Report of Investigation 2025-1

COASTAL FLOOD IMPACT ASSESSMENT FOR KWIGILLINGOK, ALASKA

Keith C. Horen, Jessica E. Christian, Autumn C. Poisson, Zachary J. Siemsen, and Nora M. Nieminski

Flood waters inundating tundra near the school in Kwigillingok, Alaska, in September 2019. Photo: Lewis Amik III.

Published by
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
2025

COASTAL FLOOD IMPACT ASSESSMENT FOR KWIGILLINGOK, ALASKA

Keith C. Horen, Jessica E. Christian, Autumn C. Poisson, Zachary J. Siemsen, and Nora M. Nieminski

Report of Investigation 2025-1

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

STATE OF ALASKA
Mike Dunleavy, Governor

DEPARTMENT OF NATURAL RESOURCES
John Boyle, Commissioner

DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS
Jennifer Athey, Acting 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:
Horen, K.C., Christian, J.E., Poisson, A.C., Siemsen, Z.J., and Nieminski, N.M., 2025, Coastal flood impact assessment for Kwigillingok, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2025-1, 44 p. https://doi.org/10.14509/31538

Contents

Figures

Tables

Appendices

COASTAL FLOOD IMPACT ASSESSMENT FOR KWIGILLINGOK, ALASKA

Keith C. Horen[1], Jessica E. Christian[2], Autumn C. Poisson[1*], Zachary J. Siemsen[1*], and Nora M. Nieminski[1]

OVERVIEW

This Division of Geological & Geophysical Surveys (DGGS) report is an investigation of the historical flood record and provides an assessment of flood impacts for the community of Kwigillingok, Alaska. This community-specific report has three sections: data description, flood impact categorization, and historical flood record. Methods used to evaluate historical floods and delineate flood impact categories (minor, moderate, major), as defined by the National Weather Service (NWS), are described in detail in Horen, Poisson, and others (2024), an update from the methods described by Buzard and others (2021). Flood and infrastructure heights are relative to the local mean higher high water (MHHW) datum in feet (ft).

SUMMARY

The community of Kwigillingok, whose name in Yup'ik is Kuigilnguq, meaning village of no river, is located on the northern shore of Kuskokwim Bay, within the Yukon Delta National Wildlife Refuge, near the mouth of the Kwigillingok River, approximately 77 miles southwest of Bethel (Alaska Institute for Justice [AIJ], 2019a; Village of Kwigillingok, 2015). Parts of the village are situated on low-lying lands where flooding is common, however most of the community residences are in areas of relatively higher ground, approximately three feet above the low-lying areas (U.S. Army Corps of Engineers [USACE], 2009). In the late-1960s, many Kwigillingok residents moved to higher ground to escape rising tidal waters, establishing the community of Kongiganak (AIJ, 2019a). A USACE (1973) flood data report states: with annual occurrence in November and December "the combination of high tide and high [south] to [southwest] winds cause pile up of ice [and] water which breaches the beach and causes some flooding. Not considered serious." Kwigillingok was considered threatened by flooding according to a 2009 U.S. Government Accountability Office (GAO) report (U.S. GAO, 2009), but later designated as low flooding risk by the 2019 Denali Commission Statewide Threat Assessment (University of Alaska Fairbanks [UAF] Institute of Northern Engineering and others, 2019). Additional data collection will improve our understanding of the flooding threat to this community.

Based on the research done for this report, Kwigillingok experienced at least 33 significant flood events between 1966 and 2024 (30 from storm surge, two from high tide flooding, and one from an event of unknown origin). We estimated the peak still water heights for 20 of these flood events, categorizing two as minor and 18 as moderate. The highest estimated flood occurred on August 17, 1990, reaching a still water height of 3.1 ft (0.95 m) MHHW. Additionally, we identified 90 flood events (89 minor and one moderate) captured by water level sensor readings between

[1]Alaska Division of Geological & Geophysical Surveys, 3651 Penland Pkwy, Anchorage, Alaska 99508
[2]Alaska Division of Geological & Geophysical Surveys, 3354 College Rd., Fairbanks, Alaska 99709
* *Formerly at DGGS; Z.J. Siemsen now at PND Engineers, Inc., 1506 W 36th Ave., Anchorage, Alaska 99503*

August 2021 and October 2024 (app. A) but not described in historical records. Due to sensor limitations and potential ambiguity, we excluded readings collected during periods when ice was likely to be present.

DATA

We used geospatial data to assess infrastructure impacts and estimate flood heights from various sources of evidence (e.g., personal accounts, photographs, and official reports). We used Esri's ArcGIS Pro version 3.2.0 to process and map these geospatial data.

Digital Elevation Models and Orthoimagery

Accurate, high-resolution elevation models and orthoimagery are used to measure flood heights in the absence of high-water mark (HWM) data. Four digital elevation models (DEMs; table 1), three orthoimages (table 2), and multiple aerial images are available for Kwigillingok, two of which were used in our analysis (table 3). DGGS collected light detection and ranging (lidar) data in 2021, with a digital surface model (DSM) and digital terrain model (DTM) created in 2022 (Zechmann and others, 2023). Orthoimagery was collected in 2004 for a Community Profile Map (CPM; Alaska Division of Community & Regional Affairs [DCRA], 2004). Aerial imagery was collected in 2015 and 2022, which was used to create DSMs and orthoimagery derived from photogrammetric structure from motion (SfM) processing (Overbeck and others, 2016; Horen, Buzard, and others, 2024). The U.S. Bureau of Land Management (BLM) collected vertical cartographic photographs over Kwigillingok in 1975, and the National Aeronautics and Space Administration (NASA) Ames Research Center collected vertical reconnaissance photographs over Kwigillingok in 1980; these images were accessed from the U.S. Geological

Table 1. Summary of digital elevation models available for Kwigillingok, Alaska.

	2015 DSM	2021 DSM	2021 DTM	2022 DSM
Collection date	2015-AUG-21	2021-AUG-18	2021-AUG-18	2022-JUN-19
Elevation type	Photogrammetric SfM	Lidar Surface	Lidar Bare Earth	Photogrammetric SfM
Vertical datum	NAVD88 (GEOID12A)	NAVD88 (GEOID12B)	NAVD88 (GEOID12B)	NAVD88 (GEOID12B)
Ground sample distance	0.7 ft (0.20 m)	1.6 ft (0.50 m)	1.6 ft (0.50 m)	0.2 ft (0.07 m)
Accuracy	0.3 ft (0.08 m)	0.2 ft (0.07 m)	0.2 ft (0.07 m)	0.3 ft (0.09 m)

Table 2. Summary of orthoimagery available for Kwigillingok, Alaska.

	2004 Orthoimagery	2015 Orthoimagery	2022 Orthoimagery
Collection date	2004-SEP-17	2015-AUG-21	2022-JUN-19
Ground sample distance	2.0 ft (0.61 m)	0.5 ft (0.15 m)	0.1 ft (0.02 m)

Table 3. Summary of aerial images used in the analysis for Kwigillingok, Alaska.

	1975 Aerial Image	1980 Aerial Image
Collection date	1975-SEP-09	1980-JUL-17
Ground sample distance	0.16 ft (0.05 m)	5.2 ft (1.61 m)
USGS Entity ID	AR4KWIG18030007	AR5800029075697

Survey (USGS) EarthExplorer application at earthexplorer.usgs.gov. Where first-floor height data were unavailable (i.e., unoccupied buildings, some facility-attached infrastructure, and private property), heights were extracted from the 2021 DTM unless a first-floor height was discernable from the 2022 SfM model, orthoimagery, and DSM (e.g., decking at entrances to buildings, visible platforms extending from building edges). All DEM, orthoimagery, and aerial images will be referenced in this report by the names assigned in tables 1–3.

First-Floor Height Survey

The Alaska Native Tribal Health Consortium (ANTHC) completed a field survey of the first-floor heights of occupied buildings in Kwigillingok on March 2 and 3, 2023. These data were collected and reported in the North American Vertical Datum 1988 with Geoid 12B applied (NAVD88 [GEOID12B]) in U.S. survey feet (usft) (app. B). The reported vertical accuracy of these data is ± 0.2 ft (0.07 m). This survey will be referenced in this report as the 2023 first-floor survey. DGGS spatially joined these first-floor heights to building footprints digitized from the 2022 orthoimagery, identifying 154 as occupied buildings (i.e., residential, public, or commercial structures in which people live or work), 111 of which are residential.

GNSS Survey

DGGS performed a Global Navigation Satellite System (GNSS) survey on June 18 and 19, 2022, during a visit to Kwigillingok. The purpose of this survey was to collect community reports and photo identified HWM data. These data were collected in the NAVD88 (GEOID12B) vertical datum in meters (m) and reported in feet (ft) (app. B). The vertical accuracy of these data is ± 0.3 ft (0.08 m) for June 18 and ± 0.3 ft (0.10 m) for June 19. This survey will be referenced in this report as the 2022 survey.

Flood Staff

DGGS installed a flood staff in Kwigillingok on June 13, 2017 (figs. 1 and 2). The flood staff was attached to a utility pole, the base of which was measured at 1.0 ft (0.30 m) MHHW during a GNSS survey. This GNSS point was collected in the NAVD88 (GEOID12B) vertical datum in meters. The vertical accuracy of this point is ± 0.1 ft (0.03 m). This flood staff was not able to be located during the 2022 survey.

With assistance from DGGS, the USGS installed a flood staff in Kwigillingok on October 17, 2023 (figs. 1 and 2). The flood staff was attached to a utility pole, the base of which was measured at 0.5 ft (0.14 m) MHHW during a GNSS survey. This GNSS point was collected in the NAVD88 (GEOID12B) vertical datum in meters. The vertical accuracy of this point is ± 0.2 ft (0.06 m).

Water Level Sensor

DGGS installed a Stilltek iGage radar water level sensor in Kwigillingok in August 2021. This sensor was replaced on June 17, 2022, and again on October 17, 2023. The sensor is attached to the southeast side of the bridge north of the village (figs. 3 and 4). Data collected by this sensor, updated hourly, are available from Alaska Water Level Watch at portal.aoos.org/#metadata/110872/station/data. The vertical accuracy of these data is ± 0.2 ft (0.07 m).

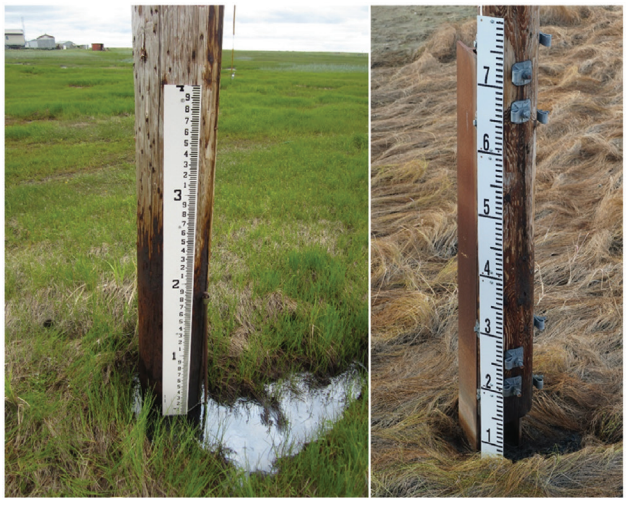


Figure 1. Flood staffs installed in Kwigillingok, Alaska, in 2017 (left) and 2023 (right).

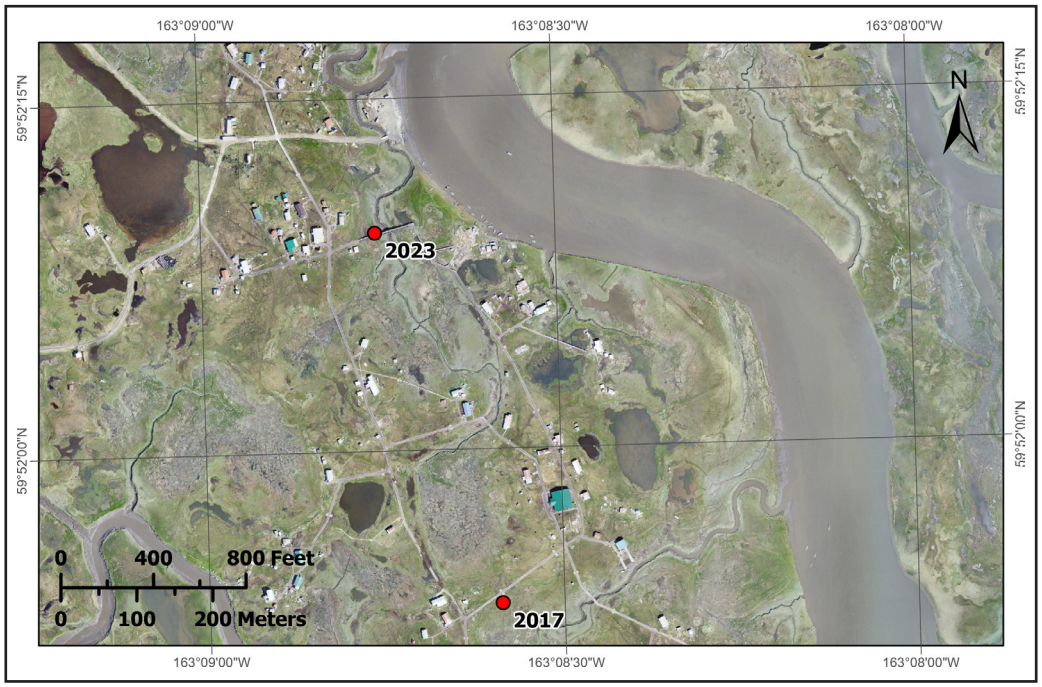


Figure 2. Location of flood staff installations in Kwigillingok, Alaska.

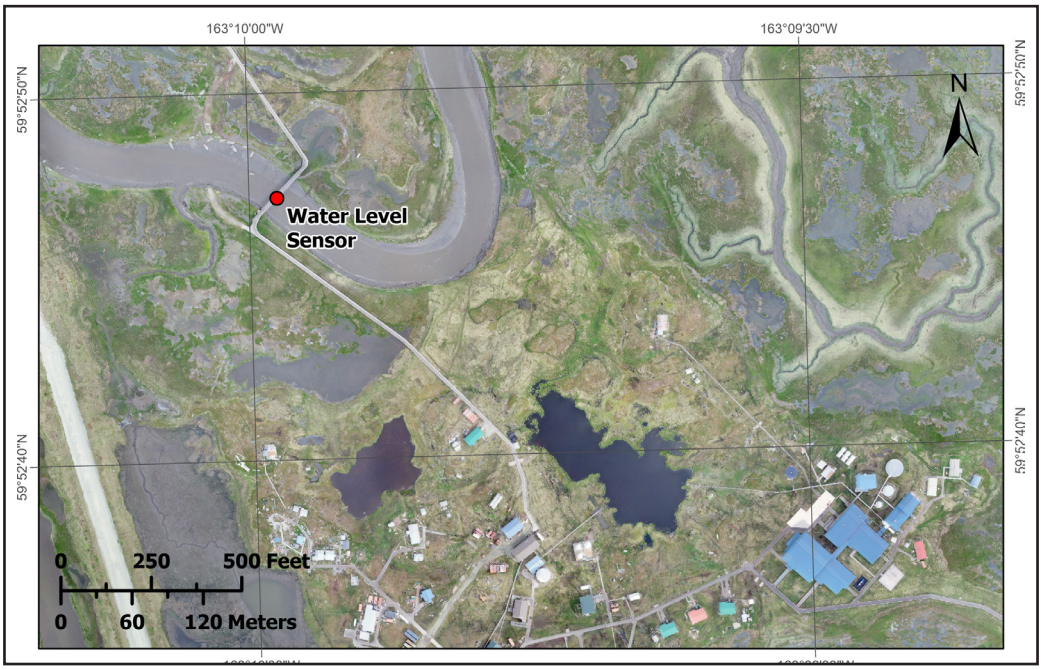


Figure 3. Location of Stilltek iGage radar water level sensor in Kwigillingok, Alaska.

Vertical Datums

Local tidal datums (table 4) for Kwigillingok are described by National Oceanic and Atmospheric Administration (NOAA) Center for Operational Oceanographic Products (CO-OPS) tide station 946 5911 available from tidesandcurrents.noaa.gov/stationhome.html?id=9465911.

FLOOD IMPACT CATEGORIES

Flood impact categories are used by the NWS to define and communicate flood risk to the public. These categories are designated as major, moderate, and minor (NWS, 2016). Definitions for these categories in the NWS guidance specific to Alaska are provided in the form of statements regarding

flood impacts, some of which are more qualitative than quantitative (NWS, 2016). To ensure impact assessments are consistent and repeatable, DGGS developed a set of quantitative criteria for each category (Horen, Poisson, and others, 2024). A fourth category, extreme flooding, as defined by DGGS, is included in this report to delineate key infrastructure situated at heights above the anticipated maximum based on the specifics of the local historical flood record, though flooding is still possible above this height (Horen, Poisson, and others, 2024).

Figure 4. Stilltek iGage radar water level sensor installation in Kwigillingok, Alaska, located on the southeast side of the bridge.

