Report of Investigation 2021-1D Alakanuk

COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—ALAKANUK

Richard M. Buzard, Jacquelyn R. Overbeck, Katie Y. Miller, and Jessica E. Christian

Photo from airplane looking at major flooding of the Alakanuk old village site on the north shore of Alakanuk Pass Slough. The photo looks east towards the Yukon River during the May 1972 ice jam flood. The old cannery is in the background to the left and the old Native Corporation Store is on the south bank to the right. Photo: Alaska Village Electric Cooperative (AVEC).

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Department of Natural Resources
Division of Geological & Geophysical Surveys

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COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—ALAKANUK

Richard M. Buzard[1], Jacquelyn R. Overbeck[1], Katie Y. Miller[1], and Jessica E. Christian[2]

OVERVIEW

This report is an assessment of the historical flood record and flood impact levels for the community of Alakanuk, Alaska. Methods used to evaluate historical floods and designate flood impact elevations (minor, moderate, or major; as defined by the National Weather Service [NWS]) are described in detail in an overview report (Buzard and others, 2021a). This community-specific report has three sections: data description, historical flood record, and flood impact categories. Flood and infrastructure elevations are relative to local mean higher high water (MHHW). All estimated uncertainties are reported to a 95 percent confidence interval. Quoted text from the sources used to estimate flood elevations can be found in Appendix A. Appendix B has tables and figures used to determine flood category elevations, including relevant results from our global navigation satellite system (GNSS) survey conducted in July 2021.

SUMMARY

Flood categories and related infrastructure elevations are listed in table 1, and estimated flood elevations are listed in table 2. The 2018 hazard mitigation plan prepared by the Division of Homeland Security and Emergency Management (DHS&EM, 2018) lists eight disaster declarations for flooding that apply to Alakanuk (1984, 1991, 1995, 2002, 2005, 2006, 2009, and 2013). From 1952 to 2021, Alakanuk experienced at least 27 significant coastal flood events. Of these reported events, we estimate the peak still water elevations of 26 floods (22 ice jams and four storm surge floods). These caused 16 minor and 10 major floods and would cause similar impacts if they occurred with Alakanuk's current infrastructure. Although homes and roads are built higher now than in the past, Alakanuk has significantly more infrastructure in general and some is relatively low-lying. The highest recorded flood occurred in 1952, reaching a still water height of 11.3 ± 1.0 ft MHHW. Moderate and major flood impacts tend to occur near the same height in Alakanuk, so we only use the minor and major categories.

In NWS flood reports, ice jam floods are typically described as needing to exceed the riverbank before flooding Alakanuk. The riverbank is the highest natural ground in Alakanuk, only exceeded by roads and airports (fig. 1). We use the average riverbank elevation to estimate some floods, but the riverbank elevation varies by four feet, so overbank flooding can occur before water reaches the average elevation (fig. 2). Ice jam floods commonly persist for one to several days, allowing overbank flooding to reach all land in the area. Storm surge can cause overbank flooding or overland flooding and is typically observed impacting the new airport and western residences first (community of Alakanuk, oral commun., 2021). Storm surge flooding is less common and, although reaching similar heights

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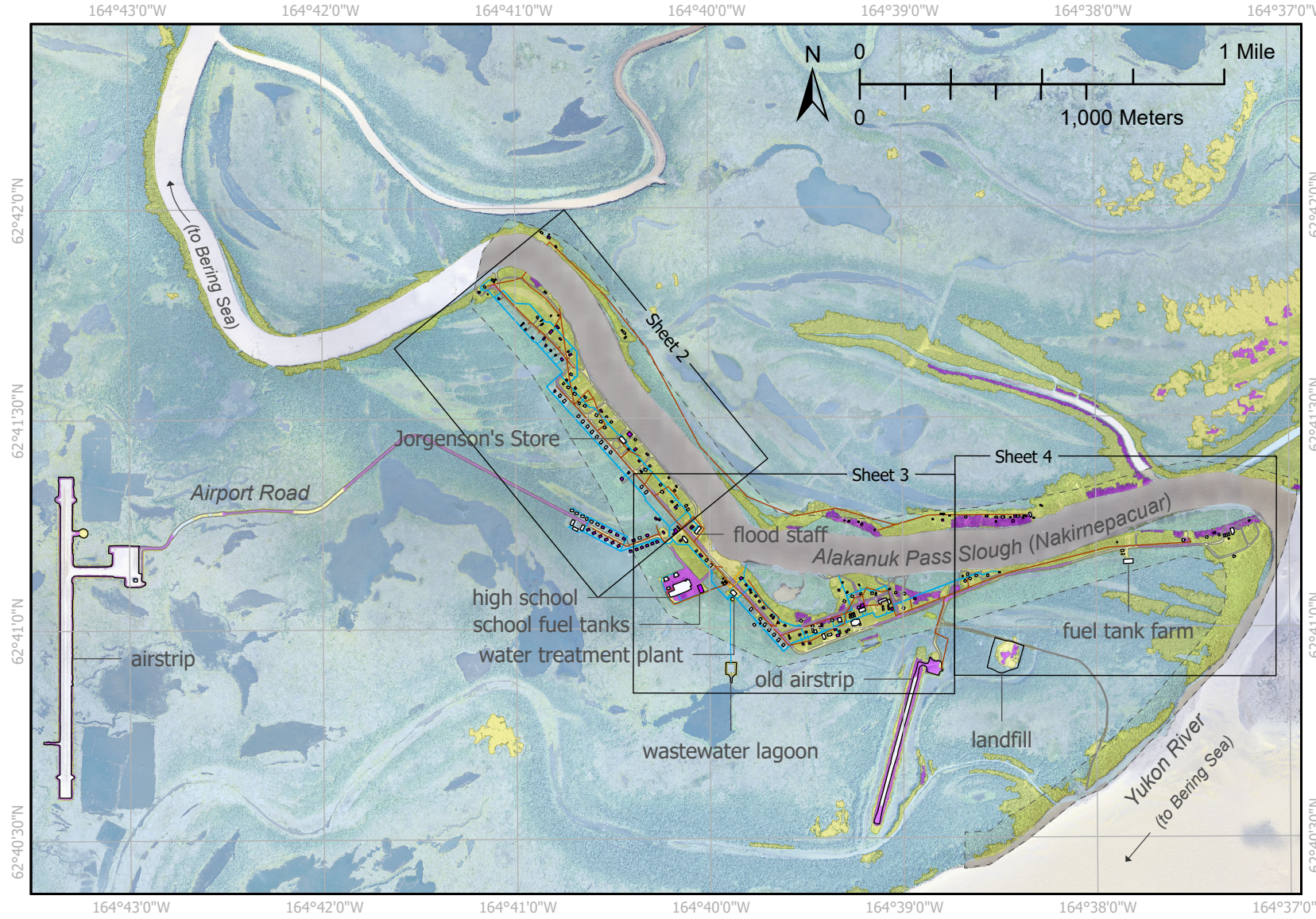
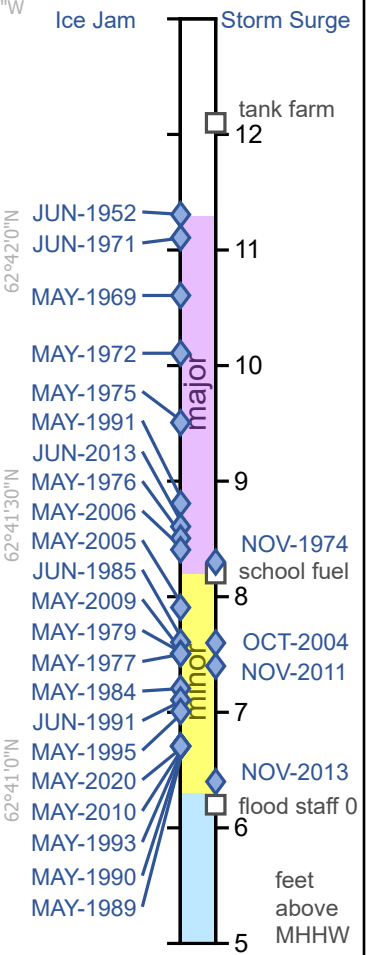
Coastal Flood Impact Map
Alakanuk, Alaska

REPORT OF INVESTIGATION 2021-1D
Buzard and others, 2021
ALAKANUK, SHEET 1 OF 4





To calculate height above
MLLW: add 2.4 ft
NAVD88: add 6.4 ft

Projection: NAD 1983 2011 UTM Zone 3N
Image dates: 2021 (dashed) and 2015
Orthoimagery available: elevation.alaska.gov

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website: dggs.alaska.gov

Road
Power
Building (color represents flood category of first floor)
Fuel
Water
2021 Image

Houses or infrastructure may have moved since DCRA linework was completed.

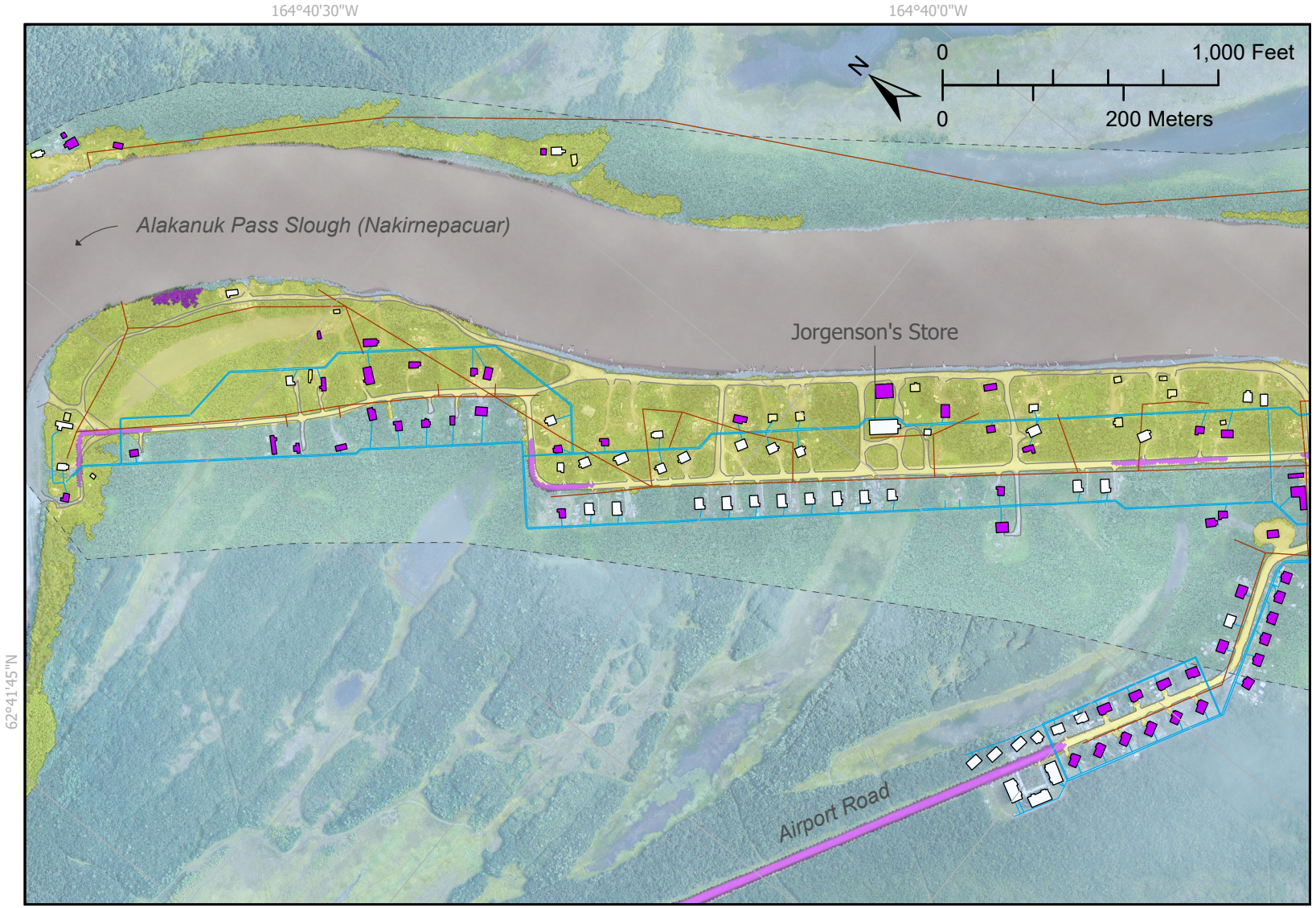
Major Flooding is defined to have extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary.

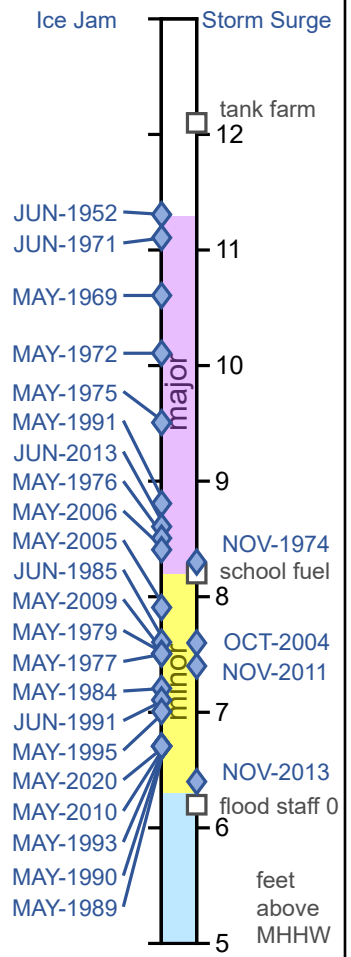
Minor Flooding is defined to have minimal or no property damage, but possibly some public threat.

This work was funded by Bureau of Indian Affairs Tribal Resilience Program through a collaborative project with the Alakanuk Village.

