Center for Environmentally Sustainable Transportation in Cold Climates

Monitoring Winter Flow Conditions on the Ivishak River, Alaska

H. Toniolo, D. Vas, J. Keech, and J. Bailey
Water and Environmental Research Center
Institute of Northern Engineering
University of Alaska Fairbanks
Fairbanks, AK 99775

Date: September 2017

Prepared for:

Center for Environmentally Sustainable Transportation in Cold Climates
Duckering Building Room 245
P.O. Box 755900
Fairbanks, AK 99775

U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Alyeska Pipeline Service Company
3700 Centerpoint Drive
Anchorage, AK 99503

INE/AUTC 17.08

REPORT DOCUMENTATION PAGE	Form approved OMB No.

Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE September 2017	3. REPORT TYPE AND DATES COVERED Final Report: Sept. 1, 2016–Aug. 31, 2017

4. TITLE AND SUBTITLE Monitoring Winter Flow Conditions on the Ivishak River, Alaska	5. FUNDING NUMBERS CESTiCC UTC: $50,070 Alyeska $50,078
6. AUTHOR(S) Name, Title, Organization/University H. Toniolo, D. Vas, J. Keech, and J. Bailey Water and Environmental Research Center Institute of Northern Engineering University of Alaska Fairbanks Fairbanks, AK 99775	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for Environmentally Sustainable Transportation in Cold Climates University of Alaska Fairbanks Duckering Building Room 245 P.O. Box 755900 Fairbanks, AK 99775-5900	8. PERFORMING ORGANIZATION REPORT NUMBER INE/AUTC 17.08
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of Transportation 1200 New Jersey Avenue, SE Washington, DC 20590	10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLENMENTARY NOTES	
12a. DISTRIBUTION / AVAILABILITY STATEMENT No restrictions	12b. DISTRIBUTION CODE

13. ABSTRACT

The Sagavanirktok River, a braided river on the Alaska North Slope, flows adjacent to the trans-Alaska pipeline for approximately 100 miles south of Prudhoe Bay. During an unprecedented flooding event in mid-May 2015, the pipeline was exposed in an area located approximately 20 miles south of Prudhoe Bay. The Ivishak River is a main tributary of the Sagavanirktok River, but little is known about its water flow characteristics and contribution to the Sagavanirktok River, especially in winter and during spring breakup. To gather this information, we installed water level sensors on two main tributaries of the Ivishak River (Upper Ivishak and Saviukviayak rivers), early in winter season 2016–2017, in open-water channels that showed promise as locations for long-term gauging stations. Our ultimate goal was to find a location for permanent deployment of water level sensors. By February, the first sites chosen were ice-covered, so two additional sensors, one on each river, were deployed in different locations. Some of the sensors were lost (i.e., carried away by the current or buried under a thick layer of sediments). Water level data gathered from the sensors showed a maximum change of 1.07 m. Winter discharge measurements indicate a 44% reduction between February and April 2017. A summer discharge measurement shows a 430% increase from winter to summer.

14- KEYWORDS :			15. NUMBER OF PAGES 26 16. PRICE CODE N/A
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT N/A

NSN 7540-01-280-5500 STANDARD FORM 298 (Rev. 2-98)

Prescribed by ANSI Std. 239-18 298-1

Monitoring Winter Flow Conditions on the Ivishak River, Alaska

FINAL REPORT

Prepared for

Center for Environmentally Sustainable Transportation in Cold Climates

and

Alyeska Pipeline Service Company

Authors:

H. Toniolo, D. Vas, J. Keech, and J. Bailey
Water and Environmental Research Center
Institute of Northern Engineering
University of Alaska Fairbanks
Fairbanks, AK 99775

INE/AUTC 17.08

September 2017

DISCLAIMER

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document. Opinions and conclusions expressed or implied in the report are those of the author(s). They are not necessarily those of the funding agencies.