Short definitions for each flood impact category are listed below and are explained in greater detail by Horen, Poisson, and others (2024). Table 5 provides a list of key infrastructure heights and the risk categories they fall within. Additional information about each piece of key infrastructure is detailed in the category blocks that follow table 5. The map series that accompanies this report depicts the potential inundation extents for each flood impact category.

Minor Flooding: "Minimal or no property damage, but possibly some public threat" (NWS, 2016).

Moderate Flooding: "Some inundation of structures and roads… Some evacuations of people and/or transfer of property to higher elevations may be necessary" (NWS, 2016).

Major Flooding: "Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary" (NWS, 2016).

Extreme Flooding: Any flooding that reaches a height above the highest estimated flood height plus the confidence of that estimate (Horen, Poisson, and others, 2024; NWS, 2018).

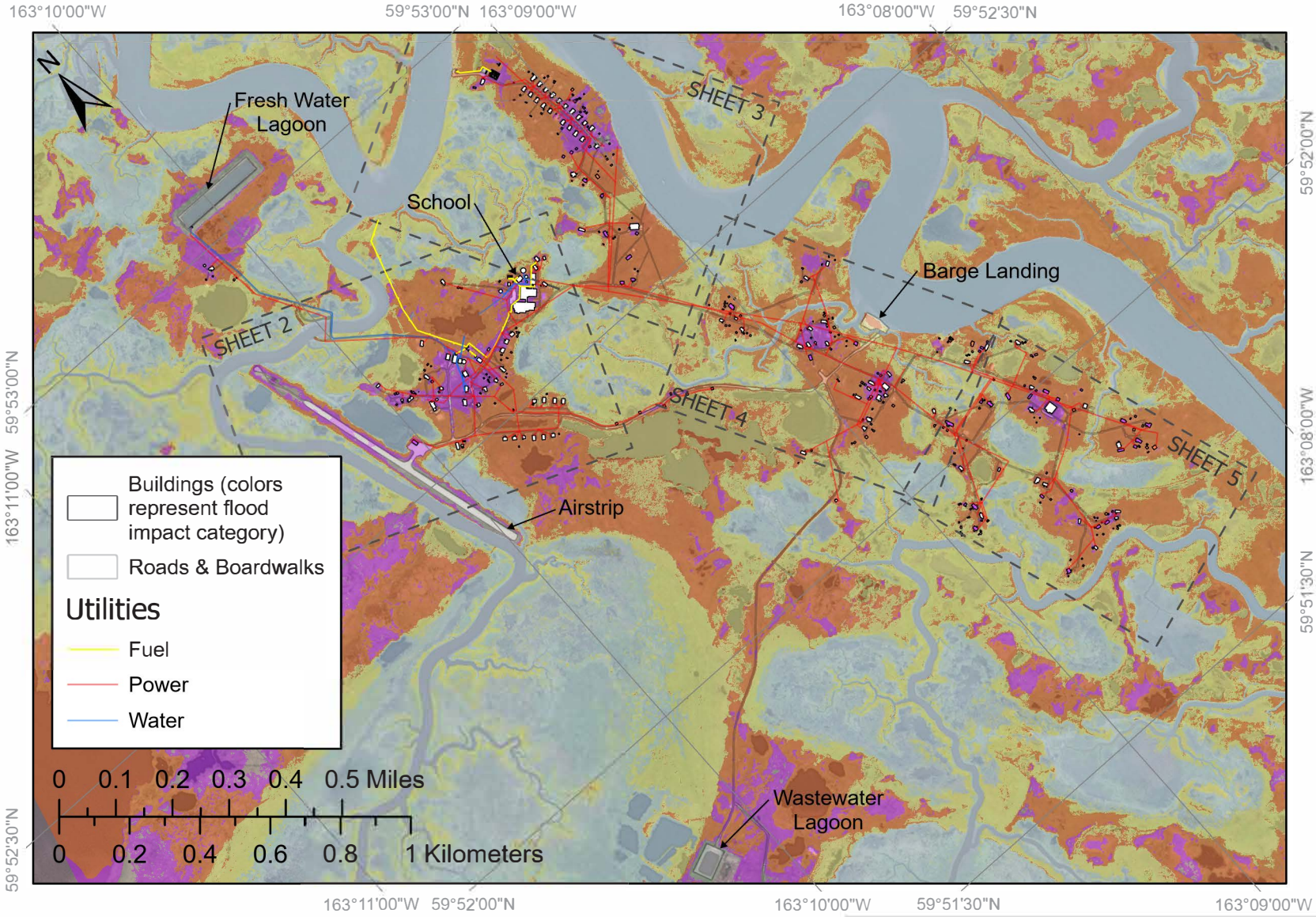
Table 4. Local tidal datums for Kwigillingok, Alaska (NOAA CO-OPS tide station 946 5911).

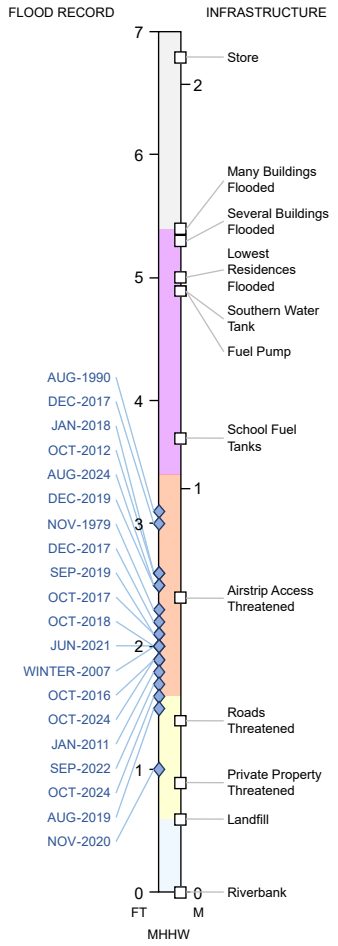
Tidal Datum	Abbreviation	ft MHHW	m MHHW	ft NAVD88 (GEOID12B)	m NAVD88 (GEOID12B)
Mean Higher High Water	MHHW	0.0	0.00	9.5	2.89
Mean High Water	MHW	-2.1	-0.64	7.4	2.26
Mean Sea Level	MTL	-5.6	-1.72	3.9	1.17
Mean Tide Level	MSL	-5.9	-1.81	3.6	1.08
North American Vertical Datum 1988 (GEOID12B)	NAVD88 (GEOID12B)	-9.5	-2.89	0.0	0.00
Mean Low Water	MLW	-9.8	-2.98	-0.3	-0.09
Mean Lower Low Water	MLLW	-10.4	-3.17	-0.9	-0.27

Coastal Flood Impact Map

Kwigillingok, Alaska

REPORT OF INVESTIGATION 2025-1
Horen and others, 2025
SHEET 1 OF 5





To calculate height above
NAVD88: add 7.75 ft (2.362 m)
MLLW: add 8.28 ft (2.525 m)

Projection: NAD83 (2011) UTM Zone 3N
Infrastructure digitized from orthoimagery
Orthoimagery and DEM available from elevation.alaska.gov

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

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

Moderate Flooding is defined as some inundation of structures and roads at lower elevations. Some evacuation of people and/or transfer of property to higher elevations are necessary.

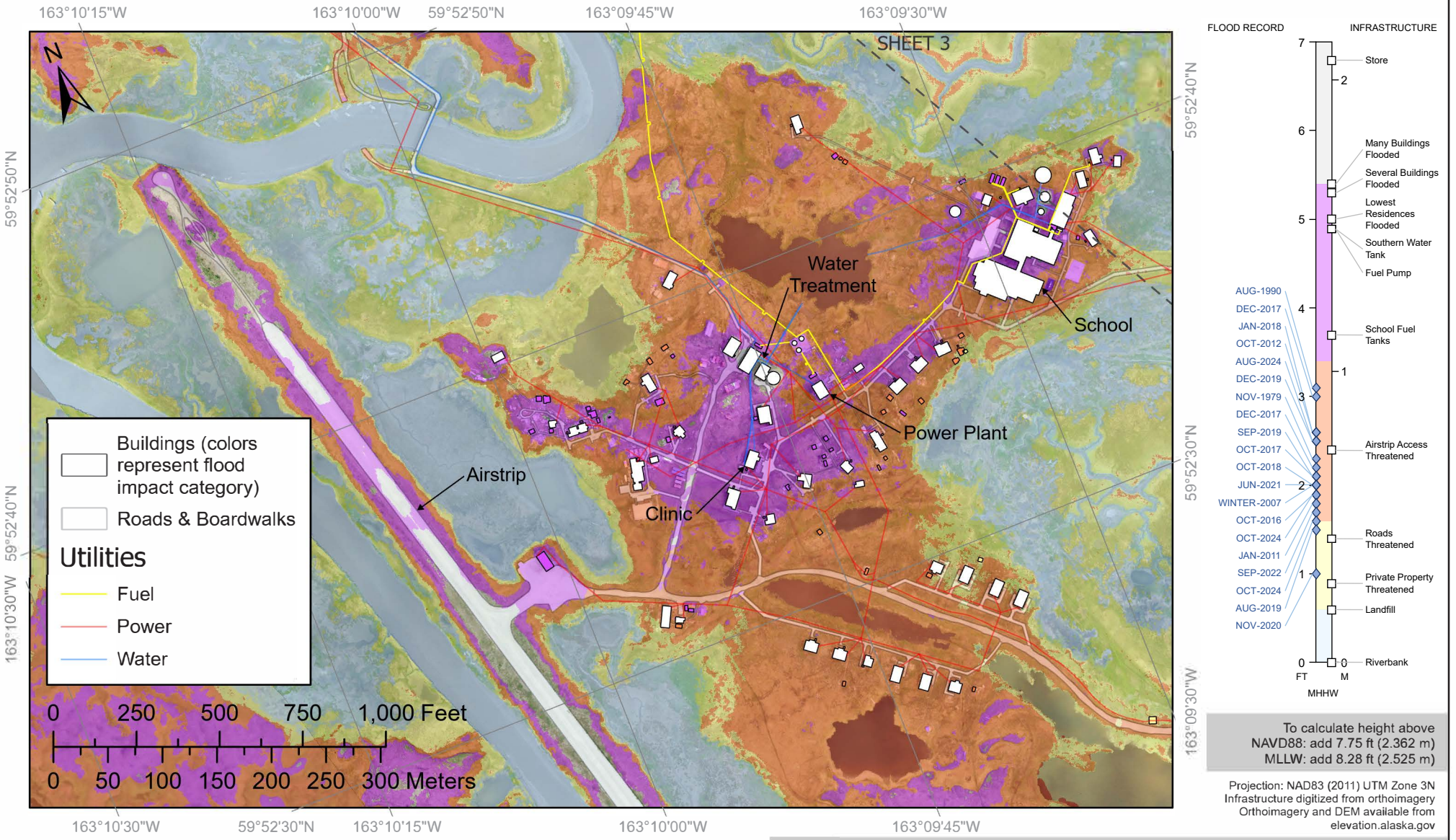
Minor Flooding is defined as minimal or no property damage. Evacuation of people and/or transfer of property to higher elevations are typically not necessary.

This work was made possible with National Fish and Wildlife Foundation's National Coastal Resilience Funding through a partnership with the Alaska Native Tribal Health Consortium.

Coastal Flood Impact Map

Kwigillingok, Alaska

REPORT OF INVESTIGATION 2025-1
Horen and others, 2025
SHEET 2 OF 5



To calculate height above
NAVD88: add 7.75 ft (2.362 m)
MLLW: add 8.28 ft (2.525 m)

Projection: NAD83 (2011) UTM Zone 3N
Infrastructure digitized from orthoimagery
Orthoimagery and DEM available from elevation.alaska.gov

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

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

Moderate Flooding is defined as some inundation of structures and roads at lower elevations. Some evacuation of people and/or transfer of property to higher elevations are necessary.

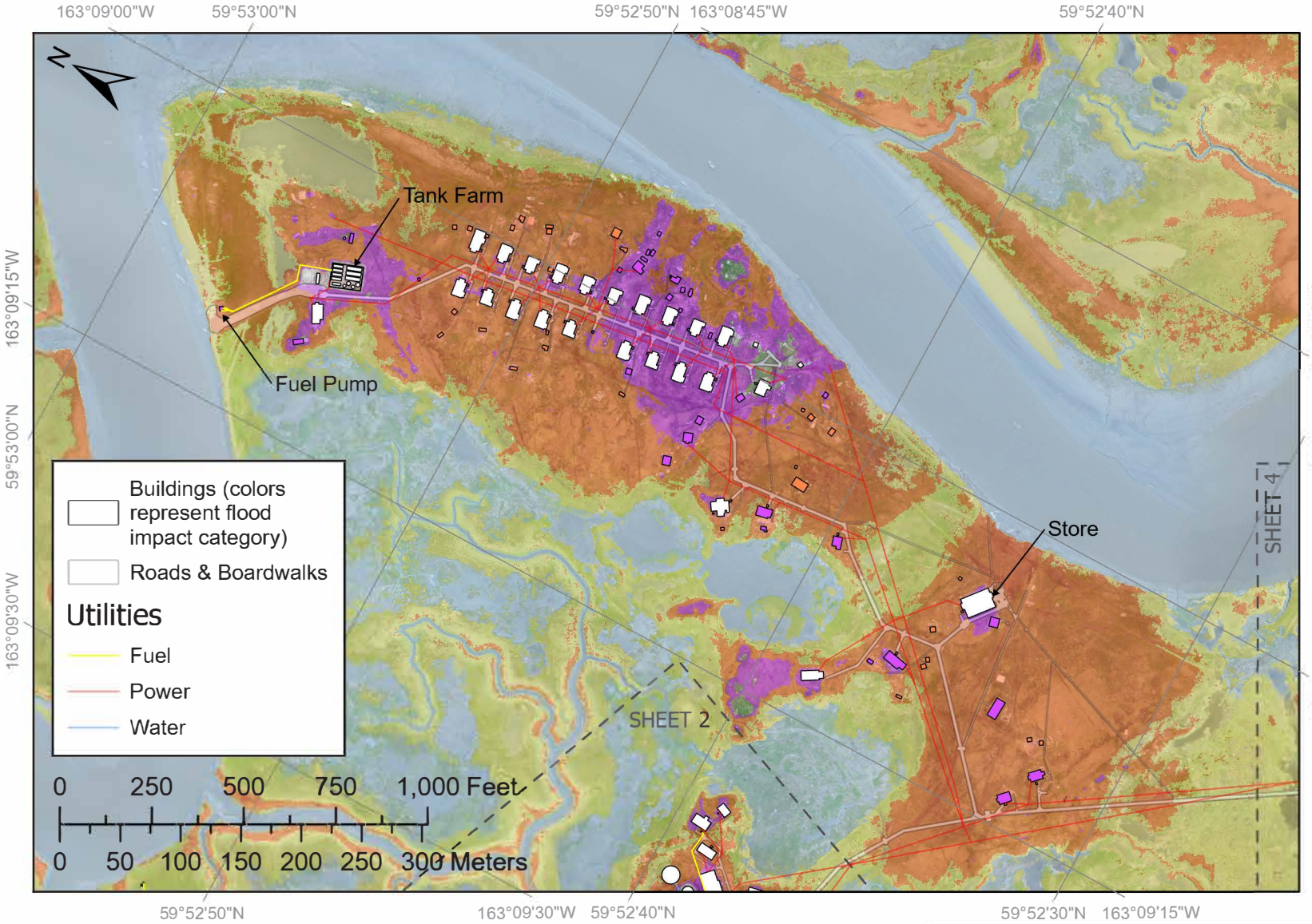
Minor Flooding is defined as minimal or no property damage. Evacuation of people and/or transfer of property to higher elevations are typically not necessary.

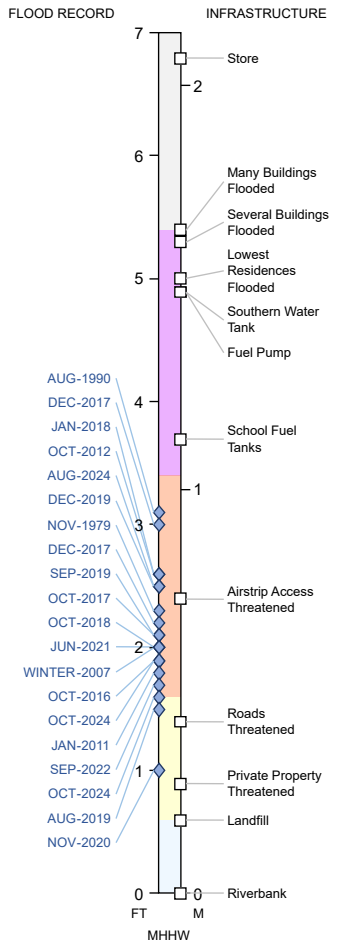
This work was made possible with National Fish and Wildlife Foundation's National Coastal Resilience Funding through a partnership with the Alaska Native Tribal Health Consortium.