Coastal Flood Impact Map
Alakanuk, Alaska

REPORT OF INVESTIGATION 2021-1D
Buzard and others, 2021
ALAKANUK, SHEET 2 OF 4





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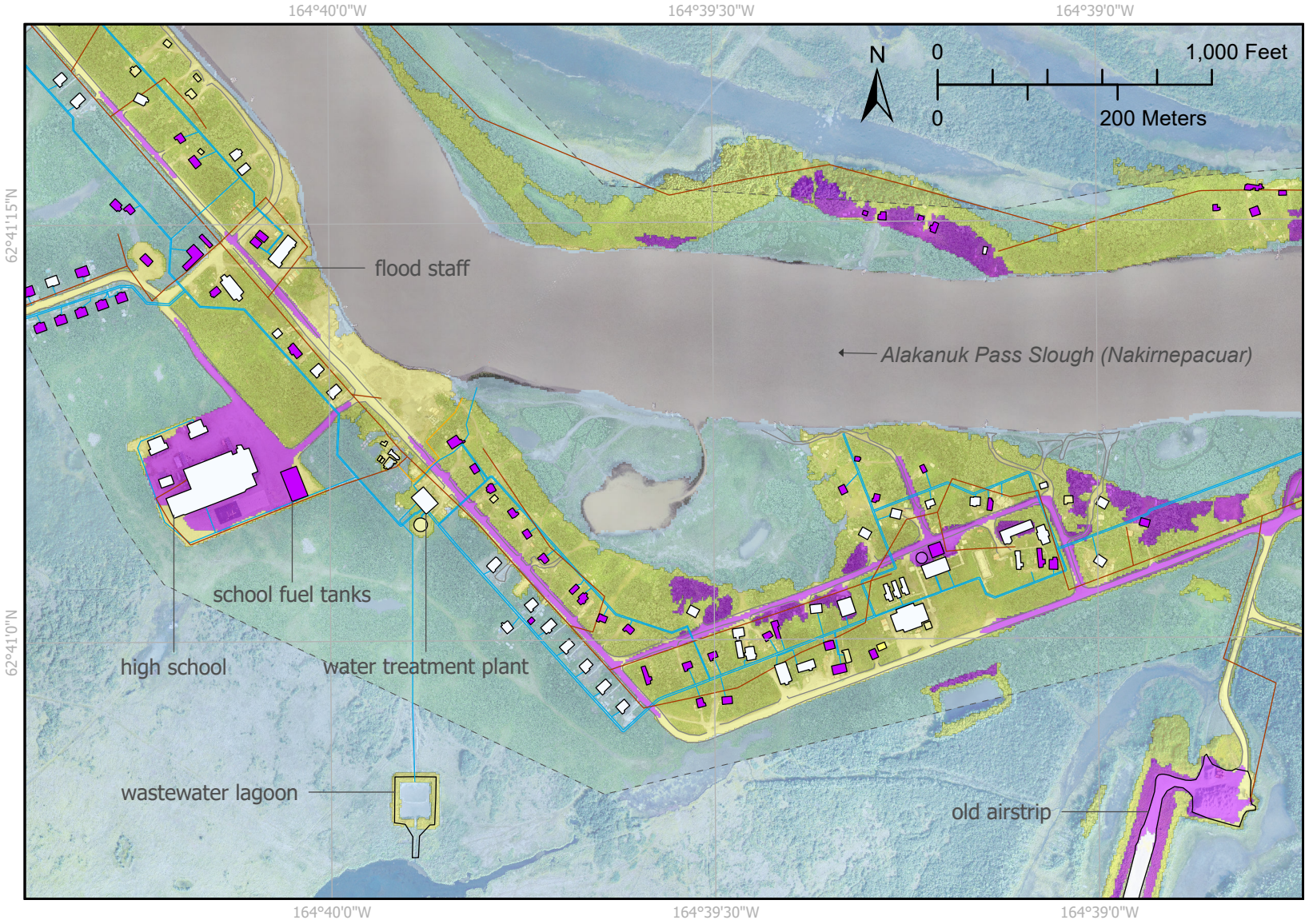
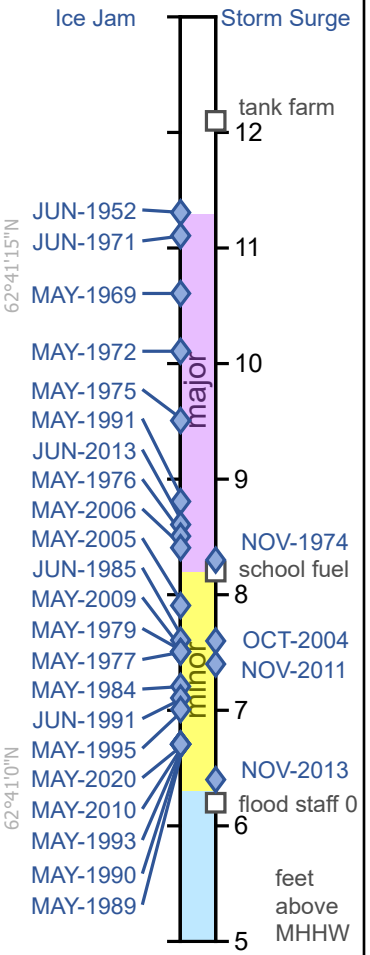
Coastal Flood Impact Map
Alakanuk, Alaska

REPORT OF INVESTIGATION 2021-1D
Buzard and others, 2021
ALAKANUK, SHEET 3 OF 4





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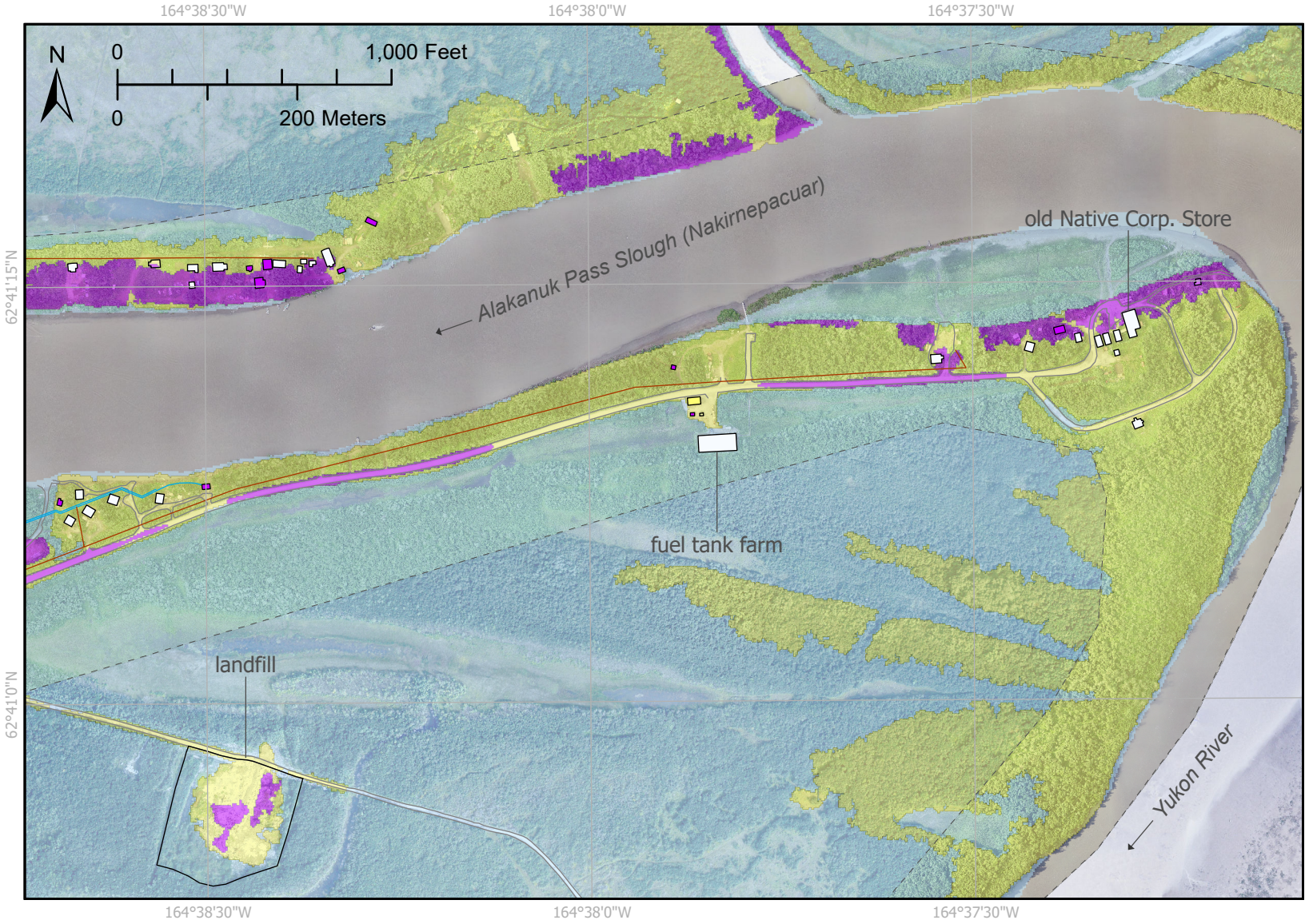
Coastal Flood Impact Map
Alakanuk, Alaska

REPORT OF INVESTIGATION 2021-1D
Buzard and others, 2021
ALAKANUK, SHEET 4 OF 4



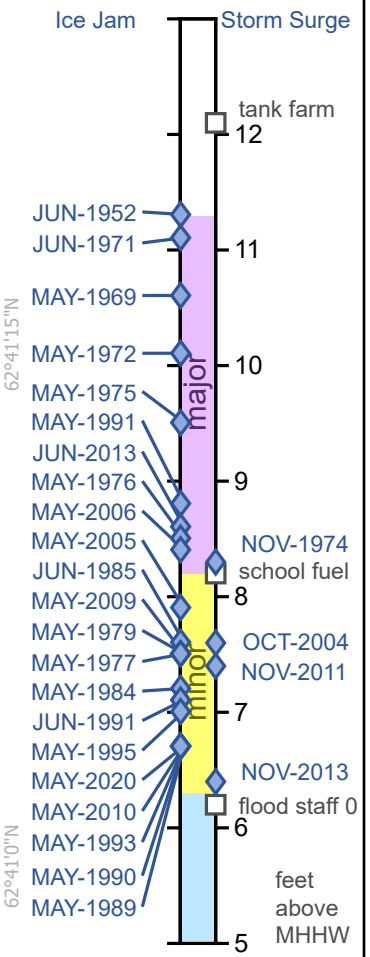


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Table 1. Summary of infrastructure heights and flood categories. Purple = major, yellow = minor. Gray represents infrastructure not expected to be impacted by coastal flooding. No infrastructure is considered subject to wave runup because there is no broadly sloping beach.

	Elevation Feature	Elevation (ft flood staff 0)	Elevation (ft MHHW)	Vertical Uncertainty (ft)
Other	Evacuation center (school)	10.2	16.4	0.1
	Airstrip covered	8.9	15.1	0.1
	Fuel tank farm	5.9	12.1	0.1
Major	Highest recorded flood (1952)	5.1	11.3	1.0
	Several buildings flooded	3.3	9.5	0.1
	Lowest residences flooded	2.9	9.1	0.1
	Airstrip access	2.4	8.6	0.8
	Wastewater facility	2.3	8.5	1.3
	Access to larger parts of town	2.2	8.4	0.1
	Fuel tanks at school	2.0	8.2	0.8
	Major	**2.0**	**8.2**	**0.8**
Minor	Lowest building	1.7	7.9	0.1
	Low-lying property	0.5	6.7	1.4
	Access road threatened	0.1	6.3	0.1
	Minor	**0.1**	**6.3**	**0.1**

Table 2. Summary of historical flood heights. Purple = major, yellow = minor. The categories are based on current infrastructure conditions, not the conditions when the flood occurred.

Floods Estimated

Flood Type	Flood Date	Elevation (ft MHHW)	Vertical Uncertainty (ft)
Ice jam	1952-JUN-06	11.3	1.0
Ice jam	1971-JUN-04	11.1	1.0
Ice jam	1969-MAY	10.6	2.1
Ice jam	1972-MAY-30	10.1	1.1
Ice jam	1975-MAY-29	9.5	1.0
Ice jam	1991-MAY-21	8.8	0.8
Ice jam	2013-JUN-04	8.6	0.8
Ice jam	1976-MAY	8.5	1.0
Ice jam	2006-MAY-28	8.4	1.2
Storm surge	1974-NOV-11	8.3	1.0
Ice jam	2005-MAY-17	7.9	0.5
Ice jam	1985-JUN-03	7.6	1.7
Storm surge	2004-OCT-18	7.6	1.8
Ice jam	1977-MAY-17	7.5	1.8
Ice jam	1979-MAY-15	7.5	1.8
Ice jam	2009-MAY-23	7.5	0.5
Storm surge	2011-NOV-09	7.4	0.5
Ice jam	1984-MAY-25	7.2	0.8
Ice jam	1991-JUN-03	7.1	1.0
Ice jam	1995-MAY-16	7.0	0.9
Ice jam	1989-MAY-29	6.7	0.9
Ice jam	1990-MAY-21	6.7	1.4
Ice jam	1993-MAY-20	6.7	0.5
Ice jam	2010-MAY-24	6.7	1.4
Ice jam	2020-MAY-16	6.7	0.9
Storm surge	2013-NOV-13	6.4	0.7

Floods Not Estimated

Flood Type	Flood Date	Elevation (ft MHHW)	Vertical Uncertainty (ft)
Ice jam	2002-MAY-29	–	–

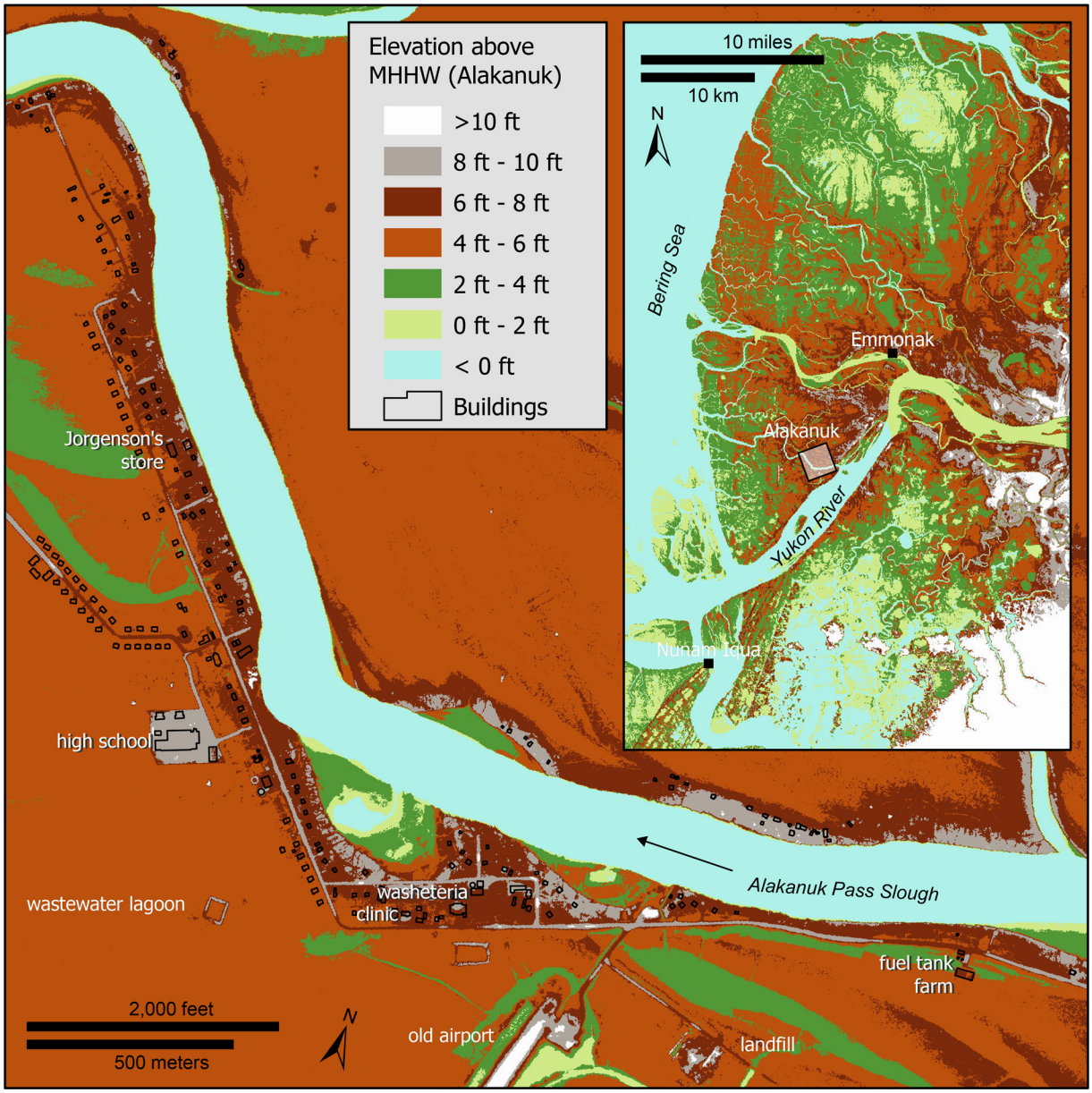

Figure 1. Elevation maps of Alakanuk and the surrounding area of the Yukon River Delta. Lower elevation areas are blue to green, and higher elevation areas are brown to white. Elevation is relative to the Alakanuk tidal datum, which is similar to Nunam Iqua and Emmonak. The inset map (IFSAR digital terrain model [DTM]) shows Alakanuk is on an island where the Yukon River forks, with ground gradually decreasing in elevation to the west. The main map (lidar DTM) highlights how the highest ground in Alakanuk is along the river edge. Buildings are outlined in black and key infrastructure highlighted in this assessment are labeled.

as other communities, has only resulted in minor flooding because most infrastructure is elevated above ground level (table 2).

DATA

Mapped data are used to interpret flood elevations from historical photographs and accounts. This section describes available data used to assess flooding for Alakanuk.