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4		mm
ft	feet	0.3048		m
yd	yards	0.914		m
mi	Miles (statute)	1.61		km
AREA				
in^2	square inches	645.2	millimeters squared	cm^2 ft^2
	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.4046	hectares	ha
MASS (weight)				
oz	Ounces (avdp)	28.35	grams	g lb
	Pounds (avdp)	0.454	kilograms	kg T
	Short tons (2000 lb)	0.907	megagrams	mg
VOLUME				
fl oz	fluid ounces (US)	29.57	milliliters	mL gal
	Gallons (liq)	3.785	liters	liters ft^3
	cubic feet	0.0283	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3

Symbol	When You Know	Multiply By	To Find	Symbol
TEMPERATURE (exact)				
ºF	Fahrenheit temperature	5/9 (ºF-32)	Celsius temperature	ºC
ILLUMINATION				
fc	Foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2
FORCE and PRESSURE or STRESS				
lbf	pound-force	4.45	newtons	N psi
	pound-force per square inch	6.89	kilopascals	kPa

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	Miles (statute)	mi
AREA				
mm^2	millimeters squared	0.0016	square inches	in^2 m^2
	meters squared	10.764	square feet	ft^2 km^2
	kilometers squared	0.39	square miles	mi^2 ha
	hectares (10,000 m^2)	2.471	acres	ac
MASS (weight)				
g	grams	0.0353	Ounces (avdp)	oz
kg	kilograms	2.205	Pounds (avdp)	lb mg
	megagrams (1000 kg)	1.103	short tons	T
VOLUME				
mL	milliliters	0.034	fluid ounces (US)	fl oz
liters		0.264	Gallons (liq)	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
TEMPERATURE (exact)				
ºC	Celsius temperature	9/5 ºC+32	Fahrenheit temperature	ºF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

32 98.6 212ºF
-40ºF 0 40 80 120 160 200
-40ºC -20 20 40 60 80
0 37 100ºC

ACKNOWLEDGMENTS

The research team is grateful for the financial support provided by the Center for Environmentally Sustainable Transportation in Cold Climates (CESTiCC) and Alyeska Pipeline Service Company (APSC). The research team acknowledges the support of APSC personnel at Pump Station 4 and the assistance of Joel Homan, who generated Figure 1, and Grace Pedersen, who edited the report. Special thanks to Scott Nickolson and Carl Terry, the helicopter pilots, for their support in the field.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Sagavanirktok River, a braided river on the Alaska North Slope, flows adjacent to the trans-Alaska pipeline for approximately 100 miles south of Prudhoe Bay. During an unprecedented flooding event in mid-May 2015, the pipeline was exposed in an area located approximately 20 miles south of Prudhoe Bay. The Ivishak River is a main tributary of the Sagavanirktok River, but little is known about its water flow characteristics and contribution to the Sagavanirktok River, especially in winter and during spring breakup. To gather this information, we installed water level sensors on the Upper Ivishak River and the Saviukviayak River, early in winter season 2016–2017, in open-water channels that showed promise as locations for long-term gauging stations. Our ultimate goal was to find a location for permanent deployment of water level sensors. By February, the first sites chosen were ice-covered, so two additional sensors, one on each river, were deployed in different locations. Some of the sensors were lost (i.e., carried away by the current or buried under a thick layer of sediments). Water level data gathered from the sensors showed a maximum change of 1.07 m. Winter discharge measurements indicate a 44% reduction between February and April 2017. A summer discharge measurement shows a 430% increase from winter to summer.

CHAPTER 1.0 – INTRODUCTION

1.1 Objective of Study

The goal of this study was to conduct preliminary monitoring of water levels in open-water channels of the Upper Ivishak River during the 2016–2017 winter season. The ultimate goal of the research team was to find a location to establish a long-term monitoring station. The Ivishak River is a main tributary of the Sagavanirktok River, but little is known about its winter flow conditions and its impact on water movement in the Sagavanirktok River.