Coastal Flood Impact Map

Kwigillingok, Alaska

REPORT OF INVESTIGATION 2025-1
Horen and others, 2025
SHEET 3 OF 5





To calculate height above
NAVD88: add 7.75 ft (2.362 m)
MLLW: add 8.28 ft (2.525 m)

Projection: NAD83 (2011) UTM Zone 3N
Infrastructure digitized from orthoimagery
Orthoimagery and DEM available from elevation.alaska.gov

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

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

Moderate Flooding is defined as some inundation of structures and roads at lower elevations. Some evacuation of people and/or transfer of property to higher elevations are necessary.

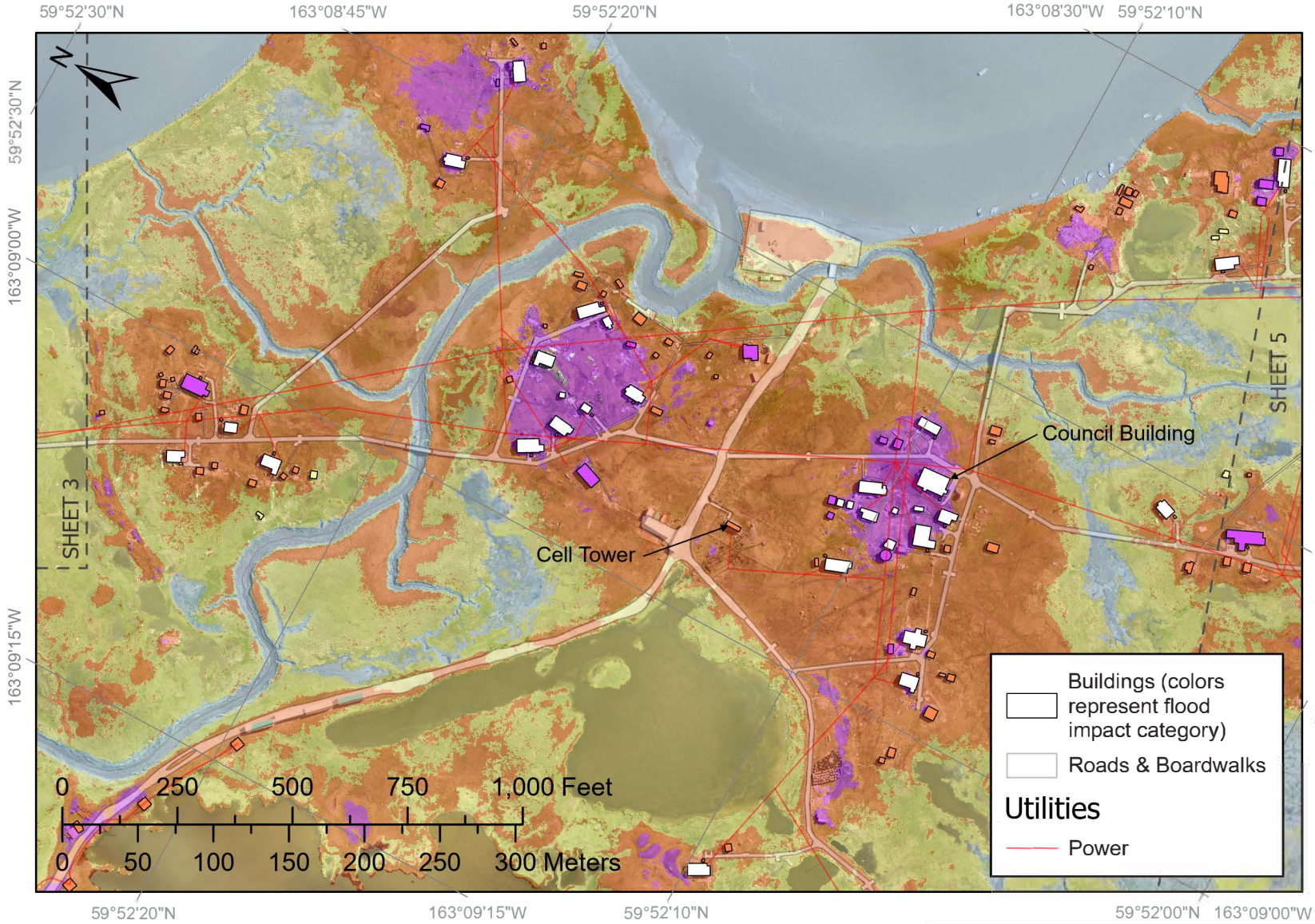
Minor Flooding is defined as minimal or no property damage. Evacuation of people and/or transfer of property to higher elevations are typically not necessary.

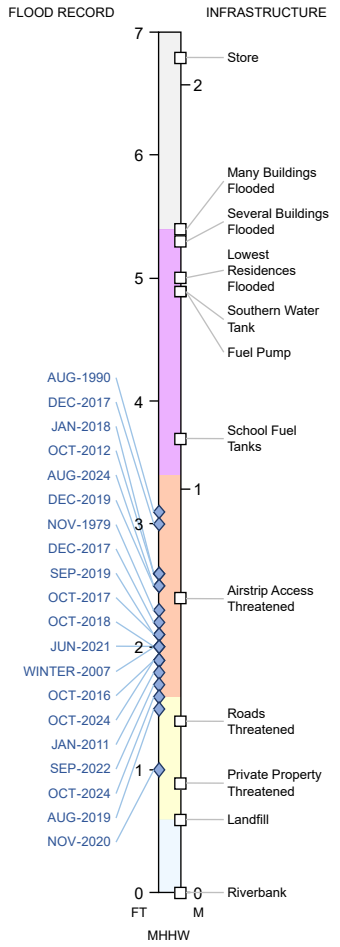
This work was made possible with National Fish and Wildlife Foundation's National Coastal Resilience Funding through a partnership with the Alaska Native Tribal Health Consortium.

Coastal Flood Impact Map

Kwigillingok, Alaska

REPORT OF INVESTIGATION 2025-1
Horen and others, 2025
SHEET 4 OF 5





To calculate height above
NAVD88: add 7.75 ft (2.362 m)
MLLW: add 8.28 ft (2.525 m)

Projection: NAD83 (2011) UTM Zone 3N
Infrastructure digitized from orthoimagery
Orthoimagery and DEM available from elevation.alaska.gov

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

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

Moderate Flooding is defined as some inundation of structures and roads at lower elevations. Some evacuation of people and/or transfer of property to higher elevations are necessary.

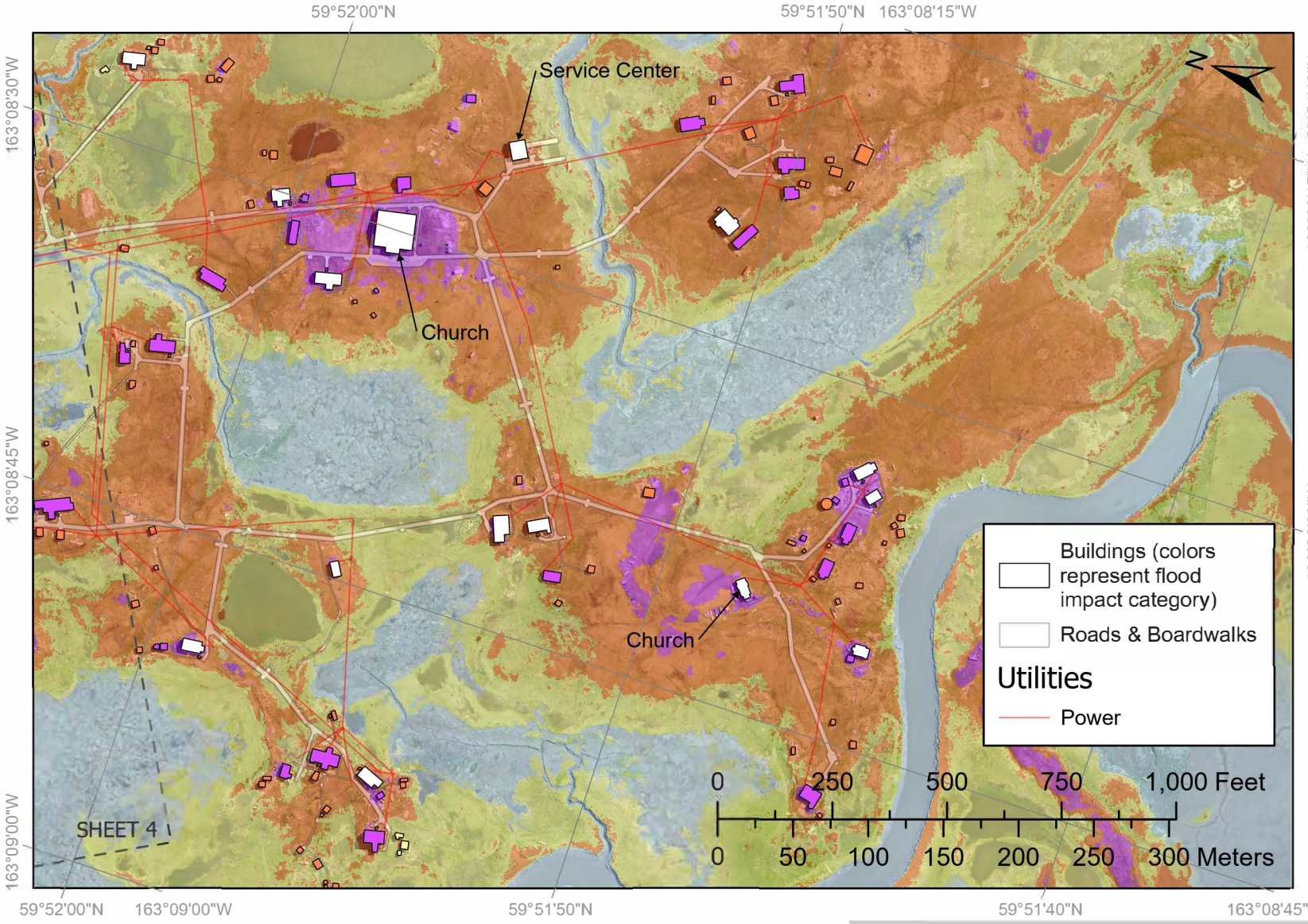
Minor Flooding is defined as minimal or no property damage. Evacuation of people and/or transfer of property to higher elevations are typically not necessary.

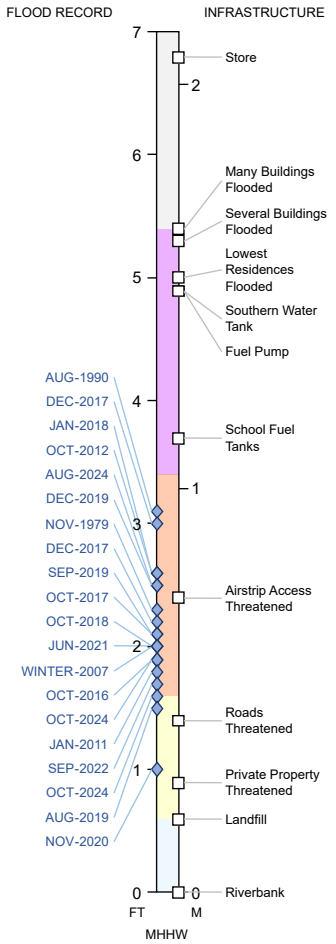
This work was made possible with National Fish and Wildlife Foundation's National Coastal Resilience Funding through a partnership with the Alaska Native Tribal Health Consortium.

Coastal Flood Impact Map

Kwigillingok, Alaska

REPORT OF INVESTIGATION 2025-1
Horen and others, 2025
SHEET 5 OF 5





To calculate height above
NAVD88: add 7.75 ft (2.362 m)
MLLW: add 8.28 ft (2.525 m)

Projection: NAD83 (2011) UTM Zone 3N
Infrastructure digitized from orthoimagery
Orthoimagery and DEM available from elevation.alaska.gov

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

Moderate Flooding is defined as some inundation of structures and roads at lower elevations. Some evacuation of people and/or transfer of property to higher elevations are necessary.

Minor Flooding is defined as minimal or no property damage. Evacuation of people and/or transfer of property to higher elevations are typically not necessary.

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

This work was made possible with National Fish and Wildlife Foundation's National Coastal Resilience Funding through a partnership with the Alaska Native Tribal Health Consortium.

Table 5. Summary of infrastructure heights and flood categories. Gray = extreme, purple = major, red = moderate, yellow = minor. The extreme category represents infrastructure situated at heights above the highest estimated flood height with confidence included. Categories are based on current infrastructure conditions.

Feature	Height (ft MHHW)	Confidence (ft)	Height (m MHHW)	Confidence (m)
School	13.2	0.2	4.03	0.07
Fresh water pump house	12.9	0.2	3.94	0.07
School generator	12.7	0.2	3.88	0.07
Power plant fuel tank containment	12.6	0.2	3.83	0.07
Clinic	11.8	0.2	3.60	0.07
Fuel tank farm containment	11.7	0.2	3.57	0.07
Washateria	11.5	0.2	3.51	0.07
Power plant	11.3	0.2	3.44	0.07
Freshwater lagoon	11.0	0.2	3.36	0.07
Sewage lagoon	9.2	0.2	2.81	0.07
School water tanks	8.6	0.2	2.61	0.07
Tribal council office	7.8	0.2	2.38	0.07
Fuel tank farm w/out containment	7.5	0.2	2.30	0.07
Water treatment plant	7.5	0.2	2.28	0.07
Community service center	7.3	0.2	2.23	0.07
Store	6.8	0.2	2.08	0.07
Extreme	**5.4**		**1.66**	
Many buildings flooded	5.4	0.2	1.63	0.07
Several buildings flooded	5.3	0.2	1.63	0.07
Lowest residences flooded	5.0	0.2	1.52	0.07
Southern water tank	4.9	0.2	1.49	0.07
Fuel pump	4.9	0.2	1.49	0.07
School fuel tanks	3.7	0.2	1.11	0.07
Major	**3.4**		**1.04**	
Airstrip Access threatened	2.4	0.3	0.73	0.09
Access to large portions of community	2.4	0.3	0.73	0.09
Moderate	**1.6**		**0.49**	
Low-lying roads threatened	1.4	0.3	0.42	0.09
Private property	0.9	0.2	0.26	0.07
Minor	**0.6**		**0.19**	
Landfill	0.6	0.3	0.17	0.09
Riverbank	**0.0**		**0.00**	

Extreme Flooding: greater than 5.4 ft (1.66 m) MHHW

School: 13.2 ± 0.2 ft (4.03 ± 0.07 m) MHHW

As the largest public building, with the highest first-floor height, the school has been identified as the most suitable flood evacuation point.

Fresh water pump house: 12.9 ± 0.2 ft (3.94 ± 0.07 m) MHHW

The water pump provides fresh water to the community from the freshwater lagoon.

School generator: 12.7 ± 0.2 ft (3.88 ± 0.07 m) MHHW

The school utility building, generator, and fuel tank share the same first-floor height and could be crucial for maintaining this location as an evacuation point.

Power plant fuel tank containment: 12.6 ± 0.2 ft (3.83 ± 0.07 m) MHHW

The fuel tanks servicing the power plant are surrounded by a containment wall. If such containment walls are breached or overtopped, the fuel tanks within may begin to float and could become damaged.

Clinic: 11.8 ± 0.2 ft (3.60 ± 0.07 m) MHHW

This is the first-floor height of the community clinic.

Fuel tank farm with containment: 11.7 ± 0.2 ft (3.57 ± 0.07 m) MHHW

All but one of the fuel tanks in the tank farm are surrounded by a containment wall at the northern end of the community.

Washateria: 11.5 ± 0.2 ft (3.51 ± 0.07 m) MHHW

Washaterias provided resources such as laundry, showers, toilets, and treated drinking water.

Power plant: 11.3 ± 0.2 ft (3.44 ± 0.07 m) MHHW

This is the primary source of power for the community.

Freshwater lagoon: 11.0 ± 0.2 ft (3.36 ± 0.07 m) MHHW

This lagoon to the north of the community is the primary reservoir of fresh water. A breach or overtopping of the berm surrounding this lagoon could contaminate this water source.

Sewage lagoon: 11.0 ± 0.2 ft (3.36 ± 0.07 m) MHHW

This lagoon to the southwest of the community is the primary wastewater disposal location. A breach or overtopping of the berm surrounding this lagoon could introduce contamination into the surrounding environment.

School water tanks: 8.6 ± 0.2 ft (2.61 ± 0.07 m) MHHW

The first-floor heights of the school water tanks range from 8.6 ft (2.61 m) to 9.1 ft (2.78 m) MHHW.

Tribal council office: 7.8 ± 0.2 ft (2.38 ± 0.07 m) MHHW

This is the first-floor height of the tribal council office.

Fuel tank without containment: 7.5 ± 0.2 ft (2.30 ± 0.07 m) MHHW

One active fuel tank at the northern end of the community is located outside of the tank farm containment wall.

Water treatment plant: 7.5 ± 0.2 ft (2.28 ± 0.07 m) MHHW

This is the first-floor height of the lowest water treatment facility.

Community service center: 7.3 ± 0.2 ft (2.23 ± 0.07 m) MHHW

This is the first-floor height of the community service center at the southern end of the community.

Store: 6.8 ± 0.2 ft (2.08 ± 0.07 m) MHHW

This is the first-floor height of the community store.