Digital Elevation Models and Orthoimagery

High-resolution and accuracy elevation models are required to measure flood heights. Three

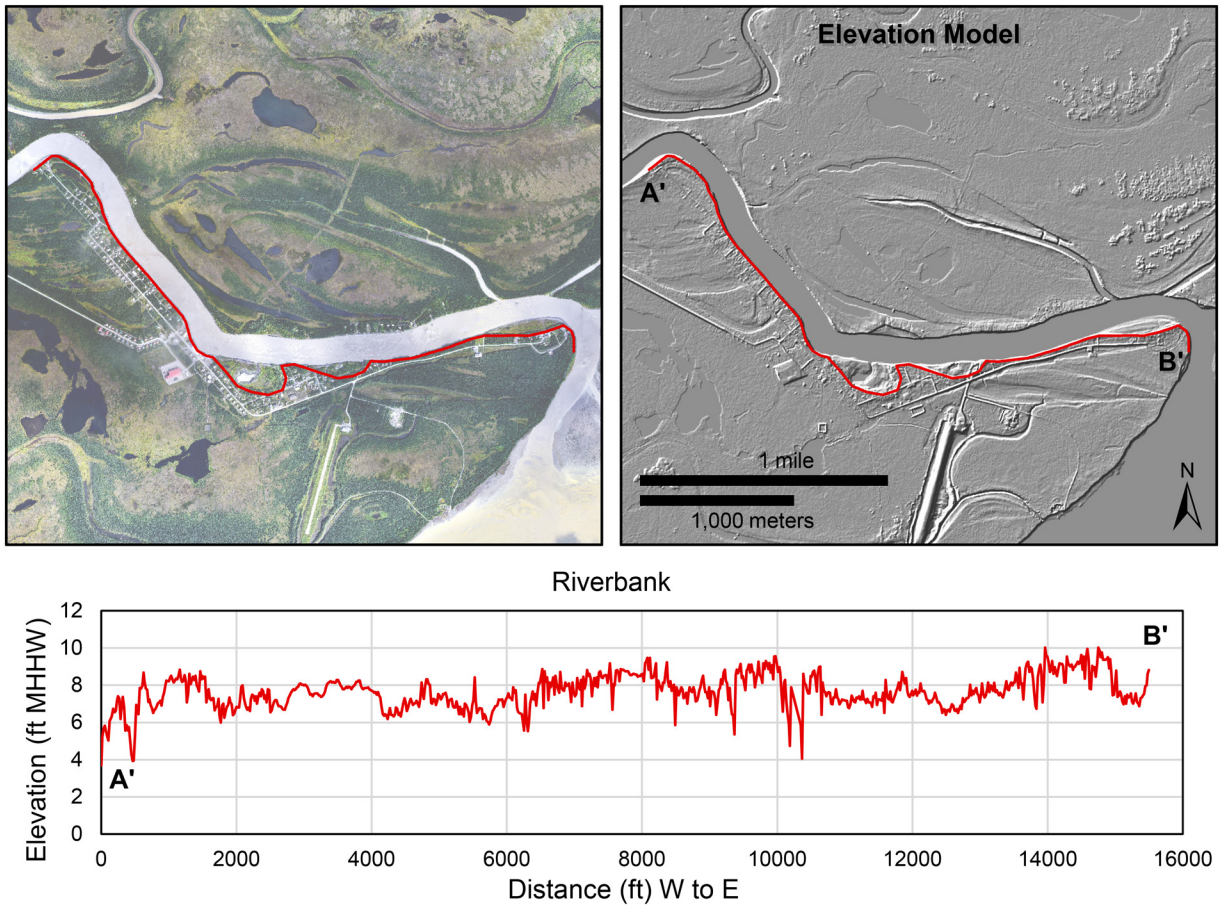

Figure 2. Elevation profile drawn on DTM shows elevation of the Alakanuk Pass riverbank is mostly between 6 and 10 ft MHHW.

digital elevation models were collected at Alakanuk (table 3). Digital surface models (DSMs) and orthoimagery were collected in 2015 (Overbeck and others, 2016) and 2021 (Buzard and others, 2021b). Woolpert (2017) created a lidar-derived DTM in 2016.

First Floor Survey

CRW Engineering Group, LLC (CRW, unpub. data, 2021) surveyed first floor heights in the NAVD88 (GEOID12B) datum. We convert these heights to the local tidal datum and use where applicable (table B1).

Tidal Datum

The Alakanuk tidal datum is computed by JOA Surveys, LLC (unpub. data, 2021) and used to convert orthometric elevations to MHHW for this report (table 4). MHHW is 6.35 ft (1.935 m) above NAVD88.

FLOOD IMPACT CATEGORIES

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

Table 3. Specifications of elevation models available for Alakanuk.

	Photogrammetric DSM	Lidar DTM	Photogrammetric DSM
Collection date	2015-AUG-31	October 15, 2016	July 11, 2021
Elevation type	Surface	Bare-earth	Surface
Ground sample distance	0.20 m	1.0 m	0.07 m
Vertical Accuracy	0.19 m (0.62 ft)	0.044 m (0.14 ft)	0.041 m
Vertical datum	NAVD88 (GEOID12B)	NAVD88 (GEOID12B)	NAVD88 (GEOID12B)

Table 4. Tidal datum for Alakanuk (JOA, unpub. data, 2021), with reference to NAVD88 using shared solution of tidal benchmark (National Geodetic Survey, 2021).

Tidal Datum	Abbreviation	ft MHHW	m NAVD88
Mean Higher High Water	MHHW	0.00	1.935
Mean High Water	MHW	-0.70	1.723
Mean Tide Level	MTL	-1.47	1.488
Mean Sea Level	MSL	-1.48	1.483
Mean Low Water	MLW	-2.24	1.252
Mean Lower Low Water	MLLW	-2.39	1.207
North American Vertical Datum of 1988	NAVD88	-6.35	0.000

flood impacts occur around the same elevation, so only the major category is used.

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

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

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

Other Infrastructure

Drinking water source: N/A

No sources indicate flooding impacts drinking water. The water "... comes from the surface water of Alakanuk Pass [Slough] and is flocculated, filtered, chlorinated, and fluoridated before use by the public" (Community of Alakanuk, 2007). Water quality is tested monthly and there have not been serious issues with flooding affecting drinking water (community of Alakanuk, oral commun., 2021).

Evacuation center: 16.4 ± 0.1 ft MHHW

There is no designated evacuation center in Alakanuk (Community of Alakanuk, 2021). The high school is commonly used as an evacuation center during major floods in rural Alaska communities. The high school first floor is 16.4 ± 0.1 ft MHHW (CRW, unpub. data, 2021; table B1), much higher than any known flood.

Airstrip covered: 15.1 ± 0.1 ft MHHW

The runway is 15.1 ± 0.1 ft MHHW, well above recorded flood heights. (fig. B1)

Fuel tank farm: 12.1 ± 0.1 ft MHHW

The main tank farm is on a raised platform approximately 12.1 ± 0.1 ft MHHW (measured from flat point on platform in 2021 DSM).

Major flooding: 8.2 ± 0.8 ft MHHW

Several buildings (flooded 1 or more ft): 9.5 ± 0.1 ft MHHW

Flooding of 9.5 ft MHHW would reach the first floor of 17 buildings, flooding 11 with at least 1 ft of water (fig. B2).

Lowest residences (flooded 0 to 1 ft): 9.1 ± 0.1 ft MHHW

The lowest residence identified by CRW (unpub. data, 2021) has a first floor elevation of 8.4 ± 0.1 ft MHHW (fig. B2). Flooding of 9.4 ± 0.1 ft MHHW would flood approximately eight residences with 0 to 1 ft of water.

Airstrip use or access: 8.6 ± 0.8 ft MHHW

The airport road is between 6 and 10 ft MHHW, averaging 8.6 ft MHHW (fig. B3). In June 2013, the road flooded 2 to 3 ft and was not drivable by four-wheeler, the most common vehicle in Alakanuk. We use this flood elevation, 8.6 ± 0.8 ft MHHW, to estimate the level at which airstrip use or access is cutoff.

Wastewater facility: 8.5 ± 1.3 ft MHHW

The wastewater lagoon berm is 8.5 ± 1.3 ft MHHW (fig. B4)

Access way to larger parts of town: 8.4 ± 0.1 ft MHHW

The main road through town is between 6 and 10 ft MHHW, averaging 8.4 ft MHHW (fig. B5). Water reaching this height would flood half of the road with about 2 ft of water, limiting access across town.

Fuel tanks at school: 8.2 ± 0.8 ft MHHW

The school fuel tank farm is on the ground at 8.2 ± 0.8 ft MHHW (the average DTM elevation of the fenced area). There is a cyclone fence but no berm to prevent flooding at the base of the tanks.

Minor Flooding: 6.3 ± 0.1 ft MHHW

Lowest building: 7.9 ± 0.1 ft MHHW

The lowest building identified in the first floor survey is a school outbuilding near the teacher housing and clinic (fig. B2). The structure is 7.9 ± 0.1 ft MHHW. There are some structures such as sheds or fish drying racks directly on the ground that are likely impacted by flooding at this elevation.

Low-lying property: 6.7 ± 1.4 ft MHHW

The May 2010 flood was relatively low but could have damaged low-lying property if residents did not relocate it. We use this elevation, 6.7 ± 1.4 ft MHHW, to estimate the flood elevation required to damage property on the ground.

Access road threatened: 6.3 ± 0.1 ft MHHW

Alakanuk's roads were elevated around 2015 (community of Alakanuk, oral commun., 2021). Alakanuk is connected by one very long road (fig. B5). The lowest part of the main road is 6.3 ± 0.1 ft MHHW and the lowest part of the airport road is 5.8 ± 0.1 ft MHHW. Water reaching 6.3 ± 0.1 ft MHHW would threaten access to the airport and begin threatening access to sections of the community.

HISTORICAL FLOOD RECORD

The historical flood record for Alakanuk, Alaska, is listed here from the earliest recorded flood to the most recent (up to November 2021). The sources used in evaluating each storm are listed along with a summary of the relevant information found within. This historical information is used to estimate the flood height where possible. This storm record depends on information that was available to the public and shared with DGGS staff during the July 2021 survey. Relevant survey data is provided in Appendix B, table B2. It is possible that storm and flood events have occurred that are not reported here. See Appendix A for the direct quotations from each source that are used to evaluate these storms.

1952-JUN-06 | 11.3 ± 1.0 ft MHHW	
Reference	**Source information relevant to flood height**
USACE (1987)	Entire town flooded up to 6 feet
USACE (1989)	Provides USACE trip report of high water mark elevations from historical records of community. Water was 5 feet deep at higher parts of the old village and 3 ft deep near the John Hanson's house. This was the highest water as of 1989.
USACE (2000) USACE (2009) USACE (2011) USACE (2017)	High water mark is 5.1 ft on flood staff
Llorente (2002)	Church and rectory destroyed June 6
DCRA (2006)	Published flood height in NAVD88 (GEOID96)
Community of Alakanuk (2007) Community of Alakanuk (2013) Community of Alakanuk (2018)	Highest water level on record

Figure 3. Flood staff on old city office. The 0 mark is 6.2 ft MHHW. The posted recommended building height is 12.3 ft MHHW.

The June 1952 flood event is considered the flood of record (Community of Alakanuk, 2018). The whole town was flooded with water 3 to 6 feet deep (USACE, 1987, 1989). At the time, houses were built with "semi-foundation," approximately 1 ft off the ground (community of Alakanuk, oral commun., 2021). The only buildings destroyed were the church and rectory due to channel erosion and floating ice (Llorente, 2002).

USACE (1989) identified high water marks and USACE (2000) installed a flood staff surveyed to the marks. The flood staff 0 mark is 6.2 ± 0.1 ft MHHW (fig. 3), making the 1952 flood estimate 11.3 ft MHHW (5.37 m NAVD88). DCRA (2006) measured the height to be 3.71 m NAVD88 (GEOID96), which is 5.50 m NAVD88 (GEOID12B), 11.7 ft MHHW. Given this slight difference and the various sources required to survey the height, we increase uncertainty to 1.0 ft to estimate the spring 1952 flood reached 11.3 ± 1.0 ft MHHW.

1969-MAY | 10.6 ± 2.1 ft MHHW	
Reference	**Source information relevant to flood height**
USACE (1980)	Water reached "3 ft above flood level."
Community of Alakanuk, oral commun. (2021)	Flooding reached up to the third step from the top of the church. That land has since eroded.

The May 1969 flood lasted approximately one week, inundated 25 homes, and residents evacuated to the catholic church (USACE, 1980; community of Alakanuk, oral commun., 2021). The church was built on the riverbank about 200 ft east of the old city office and flood staff (DCRA, 1979). The land has since eroded, but the elevation was likely similar to the current land elevation around the riverbank.

Water reached 3 ft above "flood level," which could refer to the riverbank height (bankfull stage) or be used as a term to describe when water begins to impact infrastructure (USACE, 1980). USACE (1989) estimates the "…zero damage elevation is approximately 3 feet below the [1952 flood]." By this interpretation, the zero damage elevation would be 8.3 ± 1.0 ft MHHW and the 1969 flood would have reached approximately the same height as 1952. The riverbank averages 7.6 ± 1.8 ft MHHW (fig. 2). Given the 1952 flood is considered the flood of record, we use this lower flood level proxy to estimate the May 1969 flood reached 10.6 ± 2.1 ft MHHW (table 5).

Table 5. Flood parameters used to estimate the May 1969 flood. Uncertainty is calculated using the RSS error.

Feature	Water above riverbank
Feature represents	Highest water
Water level type	Still water
Estimate of height (ft MHHW)	10.6
Uncertainty of riverbank (ft)	1.8
Uncertainty of water (ft)	1.0
Height and uncertainty (ft MHHW)	**10.6 ± 2.1**

1971-JUN-04 | 11.1 ± 1.0 ft MHHW

Reference	Source information relevant to flood height
NOAA (1971); USACE (1980) USACE (2017)	None
USACE (1989) Community of Alakanuk (2007) Community of Alakanuk (2013) Community of Alakanuk (2018)	All buildings flooded except store.
Community of Alakanuk, oral commun. (2021)	The old Native Corp. store was not flooded and is still standing.
USACE (2021)	Many people on rooftops being evacuated. Every structure damaged including school and fuel tanks. Covered airstrip. Water 3 to 5 feet deep.

The June 1971 flood reached 3 to 5 feet deep, covering the old runway and damaging nearly every structure in Alakanuk including the school and fuel tank farm (USACE, 2021). Residents awaited evacuation on rooftops and slept in boats for multiple days (community of Alakanuk, oral

commun., 2021). The flood was particularly dangerous due to ice flowing through town (community of Alakanuk, oral commun., 2021). The old Native Corporation Store was the only structure not flooded (USACE, 1989).

The old Native Corporation Store first floor height is 13.0 ± 0.1 ft MHHW (CRW, unpub. data, 2021; fig. 4; table B1). Of remaining structures that existed in 1971 and have not been raised, the Jorgenson's Store is the highest with a first-floor height of 11.1 ± 0.1 ft MHHW (CRW, unpub. data, 2021; fig. 4; table B1). Flooding of 4.0 ± 1.0 ft above the riverbank would reach 11.6 ± 2.1 ft MHHW, exceeding the 1952 flood. Considering water height ranged ± 1.0 ft and reportedly reached the Jorgenson's Store first floor but did not exceed the 1952 flood, we use the store floor and water range to estimate the June 1971 flood reached 11.1 ± 1.0 ft MHHW. The old runway was improved between 1971 and the 2016 DTM so we cannot use its height.

Figure 4. (Left) DGGS GNSS measurement at old Native Corporation Store porch. (Right) DGGS GNSS measurement at Jorgenson's Store porch near river. This photo shows buildings during a DGGS survey, however, first-floor measurements used in this assessment were collected by CRW Engineering Group, LLC. Both surveys agree to within 0.1 ft.

