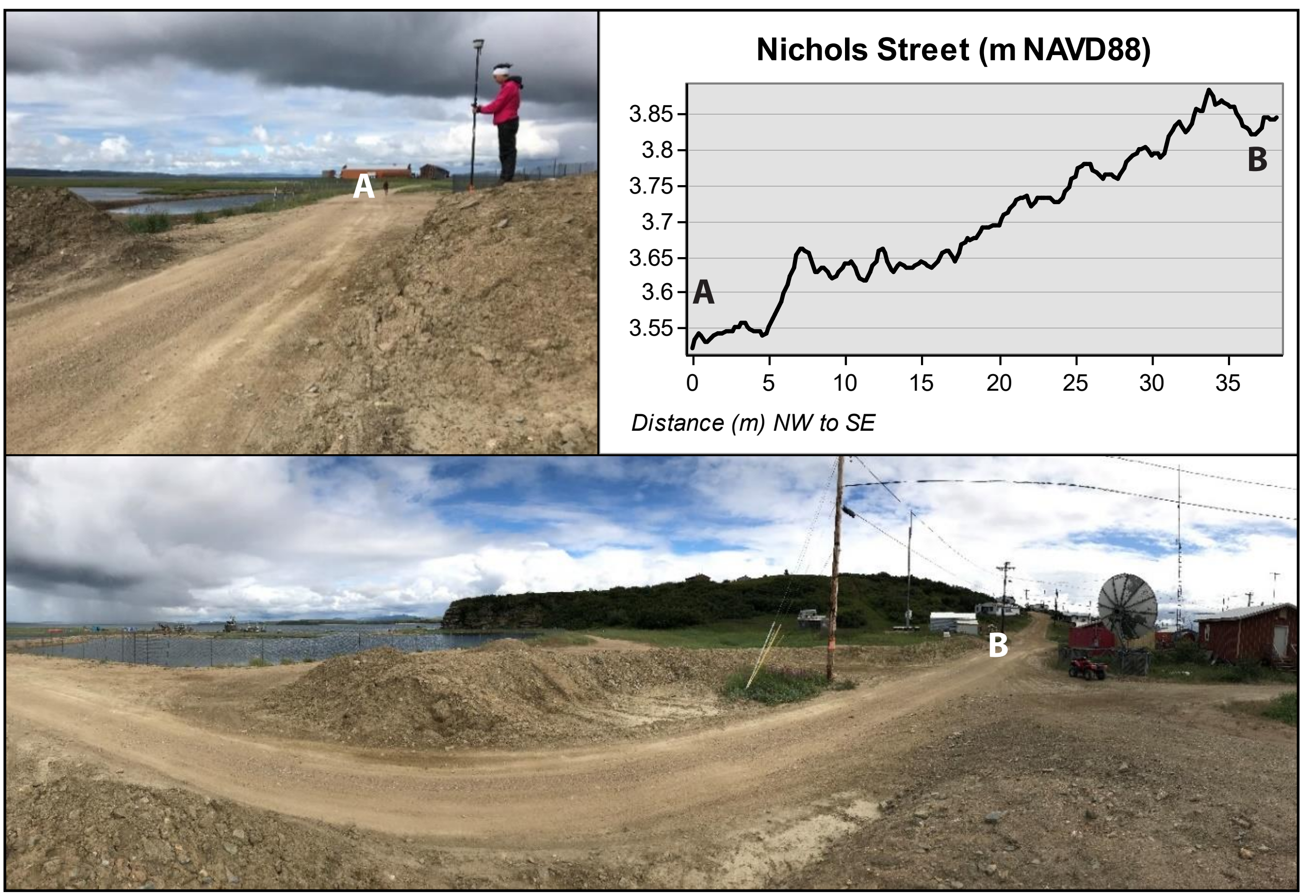



**Figure B2.** (Top left) Nichols Street flood berm in August 2018, looking towards abandoned cannery. (Top right) elevation profile of Nichols Street between the barriers. (Bottom) panorama of Nichols Street shows beach access road to the left and road to high ground to the right).