Major Flooding: 3.4 to 5.4 ft (1.04 to 1.66 m) MHHW

Many buildings flooded 1.0 ft (0.30 m) or more: 5.4 ± 0.2 ft (1.63 ± 0.07 m) MHHW

We consider "many" buildings to describe more than five occupied buildings. Occupied buildings are residential, public, or commercial structures in which people live or work.

Several buildings flooded less than 1.0 ft (0.30 m): 5.3 ± 0.2 ft (1.63 ± 0.07 m) MHHW

We consider "several" buildings to describe more than one but fewer than six occupied buildings.

Southern water tank: 4.9 ± 0.2 ft (1.49 ± 0.07 m) MHHW

This is the height of the water tank in the southern portion of the community.

Fuel pump: 4.9 ± 0.2 ft (1.49 ± 0.07 m) MHHW

This is the height of the fuel pump at the northern end of the community.

Lowest residences flooded: 4.0 ± 0.2 ft (1.22 ± 0.07 m) MHHW

This is the height at which the two lowest residential buildings would experience flooding.

School fuel tanks: 3.7 ± 0.2 ft (1.11 ± 0.07 m) MHHW

The school fuel tanks are elevated approximately 1.0 ft (0.30 m) above ground level but have no containing wall. This is the height at which water would reach the lowest point of these fuel tanks.

Moderate Flooding: 1.6 to 3.4 ft (0.49 to 1.04 m) MHHW

Airstrip access threatened: 2.4 ± 0.3 ft (0.73 ± 0.09 m) MHHW

Measured from the 2022 DSM, at this height the southern portion of the community would be cut off from access to the airstrip by water 1.0 ft (0.30 m) in depth. The NWS assumes a depth of 1.0 ft (0.30 m) to be the maximum for reasonably safe travel on flooded roads (NWS, 2023).

Access to southern portion of village threatened: 2.4 ± 0.3 ft (0.73 ± 0.09 m) MHHW

Measured from the 2022 DSM, at this height access to the southern portion of the community would be cut off from the northern portion of the community by water 1.0 ft (0.30 m) in depth.

Minor Flooding: 0.6 to 1.6 ft (0.19 to 0.49 m) MHHW

Low-lying roads threatened: 1.4 ± 0.3 ft (0.42 ± 0.09 m) MHHW

Measured from the 2022 DSM, flood waters would overtop the lowest portions of boardwalks and roads to a depth of less than 1.0 ft (0.30 m) at this height. The integrity of roads and boardwalks may be impacted by erosion and water damage, even if flood waters do not overtop these surfaces. Additionally, water on roads and boardwalks may make these surfaces difficult to traverse safely.

Private property threatened: 0.9 ± 0.2 ft (0.26 ± 0.07 m) MHHW

Measured from the 2021 DTM, flood waters would reach the lowest private property at this height. Private property may include storage sheds, boats, fishing equipment, vehicles, and other property at ground level outside of occupied structures. From the 2021 orthoimagery, we identified 327 features meeting this description and extracted the average ground heights beneath each from the 2021 DTM.

Landfill: 0.6 ± 0.3 ft (0.17 ± 0.09 m) MHHW

Measured from the 2022 DSM, flood waters would begin flooding the landfill at this height. Landfill flooding could result in dispersal of refuse and debris in the immediate vicinity of the landfill, including the river.

HISTORICAL FLOOD RECORD

The historical flood record for Kwigillingok is listed in chronological order below, with estimated floods identified by impact category. This record was compiled from local knowledge shared with DGGS staff during a June 2022 site visit and from information available to the public through open sources or upon request. It is possible that additional, undocumented flood events have impacted the community. Historical information was used in conjunction with the best available, temporally relevant geospatial data to estimate flood heights where possible.

All estimate confidences were calculated following the methods developed by Horen, Poisson, and others (2024). As described by Horen, Poisson, and others (2024), each estimate is accompanied by two confidence metrics, an estimate confidence based on the combined known potential errors and a time-based confidence based on the temporal relevance of the data used to estimate the given event. Temporal confidence values are noted with an asterisk (*) where the data used to estimate the flood event height were collected 20 years or more before or after the event: in these cases, the large temporal discontinuity may result in a value that could potentially exceed what the confidence model predicts (Horen, Poisson, and others, 2024).

For each flood event, a list and summarization of sources is included, as well as an explanation of the data used and steps performed during estimation, where relevant. Each flood height estimate is classified into a single flood impact category but estimate confidences may span more than one category. Table 6 provides a complete list of the flood events found during our research, with estimated floods categorized and listed in order from highest to lowest, and floods not estimated listed in chronological order. Figure 5 provides a timeline of the estimated flood events and a visual representation of the flood height estimates and confidences.

Table 6. Summary of historical floods in Kwigillingok, Alaska. Flood categories are included for reference: purple = major, red = moderate, yellow = minor.

	Estimated Floods							
	Flood Date	Type	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)
Moderate	1990-AUG-17	Storm Surge	3.1	± 1.3	± 1.0*	0.95	± 0.41	± 0.30*
	2017-DEC-21	Storm Surge	3.0	± 1.0	± 0.3	0.93	± 0.31	± 0.10
	2012-OCT	Storm Surge	2.6	± 0.6	± 0.5	0.78	± 0.18	± 0.16
	2018-JAN-14	Storm Surge	2.6	± 0.1	± 0.1	0.78	± 0.03	± 0.02
	2019-DEC-09	Storm Surge	2.5	± 0.3	± 0.2	0.76	± 0.10	± 0.05
	2024-AUG-18	Storm Surge	2.5	± 0.2	± 0.0	0.75	± 0.07	± 0.00
	1979-NOV-09	Storm Surge	2.3	± 0.2	± 1.0*	0.71	± 0.07	± 0.30*
	2017-DEC-14	Storm Surge	2.2	± 0.4	± 0.1	0.67	± 0.13	± 0.03
	2017-OCT-04	Surge Storm	2.1	± 0.6	± 0.1	0.65	± 0.19	± 0.03

Table 6, continued. Summary of historical floods in Kwigillingok, Alaska. Flood categories are included for reference: purple = major, red = moderate, yellow = minor.

Estimated Floods

	Flood Date	Type	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)
	2019-SEP-11	Storm Surge	2.1	± 0.1	± 0.1	0.63	± 0.03	± 0.03
	2018-OCT-04	Storm Surge	2.0	± 0.4	± 0.2	0.61	± 0.12	± 0.05
	2007-WINTER	Storm Surge	2.0	± 0.5	± 0.4	0.60	± 0.16	± 0.13
	2021-JUN-24	Storm Surge	2.0	± 0.3	± 0.0	0.60	± 0.08	± 0.00
	2016-OCT-27	Storm Surge	1.9	± 0.2	± 0.3	0.57	± 0.07	± 0.08
	2024-OCT-04	Storm Surge	1.9	± 0.2	± 0.0	0.57	± 0.07	± 0.00
	2011-JAN	Storm Surge	1.8	± 0.4	± 0.5	0.56	± 0.11	± 0.16
	2022-SEP-17	Storm Surge	1.7	± 0.2	± 0.0	0.51	± 0.07	± 0.00
	2024-OCT-21	Storm Surge	1.6	± 0.2	± 0.0	0.50	± 0.07	± 0.00
Minor	2019-AUG-02	Storm Surge	1.5	± 0.6	± 0.1	0.46	± 0.17	± 0.03
Minor	2020-NOV-20	Storm Surge	1.0	± 0.2	± 0.1	0.29	± 0.07	± 0.03

Floods Not Estimated

Date	Type
1966-FEB	Unknown
1985	Storm Surge
1987-OCT-14	Storm Surge
2000-NOV-13	Storm Surge
2003-DEC-09	Storm Surge
2004-SEP-09	Storm Surge
2004-NOV-19	Storm Surge

Date	Type
2006-SEP-07	Storm Surge
2013-NOV-07	Storm Surge
2015-DEC-25	Storm Surge
2019-AUG-29	High Tide
2019-NOV-26	Storm Surge
2020-JUL	High Tide

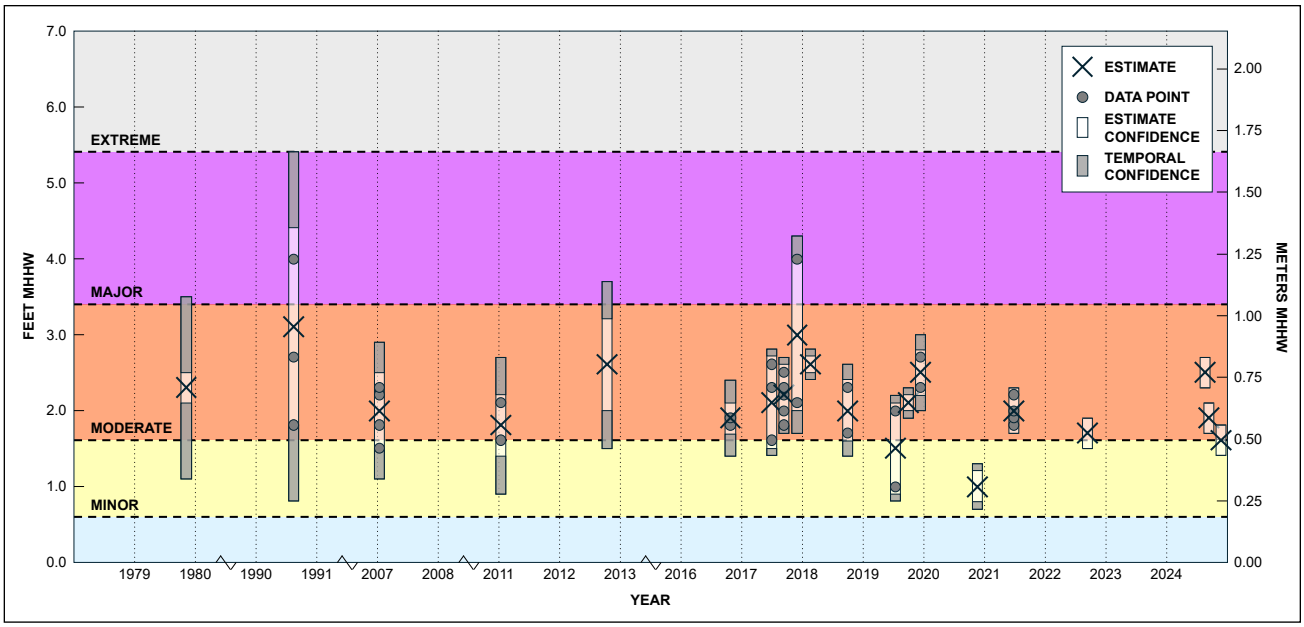


Figure 5. Timeline of estimated flood events and visual representation of flood height estimates and confidences for Kwigillingok, Alaska. Flood height estimates were calculated following the methods developed by Horen, Poisson, and others (2024). Estimates are denoted by black X symbols. Data points used during estimation are represented by dark-gray dots. Estimate confidences are displayed as vertical, light-gray boxes. Temporal confidences are displayed as vertical, dark-gray boxes. Each flood height estimate may only be classified into a single flood impact category, but total estimate confidences may exceed the upper and lower bounds of the data used during estimation and may span more than one flood impact category.

FLOOD EVENT SUMMARIES

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1966-FEB	--	--	--	--	--	--	No flood height estimate

Several documents cite a flood impacting Kwigillingok in 1966 (AIJ, 2019a; Village of Kwigillingok, 2015; Office of the Governor Rural Development Agency [RDA] and Alaska Disaster Office [ADO], 1971). The Hazard Mitigation Plan (HMP) developed by the Village of Kwigillingok (2015) stated "following a flood event in 1966… approximately one-half of the community relocated from Kwigillingok to higher ground in Kongiganak." In reference to this event, the AIJ (2019a) report and HMP (Village of Kwigillingok, 2015) cite a USACE flood data form dated September 15, 1973, which was archived with an RDA and ADO questionnaire form dated October 19, 1971. The RDA and ADO form provides the date of the last flood as February 1966 (RDA and ADO, 1971).

A flood height could not be estimated for this event because no specific impacts to the village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1979-NOV-09	2.3	± 0.2	± 1.0*	0.71	± 0.07	± 0.30*	Moderate

A letter from the Alaska Division of Emergency Services (ADES; 1980) to the USACE Alaska District provided a detailed account of a storm with "severe winds (80 mph), accompanying wave action and sea surge" affecting several communities on November 8 and 9, 1979. NOAA (1979) reported "the flooding on the Kuskokwim Bay coast was the worst in the memory of long-time residents." Specific impacts to the community of Kwigillingok included high water lifting and floating boardwalks in the community and flooding of the barreled fuel storage (ADES, 1980; AIJ, 2019a). There is also evidence of a state declared disaster in 1979 for a West Coast storm that caused extensive damage in 14 villages in the area between Nunam Iqua and Togiak (Alaska Division of Homeland Security & Emergency Management [DHS&EM], 2008).

The 2004 CPM (DCRA, 2004) has an area labeled "BIA Fuel Storage (not in use)," and the 1975 aerial image shows extensive barrel storage and tanks in this area (fig. 6).

To estimate this flood, we georeferenced the 1975 aerial image, identified the area indicated on the 2004 CPM, and overlayed the image with a simple bathtub model (Horen, Poisson, and others, 2024) applied to the 2021 DTM to approximate the height at which flood waters would reach the barrels shown in the aerial image.

Though this flood estimate is categorized as moderate, the estimate confidence range associated with this estimate could also potentially place this flood event within the minor or major impact categories.

Figure 6. 1975 USGS aerial image of the BIA Fuel Storage area in Kwigillingok, Alaska. Red circle indicates location of fuel barrels.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1985	--	--	--	--	--	--	No flood height estimate

A USACE trip report (Bethel, 1987) describes conversation between a civil engineer and Kwigillingok council member, Roland Lewis. Mr. Lewis describes "the worse [sic] floods occur when the wind comes from the south or southeast, setting up water on top of high tides. When this occurred once two years ago, it scared the villagers into vacating their homes" (Bethel, 1987; AIJ, 2019a).

A flood height could not be estimated for this event because no specific impacts to the village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1987-OCT-14	--	--	--	--	--	--	No flood height estimate

NOAA (1987) reported that "an intense Bering Sea storm brought winds to 75 mph and minor flooding to the Yukon-Kuskokwim delta coast."

A flood height could not be estimated for this event because no specific impacts to the village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1990-AUG-17	3.1	± 1.3	± 1.0*	0.95	± 0.41	± 0.30	Moderate

NOAA (1990) reported "high tides caused coastal flooding along the lower Kuskokwim River, Kuskokwim Bay, and Bristol Bay," noting Kwigillingok among the communities affected. The NOAA (1990) storm data report highlighted "the worst damage was to private property such as subsistence food, boats, motors, fishing nets, fishing camps, and homes" and noted "several roads and boardwalks were washed out, and a school and clinic in Kwigillingok were damaged." In September 1990, a disaster declaration was established to authorize assistance to those impacted by the flooding (DHS&EM, 2008).

The type and extent of damage to the clinic, school, or homes is unclear, but these would constitute the features with the greatest height to be impacted during this event. The clinic at the time of this event could not be located in the available maps or imagery, although the oldest portion of the current school is visible in the 1980 aerial image and the 2004 orthoimagery. The school is

supported on large pilings and its height is unlikely to have changed significantly in the time since it was built, but at 13.2 ft (4.03 m) MHHW, the first-floor height of the school is too high to be reasonably included in this estimate. Instead, we based our estimate on: the two lowest residential first-floor heights at 4.0 ft (1.21 m) and 4.0 ft (1.22 m) MHHW, the latter forming the upper limit of the estimate range; the lowest average ground height extracted from the 2021 DTM from beneath any school building at 2.7 ft (0.81 m) MHHW; and, as the lower limit of the estimate range, beneath residences at 1.8 ft (0.55 m) MHHW. An average of these four heights was calculated to estimate a flood height of 3.1 ft (0.95 m) MHHW.

Though this flood estimate is categorized as moderate based on the average, the relatively large confidence range associated with this estimate could also potentially place this flood event within the minor or major impact categories. The upper limit of this estimate's confidence forms the basis for the threshold between the major and extreme impact categories.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2000-NOV-13	--	--	--	--	--	--	Moderate

NOAA (2000) reported storm surge that impacted the Kuskokwim Delta on November 13, 2000, noting "a prolonged south and southwest fetch brought high water to many coastal communities" and "the onset of this coastal flooding coincided with very high tides," causing "significant damage… to several locations." Citing an article that appeared in "the Situation report from the Alaska Division of Emergency Services," NOAA (2000) quoted from ADES: "Kwigilligok [sic] has major damage to the boardwalk and bridges that connect the village."

Though a flood height could not be estimated for this event because it was not possible to link the reported impacts to an identifiable water height, we are able to classify this event into the moderate impact category based on the narrative information alone.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2003-DEC-09	--	--	--	--	--	--	No flood height estimate

NOAA (2003) reported storm surge for the Kuskokwim Delta, noting "the strong long southwest fetch across the Bering Sea resulted in a coastal storm surge along the Yukon and Kuskokwim Delta and northern Bristol Bay"

A flood height could not be estimated for this event because no specific impacts to the village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2004-NOV-19	--	--	--	--	--	--	No flood height estimate

NOAA (2004) reported flooding for the Kuskokwim Delta, noting "a west to southwest fetch across the Bering Sea, combined with high astronomical tide, resulted in coastal flooding across the west coast of the state."