1972-MAY-30 | 10.1 ± 1.1 ft MHHW	
Reference	**Source information relevant to flood height**
NOAA (1972); USACE (1980); USACE (2017)	None
USACE [1972?]	Entire village flooded with 1 to 3 ft of water.
USACE (1989) Community of Alakanuk (2007) Community of Alakanuk (2013) Community of Alakanuk (2018)	"[Approximately] 2 feet of water in the highest part of the old village. 70 houses flooded."
AVEC, written commun. (2021)	Photos of flooding available at maps.dggs.alaska.gov/photodb/search#show=96&search=Alakanuk%20May%201972
USACE (2021)	"90% of the homes had up to 3 ft of water; only 5 were dry. One house was washed away. The 2 stores and the armory were not flooded. The water was two ft deep at highest point in the village, and 4 to 5' deep in the older section of town at the crest."
Community of Alakanuk, oral commun. (2021)	The armory building was across river and has been moved. One of the stores was on the north side. The Jorgensen's store was safe.

The May 1972 ice jam flooded the entire village, with water reaching 1 to 3 ft deep in 70 houses (USACE, [1972?], 1989, 2021). One home was "washed away," and only 5 houses were above the flood level (USACE, 2021). Flooding began May 30 and receded by June 3, brought ice into the community, and reached 2 ft deep in the highest part of the old town on the north side. Two stores (Jorgenson's Store and one on the north side that is no longer present) were not flooded, nor the previous armory on the north side of the river (USACE, 2021; community of Alakanuk, oral commun., 2021). Photos taken from a plane during the flood show water covering all land, but do not appear to be taken during peak flooding because most buildings do not have water above their first floor (Alaska Village Electric Cooperative [AVEC], written commun., 2021). All structures are surrounded by water, the Bureau of Indian Affairs school is flooded, and fuel tanks are tilted (fig. 5).

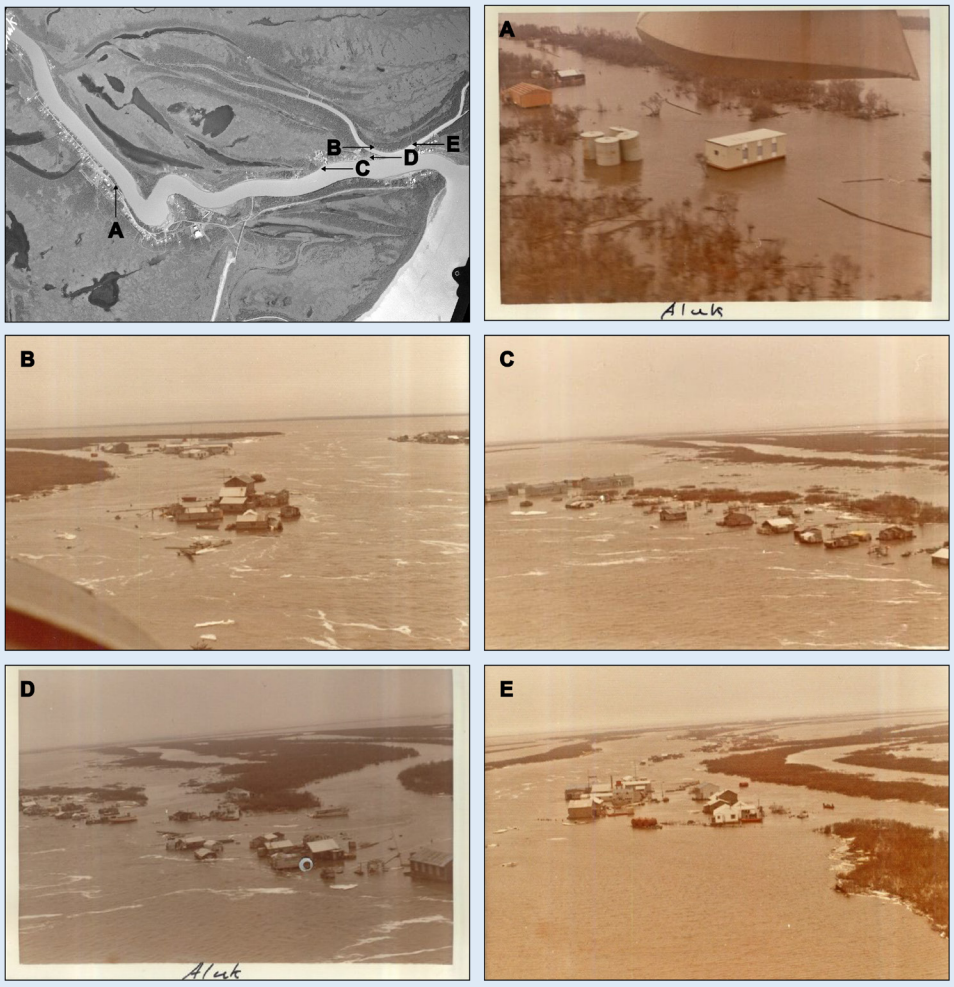

Figure 5. Aerial photos of the 1972 flood in Alakanuk archived by AVEC (written commun., 2021). (Top left) Photo locations and look direction are shown on a 1975 aerial image of Alakanuk. **A.** Fuel tanks tilted by floodwater. **B.** Floodwaters surround the old village site near the mouth of the Ala kanuk Pass Slough. The old cannery and Yukon River are in the background. **C.** The old Bureau of Indian Affairs school (three long buildings in a line in the photo's center-left) and nearby structures are all flooded. **D, E.** Floodwater surrounds all structures in the old village site on the north side of the slough.

Water did not exceed 11.1 ± 0.1 ft MHHW, the first-floor height of Jorgenson's Store (CRW, unpub. data, 2021; fig. 4; table B1). Water reached 2 to 5 ft deep depending on the part of town, which is 1 ft below the range of the 1952 flood. USACE (1989) estimates "zero damage" is 3 ft below the 1952 flood, 8.3 ± 1.0 ft MHHW. Water reaching 2.0 ± 1.0 ft above this height would flood residences with 1 to 3 ft of water while remaining 1 ft lower than the 1952 flood and not flooding Jorgenson's Store. We use the upper-lower bounds method to estimate the May 1972 flood reached 10.1 ± 1.1 ft MHHW (table 6).

Table 6. Flood parameters used to estimate the May 1972 flood. Uncertainty is calculated using the upper-lower bounds method.

Feature	Residences flooded 1-3 ft	Jorgenson's Store
Feature represents	Lowest water	Highest water
Water level type	Still water	Still water
Estimate of height (ft MHHW)	10.3	11.1
Estimate error (ft)	1.4	0.1
Lower bound (ft MHHW)	8.9	11.0
Upper bound (ft MHHW)	N/A	11.2
Height and uncertainty (ft MHHW)	**10.1 ± 1.1**	

1974-NOV-11 | 8.3 ± 1.0 ft MHHW

Reference	Source information relevant to flood height
NOAA (1974)	Low-lying property damage
Wise and others (1981)	None

The November 1974 storm caused widespread flooding in western Alaska, but impacts in Alakanuk were minor (NOAA, 1974). The storm damaged boats, motors, and snowmachines (NOAA, 1974). Given the low-lying property damage, the event exceeded the riverbank but not the first floor of residences. We estimate the November 1974 storm reached approximately the zero damage line estimated by USACE (1989), 8.3 ± 1.0 ft MHHW.

1975-MAY-29 | 9.5 ± 1.0 ft MHHW	
Reference	**Source information relevant to flood height**
NOAA (1975)	49 houses damaged by water, two by ice. Five fishing boats crushed. Transformers and utilidors flooded.
USACE (1989) Community of Alakanuk (2007) Community of Alakanuk (2013) Community of Alakanuk (2018)	"49 houses flooded, transformers underwater."
USACE (2017)	None
USACE (2021)	22 houses flooded
Community of Alakanuk, oral commun. (2021)	Few homes were raised on stilts at this time.

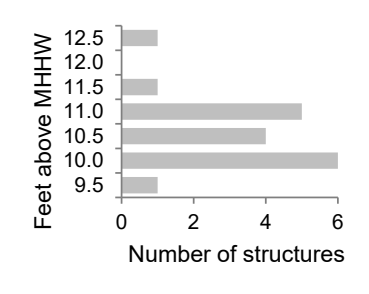

Figure 6. First floor elevation (in 2021) of structures that existed in 1975. The structures have been raised on stilts (pilings).

The May 1975 ice jam flooded Alakanuk for three days, damaging 49 houses and the new power system (NOAA, 1975; USACE; 1989; USACE 2021). Ice flowing through the community caused further damage and crushed five fishing boats (NOAA, 1975). Twenty-nine residents evacuated to local public buildings, but none evacuated the community (USACE, 2021).

We identified structures that exist in both 1975 and 2021 aerial imagery. Of over 20 structures, the lowest first floor elevation is 9.5 ± 0.1 ft MHHW, and the average is 10.4 ± 1.3 ft MHHW (fig. 6). These structures appear to be elevated on stilts higher than they were in 1975 (community of Alakanuk, oral commun., 2021). Fewer homes flooded than in 1972 when water reached 10.1 ± 1.1 ft MHHW. Given these observations, we estimate water was within 1 ft of the lowest 1975 stilt house. The May 1975 flood reached 9.5 ± 1.0 ft MHHW.

1976-MAY | 8.5 ± 1.0 ft MHHW	
Reference	**Source information relevant to flood height**
NOAA (1976)	Flooding of older residences. These residents evacuated to homes on pilings.
USACE (1980)	None
Community of Alakanuk, oral commun. (2021)	Water almost got to doorsill of homes of somewhat raised houses.

The May 1976 ice jam flooded the older, lower residences in Alakanuk (NOAA, 1976). Water nearly reached the doorsill of raised houses (community of Alakanuk, oral commun., 2021). The lowest known raised house from 1975 is 9.5 ± 0.1 ft MHHW (fig. 6). We estimate the May 1976 flood reached 0 to 2 ft below this elevation, 8.5 ± 1.0 ft MHHW.

1977-MAY-17 | 7.5 ± 1.8 ft MHHW

Reference	Source information relevant to flood height
NOAA (1977a)	Minor flooding
NOAA (1977b)	None

The May 1977 ice jam flood caused minor impacts in Alakanuk (NOAA, 1977a). We estimate the May 1977 flood reached halfway between the lowest and highest known minor floods, 7.5 ± 1.8 ft MHHW (using the upper-lower bounds of their uncertainties).

1979-MAY-15 | 7.5 ± 1.8 ft MHHW

Reference	Source information relevant to flood height
NOAA (1979)	Minor flooding

The May 1979 ice jam flood caused minor impacts in Alakanuk (NOAA, 1979). No further information was found, so we estimate this reached the same height as May 1977, 7.5 ± 1.8 ft MHHW.

1984-MAY-25 | 7.2 ± 0.8 ft MHHW

Reference	Source information relevant to flood height
NOAA (1984); USACE (2009a) USACE (2017)	None
USACE (1987)	Six homes flooded. "[Half] of public roads under water and damaged."
USACE (1989) Community of Alakanuk (2007) Community of Alakanuk (2013) Community of Alakanuk (2018)	"2 or 3 older houses flooded, most [houses] surrounded."
DHS&EM (2013) DHS&EM (2018)	Road damage
USACE (2021)	"...water had flooded two or three houses and surrounded most others."
Community of Alakanuk, oral commun. (2021)	Most houses were on stilts by this time and floods were starting to be lower.

The May 1984 ice jam flooded Alakanuk from May 25 to 29, surrounding most homes and entering two to six (USACE 1987, 1989, 2021). Approximately half of all roads were under water (USACE, 1987). Most houses were raised on stilts by this time, so only the older houses flooded (community of Alakanuk, oral commun., 2021).

We examined aerial imagery from 1980 and 1992 to identify structures from this period that still exist in 2021. The lowest structure is 7.9 ± 0.1 ft MHHW and was built during this period. Given the construction date, this building was likely built on stilts and not flooded in this event. Most structures were surrounded by water (USACE, 1989). Half of all structures in 2021 are on ground at or below 6.5 ± 0.1 ft MHHW (fig. B2). Water reaching 7.9 ± 0.1 ft MHHW would cover ground underneath 80 percent of structures in 2021. We estimate the May 1984 flood reached within this range, 7.2 ± 0.8 ft MHHW (table 7).

Table 7. Flood parameters used to estimate the May 1984 flood. Uncertainty is calculated using the upper-lower bounds method.

Feature	50 percent structure ground height	Lowest stilt structure from 1980s
Feature represents	Lowest water	Highest water
Water level type	Still water	Still water
Estimate of height (ft MHHW)	6.5	7.9
Estimate error (ft)	0.1	0.1
Lower bound (ft MHHW)	6.4	7.8
Upper bound (ft MHHW)	6.6	8.0
Height and uncertainty (ft MHHW)	**7.2 ± 0.8**	

1985-JUN-03 | 7.6 ± 1.7 ft MHHW

Reference	Source information relevant to flood height
USACE (1989) Community of Alakanuk (2007) Community of Alakanuk (2013) Community of Alakanuk (2018)	"High water 6.0 feet from the top of the 2 x 4 deck on the upstream, landward side of the school."
USACE (2017); USACE (2021)	None
Community of Alakanuk, oral commun. (2021)	Floodwater under high school was common.

The June 1985 ice jam flooded low-lying areas of Alakanuk and Emmonak (USACE, 2021). Water reached 6.0 ± 0.5 ft below the deck at the high school (USACE, 1989). This high school has since been demolished. Photos provided by DCRA (2006) show the deck is 7 to 8 ft above the ground, so water likely reached 1.0 ± 1.0 ft above ground level (fig. 7). The average ground level is 6.4 ± 0.4 ft

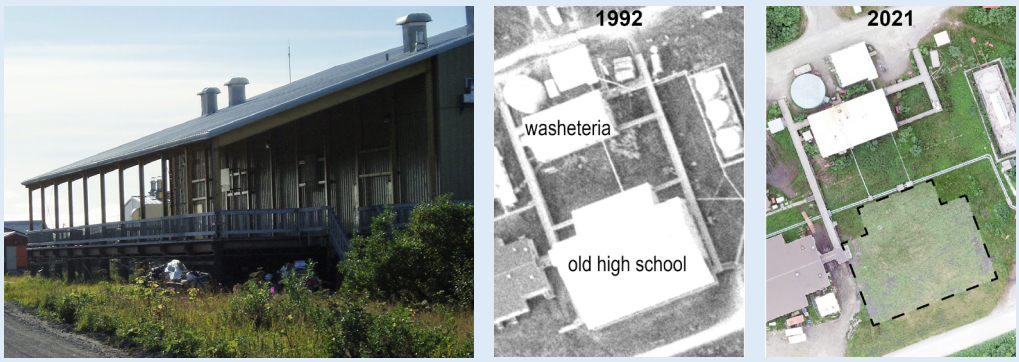

Figure 7. (Left) The old high school deck (DCRA, 2006). (Center) Aerial image of old high school and washeteria in 1992 shows the shared boardwalk complex and staircases. (Right) aerial image of the same area in 2021 after the school (dashed outline) was demolished.

MHHW, although the ground has been modified due to demolition, so we increase uncertainty to 1.0 ft. The nearby washeteria was connected via an elevated boardwalk and has the same siding and roofing, indicating it may have been built at the same height as the old high school. The washeteria first floor is 14.8 ft MHHW. We estimate the June 1985 flood reached 7.6 ± 1.7 ft MHHW (table 8).

Table 8. Flood parameters used to estimate the June 1985 flood. Uncertainty is calculated using the upper-lower bounds method.

Feature	Water above ground at old school	Water below washeteria floor
Feature represents	Highest water	Highest water
Water level type	Still water	Still water
Estimate of height (ft MHHW)	7.4	8.8
Estimate error (ft)	1.4	0.5
Lower bound (ft MHHW)	6.0	8.3
Upper bound (ft MHHW)	8.8	9.3
Height and uncertainty (ft MHHW)	**7.6 ± 1.7**	

1989-MAY-29 | 6.7 ± 0.9 ft MHHW

Reference	Source information relevant to flood height
NOAA (1989); USACE (1989) USACE (2000); USACE (2011) USACE (2017)	None
USACE (2021)	Water reaches bankfull stage May 29 and "approaching flood stage" but no reports of flooding.

The lower Yukon River ice jams from mid to late May caused a disaster declaration for six communities (NOAA, 1989). In Alakanuk, water reached bankfull stage May 29, but there were no further reports of rising water (USACE, 2021). We estimate the May 1989 flood reached within the lower half of the riverbank height, 6.7 ± 0.9 ft MHHW (fig. 2).