To better understand the winter flow dynamics of the Ivishak River, we deployed water level sensors (which read water levels every 15 minutes) in two open-water channels early in the 2016–2017 winter season. The sites selected were on two main tributaries of the Ivishak River (the Upper Ivishak and the Saviukviayak), where areas of open water were noticed during aerial surveillance conducted in the Sagavanirktok River watershed during the 2015–2016 winter season. Long-term hydrological monitoring of the Ivishak River is necessary to improve flooding prediction in the Sagavanirktok River area.

1.2 Study Area and Site Locations

The Ivishak River watershed is located on the east side of the mountain region of the Sagavanirktok River watershed (Fig. 1.1) and has an approximate area of 5200 km^2 (Toniolo et al. 2015). These watersheds are located on the Alaska North Slope, an area characterized by long, dark, and extremely harsh winters. Access to these sites and the time available for fieldwork are, in general, limited and highly unpredictable.

The Ivishak River stretches for 95 miles from the Philip Smith Mountains in the Arctic National Wildlife Refuge to its confluence with the Sagavanirktok River on the coastal plain, south of Prudhoe Bay. A glacier- and spring-fed braided river, the Ivishak has a section of open-water channels year-round (National Wild and Scenic Rivers System, n.d.).

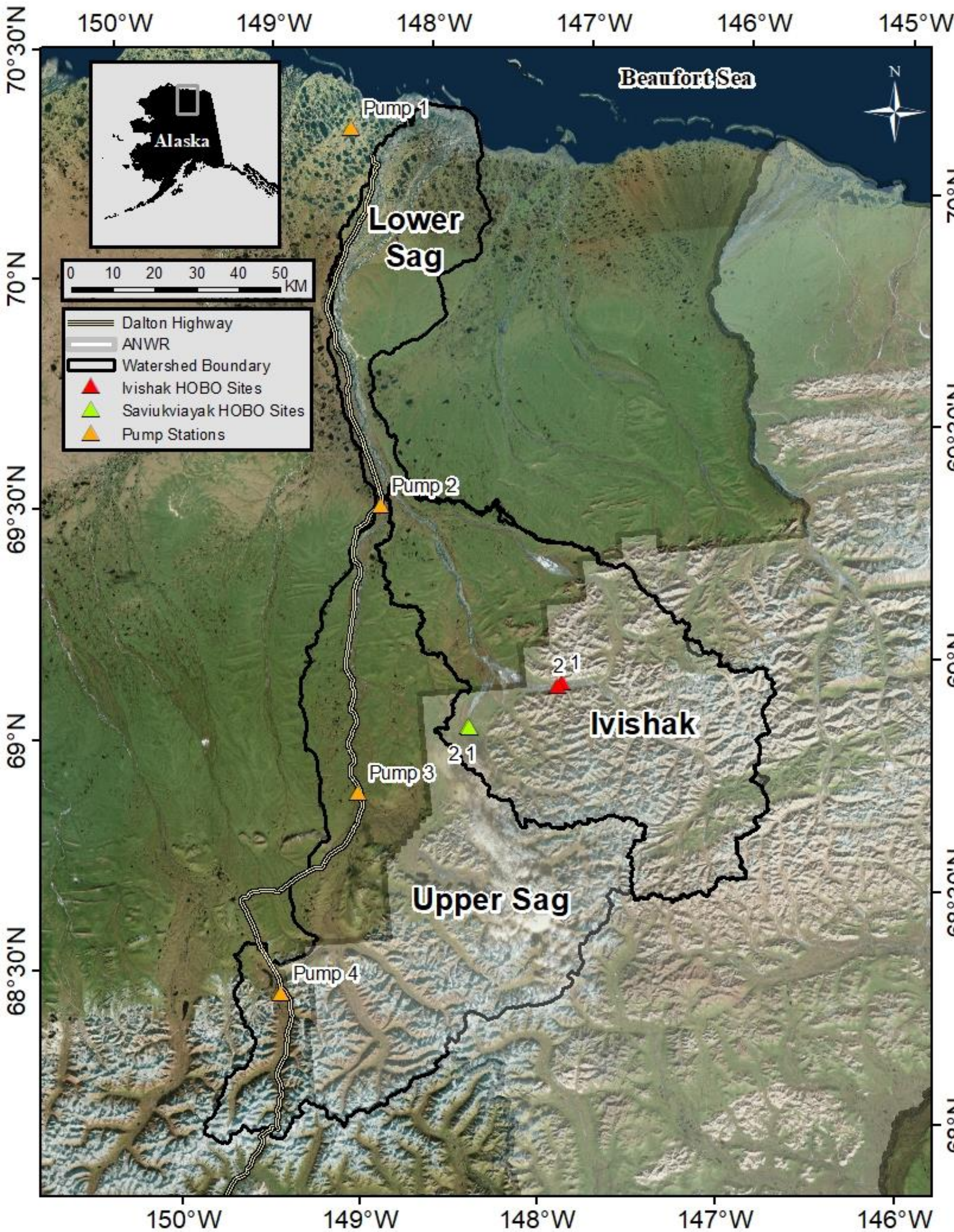


Figure 1.1 Study area and water elevation sensor (HOBO) locations.

CHAPTER 2.0 – METHODOLOGY AND EQUIPMENT