A flood height could not be estimated for this event because no specific impacts to the village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2006-SEP-07	--	--	--	--	--	--	No flood height estimate

NOAA (2006) reported coastal flooding for the Kuskokwim Delta, noting "the Remnants of super typhoon Ioke… produced strong west wind across the Bering Sea that produced seas in excess of 30 feet" and "coincided with very high astronomical tides along the Bristol Bay coast and the coast of the Kuskokwim Delta" with "the combination of the storm surge and the very high tides" producing "minor coastal flooding."

A flood height could not be estimated for this event because no specific impacts to the village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2007-WINTER	2.0	± 0.5	± 0.4	0.60	± 0.16	± 0.13	Moderate

The Village of Kwigillingok (2015) Hazard Mitigation Plan included photographic evidence, provided by Darrel John and the planning team, of flooding and *venuq* (ice override) that occurred in the winter of 2007 and impacted the barge landing and at least one portion of boardwalk (fig. 7).

To estimate this flood, we identified the barge landing, buildings, and boardwalk in the photographs, located these within the 2022 orthoimagery, and overlayed this orthoimagery with a simple bathtub model applied to the 2015 DSM to approximate the height flood waters reached based on the location and disposition of the ice debris. Since the ice debris is concentrated along the top of the riverbank in the barge landing area, we modeled both the minimum water height at which water

would overtop the riverbank at 1.5 ft (0.46 m) MHHW and the extent of the ice debris at 1.8 ft (0.56 m) MHHW, the former of which formed the lower limit of the estimate range. We modeled a minimum and maximum likely water height at the boardwalk location, 2.2 ft (0.67 m) and 2.3 ft (0.69 m) MHHW, respectively, the latter of which formed the upper limit of the estimate range. An average of these four heights was calculated to estimate a flood height of 2.0 ft (0.60 m) MHHW.

Though this flood estimate is categorized as moderate based on the average, the estimate confidence range could also potentially place this flood event within the minor impact category.

Figure 7. Flooding and venuq at the barge landing (top-left and top-right) and boardwalk near the armory (bottom) in the winter of 2007 in Kwigillingok, Alaska (Village of Kwigillingok, 2015).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2011-JAN	1.8	± 0.4	± 0.5	0.56	± 0.11	± 0.16	Moderate

A community profile report from AIJ (2019a) described "mid-winter floods in January 2011" with "homes located in the south end of the village… almost impacted by ice."

To estimate this flood, we identified the residential building in the southern half of the village with the lowest average ground height beneath it extracted from the 2021 DTM, forming the upper limit of the estimate range at 2.1 ft (0.64 m) MHHW. We then located this building in the 2022

orthoimagery and overlayed this orthoimagery with a simple bathtub model applied to the 2021 DTM to approximate the minimum height at which flood waters would touch the structure, forming the lower limit of the estimate range at 1.6 ft (0.48 m) MHHW. An average of these two heights was calculated to estimate a flood height of 1.8 ft (0.56 m) MHHW.

Though this flood estimate is categorized as moderate based on the average, the estimate confidence range could also potentially place this flood event within the minor impact category.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2012-OCT	2.6	± 0.6	± 0.5	0.78	± 0.18	± 0.16	Moderate

The Village of Kwigillingok (2015) HMP states "community residents reported a significant flood event in 2012" with "damage to bridges and other structures." Additionally, the HMP included a photograph (fig. 8) and description of flooding affecting "the landfill across the river from the village" (Village of Kwigillingok, 2015). A Coastal Impact Assistance Program, Waste Erosion Assessment and Review report from the Alaska Department of Environmental Conservation (ADEC) noted "during the storm of October 2012, the landfill flooded to depths of two feet, washing away much of the waste as far as a mile inland of the landfill" (ADEC, 2012).

To estimate this flood, we identified the landfill in the 2022 orthoimagery and overlayed this orthoimagery with a simple bathtub model applied to the 2022 DSM because this was the only DEM with coverage of the landfill area. The landfill begins to flood at 0.6 ft (0.17 m) MHHW, and we added 2.0 ft (0.61 m) to this height.

Though this flood estimate is categorized as moderate, the estimate confidence range could also potentially place this flood event within the minor or major impact categories.

Figure 8. Landfill flooding in October 2012 in Kwigillingok, Alaska, (credit: Ryan Maroney [Village of Kwigillingok, 2015]).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2013-NOV-07	--	--	--	--	--	--	No flood height estimate

NOAA (2013) reported coastal flooding for the Kuskokwim Delta, noting "an intense and large storm in the Bering Sea produced a long fetch of strong wind across the Bering Sea aligned with the Kuskokwim Delta coast November 6th through the 9th" that "produced a surge of up to 5 feet along the Kuskokwim Delta Coast."

A flood height could not be estimated for this event because no specific impacts to the Village of Kwigillingok were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2015-DEC-25	--	--	--	--	--	--	No flood height estimate

The community profile report from AIJ (2019a) included several photographs provided by Gavin Phillip that depicted flooding during an event in December 2015, but the report does not provide any details about this event. The National Centers for Environmental Information (NCEI) Storm Events Database (2015a) reported a "storm surge/tide" event in the Bristol Bay area that occurred December 24–26, 2015. The same narrative was provided for a "winter weather" event for the Kuskokwim Delta on December 24, 2015 (NCEI, 2015b), with both database entries reporting "prolonged periods of high winds and heavy waves caused damage along the West Coast" (NCEI, 2015a, 2015b).

A flood height could not be estimated for this event because we were unable to identify the building shown in the AIJ report.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2016-OCT-27	1.9	± 0.2	± 0.3	0.57	± 0.07	± 0.08	Moderate

The community profile report from AIJ (2019a) stated "several flooding events and high winds affected Kwigillingok. One resident had to move equipment to higher ground because of flooding under his house. Several skiffs were damaged."

To estimate this flood, we extracted the two lowest average ground heights beneath residential buildings from the 2021 DTM, 1.8 ft (0.55 m) and 1.9 ft (0.59 m) MHHW. These values form the

upper and lower limits of our estimate range. An average of these two heights was calculated to estimate a flood height of 1.9 ft (0.57 m) MHHW.

Though this flood estimate is categorized as moderate based on the average, the estimate confidence range could also potentially place this flood event within the minor impact category.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2017-OCT-04	2.1	± 0.6	± 0.1	0.65	± 0.19	± 0.03	Moderate

The community profile report from AIJ (2019a) detailed "flooding lasted ~6 days, with south winds getting as high as 57MPH. On Oct. 5th, there was a full moon, so the tides were higher. No damage to infrastructure." Information and photographs of flooding during the event were provided to AIJ by Lewis Amik III and Gavin Phillip (AIJ, 2019a) and a photograph of the 2017 flood staff was provided to DGGS by Lewis Amik III (fig. 9).

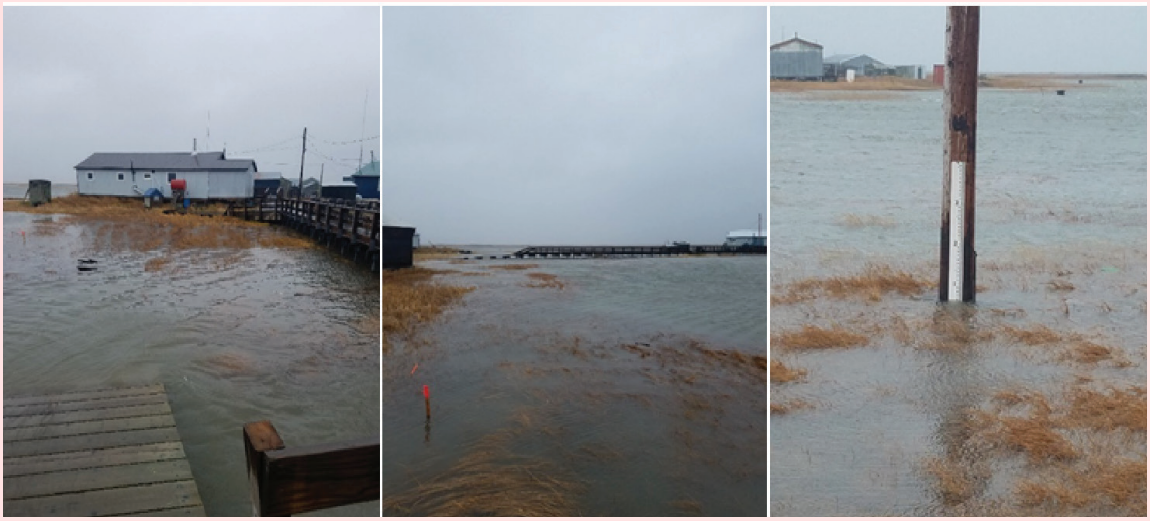


Figure 9. Photographs of flooding on October 4, 2017, in Kwigillingok, Alaska. Storm waters near a residence (left), flooding under boardwalk (middle), and DGGS-installed flood-staff reading a water level of 1.6 ft (0.48 m) MHHW (right) (credit: Lewis Amik III [AIJ, 2019a]).

To estimate this flood, we identified the water height depicted in the photograph in relation to the flood staff, 0.6 ft (0.18 m). Adding this value to the height of the base of the flood staff, 1.0 ft (0.30 m) MHHW, provides a height of 1.6 ft (0.48 m) MHHW. To corroborate this finding, we also identified the buildings and boardwalks in the photographs provided to AIJ, located these structures within the 2015 orthoimagery, and overlayed this orthoimagery with a simple bathtub model applied to the 2015 DSM to approximate the height of flood waters depicted. The photographic comparison yielded heights of 2.6 ft (0.78 m) and 2.3 ft (0.69 m) MHHW.

Based on the significant range of these results, especially with the photographic evidence depicting flood heights as much as 1.0 ft (0.30 m) higher than the flood staff indicates, we chose to include the results from all evidence in our estimate. An average of these three heights was calculated to estimate a flood height of 2.1 ft (0.65 m) MHHW, with an upper and lower limit of 1.6 ft (0.48 m) and 2.6 ft (0.78 m) MHHW, respectively.

Though this flood estimate is categorized as moderate based on the average, the estimate confidence range could also potentially place this flood event within the minor impact category.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2017-DEC-14	2.2	± 0.4	± 0.1	0.67	± 0.13	± 0.03	Moderate

According to the December 2017 Storm and Weather Narratives report from AIJ (2017), "flooding began at 11pm on Dec. 14 and lasted until Dec. 16 at 1:30pm, when the tide went down. The water came up fast, and as a result, residents could not access the downtown area through the trails. The boardwalk system was accessible in some areas." The narrative report (AIJ, 2017) and the Kwigillingok Community Profile report from AIJ (2019a) reported no damage associated with this event. Lewis Amik III and Ephraim Andrew provided photographs of the flooding to AIJ (2017) (figs. 10–12).

To estimate this flood, we identified the buildings and boardwalks in the photographs, located these within the 2015 orthoimagery, and overlayed this orthoimagery with a simple bathtub model applied to the 2015 DSM to approximate the height flood waters reached. An average of these six heights (table 7) was calculated to estimate a flood height of 2.2 ft (0.67 m) MHHW.

Figure 10. Photographs of flooding taken approximately 330 ft (100 m) southwest of Naruyatalik subdivision in Kwigillingok, Alaska, on December 14 at 11:00 PM (**A**) facing south toward store and (**B**) facing north (credit: Lewis Amik III [AIJ, 2017]).

Figure 11. Photographs of flooding in Kwigillingok, Alaska, on December 15, 2017, taken around 3:00 PM (**A**) approximately 300 ft (90 m) northeast of the police office facing north and (**B**) approximately 500 ft (150 m) south of National Guard building, facing north-northwest (credit: Lewis Amik III [AIJ, 2017]).

Figure 12. Photographs of flooding in Kwigillingok, Alaska, on December 15, 2017, taken around 3:00 PM (**A**) approximately 985 ft (300 m) south of store, facing north-northwest and (**B**) approximately 115 ft (35 m) south of school, facing south-southwest (credit: Ephraim Andrew [AIJ, 2017]).

Table 7. Estimated flood heights derived from photographic evidence associated with the flood event on December 14, 2017, in Kwigillingok, Alaska.

Photograph		Height (MHHW)	
Figure	Identifier	ft	m
10	A	2.2	0.66
10	B	2.5	0.77
11	A	2.3	0.69
11	B	1.8	0.56
12	A	2.3	0.71
12	B	2.0	0.62

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2017-DEC-21	3.0	± 1.0	± 0.3	0.93	± 0.31	± 0.10	Moderate

The AIJ (2017) December 2017 Storm and Weather Narratives reported "a southerly wind storm during the night of December 19 through December 22, which ultimately resulted in a flooding event in the downtown… and midtown… area of Kwigillingok." AIJ (2017) further noted "the houses on the coastal side to the south side of the community had flooding" with community members unable to "use boardwalks or reach the tide staff" and several mentions of water beneath homes.

To estimate this flood, we identified 29 residential buildings at the southern end of the community near the location of the flood staff present at the time of this event. Using the 2021 DTM, we extracted the lowest average ground height beneath these buildings—2.1 ft (0.64 m) MHHW—to form the lower limit of our estimate range. We then found the lowest first-floor height among these buildings from the 2023 survey—4.0 ft (1.22 m) MHHW— to form the upper limit of our estimate range. An average of these two heights was calculated to estimate a flood height of 3.0 ft (0.93 m) MHHW.

Though this flood estimate is categorized as moderate based on the average, the estimate confidence range could also potentially place this flood event within the major impact category.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2018-JAN-14	2.6	± 0.1	± 0.1	0.78	± 0.03	± 0.02	Moderate

The AIJ (2018a) January 2018 Storm and Weather Narratives reported "high water began to rise over the riverbank at 7pm and high tide occurred at 11pm… In some places, flooding overtopped the boardwalks… and they became inaccessible." A map with areas of flooding circled was provided to AIJ by Lewis Amik III, along with photographs of flooding at the peak of high tide on January 14, 2018 (AIJ, 2018a).

Since the peak of flooding during this event occurred at night, the locations depicted in the photographs provided to AIJ were difficult to identify. However, through a photographic pixel height comparison of the 2017 flood staff (fig. 1), we were able to identify the water height shown was 1.6 ft (0.49 m), which, added to the height of the flood staff (1.0 ft [0.30 m] MHHW), resulted in an estimated height of 2.6 ft (0.78 m) MHHW (fig. 13). To corroborate this finding, we overlayed the 2022 orthoimagery with a simple bathtub model applied to the 2021 DTM to approximate the height identified from the flood staff. The modeled extents of flooding are consistent with the areas indicated on the map provided to AIJ (2018a; fig. 14).

Figure 13 (above). Photograph of flood staff at the peak of high tide on January 14, 2018, in Kwigillingok, Alaska, reading a water level of 2.6 ft (0.78 m) MHHW (credit: Lewis Amik III [AIJ, 2018a]).

Figure 14 (right). Map with areas of flooding circled in black corresponding to the flood event on January 14, 2018, in Kwigillingok, Alaska (credit: Lewis Amik III [AIJ, 2018a]).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2018-OCT-04	2.0	± 0.4	± 0.2	0.61	± 0.12	± 0.05	Moderate

The AIJ (2018b) October 2018 Storm and Weather Narratives reported "flooding began in the afternoon of Oct. 3… and lasted until the evening of Oct. 5" but "no damage to infrastructure was reported." Community members provided photographs and a map of flooding to AIJ (2018b), although the locations in the photographs could not be definitively identified.

To estimate this flood, we overlayed the 2015 orthoimagery with a simple bathtub model applied to the 2021 DTM to approximate the extents depicted in the map provided to AIJ (2018b; fig. 15). We found the highlighted areas matched a flood height between 1.7 and 2.3 ft (0.51 and 0.71 m) MHHW. An average of these two heights was calculated to estimate a flood height of 2.0 ft (0.61 m) MHHW.

Though this flood estimate is categorized as moderate, the estimate confidence range could also potentially place this flood event within the minor impact category.

Figure 15. Map with areas of flooding highlighted in yellow corresponding to the flood event on October 4, 2018, in Kwigillingok, Alaska (credit: Gavin Phillip [AIJ, 2018b]).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2019-AUG-02	1.5	± 0.6	± 0.1	0.46	± 0.17	± 0.03	Minor

The AIJ (2019b) August 2019 Storm and Weather Narratives reported "strong wind, heavy rain, tide surge, and minor flooding" lasting for multiple days, with peak water level "about one or two feet above the riverbank." No damage was recorded. Photographs taken on August 2, 2019, were provided to AIJ by Darryl John (AIJ, 2019b).