1990-MAY-21 | 6.7 ± 1.4 ft MHHW

Reference	Source information relevant to flood height
USACE (2021)	Flooding at airport, streets under water, water under houses.
Community of Alakanuk, oral commun. (2021)	Annual flooding, flooding around old airport.

The May 1990 ice jam flooded around the airport, over streets, and underneath houses (USACE, 2021). This was considered annual flooding (community of Alakanuk, oral commun., 2021). The DCRA (1994) community profile map shows many residences at this time were in the same area as in

2021. The ground height under houses averages 6.7 ± 1.4 ft MHHW (fig. B2). A flood reaching this height can surround the old airport and would cover roads that are not elevated to modern heights. We estimate the May 1990 flood reached 6.7 ± 1.4 ft MHHW.

1991-MAY-21 | 8.8 ± 0.8 ft MHHW	
Reference	**Source information relevant to flood height**
USACE (2009a)	None
DHS&EM (2013); DHS&EM (2018)	Flooding due to record snowfall and spring melt.
USACE (2021)	Eight houses flooded, three tanks floated, no roads visible, runway not flooded but the apron is flooded. Water reached ramp at school. Water 1.5 to 2 ft below houses with raised floors.
Community of Alakanuk, oral commun. (2021)	Flood reached porch step at house. Fish camps upriver were flooded.

The May 1991 ice jam caused major flooding in Alakanuk and Emmonak (DHS&EM, 2013). Water entered eight homes, floated three fuel tanks, and covered every road (USACE, 2021). The runway was clear except for a washout at the south end, and the apron was covered (USACE, 2021). The power plant sustained damage but was repaired relatively quickly (USACE, 2021).

The old runway appears to have no renovations between 1992 and 2006 (within this period it was replaced by the new runway), so measurements on the DTM should reflect elevations at the time. The runway is 12.2 ± 1.9 ft MHHW (fig. 8), and the apron is 9.1 ± 0.5 ft MHHW (fig. 9; table B2).

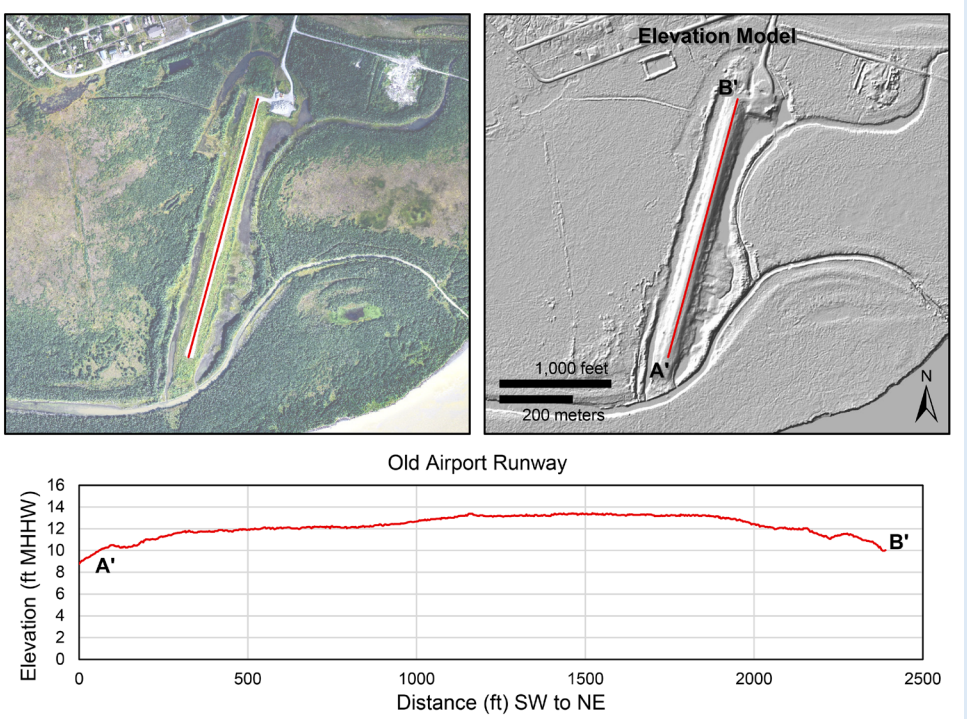

Figure 8. Elevation profile drawn on old airport runway shows most of the runway is above 12 ft MHHW.

Figure 9. Elevation measurements taken at the old airport apron.

Figure 10. Elevation measurement taken at porch step reached by the May 1991 flood.

The community of Alakanuk (oral commun., 2021) identified a porch step where water peaked at 8.1 ± 0.1 ft MHHW (fig. 10), indicating water was higher towards the Yukon River. As of 2021, the eight lowest structures have a first floor height below 9.0 ft MHHW (fig. B2). We use the observed height at the residence and the apron to estimate the May 1991 flood reached 8.8 ± 0.8 ft MHHW (table 9). This is high enough to flood a few structures and cause the other observed impacts without inundating the old runway.

Table 9. Flood parameters used to estimate the May 1991 flood. Uncertainty is calculated using the upper-lower bounds method.

Feature	Water up to step	Water on apron
Feature represents	Highest water	Highest water
Water level type	Still water	Still water
Estimate of height (ft MHHW)	8.1	9.1
Estimate error (ft)	0.1	0.5
Lower bound (ft MHHW)	8.0	8.6
Upper bound (ft MHHW)	8.2	9.6
Height and uncertainty (ft MHHW)	**8.8 ± 0.8**	

1992-JUN-03 | 7.1 ± 1.0 ft MHHW	
Reference	**Source information relevant to flood height**
USACE (2021)	Water surrounded 25 homes but no reported water inside homes. Some roads flooded.

The June 1992 ice jam exceeded the riverbank in some areas, damaged some roads, and flooded low-lying areas but water did not enter any homes (USACE, 2021). We identified approximately 70 residences from the 1992 and 1980 aerial images and measured the average ground height in the DTM to determine the lowest 25 residences are on ground at or below 7.1 ± 0.1 ft MHHW. This is high enough to exceed the riverbank in some locations and flood low-lying areas without causing substantial impacts to the community. We increase the uncertainty to estimate the June 1992 flood reached 7.1 ± 1.0 ft MHHW.

1993-MAY-20 | 6.7 ± 0.5 ft MHHW	
Reference	**Source information relevant to flood height**
USACE (2021)	Flooding of about five buildings. Roads mostly flooded. No significant damage.
Community of Alakanuk, oral commun. (2021)	Water not in structures themselves.

The May 1993 ice jam flooded underneath five structures and over most roads in Alakanuk (USACE, 2021; community of Alakanuk, oral commun., 2021). Five structures from 1992 are on ground at or below 6.2 ± 0.1 ft MHHW. This is too low to exceed the riverbank in most locations, so we estimate water was 0.5 ± 0.5 ft higher in order to begin overbank flooding at the lowest structures. We estimate the May 1993 flood reached 6.7 ± 0.5 ft MHHW.

1995-MAY-16 | 7.0 ± 0.9 ft MHHW	
Reference	**Source information relevant to flood height**
NOAA (1995)	Low-lying areas and roads flooded.
USACE (2009)	None
DHS&EM (2013) DHS&EM (2018)	Damage to roads.
USACE (2021)	Knee deep water near the power plant. Only roads and low areas flooded.
Community of Alakanuk, oral commun. (2021)	1995—power plant on low ground still in same location today.

The May 1995 ice jam flooded roads and low-lying areas of Alakanuk (USACE, 2021). Water was knee deep at the power plant at the time, where the ground height averages 6.0 ± 0.7 ft MHHW. We estimate water reached 1.0 ± 0.5 ft higher, to a total elevation of 7.0 ± 0.9 ft MHHW (table 10).

Table 10. Flood parameters used to estimate the May 1995 flood. Uncertainty is calculated using the RSS error.

Feature	Knee-deep water at old power plant
Feature represents	Highest water
Water level type	Still water
Estimate of height (ft MHHW)	7.0
Uncertainty of ground (ft)	0.7
Uncertainty of water (ft)	0.5
Height and uncertainty (ft MHHW)	**7.0 ± 0.9**

2002-MAY-29 | no water level estimate

Reference	Source information relevant to flood height
U.S. General Accounting Office (2009)	"Alakanuk received $208,898 to relocate and elevate 15 homes and 1 city building after a 2002 flood."
USACE (2009a) DHS&EM (2013) DHS&EM (2018)	Disaster due to flooding in May.

The May 2002 ice jam flooded several communities on the Yukon River, causing a state and federal disaster (DHS&EM, 2013). There were no descriptions of flooding in Alakanuk so an estimate could not be made.

2004-OCT-18 | 7.6 ± 1.8 ft MHHW

Reference	Source information relevant to flood height
NOAA (2004) Community of Alakanuk (2018)	None
Community of Alakanuk, oral commun. (2021)	Flooding of low-lying areas. Water under buildings but not inside.

The October 2004 storm surge reached near bank level and flooded low-lying areas around the Jorgenson's store (community of Alakanuk, oral commun., 2021). We use the riverbank elevation to estimate the October 2004 flood reached 7.6 ± 1.8 ft MHHW (fig. 2).

2005-MAY-17 | 7.9 ± 0.5 ft MHHW	
Reference	**Source information relevant to flood height**
NWS (2005)	Water exceeds bank for 80 percent of village.
NOAA (2005) Community of Alakanuk (2018)	Minor flooding, roads flooded, no structures flooded.
Community of Alakanuk (2007) Community of Alakanuk (2013) DHS&EM (2013) Community of Alakanuk (2018)	Road damage.
USACE (2017)	None
DHS&EM (2018)	Roads inundated and eroded.
USACE (2021)	Minor flooding, roads flooded, water exceeded bank.
Community of Alakanuk, oral commun. (2021)	Some homes were close to being flooded inside in low lying areas. Roads were not elevated to current heights.

The May 2005 ice jam flooded most roads in Alakanuk (NWS, 2005). Water came close to entering some homes (community of Alakanuk, oral commun., 2021). The contours from DCRA (2006) show most roads ranged between 8 and 10 ft NAVD88 (GEOID96), which is 8.5 ± 1.0 ft MHHW. The lowest residence first floor height is 8.4 ± 0.1 ft MHHW and was not flooded (CRW, unpub. data, 2021; community of Alakanuk, oral commun., 2021). We estimate water reached 0.5 ± 0.5 ft below the lowest residence to cover most roads and nearly flood residences and structures. We estimate the May 2005 flood reached 7.9 ± 0.5 ft MHHW.

2006-MAY-28 | 8.4 ± 1.2 ft MHHW	
Reference	**Source information relevant to flood height**
NWS (2006)	Most land under water. Water at least three ft deep. Sewage lagoon inundated. Airport apron partly under water. Fuel tanks tilted.
NOAA (2006) Community of Alakanuk (2018)	Moderate flooding of three ft. Lowest portions of homes soaked. Fuel tank tilted. Airport apron partially flooded. Sewage lagoon flooded.
Community of Alakanuk (2007) Community of Alakanuk (2013)	Flood damage to roads and many homes.
USACE (2009a); USACE (2017)	None
DHS&EM (2013)	Several roads inundated and eroded.
DHS&EM (2018)	Water depth up to six ft. One home that had been moved but not elevated was damaged by four to five ft of water.
Community of Alakanuk, oral commun. (2021)	The lowest portion of homes were soaked in lower lying areas. The lagoon and dump are in a lowland.

The May 2006 ice jam reached the insulation of multiple homes and flooded the wastewater lagoon, landfill, and part of the airport apron (NOAA, 2006; community of Alakanuk, oral commun., 2021). The flood reached at least to the wastewater lagoon berm, 8.5 ± 1.3 ft MHHW (fig. B4). The flood peaked near the mean old runway apron height of 9.1 ± 0.5 ft MHHW (fig. 9; table B2). Floods reaching in this range can cause the described impacts, including flooding of the landfill, 6.8 ± 1.0 ft MHHW (table B2, fig. 11). We estimate the May 2006 flood reached 8.4 ± 1.2 ft MHHW (table 11).

Figure 11. GNSS measurement at the landfill entrance.

Table 11. Flood parameters used to estimate the May 2006 flood. Uncertainty is calculated using the upper-lower bounds method.

Feature	Wastewater lagoon berm	Old runway apron
Feature represents	Lowest water	Highest water
Water level type	Still water	Still water
Estimate of height (ft MHHW)	8.5	9.1
Estimate error (ft)	1.3	0.5
Lower bound (ft MHHW)	7.2	8.6
Upper bound (ft MHHW)	9.8	9.6
Height and uncertainty (ft MHHW)	**8.4 ± 1.2**	

2009-MAY-23 | 7.5 ± 0.5 ft MHHW	
Reference	**Source information relevant to flood height**
NWS (2009)	Numerous roads flooded and impassable. Water 1 to 2 ft below new housing.
NOAA (2009)	Several homes in low-lying areas inundated with 1 to 3 ft of water.
USACE (2009)	1.3 ft on flood staff, 3.8 ft lower than 1952 flood. This was a common flood.
DHS&EM (2013) USACE (2017) DHS&EM (2018)	None
Community of Alakanuk (2018)	Several homes flooded with 1 to 3 ft of water.
Community of Alakanuk, oral commun. (2021)	The two homes with interior damage were right on the ground.

The May 2009 ice jam flooded two homes that were directly on the ground with 2 to 3 ft of water (NWS, 2009; NOAA 2009; community of Alakanuk, oral commun., 2021). Most roads were impassable (NWS, 2009). USACE (2009) estimate the flood reached 1.3 ft on the flood staff, 7.5 ft MHHW. It was not a particularly high flood event, but homes may have been directly on the ground due to the relocation and raising process (like in May 2006). We use an uncertainty of 0.5 ft for USACE (2009) measurements to estimate the May 2009 flood reached 7.5 ± 0.5 ft MHHW.

2010-MAY-24 | 6.7 ± 1.4 ft MHHW

Reference	Source information relevant to flood height
NWS (2010)	Minor flooding in low-lying areas, over roads, under some homes. Roads still passable. Property moved out of low-lying areas prior to flood.
USACE (2017)	None
USACE (2021)	Minor flooding of roads and around homes. Roads were still passable.
Community of Alakanuk, oral commun. (2021)	Minor flooding around homes.

The May 2010 ice jam caused minor flooding in Alakanuk (NWS, 2010). Residents prepared by moving equipment to higher ground. Water came underneath homes and over roads, but travel was still possible (NWS, 2010). We use the average ground height underneath homes to estimate the May 2010 flood reached 6.7 ± 1.4 ft MHHW (fig. B2).

2011-NOV-09 | 7.4 ± 0.5 ft MHHW

Reference	Source information relevant to flood height
NOAA (2011)	High water levels.
Community of Alakanuk (2018)	No damage.
Community of Alakanuk, oral commun. (2021)	Some damage from flooding. Water came over the bank and flooded about 2 ft by house.

Figure 12. GNSS measurement of ground near house where water reached 2 ft deep during the November 2011 flood.

The November 2011 storm caused major flooding across western Alaska, but Alakanuk experienced minor flooding (NOAA, 2011). The river is typically frozen over in November, but the fall was unusually warm and the river had no ice (community of Alakanuk, oral commun., 2021). Water reached 2.0 ± 0.5 ft above the ground at one residence on the airport road (fig. 12; table B2). We estimate the November 2011 flood reached 7.4 ± 0.5 ft MHHW.

2013-JUN-04 | 8.6 ± 0.8 ft MHHW

Reference	Source information relevant to flood height
NWS (2013)	Four to five houses flooded, road to airport has 2 to 3 ft water.
NOAA (2013)	Water 2 to 3 ft deep on airport road. Three to four homes with water inside. Wastewater lagoon inundated.
DHS&EM (2013) USACE (2017) DHS&EM (2018)	None
Community of Alakanuk (2018)	Similar to NWS (2013) and NOAA (2013).
USACE (2021)	Flooding of two homes and the road to the airport.