Two Onset HOBO U20 water level sensors—HOBO 1—were deployed on December 7, 2016: one on the Upper Ivishak River and one on the Saviukviayak River. Because these two locations developed ice cover, two more Onset HOBO U20 water level sensors—HOBO 2—were deployed in February 2017 in locations with open water on both rivers (Figures 2.1 and 2.2). Barometric data collected with a Vaisala PTB110 sensor at ASM3 (an existing weather station located approximately 11 miles west of the Onset HOBO U20 sensors) were used to correct the HOBO water level data (Table 2.1). Basic equipment information is provided in Table 2.2.

Temporary survey benchmarks were installed at all four HOBO sites on February 19, 2017, and a temporary local datum was established for water level data corrections. In mid-April, the temporary local datum at Saviukviayak River HOBO 1 and 2 sites and Upper Ivishak HOBO 1 site were referenced to the North American Vertical Datum of 1988 (NAVD88), GEOID12B using a Hemisphere S321 differential global positioning satellite (DGPS). The water levels from the sensors located at these sites were reported on the NAVD88 datum, except for Upper Ivishak HOBO 2 due to weather conditions at the site. Water levels from the Upper Ivishak HOBO 2 sensor were reported as water level above the sensor. Because of site conditions, discharge measurements were conducted with a Model AA current velocity meter at the Upper Ivishak HOBO 2 site on February 18 and April 17, 2017, at the Saviukviayak HOBO 2 site on February 19, 2017, and at the Saviukviayak HOBO 1 site on April 17, 2017. River discharge was also measured with an RDI RiverPro Acoustic Doppler Current Profiler (ADCP) on August 1, 2017, at the Saviukviayak HOBO 1 site and on August 2, 2017, at the Upper Ivishak HOBO 1 site.