To estimate this flood, we identified the riverbank height—0.0 ft (0.00 m) MHHW—and added the average of the reported heights above this feature, 1 and 2 ft (0.30 and 0.61 m), for a flood estimate of 1.5 ft (0.46 m) MHHW. To corroborate this finding, we identified the buildings and boardwalks in the photographs provided to AIJ (2019b; fig. 16), located these within the 2022 orthoimagery, and overlayed this orthoimagery with a simple bathtub model applied to the 2021 DTM to approximate the heights of flood water depicted in the photographs.

Though this flood is categorized as minor based on the average, the estimate confidence range could also potentially place this flood event within the moderate impact category.

Figure 16. Photographs of flooding on August 2, 2019, in Kwigillingok, Alaska (credit: Darryl John [AIJ, 2019b]).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2019-AUG-29	--	--	--	--	--	--	No flood height estimate

In an update to the 2019 community profile report from AIJ (2021), two flood events are listed unrelated to storm events: the first on August 29, 2019, and the second in July 2020. It is unclear which of these two events the photographs included in the AIJ document depict because the same photographs appear to have been labeled for both events.

Based on the predicted high-tide height for August 29, 2019, it is likely flooding occurred on that day, but a flood height could not be estimated for this event due to the ambiguity of the photographic evidence.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2019-SEP-11	2.1	± 0.1	± 0.1	0.63	± 0.03	± 0.03	Moderate

The AIJ (2019c) September and October 2019 Storm and Weather Narratives reported "Kwigillingok was flooded for approximately three hours with the high tide peaking at 1:00 pm… There was no damage to any of the boardwalks." Photographs of flooding during the event, including a photograph of the flood staff that was installed in 2017 (fig. 17), were provided to AIJ by Lewis Amik III and Gary Evon (AIJ, 2019c).

Figure 17. Photograph of flooding in relation to the 2017 flood staff, taken on September 11, 2019, in Kwigillingok, Alaska (credit: Lewis Amik III [AIJ, 2019c]).

To estimate this flood, we identified the flood staff height reading depicted in the photograph—1.1 ft (0.34 m)—and added this to the height of the flood staff—1.0 ft (0.30 m) MHHW—for a flood estimate of 2.1 ft (0.63 m) MHHW. To corroborate this finding, we identified the buildings and boardwalks in the photographs provided to AIJ (2019c; fig. 18), located these within the 2022 orthoimagery, and overlayed this orthoimagery a with simple bathtub model applied to the 2021 DTM to approximate the heights of flood water depicted in the photographs. The modeled extents of flooding are consistent with the areas indicated in the photographs provided to AIJ (2019c).

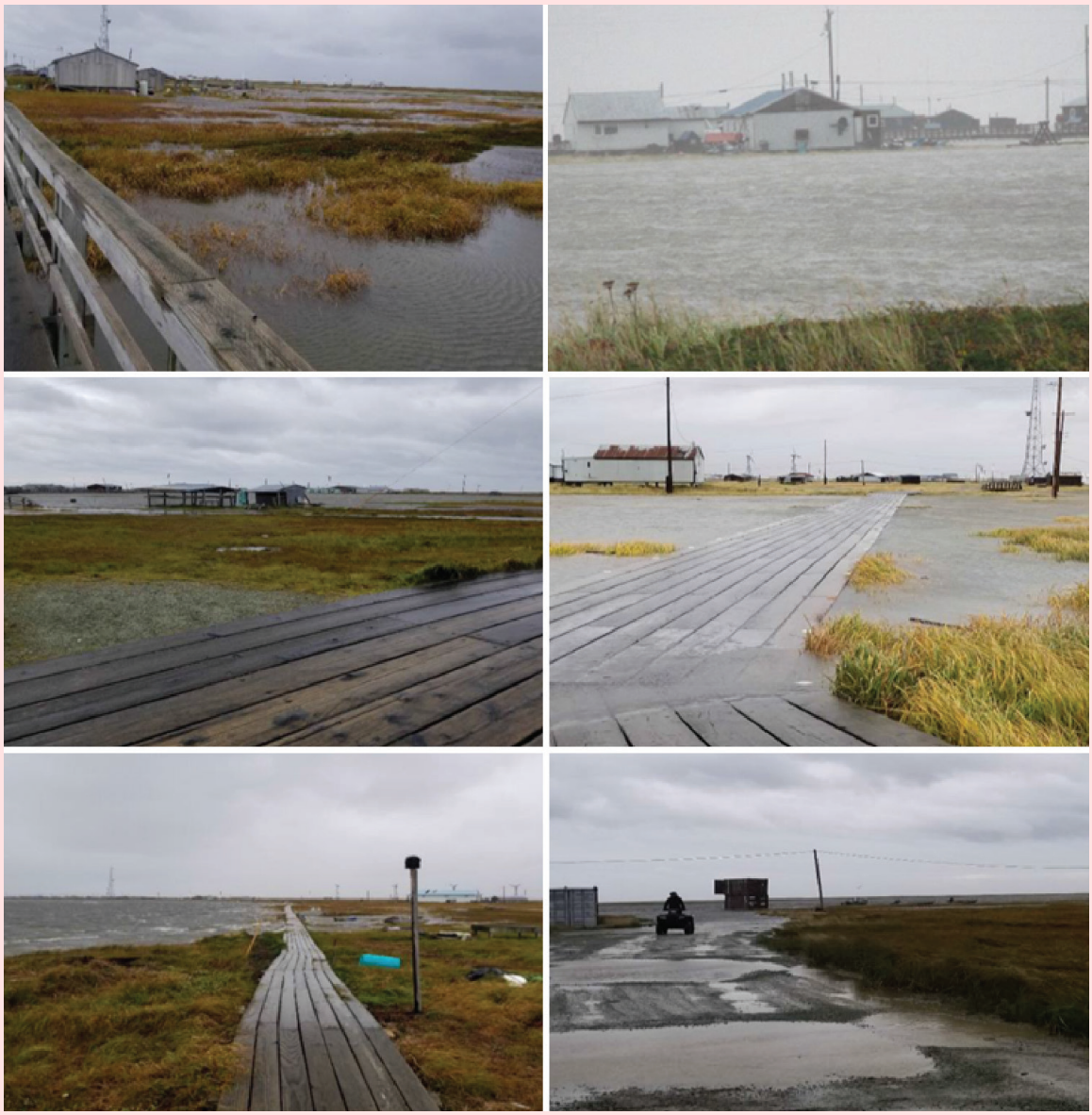


Figure 18. Photographs of flooding on September 11, 2019, in Kwigillingok, Alaska.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2019-NOV-26	-	-	-	-	-	-	No flood height estimate

The AIJ (2019d) November 2019 Storm and Weather Narratives did not report any specifics regarding flood height or infrastructure impacts during an event on November 26. Photographs of flooding during the event were provided to AIJ by Lewis Amik III (AIJ, 2019d; fig. 19), however, we were unable to locate the areas depicted because the photographs were taken at night, did not contain identifiable infrastructure, and were not thoroughly described in the report.

Figure 19. Photographs of flooding on November 26, 2019, in Kwigillingok, Alaska.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2019-DEC-09	2.5	± 0.3	± 0.2	0.76	± 0.10	± 0.05	Moderate

The AIJ (2019e) December 2019 Storm and Weather Narratives reported "major flooding minor damage to infrastructure" and "winds 35 mph with gusts 45 mph south southwest." Photographs taken on December 9 and 10, were included in the AIJ (2019e) report.

To estimate this flood, we identified the locations from which the photographs were taken and the infrastructure depicted, located these within the 2022 orthoimagery, and overlayed this orthoimagery with simple bathtub models applied to the 2021 DTM and the 2022 DSM to approximate the height of the flood waters depicted. We applied the simple bathtub model to the 2022 DSM for the photographs taken on December 9 (fig. 20) because of the prominence of the boardwalks and bridges, which would be absent from the 2021 DTM. These photographs matched flood heights of 2.3 ft (0.71 m) and 2.7 ft (0.81 m) MHHW. We applied the simple bathtub model to the 2021 DTM for the photographs taken on December 10 (fig. 21) because of the prominence of the bare ground along the banks of the stream, which would be obscured by vegetation in the 2022 DSM. These photographs matched flood heights of 1.0 ft (0.31 m) and 1.5 ft (0.46 m) MHHW, significantly lower than the results from the photographs taken the previous night.

Due to the large disparity in the heights depicted, we chose to base our estimate on only the heights derived from the photographs taken on the night of December 9. An average of these two heights was calculated to estimate a flood height of 2.5 ft (0.76 m) MHHW.

Figure 20. Photographs of flooding on December 9, 2019, in Kwigillingok, Alaska (AIJ, 2019e).

Figure 21. Photographs of flooding on December 10, 2019, in Kwigillingok, Alaska (AIJ, 2019e).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2020-JUL	--	--	--	--	--	--	No flood height estimate

In the update to the 2019 community profile report from AIJ (2021), two flood events are listed unrelated to storm events: the first on August 29, 2019, and the second in July 2020. It is unclear which of these two events is depicted in the photographs included in the AIJ document because the exact same or related photographs appear to have been labeled for both events.

Based on the predicted tide heights for July 2020, it is likely flooding occurred during that month, but a flood height could not be estimated for this event due to the ambiguity of the photographic evidence.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2020-NOV-20	1.0	± 0.2	± 0.1	0.29	± 0.07	± 0.03	Minor

In the update to the 2019 community profile report from AIJ (2021), an evaluation by Rick Thoman, a climate specialist at UAF, stated "a strong, slow-moving and very slowly weakening storm moved from near Adak early morning of the 19th to northeast of St. Paul Island evening of the 20th. South to southeast winds ahead of the storm sustained over water 25 to 45 mph. These factors contributed to the flood issues at Kwig [sic] with online ocean water transport." The AIJ (2021) report included photographs of ice debris and flood waters taken during the event and provided by Gary Evon.

To estimate this flood, we identified the building depicted in one of the photographs included in the AIJ (2021) report (fig. 22), located it within the 2015 orthoimagery because the structure appears to have been moved sometime between June 2021 and June 2022, then overlayed this orthoimagery with a simple bathtub model applied to the 2021 DTM to approximate the height of the flood water depicted.

Figure 22. Photograph of ice debris and flooding on November 20, 2020, in Kwigillingok, Alaska (credit: Gary Evon [AIJ, 2021]).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2021-JUN-24	2.0	± 0.3	± 0.0	0.60	± 0.08	± 0.00	Moderate

In the update to the 2019 community profile report from AIJ (2021), photographs of flooding on June 24, 2021, were provided by Darren John and Gary Evon. A June 27, 2021, Alaska Public Media article, citing environmental coordinator Gary Evon, reported "water did not enter any structures… but 6 inches of water covered the ground beneath" (Kim, 2021).

To estimate this flood, we identified the buildings and infrastructure in the photographs from the AIJ (2021) report (fig. 23), located these within the 2015 or 2022 orthoimagery, and overlayed the orthoimages with a simple bathtub model applied to the 2021 DTM to approximate the height of the flood waters depicted. These photographs matched flood heights of 2.2 ft (0.66 m), 2.0 ft (0.61 m), 1.9 ft (0.58 m), and 1.8 ft (0.56 m) MHHW. An average of these four heights was calculated to estimate a flood height of 2.0 ft (0.60 m) MHHW.

Though this flood estimate is categorized as moderate based on the peak recorded water level, the estimate confidence range could also potentially place this flood event within the minor impact category.

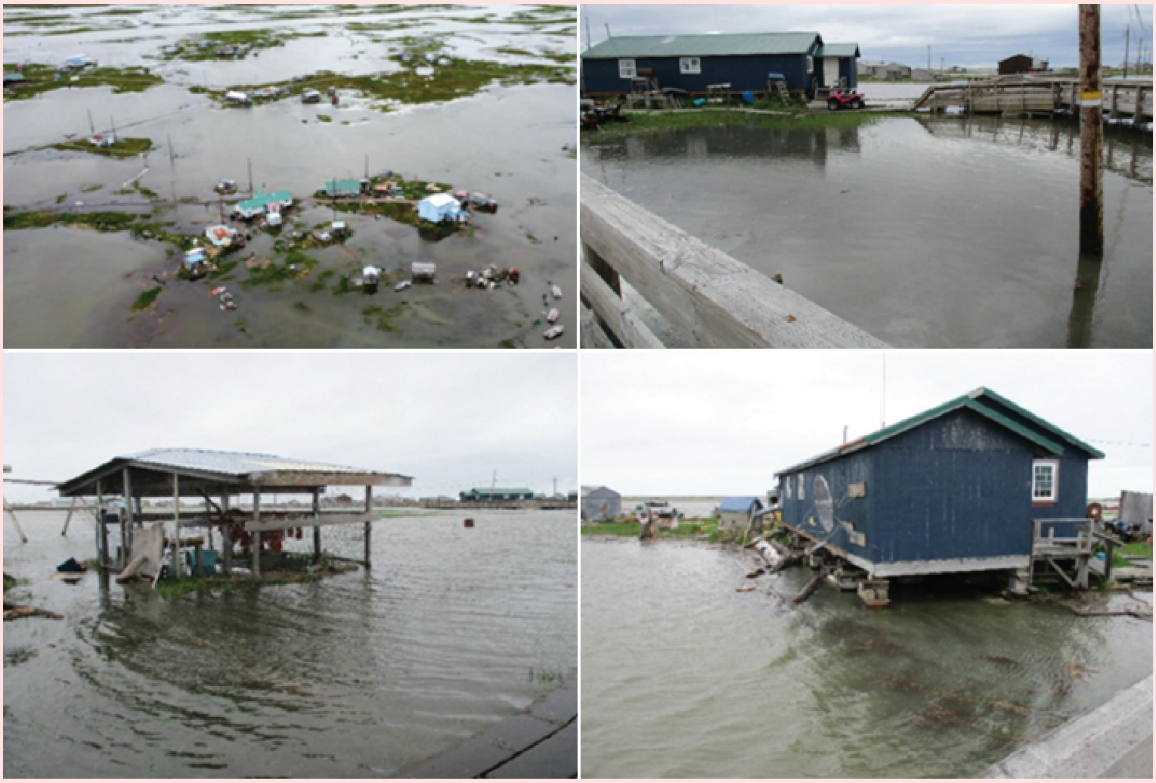


Figure 23. Photographs of flooding on June 24, 2021, in Kwigillingok, Alaska (credit: Darren John and Gary Evon [AIJ, 2021]).

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2022-SEP-17	1.7	± 0.2	± 0.0	0.51	± 0.07	± 0.00	Moderate

The NCEI Storm Events Database (2022) reported "a myriad of impacts were noted across the West Alaska Coastline" as the remnants of Typhoon Merbok reached the Kuskokwim Delta coast in the early evening on September 16, 2022, noting that "impacts, including damaging wind gusts and storm surge, were observed from the Kuskokwim Delta to the Yukon Delta…" (NCEI, 2022).

To estimate this flood, we gathered water level data from the Stilltek iGage located in Kwigillingok (figs. 1 and 2) for the time period relevant to this flood event (fig. 24). The peak recorded water level during this event was 1.7 ft (0.51 m) MHHW.

Though this flood estimate is categorized as moderate based on the peak recorded water level, the estimate confidence range could also potentially place this flood event within the minor impact category.

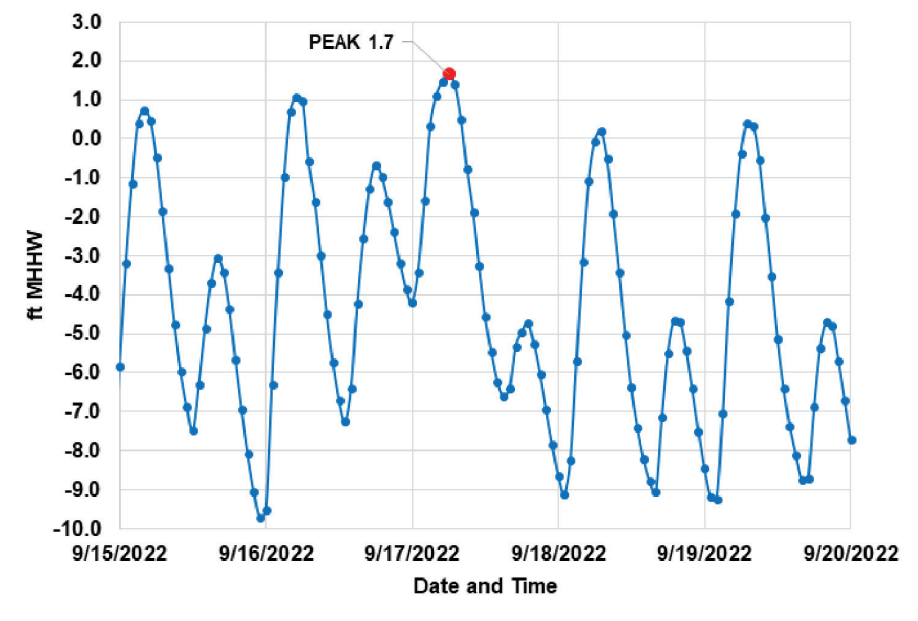


Figure 24. Water level heights collected in Kwigillingok, Alaska, from 12:00 AM AKDT on September 14, 2022, to 12:00 AM AKDT on September 20, 2022.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2024-AUG-18	2.5	± 0.2	± 0.0	0.75	± 0.07	± 0.00	Moderate

Yukon-Kuskokwim Delta public media outlet, KYUK, published an article on August 18, 2024, that included a photograph of flooding in Kwigillingok and noted: "A series of large storms have left some Western Alaska communities grappling with flooding and erosion. Some residents report that the flooding is worse than Typhoon Merbok…" (Erickson and Smiley, 2024). A follow-up article from KYUK published on August 21, 2024, included several additional photographs of the flooding in Kwigillingok during this event and stated: "While communities have not reported serious injuries or deaths as a result of the series of storms, many communities saw damage to snowmachines, boats, and some infrastructure" (Smiley, 2024).