The June 2013 ice jam flooded four to five houses, inundated the wastewater lagoon, and floated propane tanks (NWS, 2013). The airport road had 2 to 3 ft of water but was passable using a truck (NWS, 2013). The wastewater lagoon berm is 8.5 ± 1.3 ft MHHW (fig. B4). The airport road averages 8.6 ± 3.0 ft MHHW with the lowest section being 6.0 ft MHHW. Two to three ft of flooding over the lowest section would reach 8.5 ± 0.5 ft MHHW. The four lowest residences are between 8.4 and 8.9 ft MHHW, averaging 8.7 ± 0.2 ft MHHW. We take the average height and root-mean-square error of their uncertainties to estimate the June 2013 flood reached 8.6 ± 0.8 ft MHHW.

2013-NOV-13 | 6.4 ± 0.7 ft MHHW

Reference	Source information relevant to flood height
Community of Alakanuk, oral commun. (2021)	Reached houses on airport road but was not as high as November 2011.

The November 2013 storm caused major flooding for several communities around Norton Sound and western Alaska, but impacts in Alakanuk were minor (community of Alakanuk, oral commun., 2021). Water reached the same residence as in November 2011 but was not as high. We estimate the November 2013 flood reached 1.0 ± 0.5 ft lower, 6.4 ± 0.7 ft MHHW.

2020-MAY-16 | 6.7 ± 0.9 ft MHHW

Reference	Source information relevant to flood height
NWS (2020)	Flooding of low-lying roads, including low areas of airport road. Water is 4 to 5 ft below home first floors.
Community of Alakanuk, oral commun. (2021)	Flooding of roads.

The May 2020 ice jam flooded low-lying roads and some ground-level structures (NWS, 2020). Water was 2 to 4 ft below residence first floors and flooded low areas on airport road (NWS, 2020). The lowest section of the airport road is 6.0 ± 0.1 ft MHHW (fig. B3). Water 4 ft below the average residence first floor height would reach 7.5 ± 0.1 ft MHHW (fig. B2), high enough to flood ground-level structures but remain about 1 ft below the lowest home. We use the range between the airport road low spots and water below average residence heights to estimate the May 2020 flood reached 6.7 ± 0.9 ft MHHW.

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APPENDIX A: FLOOD-RELATED ACCOUNTS

There are many written reports that contain flood information for Alakanuk. Reports may be difficult to find in the future as their online linked location can change. This appendix provides the exact relevant text from each source used in this report to preserve the information. Any added commentary or summary information is enclosed by brackets.

Alaska Division of Community & Regional Affairs, 2006, Community profile map, Alakanuk: Department of Commerce, Community, and Economic Development.
www.commerce.alaska.gov/web/dcra/PlanningLandManagement/CommunityProfileMaps.aspx

Flood Data: The U.S. Army Corps of Engineers (USACE) report "Alaska Communities Flood Hazard Data 1997" has published flood of record which [occurred] in 1952 with a flood elevation of 12.16 feet based upon this map's vertical control. The high water elevation sign was placed on the flood gauge with the water symbol located on a the [*sic*] southerly corner of the Alakanuk Tribal and City Offices. The City of Alakanuk is all located below the 1952 floodline, except for portions of the airport and areas near the Tribal Hall.

Community of Alakanuk, 2007, City of Alakanuk hazard mitigation plan: URS, 124 p.

Typically, spring floods cover the community to a depth of three to four feet.

B. Previous Occurrences for Flooding

[Lists events from USACE (1989)]

2005 (May 14) flood – flood damage caused approximately $700,000 in damage to public roads including the subdivided road in the new AVCP housing area.

2006 spring flood - flood damage to public roads, many homes causing approximately $750,000 in damage.

The US Army Corps of Engineers has designated the Alakanuk area as a high flood hazard community. The entire community of Alakanuk is vulnerable to the effects of flooding. Conversations with residents indicate that flooding usually occurs during spring breakup and typically covers the entire community to a depth of 2 to 4 feet. High water marks were established at two locations by the USACOE based on the water level of the 1952 flood.

———2013, City of Alakanuk hazard mitigation plan—2012 update: Community of Alakanuk, 122 p.

[Same flood history as 2007 hazard mitigation plan]

[Includes high water mark survey information from USACE (1989)]

———2018, City of Alakanuk local hazard mitigation 2018 plan update: LeMay Engineering & Consulting, Inc., 132 p.

[Same flood history as 2007 and 2013 hazard mitigation plans with the following additions:]

2009 - Several homes along the river were flooded with one to three feet of water. A preliminary estimate of property damage was estimated at $35,000.

2011 - Coastal flood/storm surge caused water levels to rise significantly in lower Yukon river. No damage was reported in Alakanuk.

2013 - Water was two to three feet deep in spots in Alakanuk. Three or four homes had water in them and the residents of these homes were evacuated. The sewage lagoon was inundated, and it was noted that some propane tanks were floating in town.

[Includes high water mark survey information from USACE (1989)]

[Includes flood gauge photos from USACE (2011)]

[Table of winter storm events from 2001 to 2016 that may have impacted Alakanuk. All data from NOAA Storm Data reports]

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

28. Alakanuk, June 13, 1984: Ice jam caused flooding caused extensive damage to the village road system. Subsequent to the Governor's Proclamation, the State awarded a categorical grant to the city to repair the roads.

132–142. Fairbanks/North Star Borough, Aniak, McGrath, Red Devil, Anvik, Grayling, Emmonak, Holy Cross, Alakanuk, Shageluk, Galena. the Governor declared on May 3-23, 1991 FEMA declared May 30, 1991: Flooding. Record snowfalls in the interior combined with sudden Spring melt caused flooding all along the Yukon and Kuskokwim River systems. [State and federal disaster]

176. Yukon Kuskokwim Delta: On June 5, 1995, the Governor declared a condition of disaster emergency exist in the Cities of Akiak, Kwethluk, Napaskiak, Emmonak, and Alakanuk, as a result of inundation. As a result of this disaster roads, boardwalks, and other public works essential to vital community services were damaged. (closed after Jan 03)

2–200 02 Interior Floods (AK-DR-1423) Declared May 29, 2002 by Gov Knowles then FEMA Declared (DR-1423) on June 26 2002: Flooding occurred in various interior and western Alaska river drainages… The following conditions exist as a result of this disaster: widespread damage to public facilities and infrastructure, including damage to public airports, roads, and buildings; to public utilities, including water , sewer, and electrical utilities; to personal residences, in some areas requiring evacuation and sheltering of residents; to commercial operations; and to other public and private real and personal property… Gov amendment dated July 12, 2002 added Alakanuk to the State Declaration.

5–213 2005 Spring Floods (AK-05-213) declared July 20, 2005 by Governor Murkowski: Beginning May 13, 2005, a large ice jam blocked the mouth of the Lower Yukon River and caused widespread flooding to the cities of Emmonak and Alakanuk. In both cities, several roads were inundated and eroded by the floodwaters. Floodwaters also inundated city infrastructure to include the above-ground circulating water and vacuum sewage systems which were displaced and/or knocked off their mounting supports. Both cities have submitted local disaster declarations requesting State assistance. There were no life safety issues during this event. Floodwaters subsequently subsided to normal levels within the river banks on or about May 18, 2005.

6–218 2006 Spring Floods (AK-06-218) declared June 27,2006 by Governor Murkowski then FEMA declared (DR-1657) on August 04, 2006: Beginning May 5, 2006 continuing through

May 30, 2006, the National Weather Service (NWS) issued flooding warnings and watches across the state as excessive snowmelt and ice jams caused flooding along the Yukon, Kuskokwim, and Koyukuk river drainages. The most serious impacts were reported in the communities of Hughes, Koyukuk, Kwethluk, Alakanuk, and Emmonak, along with substantial damage to State-maintained airports, roads, and highways. In each community, large portions of the village, city infrastructure, and several roads were inundated and eroded by the floodwaters.

9–227 2009 Spring Flood declared by Governor Palin on May 6, 2009 then FEMA declared under DR-1843 on June 11, 2009: Extensive widespread flooding due to snow melt and destructive river ice jams caused by rapid spring warming combined with excessive snow pack and river ice thickness beginning April 28, 2009 and continuing. The ice jams and resultant water backup along with flood waters from snow melt left a path of destruction along 3,000 miles of interior rivers, destroying the Native Village of Eagle and forcing the evacuation of multiple communities. [Impacted several communities including Alakanuk]

13–242 2013 Spring Floods declared by Governor Parnell on May 30, 2013 then FEMA declared on June 25, 2013 (DR-4122): Beginning on May 17, through June 10 2013, excessive snow pack and ice thickness, combined with rapid spring warming caused ice jams and severe flooding. [Impacted several communities including Alakanuk]. The impact of the flooding resulted in severe damage to approximately 194 homes (requiring evacuations and sheltering) to include loss and damage to personal property, multiple businesses (including loss of revenue), and public infrastructure to include: hazardous and non-hazardous debris removal, emergency protective measures (leading to ongoing mass care operations), damage to city and state roads, bridges, water and sewer systems, electrical generation and distribution systems, recreation areas and fuel storage facilities.

———2018, State of Alaska hazard mitigation plan 2018: Department of Military and Veterans Affairs, 569 p.

[Lists same disasters as DHS&EM (2013)]

In 2005, eight homes and the City of [Alakanuk] office building were relocated, and all but one of the homes were elevated, most of them to a height of 6 feet above the natural ground surface, which is the recommended building elevation designated by the Corps of Engineers. The relocation and elevation project was funded with a $265,000 grant from FEMA's Hazard Mitigation Grant Program (HMGP); the grant application was processed and the funds administered by the Alaska Division of Homeland Security and Emergency Management (DHS & EM).

In May 2006, snowmelt and ice-jam flooding on the lower Yukon caused inundation of Alakanuk with ice-laden water to depths up to 6 feet. At least one home, which had been within 30 feet of the river before it was relocated and elevated, would surely have been destroyed by the water and ice blocks the size of cars at its original site. This home and the six others that had been relocated and elevated escaped damage to the main structure. In the home that had been moved but not yet elevated when the floodwaters struck Alakanuk in 2006, the floor and some insulation was damaged by 4 to 5 feet of water.

The severity of and damage caused by ice-jam floods along the lower reaches of the Yukon and other western Alaska rivers varies from year to year. The relatively severe flooding in May 2006 tested the effectiveness of the relocation and elevation project in Alakanuk; except for the single home that had not been elevated, the project "passed." Spring flooding in each of the subsequent years, most recently in late May 2009, was less severe, and the community was only minimally affected.

[photo of home with person pointing to flood height]

This Alakanuk home had been moved but not yet elevated when the 2005 floods struck [the article is actually referring to the May 2006 flood]. The owner's son is pointing at the level reached by the flood.

Llorente, Segundo, 2002, Memoirs of a Yukon priest: Georgetown University Press, 252 p.

This must have been around 6:00 P.M. One hour later news came that the Yukon ice had jammed just below the town of Alakanuk. The town had flooded. The current had cut a channel between the Catholic church and the rectory. The ice had pushed both buildings into the lake and both had disappeared. The cabin near the church had been totally demolished and had disappeared also.

I left immediately for Alakanuk and I saw the disaster with my own eyes. Mine were the only buildings destroyed; the rest of the village had suffered practically nothing. Where the church and rectory had stood, there was now nothing but mud. The same with the cabin… This was the sixth day of June 1952.

National Weather Service, 2021, River notes: NOAA [website]: found at www.weather.gov/aprfc/riverNotes

[Alaska River Notes are accessible online and maintained by the National Weather Service. As of this publication, there are eight pages of river notes from 2005 to 2021. Please visit the link above to access source data.]

NOAA Climatological Data Reports

[1971-MAY]

Major ice-jam flooding occurred in southwestern Alaska towards the end of May. Many of the inhabitants in the eastern half of Bethel, Alaska, were forced to leave due to the high water on the Kuskokwim River. Most of the residents of Napakiak, Oscarville, and [Napaskiak] were evacuated. On the Yukon River, ice-jam flooding extended about 100 miles upstream of the town of Russian Mission to Grayling. The town of Anvik was the hardest hit with the inundation of its power plant. In northwestern Alaska, backwater from Ice jams flooded the village of Kobuk on the Kobuk River.

[1971-JUNE]

Serious flooding occurred during June in Alaska on the lower Yukon, Kuskokwim, and Kobuk Rivers due to ice jams and greater than normal snowpack.

[1972-MAY]

May 15-31: The worst ice-jam flooding in memory of long time residents occurred on the Kuskokwim and Yukon Rivers in Alaska. The towns of Oscarville and [Napaskiak] were completely inundated. Anvik, on the Yukon, had its worst flooding in over 40 years. The last time the Yukon and Kuskokwim Rivers "flowed as one" was about 1890.

[1975-MAY]

On the 24th, 2 ice jams downstream of Pilot Station caused flooding at Pilot Station and 22 houses were in water for 1 day. Ice jams at the mouth of the Yukon caused the villages of Emmonak and Alakanuk to flood on the 29th until the morning of the 31st. During the flooding at Emmonak, the runway was covered (6" at the high end), 36 houses received water damage above the first floor

level, and 3 houses had physical damage from ice chunks or floes moving through the village. At Alakanuk 49 houses had water damage, 2 physical damage from ice floes and 5 fishing boats were crushed by ice. Transformers and utilidors of the new power system in Alakanuk were also flooded. A lake also formed on the delta at this time covering approximately 1045 square miles.

[1976-MAY]

At the mouth of the Yukon ice jamming caused minor flooding in the villages of Emmonak and Alakanuk, (combined population est. 1000). No evacuations from the villages were necessary, although residents of older dwellings were forced to move in with neighbors in some of the newer homes erected on pilings.

[1977-MAY]

The jam causing the flood at Galena broke late on the 17th and by the 23d there were 300 miles of moving ice on the Yukon River, from Grayling to Pilot Station, converging on the Delta villages. Minor flooding occurred at the villages of Pilot Station, St. [Mary's], Alakanuk, and Emmonak on the lower Yukon River. The last of the Yukon River ice went out to sea on June 1.

NOAA Storm Data Reports

[1974-NOV-11]

Alakanuk: Loss of boats, motors, and snow machines. Estimate approximately 22 claims for unmet losses.

[1977-MAY-16]

Major flooding due to ice jams during spring breakup occurred in the central Yukon River valley May 16-18. The town of Galena sustained considerable flood damage to buildings. The Yukon River at Galena crested about 5 feet above flood stage late on May 17.

[Flooding on Kuskokwim River]

[1979-MAY-05]

[Flooding of upper Yukon communities including Dawson City, Eagle, Circle, Fort Yukon, and Birch Creek.]

Minor flooding occurred at Emmonak and Alakanuk, on the Yukon Delta, on May 15, due to ice jams, as the 1979 breakup drew to a close.

[1984-MAY]

[May 19: ice jam flooding in Bishop Rock and Galena]

[May 22-23: Ice jam flooding of Anvik]

[**1989-MAY]**

[May 16-26:] Ice jams along the Kuskokwim and Yukon rivers during this period produced floods due to their damming effect. Alaska's governor announced on 26 May an emergency disaster declaration for six villages along the rivers. Damages were most significant at the community of Aniak.

[1995-MAY]

[May 01-31:] Typical of this time of year is the seasonal breakup process across mainland Alaska.

Major rivers, which serve as transportation corridors around the state, undergo the change from ice covered roadways (even plowed by the state) to summer boat/barge traffic. May 6th and 7th brought flooding to Bethel, on the Kuskokwim River… Other villages affected by breakup on the Kuskokwim River were (in order) Aniak (damaged roads and damaged dike), Akiak, Akiachak, Kwethluk (airport road damage, extensive boardwalk damage, and insulation damage to 13 homes), Oscarville (flooded sewage lagoon, flooded streets and boardwalk, and a few flooded structures), and then Napaskiak (flooded roads and the new runway was isolated, insulation damage to six homes). Upper and Lower Kalskag were also affected by "minor" breakup flooding. Minor flooding was reported along the Yukon River at Pilot Station, Marshall, Emmonak (six houses), and Alakanuk (roads and other low lying areas).

[2004-OCT]

[October 18-20:] Alakanuk, Kotlik, surge heights unknown… Alakanuk, Emmonak: Power poles and lines damaged.