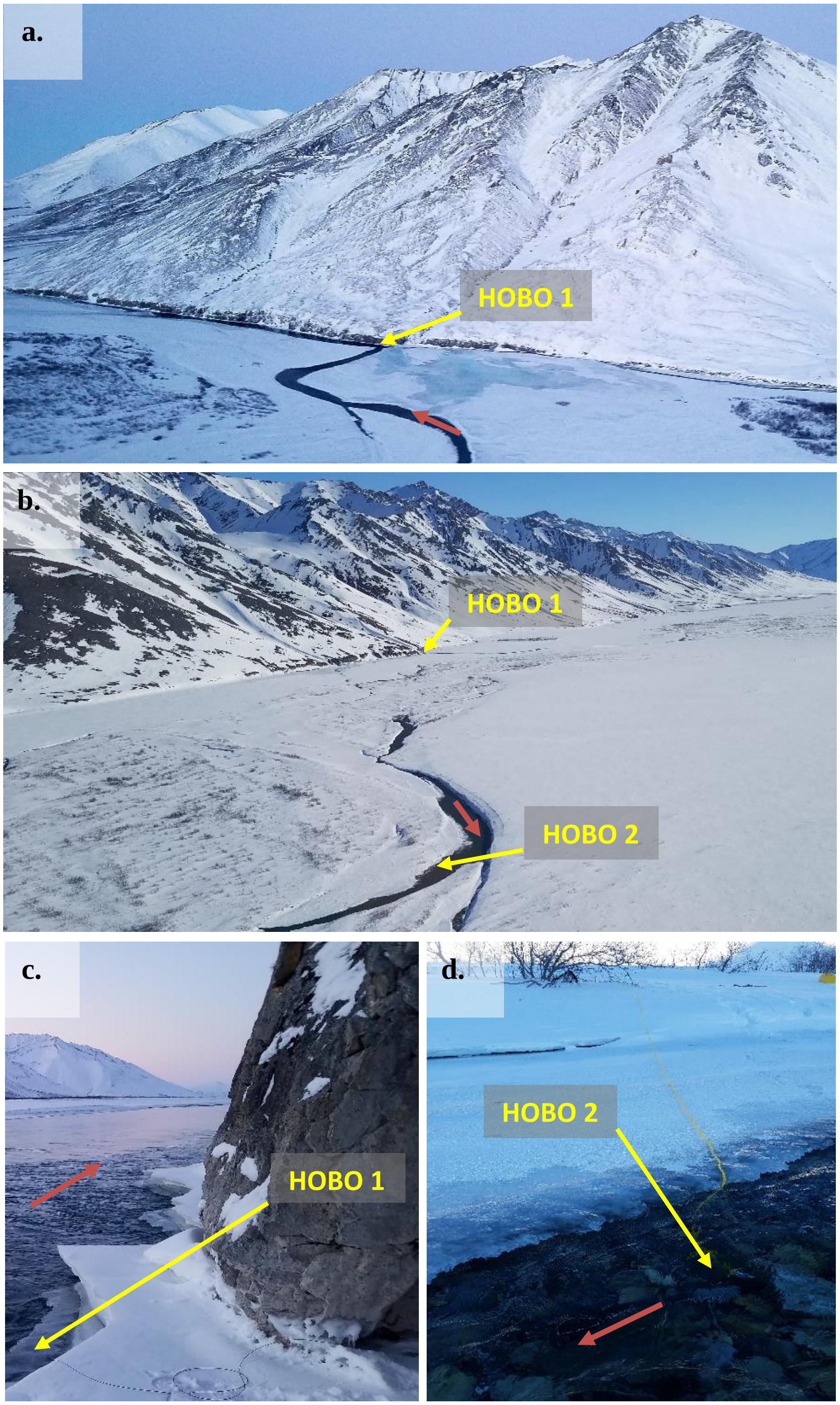


Figure 2.1 Upper Ivishak River HOBO sites: (a) Downstream aerial view of HOBO 1 site on 12/7/2016; (b) upstream HOBO 1 and 2 sites on 2/21/2017; (c) site view of HOBO 1 on 12/7/2016; (d) site view of HOBO 2 on 2/20/2017. Orange arrows indicate flow direction.