To estimate this flood, we gathered water level data from the Stilltek iGage located in Kwigillingok (figs. 1 and 2) for the time period relevant to this flood event (fig. 25). The peak recorded water level during this event was 2.5 ft (0.75 m) MHHW.

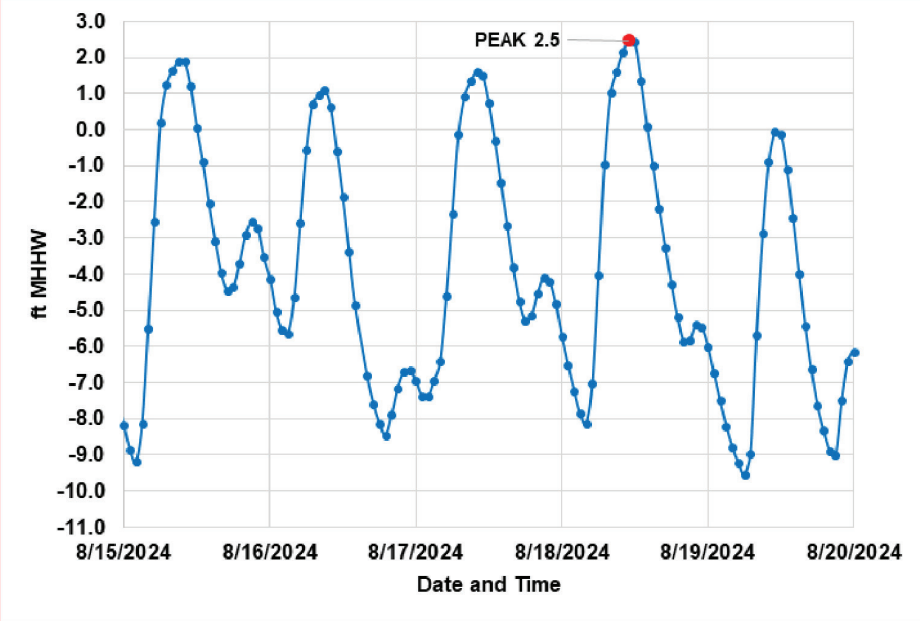


Figure 25. Water level heights collected in Kwigillingok, Alaska, from 12:00 AM AKDT on August 15, 2024, to 12:00 AM AKDT on August 20, 2024.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2024-OCT-04	1.9	± 0.2	± 0.0	0.57	± 0.07	± 0.00	Moderate

We were unable to locate any reports or narrative evidence corroborating the water level sensor readings associated with this event. Weather data gathered from the Automated Surface/Weather Observing Systems station approximately 30 miles (48 km) to the west in Kipnuk, Alaska (accessible from https://mesonet.agron.iastate.edu/request/download.phtml?network=AK_ASOS), demonstrated this event coincided with a period of low atmospheric pressure and high wind.

To estimate this flood, we gathered water level data from the Stilltek iGage located in Kwigillingok (figs. 1 and 2) for the time period relevant to this flood event (fig. 26). The peak recorded water level during this event was 1.9 ft (0.57 m) MHHW.

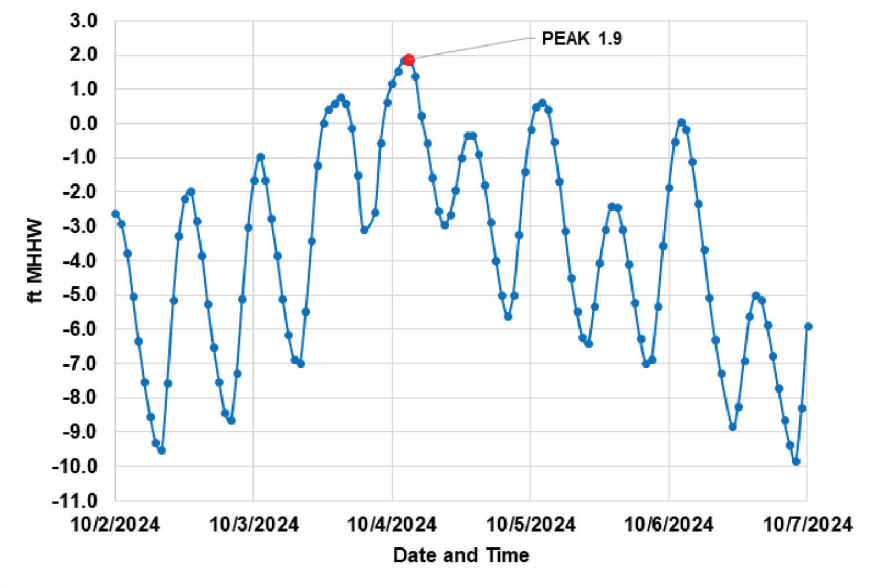


Figure 26. Water level heights collected in Kwigillingok, Alaska, from 12:00 AM AKDT on October 2, 2024, to 12:00 AM AKDT on October 7, 2024.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2024-OCT-21	1.6	± 0.2	± 0.0	0.50	± 0.07	± 0.00	Moderate

The Fairbanks, Alaska, NWS office posted to social media on October 21, 2024, regarding coastal flooding along the west coast of the state (NWS, 2024). While Kwigillingok was not among the locations included in this advisory, the local water level sensor recorded higher than average water heights during the event.

To estimate this flood, we gathered water level data from the Stilltek iGage located in Kwigillingok (figs. 1 and 2) for the time period relevant to this flood event (fig. 27). The peak recorded water level during this event was 1.6 ft (0.50 m) MHHW.

Though this flood estimate is categorized as moderate based on the peak recorded water level, the estimate confidence range could also potentially place this flood event within the minor impact category.

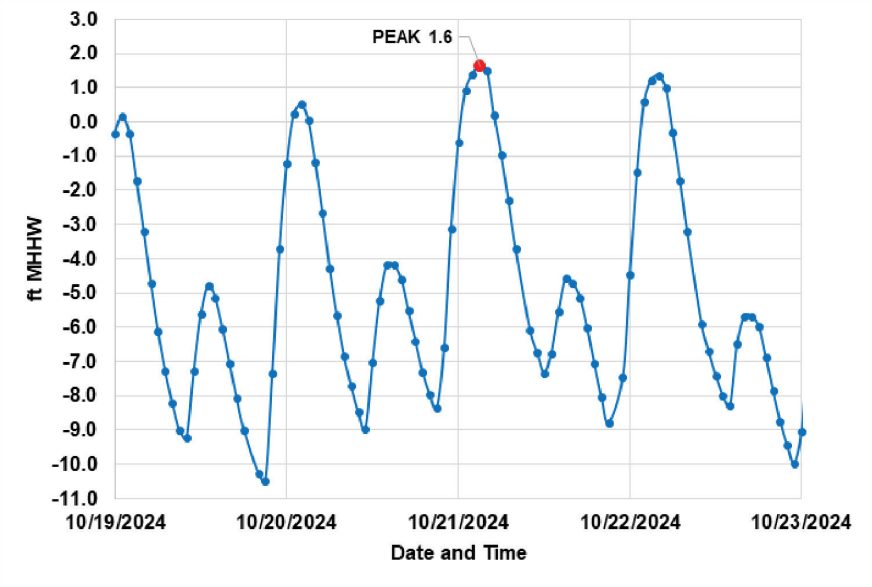


Figure 27. Water level heights collected in Kwigillingok, Alaska, from 12:00 AM AKDT on October 19, 2024, to 12:00 AM AKDT on October 23, 2024.

ACKNOWLEDGMENTS

We thank the Native Village and City of Kwigillingok for supporting this work, made possible with the National Fish and Wildlife Foundation's National Coastal Resilience Funding through DGGS partners at the Alaska Native Tribal Health Consortium. The authors also thank Richard Buzard and Jacquelyn Overbeck for their contribution to the data collection that was instrumental to this work. Sincere thanks to Dustin Evon, of Kwigillingok, for reviewing this report before publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government, the National Fish and Wildlife Foundation, or the National Fish and Wildlife Foundation's funding sources. Mention of trade names or commercial products does not constitute endorsement by the U.S. Government, the National Fish and Wildlife Foundation, or the National Fish and Wildlife Foundation's funding sources.

REFERENCES

Alaska Department of Environmental Conservation (ADEC), 2012, Coastal impact assistance program (CIAP) waste erosion assessment and review (WEAR) trip report—Kwigillingok, 3 p.

Alaska Division of Community & Regional Affairs (DCRA), 2004, Community profile map, Kwigillingok: Department of Commerce, Community, and Economic Development. https://dcced.maps.arcgis.com/apps/webappviewer/index.html?id=18fdb060875740fdad22099ca779d637

Alaska Division of Emergency Services (ADES), 1980, Flood hazard data memo, 2 p.

Alaska Division of Homeland Security & Emergency Management (DHS&EM), 2008, ALASKA: Weather-related disasters 1978–2008, 62 p.

Alaska Institute for Justice (AIJ), 2017, December 2017 storm and weather narratives, 23 p.

———2018a, January 2018 storm and weather narratives, 12 p.

———2018b, October 2018 storm and weather narratives, 7 p.

———2019a, Kwigillingok: Community profile, 21 p. https://www.akijp.org/wp-content/uploads/2020/12/Kwigillingok-Report-8-20-2019.pdf

———2019b, August 2019 storm and weather narratives, 17 p.

———2019c, September and October 2019 storm and weather narratives, 14 p.

———2019d, November 2019 storm & weather narratives, 5 p.

———2019e, December 2019 storm & weather narratives, 3 p.

———2021, Kwigillingok: Community profile August 2021 update, 8 p.

Bethel, Don, 1987, Trip report: Kwigillingok erosion inspection: U.S. Army Corps of Engineers Memorandum no. CENPA-EN-PL-FP (690c), 3 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, 16 p. https://doi.org/10.14509/30573

Erickson, Evan, and Smiley, Sage, 2024, Bering Sea storm brings erosion and flooding to Western Alaska communities: KYUK, at https://www.kyuk.org/public-safety/2024-08-18/bering-sea-storm-brings-erosion-and-flooding-to-western-alaska-communities.

Horen, K.C., Buzard, R.M., Overbeck, J.R., Poisson, A.C., and Siemsen, Z.J., 2024, Photogrammetry-derived orthoimagery and elevation data for Kwigillingok, Alaska, collected June 18–19, 2022: Alaska Division of Geological & Geophysical Surveys Raw Data File 2024-21, 8 p. https://doi.org/10.14509/31289

Horen, K.C., Poisson, A.C., Christian, J.E., and Nieminski, N.M., 2024, Methods for evaluating coastal flood impacts in Alaska communities: Alaska Division of Geological & Geophysical Surveys Miscellaneous Publication 177, 13 p. https://doi.org/10.14509/31279

Kim, Greg, 2021, Southwest Alaska community on Bering Sea coast experiences severe flooding: Alaska Public Media, at https://alaskapublic.

org/2021/06/27/southwest-alaska-community-on-bering-sea-coast-experiences-severe-flooding/.

National Centers for Environmental Information (NCEI), 2015a, Storm events database: National Oceanic and Atmospheric Administration, 1 p. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=607476

———2015b, Storm events database: National Oceanic and Atmospheric Administration, 1 p. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=607472

———2022, Storm events database: National Oceanic and Atmospheric Administration, 1 p. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=1058050

National Oceanic and Atmospheric Administration (NOAA), 1979, Storm data—November 1979: U.S. Department of Commerce, v. 21, no. 11, 10 p.

———1987, Storm Data—October 1987: U.S. Department of Commerce, v. 29, no. 10, 32p.

———1990, Storm data—August 1990: U.S. Department of Commerce, v. 32, no. 8, 168 p.

———2000, Storm data—November 2000: U.S. Department of Commerce, v. 42, no. 11, 106 p.

———2003, Storm data—December 2003: U.S. Department of Commerce, v. 45, no. 12, 144 p.

———2004, Storm data—November 2004: U.S. Department of Commerce, v. 46, no. 11, 174 p.

———2006, Storm data—September 2006: U.S. Department of Commerce, v. 48, no. 9, 196 p.

———2013, Storm data—November 2013: U.S. Department of Commerce, v. 55, no. 11, 294 p.

National Weather Service (NWS), 2016, High water level terminology, accessed July 8, 2024, at https://www.weather.gov/aprfc/terminology.

———2018, Coastal flood categories: National Weather Service Eastern Region supplement 01-2018, 9 p. https://www.weather.gov/media/directives/010_pdfs/pd01001003a012018curr.pdf

———2023, During a flood [flood safety], accessed May 8, 2024, https://www.weather.gov/safety/flood-during.

———2024, Coastal flooding update: U.S. National Weather Service Fairbanks Alaska, accessed December 10, 2024, at https://www.facebook.com/share/p/16aZnYuv9m.

Office of the Governor Rural Development Agency (RDA) and Alaska Disaster Office (ADO), 1971, Questionnaire for RDA grant program and Alaska Disaster Office, 6 p.

Overbeck, J.R., Hendricks, M.D., and Kinsman, N.E.M., 2016, Photogrammetric digital surface models and orthoimagery for 26 coastal communities of western Alaska: Alaska Division of Geological & Geophysical Surveys Raw Data File 2016-1, 3 p. https://doi.org/10.14509/29548

Smiley, Sage, 2024, Community slideshow: Early fall storm floods the Y-K Delta: KYUK, at https://www.kyuk.org/science-and-environment/2024-08-21/community-slideshow-early-fall-storm-floods-the-y-k-delta.

United States Government Accountability Office (U.S. GAO), 2009, Alaska Native Villages: Limited progress has been made on relocating villages threatened by flooding and erosion: Report to Congressional Requesters GAO-09-551, 53 p.

University of Alaska Fairbanks Institute of Northern Engineering, U.S. Army Corps of Engineers Alaska District, U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory, 2019, Statewide threat assessment: identification of threats from erosion, flooding, and thawing permafrost in remote Alaska communities, report prepared for the Denali Commission, 99 p.

U.S. Army Corps of Engineers (USACE), 1973, Kwigillingok flood data: USACE Alaska District, 1 p.

———2009, Community erosion assessment: Kwigillingok, Alaska, 8 p.

Village of Kwigillingok, 2015, Village of Kwigillingok hazard mitigation plan, 174 p.

Zechmann, J.M., Herbst, A.M., and Buzard, R.M., 2023, Lidar-derived elevation data for Kwigillingok, Southwest Alaska, collected August 18, 2021: Alaska Division of Geological & Geophysical Surveys Raw Data File 2023-19, 8 p. https://doi.org/10.14509/31035

APPENDIX A: FLOOD EVENTS IDENTIFIED FROM WATER LEVEL SENSOR READINGS IN KWIGILLINGOK, ALASKA

DGGS installed a Stilltek iGage radar water level sensor in Kwigillingok in August 2021. This sensor was replaced on June 17, 2022, and again on October 17, 2023. Data collected by this sensor, updated hourly, are available from Alaska Water Level Watch at portal.aoos.org/#metadata/110872/station/data. The vertical accuracy of these data is ± 0.2 ft (0.07 m) and constitutes the height estimate confidence for all flood events listed, with the temporal confidence being negligible because all readings were collected in real-time. All estimates listed are categorized as minor, with the exception of October 11, 2021, which is categorized as moderate (highlighted). The estimate confidence range for events marked with an asterisk (*) could place these events within either the minor or moderate impact categories. We did not find additional evidence of these events (i.e., reports or narratives) while conducting our research of historical records. Due to sensor limitations and potential ambiguity, we excluded readings collected during periods when ice was likely to be present.