[2005-MAY]

[May 15-19:] An Ice Jam on the Yukon River produced minor flooding throughout the village of Alakanuk. Roads were flooded but no structures were flooded or impacted. Damage amount unknown.

[2006-MAY]

[May 28-29:] An ice [jam] formed 5–10 river miles downstream of the villages of Alakanuk and Emmonak on the Yukon River, causing moderate flooding at these villages.

At Alakanuk, moderate flooding with water up to 3 feet in depth occurred, soaking some of the lowest portions of homes, causing large village fuel tanks to tilt, some ice chunks may have hit several buildings. The apron at the airport was partially flooded, though the airstrip remained dry. The sewage lagoon was flooded.

At Emmonak, water levels rose to within inches of the need to shut down the village's power plant. Airport apron received water though the airstrip and tarmac remained dry. Moderate flooding occurred across the village.

Monetary amount of damages was $227,000 in Emmonak and $306,100 in Alakanuk.

[2009-MAY]

Minor to moderate flooding was observed downstream with the worst of the flooding along the Yukon Delta in the villages of Emmonak and Alakanuk on May 23–26, 2009. Several homes in the low lying areas in the villages were inundated with 1 to 3 feet of water.

A significant amount of water and ice combined with ice jams in the vicinity of the village as well as downriver produced flooding in the village of Alakanuk. The flooding was compounded by 2 to 5 miles of shore-fast ice at the mouth of the Yukon River. The water levels rose during the early morning hours on the 23rd, and started to flood parts of the village. By the afternoon of the 23rd, water inundated many of the low lying structures. The water levels continued to rise, and by the 24th there were several homes along the river that were flooded with 1 to 3 feet of water. The water levels began to fall later in the evening, and were back within bank full by the late evening hours of the 25th or the early morning hours on the 26th. No information available on property damage, a preliminary estimate is guessed at $35,000.

[2011-NOV]

[On the morning of the 9th] The storm caused water levels to rise significantly in the lower Yukon river with high water levels at Scammon Bay and Alakanuk.

[2013-JUN]

An ice jam formed downstream of Alakanuk causing water to rise in Alakanuk and Emmonak on the 4th into the morning of the 6th. Water flowed over the road to the airport in each village.... it was 2-3 feet deep in spots at Alakanuk. The taxi way at the Emmonak airport was washed out. At Alakanuk, 3 to 4 homes had water in them and the residents of these homes were evacuated. The sewage lagoon was inundated and it was noted that some propane tanks to home heating were floating in town. By mid-morning on the 6th, the ice jam had moved out and river levels had fallen in both communities.

U.S. Army Corps of Engineers, [1972?], Flood data survey—Alakanuk: USACE Alaska District, 1 p.

Floods of Record and Cause:

Mo. & Year: June 72

% Flooded: entire village

Maximum Depth: 1' to 3'

Cause: Ice Jam

Location of high water mark and description: On flag pole pole [*sic*] near the church on the shore of Alakanuk Pass. The high water mark is copper label tape and contains the words "High Water C.E. 1972"

———1980, Flood data survey—Alakanuk: USACE Alaska District, 1 p.

Worst Flood Known (cause and date): May, 1969

Depth of Flood (MAXIMUM): 3 ft above flood level

Highwater Marks (Describe & Locate): Around power plant, native store, D.F. Jorgensen Store, High School, BIA elementary school

Number of Homes Flooded: 25 homes were flooded in May, 1969

Number of Public Facilities and Type Flooded: NONE

Total Damage in $ N/A

Most frequent cause of flooding (ice jams, stream overflow, wind driven waves, etc.): Ice-Jams, river overflow due to ice-jams

Other Years Flooded: 1971, 1972, 1976

Number of Homes: 45

———1987, Flood data survey—Alakanuk: USACE Alaska District, 1 p.

Worst Flood Known (cause and date): Ice jam, 1952

Depth of Flood (MAXIMUM): 6 ft. from High tide mark.

Highwater Marks (Describe & Locate): unknown

Number of Homes Flooded: whole town

Number of Public Facilities and Type Flooded: N/A

Total Damage in $ N/A

Most frequent cause of flooding (ice jams, stream overflow, wind driven waves, etc.): Ice jams, river overflow,

Other Years Flooded: 1984

Number of Homes: 6

Public Facilities: None / ½ of public roads under water and damaged.

———1989, Alakanuk trip report—High water mark elevations; USACE Alaska District, 7 p.

Date of Visit: 12 July 1989

Purpose of Visit: To obtain high water mark elevations for FEMA work assignment to determine base flood elevations resulting from 1989 spring breakup flood, or other high water historical floods where the information was available. We also estimated the relative top of bank elevation which was generally the zero damage elevation.

General Observations/Comments:

The community of Alakanuk is located principally on the left bank of Alakanuk Pass in the lower Yukon River delta. The topographic relief in Alakanuk is very low and the entire area is within the flood plain on the Yukon River.

According to John Hanson the 1952 flood event was the highest water level of record. The pilings on John [Hanson's] home and all of the pilings of the HUD homes have been built with their pilings set 1 foot above the 1952 flood level. The Hanson home is located at the upstream end of Alakanuk Pass near the Yukon River.

John Hanson's house is located on some of the highest ground in the area. This has been confirmed by observations of the area during flood conditions in the early 1970s.

The high water marks (HWM) established by the Corps of Engineers (COE) in the community of Alakanuk are based on the water level of the 1952 event and are believed to represent the Base Flood Elevation (BFE).

Corps of Engineers High Water Marks (COE-HWM) were established at two locations in the community. The COE-HWM consists of a 1.5 inch diameter silver colored washer attached with a lag bolt. The washer is stamped with the letters COE/HWM and was painted with fluorescent red paint at the time of installation. At Alakanuk these HWM's which represent the BFE are based on the 1952 flood event.

HWM # 1(RP-1) Located on the downstream, shore side of the support piling of John Hanson's house (NW corner).

HWM # 2(RP-2) Located on the utility pole downstream and inland (approximately 100 yards SW) of John Hanson's house.

Historical Record of High Water:

There is no established river gage at Alakanuk and only generalized historical information is available. There is not sufficient information available to develop a stage frequency curve for Alakanuk.

1952 Highest water level of record, approximately 5 feet deep in the highest part of the old village.

1971 All buildings flooded except store.

1972 [Approximately] 2 feet of water in the highest part of the old village. 70 houses flooded.

1975 49 houses flooded, transformers underwater.

1984 2 or 3 older houses flooded, most [houses] surrounded.

1985 High water 6.0 feet from the top of the 2 x 4 deck on the upstream, landward side of the school.

1989 [no entry]

Findings and Recommendations:

The entire community of Alakanuk and the surrounding area is located within the flood plain of the Yukon River delta. There is no high ground in the immediate vicinity.

The estimated Base Flood Elevation (BFE) for Alakanuk is the elevation of the COE/HWM's established on John Hanson's house and the nearby utility pole. This BFE is based on the 1952 flood event.

The estimated zero damage elevation is approximately 3 feet below the established COE/HWM's (BFE) at John Hanson's house. It is estimated this level would be 2 to 3 feet lower at the downstream end of the village. According to the historical records of the 1952 flood waters were 5 feet deep at the higher parts of the old village, while they were approximately 3 feet deep near John Hanson's house.

The recommended minimum building elevation is 1 foot above the 1952 flood elevation, or 1 foot above the established COE/HWM level.

[2 aerial photos of Alakanuk on July 12, 1989]

[Photo of HWM mark 1 and 2]

Note: The following page(s) of this report are field notes on WS Form E-39 titled RECORD OF LEVELING AND OTHER MEASUREMENTS. On this form only, the term HWM # is used to refer to and identify a specific observed high water mark, which was usually from the 1989 flood event and identifiable in the field from silt marks, water stains, etc. On the same form the term RP # is an abbreviation for reference point, which may in some cases be the COE/HWM marker established at the level of the Base Flood Elevation (BFE).

1985 HW 6.0' [from] top of 2 x 4 deck on [upstream] landward side of school – surveyed by MAC

1984 "Airport 80' but usable"; 2 or 3 older houses flooded, most houses surrounded

1975 49 houses flooded, Transformers underwater

1972 Highest point in old village had 2' water

1971 All buildings flooded except a store

1952 water reportedly 3' higher than in 1972; this would be 5' deep at highest point in old village

[Lists flood impacts in Emmonak]

———2000, Flood hazard data—Alakanuk: USACE Alaska District, 1 p.

Last flood event: 1989

Flood of record: 1952

Flood cause: ice jam

Comments: The flowing elevations are based on the flood gauge. Zero on the gauge is ground level at the gauge.

Recommended building elevation: 6.1

1952 flood elevation: 5.1

School floor: 8.3

Power plant floor: 3.3

High Water Marks (HWM) established by the Corps are based on the water level of the 1952 flood and are considered to represent the Base Flood Elevation (100-year flood level). HWM #1 is located on the downstream, shoreside of the support piling of John Hanson's house (NW corner). HWM #2 is located on the utility pole downstream and shoreward (approximately 300 ft SW) of John Hanson's house. Estimated zero damage is approximately 3 ft below HWM #1. The estimated zero damage for the downstream end of the village would be 2 ft lower.

———2009a, Alaska baseline erosion assessment—study findings and technical report: USACE Alaska District, 65 p.

[Years with flood disaster declaration:] 1984, 1991, 1995, 2002, 2005, 2006

———2009b, Flood stage measurement of Alakanuk, Alaska trip report; USACE Alaska District, 10 p.

1. Purpose of Visit. On 5 June 2009, Crane Johnson and Nathan Epps from the U.S. Army Corps of Engineers Alaska District visited the community of Alakanuk, Alaska to measure high water marks from the break-up flood of 2009 on the Yukon River. This work was performed under Corps of Engineers authority to provide emergency assistance under PL 84-99. This memorandum describes the physical measurements performed at Alakanuk.

2. Location and Background. Alakanuk is a community of 670 people located on the south bank of the Alakanuk Pass of the Yukon River approximately 8 air miles southeast of Emmonak, 128 air miles south of Nome and 160 air miles northwest of Bethel. Late this April, the state experienced a period of below average temperatures followed by a period of higher than average temperatures. This caused a rapid melting of snow packs resulting in high flows in many basins, including the Yukon River.

3. Flood of Record. The flood of record in Alakanuk occurred in 1952 and was marked by Corps of Engineers by placing washers in a house and telephone pole in 1989 based on the accounts of residents. A flood gage was placed on the tribal office with the flood of record corresponding to 5.1 feet on the gage. The 2009 flood was 3.8 feet lower than the flood of record and measured 1.3 feet on the flood gage. The team located the washer placed on a telephone pole with high water marks from the recent flood nearby. The foundation of the house which had the other washer was replaced, but from the record account and photographic evidence, the team determined the equivalent elevation to be one foot below the siding of the house. The 2009 flood was estimated to be 3.2’ below the 1952 flood of record in this upstream survey area.

4. Survey of High Water Marks. Since the community covers a long stretch of river bank, two survey areas were established to measure water levels. Survey Area 1 covers the upstream extent of Alakanuk including the residences upstream of the Native Store. Survey Area 2 covers the portion of Alakanuk from the barge landing at the bend in Alakanuk Pass to the location of the survey monument near the last pole on Anderson Street. At Survey Area 1, a temporary benchmark was established using the high water mark washer mounted on a telephone pole near the Native Store. At Survey Area 2, a temporary benchmark was established on a foundation bolt of a satellite dish. This benchmark was tied into the Corps of Engineers flood gage mounted on the back of the city and tribal office building. This gage was installed in 1989 as part of the Corps of Engineers flood plain management program. All elevations in Survey Areas 1 are referenced to this Corps of Engineers flood gage. The flood elevation in Survey Area 1 based on good to excellent high water marks was 7.16 feet, which is 2.84 feet below the which is 3.77 feet below the flood of record.

5. Vertical Control. The team attempted to locate vertical control monuments to use as a datum for these measurements without success. A search through the online NGS database revealed 1 vertical control monument in Alakanuk set by BLM named C3TRG at the downstream end of Survey Area 2. This monument is also used as the basis for the DCED community map. A thorough search of the coordinates revealed a pipe firmly embedded into the ground with no cap which appeared to have been damaged. Ground elevation was measured at this location, but the monument itself was destroyed.

[Map locations of survey areas]

Water LevelMark	Description	Latitude[2]	Longitude[2]	Quality	Elevation	WaterDepth
ARHW	COE HWM Marker from1952 flood	N62°41'13.58"	W164°37'12.19"	N/A	10.00[1]	3.60
AHW1	Silt line onmoss	N62°41'13.45"	W164°37'12.44"	Fair	6.80[1]	N/A
AHW2	Silt line on moss	N62°41'13.62"	W164°37'12.16"	Fair	6.84[1]	N/A
AHW4	Silt line on buried snowmachine	N62°41'15.21"	W164°37'13.67"	Good	7.16[1]	0.68
ASTAFF1	COE FLOODGAGE	N62°41'28.01"	W164°40'24.48"	N/A	1.33[2]	1.30
AHW10	Water stain on piling	N62°41'28.01"	W164°40'24.48"	Fair	1.46[2]	1.35
AHW11	Silt line onculvert	N62°41'15.54"[3]	W164°40'09.72"[3]	Good	0.10[2]	1.15
AHW14	Water stain on piling	N62°41'23.47"	W164°40'27.85"	Fair	1.00[2]	2.05
AHW15	Silt line onpiling	N62°41'23.47"	W164°40'27.85"	Good	1.00[2]	2.24
AHW16	Debris line on skirt fence	N62°41'28.01"	W164°40'24.48"	Good	0.80[2]	1.33

[1]Vertical survey control in Survey Area 1 was ARHW which was a high water mark washer mounted on a telephone pole near the Native Store. ARHW was assigned an arbitrary elevation of 10.0 feet.
[2]Vertical survey control in Survey Area 2 was ATBM1 which was a bolt in the foundation in the satellite dish near the City Office. The elevation assigned to this bolt is 4.035 feet referenced to the flood gage on the city office set by the Corps of Engineers. No monuments were found intact in the community.
[3]Horizontal datum for all coordinates obtained by handheld GPS unless noted (WGS84 Datum).
[4]Horizontal coordinates estimated from geo-referenced aerial photography (WGS94 Datum).

[Photos of markers]

[From field book notes] Rita Alstrom 22 years in town. Flooding not bad this year. Some areas that normally flood did not flood this year.

Everyone we talked to mentioned that this flood was not bad / Average year for flooding. Town floods every year.

———2011, Flood hazard data—Alakanuk: USACE Alaska District, 2 p.

[Same as USACE (2011)]

High Water Marks (HWM) established by the Corps are based on the water level of the 1952 flood and are considered to represent the Base Flood Elevation (100-year flood level). Estimated zero damage is approximately 3 ft below HWM #1. The estimated zero damage for the downstream end of the village would be 2 ft lower.

[Photos of flood gauge location and HWM locations]

———2017, Alakanuk Flood Report; USACE Alaska District, 1 p.

Floodplain Notes: Elevations are referenced to TBM established [during] 2009 survey. See 2009-06-05 Alakanuk HH Trip Report.

HWM marker from 1952 flood, 10.0 ft (5.1 ft from 1997 survey) Flood Gage, 1.33 ft

Flood of record was the 1952 event - where approximately 5 ft of water was observed in the highest part of the old village. Estimated zero damage is approximately 3 ft below HWM #1. The estimated zero damage for the downstream end of the village would be 2 ft lower. Flooding events [occurred] in 1971, 1972, 1975, 1984, 1985, 1989, 1997, 2005, 2006, 2007, 2009,2010, 2013

———2021, Ice jam database: USACE [website]: found at icejam.sec.usace.army.mil/

[The Ice Jam Database is accessible online and maintained by USACE. As of this publication, there are ten pages of ice jam data for Alakanuk from 1964 to 2013. Please visit the link above to access source data.]

U.S. General Accounting Office, 2009, Alaska Native Villages: limited progress has been made on relocating villages threatened by flooding and erosion: U.S. Government Accountability Office, GAO-09-551, 53 p.

Alakanuk received $208,898 to relocate and elevate 15 homes and 1 city building after a 2002 flood.

Wise, J.L., Comiskey, A.L., and Becker, R., Jr., 1981, Storm surge climatology and forecasting in Alaska: Anchorage, Alaska, Arctic Environmental Information and Data Center, University of Alaska, 32 p.

[1974-NOV-10-12 lists Alakanuk as impacted]

APPENDIX B: FLOOD CATEGORY CALCULATION FIGURES

DGGS staff visited Alakanuk in July 2021 and surveyed points relevant to the flood history and category study. The Trimble R10 base station was installed over a benchmark with a published solution (found at www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBHM71). Points were surveyed with the Trimble R8s receiver. Horizontal coordinates are provided in WGS84 latitude and longitude and NAD83 (2011) UTM Zone 3N easting and northing. Elevations are provided in orthometric height (meters above NAVD88 [GEOID12B]) and converted to feet above local MHHW using the tidal datum by JOA (unpub. data, 2021). MHHW is 6.35 ft (1.935 m) above NAVD88.

Table B1. First floor heights of buildings used in report, as measured by CRW Engineering Group, LLC, in 2021.

Building	Figure	Height (ft NAVD88)	Height (ft MHHW)
Old Native Corporation Store	4	19.3	13.0
Jorgenson's Store	4	17.4	11.1
High school	NA	22.7	16.4

Table B2. Coordinates and heights of surveyed features. Latitude and longitude are in decimal degrees WGS84. Northing and easting are in meters NAD83 (2011) UTM Zone 3N. Orthometric heights are in meters above NAVD88 (GEOID12B).

Feature	Figure	Latitude	Longitude	Northing	Easting	Ortho. Height (m)	Height above MHHW (ft)
Flood staff ground	3	62.68707	-164.66776	6950768.271	517008.521	3.902	6.45
Old runway apron	9	62.68175	-164.6475	6950180.622	518048.815	4.864	9.61
Old runway apron	9	62.68175	-164.64715	6950181.427	518066.771	4.539	8.54
Porch step from 1991 flood	10	62.68679	-164.67312	6950735.348	516734.641	4.404	8.1
landfill	11	62.68271	-164.64039	6950289.336	518412.413	3.983	6.72
ground height of fall storms	12	62.68682	-164.67304	6950738.785	516738.489	3.585	5.41

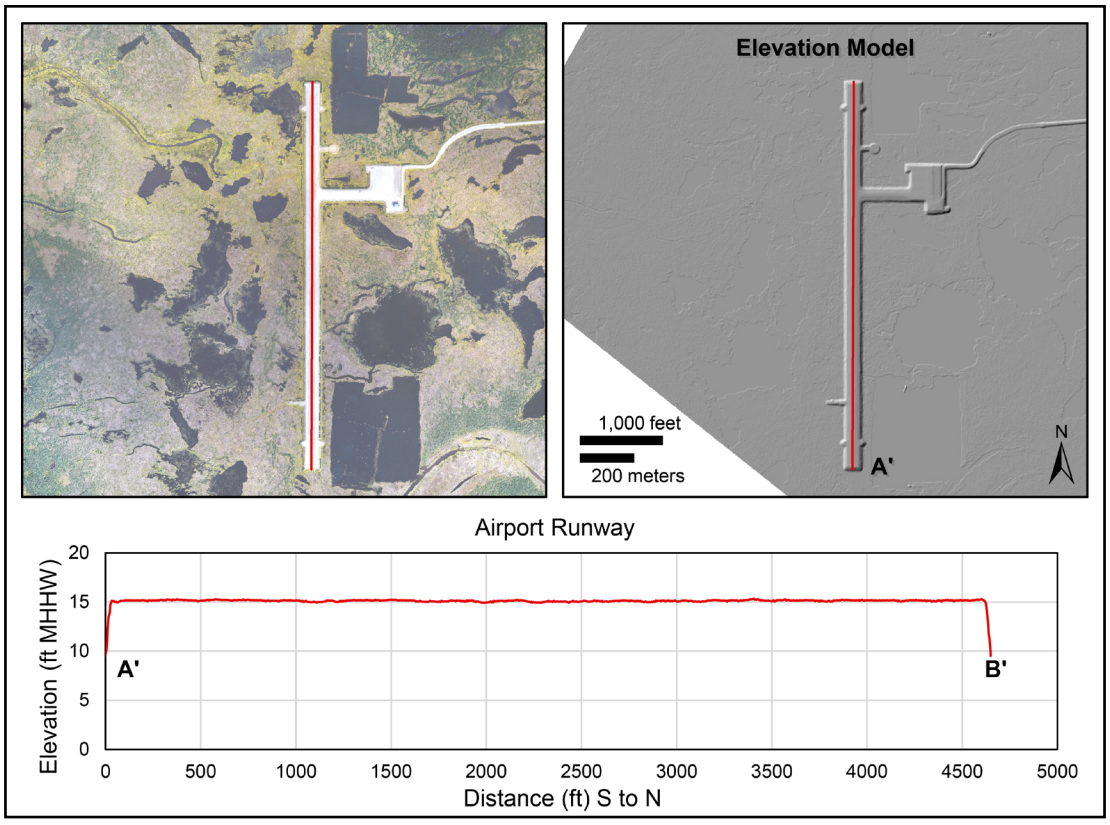

Figure B1. Elevation profile drawn on DTM shows the airport runway is 15.1 ft MHHW.

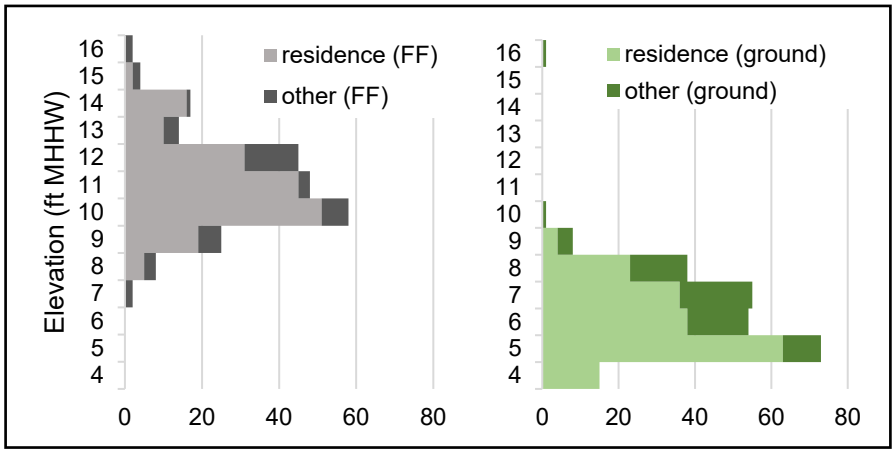

Figure B2. Histogram of building first-floor elevations (left) and the mean ground elevation (right) underneath the structure in Alakanuk. Residences are lighter color and other structures are darker color. The average ground height is 6.7 ft MHHW and the average first floor height is 11.6 ft MHHW.

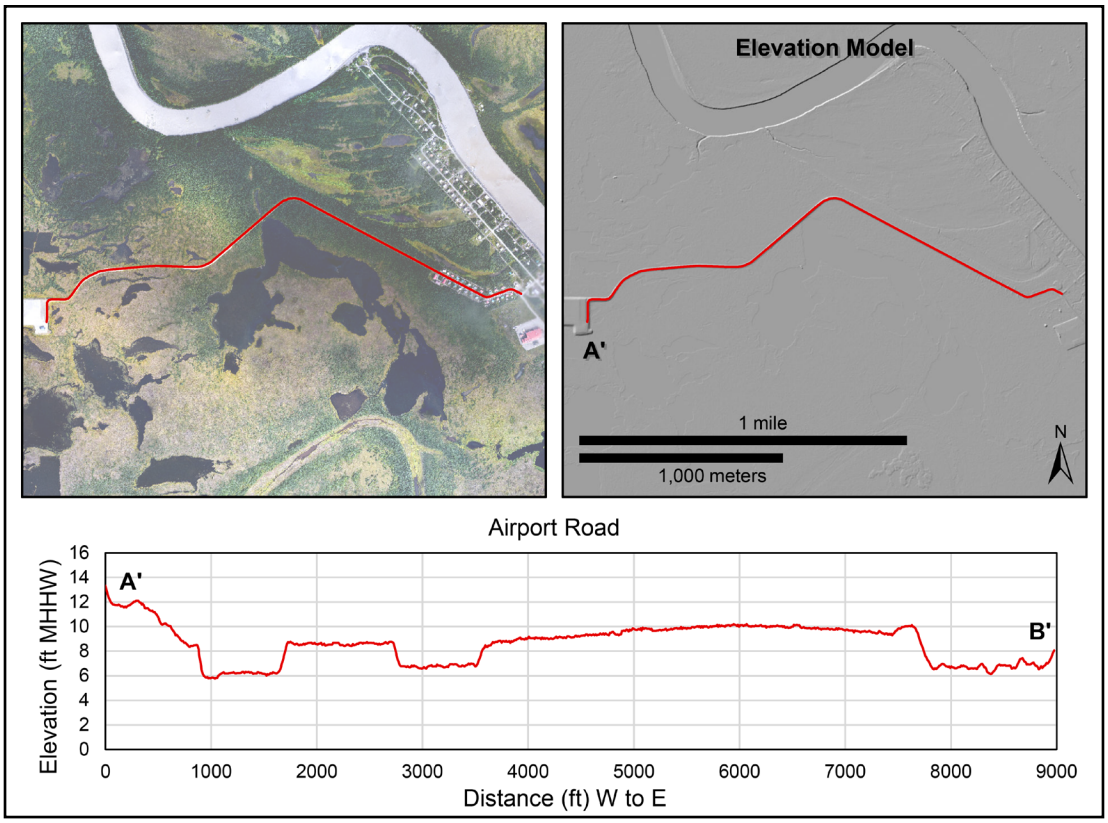

Figure B3. Elevation profile drawn on DTM shows the airport road is typically between 6 and 10 ft MHHW.

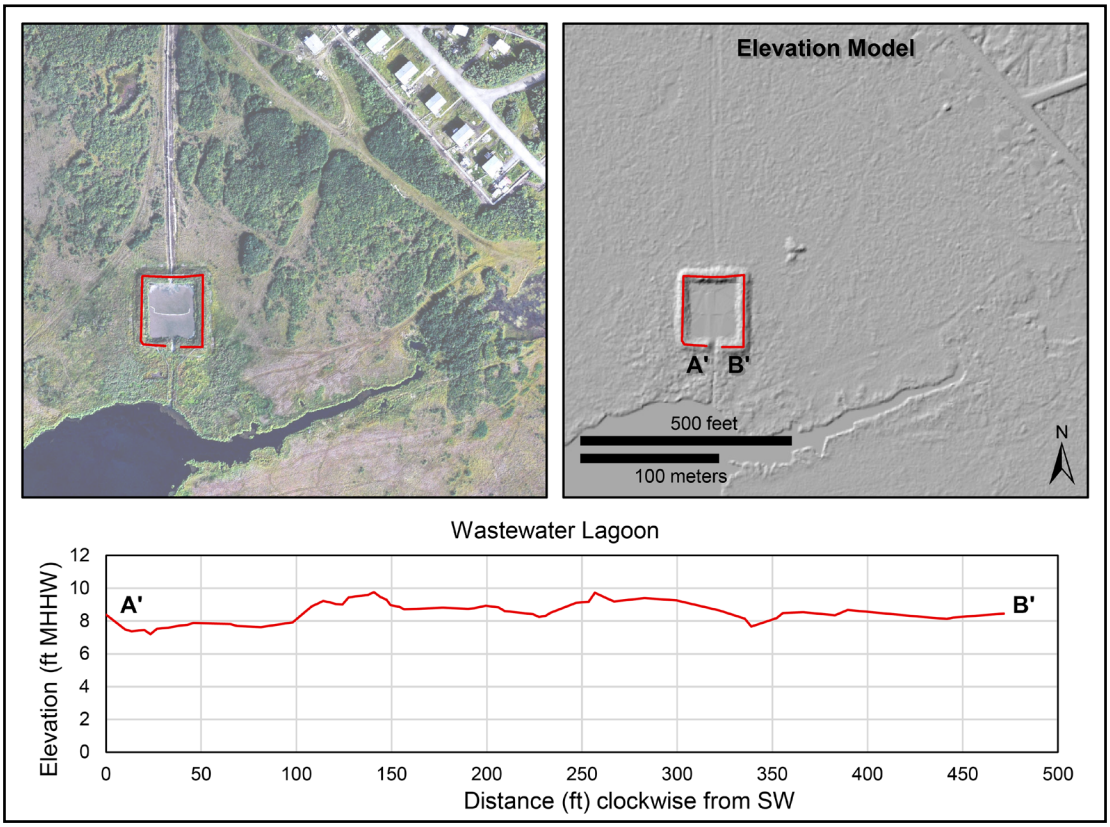

Figure B4. Elevation profile drawn on DTM shows the wastewater lagoon berm typically ranges between 8 and 10 ft MHHW.

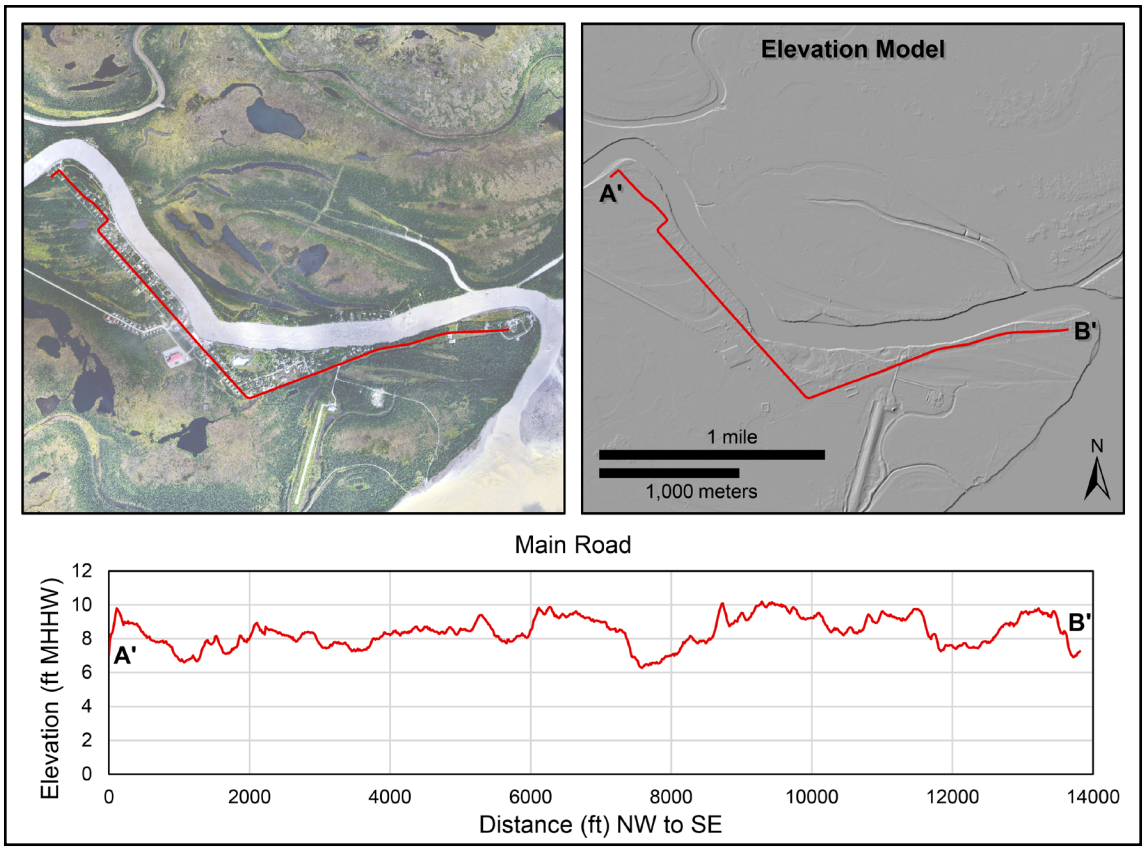

Figure B5. Elevation profile drawn on DTM shows the main road is between 6 and 10 ft MHHW.