Date	Height (MHHW)	
	ft	m
2021-AUG-19	1.0	0.29
2021-AUG-22	1.1	0.32
2021-SEP-11	0.7	0.20
2021-SEP-13	0.9	0.27
2021-SEP-15	0.8	0.23
2021-SEP-16	0.8	0.25
2021-OCT-08	1.0	0.30
*2021-OCT-11	1.6	0.50
2021-OCT-12	0.7	0.22
2021-OCT-13	0.6	0.20
2021-OCT-22	1.0	0.30
2021-OCT-27	0.8	0.25
2022-JUN-18	1.0	0.30
2022-JUN-26	1.2	0.37
2022-JUN-30	0.6	0.20
2022-JUL-01	1.0	0.30
2022-JUL-12	0.9	0.27
2022-JUL-13	1.0	0.29
2022-JUL-14	1.2	0.35
2022-JUL-15	1.1	0.34
2022-JUL-16	1.0	0.31
2022-JUL-17	0.8	0.24
2022-JUL-25	0.8	0.25
*2022-AUG-07	0.7	0.20

Date	Height (MHHW)	
	ft	m
2022-AUG-25	1.6	0.47
2022-SEP-06	0.9	0.28
2022-SEP-07	1.0	0.30
2022-SEP-08	0.7	0.20
2022-SEP-11	0.7	0.21
2022-OCT-01	1.0	0.30
2022-OCT-02	1.3	0.41
2022-OCT-03	1.2	0.36
2022-OCT-04	0.8	0.23
2022-OCT-06	0.7	0.22
2022-OCT-17	0.8	0.23
2023-JUN-03	0.7	0.20
2023-JUN-04	0.7	0.20
2023-JUN-05	0.9	0.26
*2023-JUN-06	1.4	0.44
2023-JUN-07	1.2	0.37
2023-JUN-08	1.0	0.32
2023-JUN-09	0.8	0.25
2023-JUN-20	0.6	0.20
2023-JUL-02	1.0	0.31
2023-JUL-03	1.3	0.40
2023-JUL-04	1.3	0.40
*2023-JUL-05	1.4	0.44
2023-JUL-06	1.1	0.34

Date	Height (MHHW)	
	ft	m
2023-JUL-07	0.7	0.21
2023-JUL-08	1.1	0.35
2023-JUL-31	0.8	0.24
2023-AUG-01	0.9	0.27
2023-AUG-02	1.0	0.29
2023-AUG-03	1.1	0.32
2023-AUG-04	0.9	0.26
2023-AUG-12	0.7	0.22
2023-AUG-13	1.1	0.32
2023-AUG-25	1.2	0.37
2023-AUG-29	0.7	0.23
2023-AUG-30	0.8	0.25
2023-AUG-31	1.1	0.33
2023-SEP-23	0.9	0.26
2023-SEP-24	0.8	0.24
2023-SEP-25	0.7	0.21
2023-OCT-06	0.8	0.26
2024-MAY-23	1.2	0.36
2024-MAY-24	0.6	0.20
2024-JUN-06	0.8	0.25
2024-JUN-07	0.9	0.27

Date	Height (MHHW)	
	ft	m
2024-JUN-08	0.8	0.23
2024-JUN-09	0.9	0.28
2024-JUN-24	0.8	0.23
2024-JUN-25	0.9	0.27
*2024-JUN-26	1.6	0.48
2024-JUN-27	0.9	0.28
2024-JUL-04	1.2	0.35
2024-JUL-05	0.7	0.21
2024-JUL-06	0.7	0.20
2024-JUL-22	0.7	0.21
2024-JUL-29	0.9	0.28
2024-AUG-01	0.7	0.20
2024-AUG-02	0.8	0.25
2024-AUG-03	0.9	0.27
2024-AUG-04	1.4	0.42
2024-AUG-26	1.3	0.40
*2024-AUG-27	1.5	0.45
*2024-SEP-14	1.4	0.43
2024-SEP-15	1.3	0.40
2024-SEP-17	1.3	0.40
2024-SEP-27	0.7	0.21

APPENDIX B: KWIGILLINGOK, ALASKA, FIRST-FLOOR HEIGHT SURVEY

ALASKA NATIVE TRIBAL HEALTH CONSORTIUM
Environmental Health & Engineering

March 23, 2023

Kwigillingok, Alaska Finish Floor Elevation Study
ANTHC Project No. 10-0189-01-01

The data provided is from a field survey completed by ANTHC on March 2 and 3, 2023. Project elevations are NAVD88 Orthometric heights (U.S. Feet), computed using GEIOD12B, and were measured utilizing Trimble R10 GPS Receivers using RTK GPS.

BASIS OF HORIZONTAL CONTROL:
The Basis of Horizontal Control is ANTHC Point 401, a 6" steel spike, set in a grassy area approximately 100' southwest of the Kwigillingok School. The position for this point was derived through a static GPS session using a Trimble R10 GPS Receiver post processed using the National Geodetic Survey (NGS) Online Positioning User Service (OPUS). Said point has the following coordinates:

NAD83(2011)(EPOCH2010.00) Geodetic Coordinates:
Latitude = 59° 52' 35.15250" N
Longitude = 163° 09' 31.74552" W

NAD83(2011)(EPOCH2010.00) Alaska State Plane Zone 7, U.S. Feet:
Northing = 2,148,591.6825'
Easting = 1,427,509.0933'

BASIS OF VERTICAL CONTROL:
The Basis of Vertical Control is ANTHC Point 401, a 6" steel spike, set in a grassy area approximately 100' southwest of the Kwigillingok School. The position for this point was derived through a static GPS session using a Trimble R10 GPS Receiver post processed using the National Geodetic Survey (NGS) Online Positioning User Service (OPUS). Said point has a NAVD88 Orthometric height of 3.878m/12.72'.

Sincerely,

Paul Russell, PLS
Survey Manager

Enclosures:
- Kwigillingok-FF_AKSPZ7.csv
- Kwigillingok-FF_NAD83(2011).csv
- OPUS Report_Pt-401_20230303.pdf
- Published Bench Mark Sheet for 9465911 KWIGILLINGOK AK.pdf

Alaska Native Tribal Health Consortium//Division of Environmental Health & Engineering
4500 Diplomacy Drive, Suite 454, Anchorage, Alaska 99508//Main: (907) 729-3600 //Fax: (907) 729-4090//anthc.org

Point ID	Northing	Easting	Elevation (ft)	Point Description
401	2148591.68	1427509.09	12.72	SPIKE
403	2148792.64	1428729.69	18.43	5911 F 2019
404	2149153.85	1426771.12	18.43	5911 D 2019
4001	2148656.72	1427335.12	19.81	FF HOME
4002	2148605.35	1427261.63	20.44	FF HOME
4003	2148585.99	1427215.79	20.49	FF HOME
4004	2148688.28	1427086.21	16.7	FF HOME
4005	2148491.12	1427054.83	17.09	FF HOME
4006	2148691.62	1426989.12	20.79	FF POWER PLANT
4007	2148799.56	1426985.63	19.87	FF FUEL TANKS
4008	2148754.63	1426834.08	22.84	FF WATER TANKS
4009	2148762.78	1426831.7	22.2	FF WATER TREATMENT
4010	2148832.65	1426774.43	21.73	FF WATER TREATMENT
4011	2148862.26	1426771.5	16.97	FF WATER TREATMENT
4012	2148886.41	1426481.08	15.69	FF HOME
4013	2149151.26	1426704.44	15.88	FF HOME
4014	2149144.36	1426094.55	17.8	FF HOME
4015	2148873.87	1426196.24	18.18	FF HOME
4016	2148873.81	1426196.17	18.2	FF HOME
4017	2148834.6	1426217.58	17.82	FF HOME
4018	2148669.98	1426412.27	16.9	FF HOME
4019	2148646.33	1426344.7	16.3	FF STORE
4020	2148468.68	1426341.78	20.13	FF HOME
4021	2148433.38	1426492.46	20.12	FF HOME
4022	2148364.05	1426437.41	20.15	FF HOME
4023	2148300.33	1426384.35	20.06	FF HOME

Point ID	Northing	Easting	Elevation (ft)	Point Description
4024	2148246.71	1426307.57	16.85	FF ANTHC BUILDING
4025	2148191.15	1426330.95	15.42	FF HOME
4026	2147956.8	1426665.6	18.01	FF HOME
4027	2147936.84	1426711.07	17.74	FF HOME
4028	2147875.37	1426801.69	18.31	FF HOME
4029	2147816.29	1426867.6	18.88	FF HOME
4030	2147761.42	1426937.8	18.22	FF HOME
4031	2147689.93	1426979.66	17.75	FF HOME
4032	2147851.85	1427305.38	17.85	FF HOME
4033	2147909.17	1427249.72	17.84	FF HOME
4034	2147981.53	1427180.67	17.74	FF HOME
4035	2148028.3	1427081.36	17.16	FF HOME
4036	2148362.88	1426952.35	16.44	FF HOME
4037	2148447.62	1426963.41	16.92	FF HOME
4038	2148455.57	1426802.15	16.69	FF HOME
4039	2148629.84	1426792.37	21	FF WASHATERIA
4040	2148549.55	1426727.02	21.3	FF CLINIC
4041	2148487.76	1426628.45	20.71	FF POST OFFICE
4042	2148369.3	1426664.17	17.01	FF HOME
4043	2148486.65	1426014.63	14.49	FF AIRPORT GARAGE
4044	2148701.54	1426530.71	19.17	FF HOME
4045	2148673.43	1426444.5	17.94	FF HOME
4046	2149413.25	1427199.24	16.16	FF HOME
4047	2148881.66	1427676.41	22.72	FF SCHOOL
4050	2147397.12	1428890.3	14.96	FF HOME
4051	2147415.63	1429029.11	14.53	FF HOME

Point ID	Northing	Easting	Elevation (ft)	Point Description
4052	2147348.93	1428980.61	15.76	FF HOME
4053	2147206.36	1428945.38	15.63	FF HOME
4054	2147146.25	1429726.07	15.55	FF HOME
4055	2147154.07	1429965.51	15.52	FF HOME
4056	2146729.85	1429591.64	15.72	FF HOME
4057	2146702.35	1429565.25	15.89	FF HOME
4058	2146807.88	1429418.83	17.85	FF HOME
4059	2146731.57	1429395.4	16	FF SHED
4060	2146679.77	1429379.65	15.72	FF SHED
4061	2146678.9	1429321.86	16.33	FF HOME
4062	2146709.8	1429260.08	16.27	FF HOME
4063	2146571.67	1429451.38	16.22	FF HOME
4064	2146426.19	1429671.98	13.29	FF OLD POST OFFICE
4065	2146001.82	1429341.66	15.4	FF HOME
4066	2146034.65	1429462.9	17.12	FF HOME
4067	2146067.4	1429473.84	16.19	FF SHED
4068	2146086.22	1429450	15.71	FF SHED
4069	2146095.89	1429416.99	14.36	FF SHED
4070	2146099.97	1429467.22	14.93	FF SHED
4071	2146015.34	1429539.3	17.19	FF HOME
4072	2145976.87	1429490.39	16.62	FF SHED
4073	2145941.11	1429391.23	14.38	FF WATER TANK
4074	2145957.22	1429439.21	15.14	FF SHED
4075	2145865.98	1429460.91	17.32	FF HOME
4076	2145799.64	1429246.19	16.49	FF HOME
4077	2145837.9	1429234.09	14.48	FF SHED
4078	2145761.23	1429163.68	16.24	FF HOME
4079	2145967.02	1428607.53	15.19	FF HOME
4080	2145471.61	1428534.48	16.57	FF POLICE OFFICE
4081	2145916.26	1429527.94	16.67	FF SHED
4082	2145849.04	1429537.67	16.02	FF HOME
4083	2145892.54	1429580.22	17.31	FF TRIBAL COUNCIL OFFICE
4084	2146008.65	1429687.01	17.41	FF HOME
4085	2145383.64	1430758.92	15.89	FF HOME
4086	2145551.79	1430508.31	17.46	FF HOME
4087	2145558.52	1430314.37	15.69	FF HOME
5001	2148319.9	1428425.85	13.97	FF HOME
5002	2148231.99	1428562.65	13.47	FF HOME
5003	2148425.76	1428677.09	13.85	FF HOME
5004	2148628.09	1428835.46	17.64	FF STORE
5005	2148699.21	1428619.3	13.99	FF HOME
5006	2148895.23	1428520.86	15.65	FF HOME
5007	2149005.66	1428825.09	14.79	FF HOME
5008	2149268.04	1428837.61	14.92	FF HOME
5009	2149312.41	1428784.93	16.37	FF HOME
5010	2149384.03	1429154.99	19.47	FF HOME
5011	2149549.29	1429167.59	21.97	FF HOME
5012	2149628.12	1429153.46	21.64	FF HOME
5013	2149707.96	1429145.17	22.98	FF HOME
5014	2149786.07	1429135.84	21.57	FF HOME
5015	2149865.69	1429123.37	22.48	FF HOME
5016	2149945.84	1429118.72	23.05	FF HOME

Point ID	Northing	Easting	Elevation (ft)	Point Description
5017	2150024.4	1429107.16	22.45	FF HOME
5018	2150106.99	1429098.92	22.14	FF HOME
5019	2150188.12	1429088.02	21.39	FF HOME
5020	2150262.6	1429081.92	21.08	FF HOME
5021	2150562.89	1428778.94	15.77	FF FUEL BLDG
5022	2150809.96	1428633.79	14.38	FF FUEL PUMP
5023	2150607.14	1428817.87	16.17	FF FUEL CONTAINMENT BOTTOM
5024	2150606.79	1428818.39	17.02	FF FUEL CONTAINMENT TOP
5025	2150572	1428823.77	19.88	FF FUEL CONTAINMENT BOTTOM
5026	2150572.39	1428824.38	21.21	FF FUEL CONTAINMENT TOP
5027	2150260.28	1429029.81	22.25	FF HOME
5028	2150182	1429036.57	21.44	FF HOME
5029	2150096.47	1429047.25	20.59	FF HOME
5030	2150027.49	1429058.86	20.86	FF HOME
5031	2149946.15	1429063.06	22.19	FF HOME
5032	2149866.51	1429069.86	20.03	FF HOME
5033	2149783.04	1429083.24	21.75	FF HOME
5034	2149705.62	1429087.9	21.19	FF HOME
5035	2149629.04	1429096.31	21.37	FF HOME
5036	2149551.26	1429109.3	21.95	FF HOME
5037	2148752.74	1427887.47	18.39	FF SCHOOL BLDG
5038	2148837.62	1427836.26	22.22	FF SCHOOL UTIL BLDG
5039	2148931.15	1427922.42	17.45	FF SCHOOL BLDG
5040	2148923.05	1427785.5	18.1	FF SCHOOL TANK
5041	2148927.41	1427822.05	18.6	FF SCHOOL TANK
5042	2149041.62	1427834.88	18.04	FF SCHOOL TANK
5043	2148982.64	1427986.06	17.69	FF SCHOOL BLDG
5044	2148952.1	1428043.15	16.15	FF SCHOOL BLDG
5045	2149000.2	1427566.18	22.1	FF SCHOOL TANK
5046	2149079.6	1427698.33	13.14	FF SCHOOL FUEL CONTAINMENT TOP
5047	2149055.62	1427678.69	11.43	FF SCHOOL FUEL CONTAINMENT BOTTOM
5048	2149014.24	1427673.8	16.45	FF SCHOOL BLDG
5049	2148949.96	1427743.3	22.96	FF TEACHER HOUSING
5052	2144659.41	1429861.25	17.23	FF HOME
5053	2144854.3	1429577.03	18.82	FF HOME
5054	2144595.61	1429375.47	14.66	FF HOME
5055	2144573.56	1429430.48	14.44	FF HOME
5056	2144469.03	1429435.61	16.56	FF HOME
5057	2144364.34	1429336.81	14.71	FF HOME
5058	2144210.58	1429957.46	13.48	FF HOME
5059	2144294.68	1430017.2	16.99	FF HOME
5060	2144267.05	1430044.28	15.42	FF HOME
5061	2143535.01	1429681.79	14.51	FF HOME
5062	2143510.49	1430008.97	15.57	FF HOME
5063	2143760.29	1430052.55	16.13	FF CHURCH
5064	2143623.58	1430134.93	14.75	FF HOME
5065	2143601.99	1430223.47	14.28	FF HOME
5066	2143589.64	1430344.87	15.42	FF HOME
5067	2143611.16	1430367.3	15.89	FF HOME
5068	2143981.61	1430835.21	13.82	FF AK GUARD BLDG

Point ID	Northing	Easting	Elevation (ft)	Point Description
5069	2144028.47	1430835.72	19.01	FF BLDG
5070	2143959.8	1430935.6	13.89	FF HOME
5071	2143983.69	1430968.17	13.83	FF HOME
5072	2143973.8	1431141.14	14.69	FF HOME
5073	2143825.41	1431078.91	12.32	FF BLDG
5074	2144159.45	1431014.62	14.27	FF HOME
5075	2144515.41	1430858.82	16.79	FF KWK SERVICE CENTER
5076	2144582.7	1430756.6	12.79	FF BLDG
5077	2144720.8	1430639.67	18.84	FF MORAVIAN CHURCH
5078	2144751.74	1430671.89	13.94	FF UNOCCUPIED HOME
5079	2144845.94	1430667.67	13.22	FF UNOCCUPIED HOME
5080	2144934.89	1430498.13	13.56	FF UNOCCUPIED HOME
5081	2144877.9	1430457.13	16.09	FF HOME
5082	2145057.5	1430371.85	13.73	FF HOME
5083	2144993.72	1430557.7	15.7	FF HOME
5084	2145180.16	1430208.29	13.71	FF HOME
5085	2145208.41	1430169.18	13.98	FF HOME
5086	2145467.97	1429789.16	15.39	FF HOME
5087	2145314.41	1429794.05	14.05	FF HOME
5088	2150974.59	1425701.74	19.61	FF HOME
5089	2151068.21	1425674.08	19.1	FF SHED
5090	2151399.53	1425824.6	22.42	FF PUMP HOME