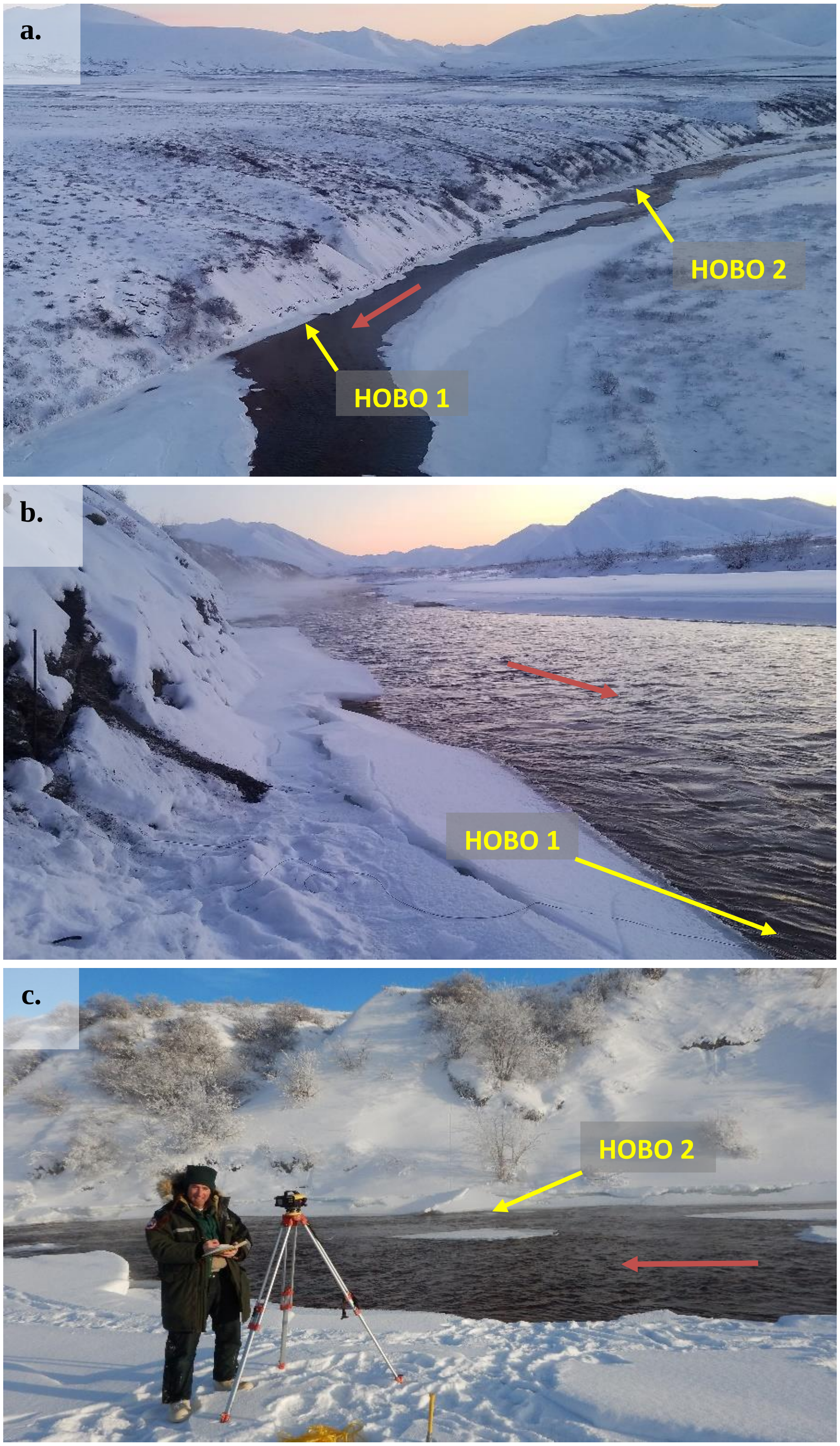


Figure 2.2 Saviukviayak River HOBO sites: (a) Upstream aerial view of HOBO 1 and 2 sites 12/7/2016; (b) site view of HOBO 1 on 12/7/2016; (c) site view of HOBO 2 on 2/18/2017. Orange arrows indicate flow direction.

Table 2.1 HOBO water elevation sensor and barometric pressure sensor locations and deployment dates

Site	Deployed	Latitude	Longitude
Ivishak HOBO 1	12/7/2016	69.0429	147.5745
Ivishak HOBO 2	2/19/2017	69.0364	147.6068
Saviukviayak HOBO 1	12/7/2016	68.9650	148.1480
Saviukviayak HOBO 2	2/19/2017	68.9632	148.1446
ASM3 Weather Station	6/12/2016	69.1338	147.9234

Table 2.2 Equipment used in the project

Category	Item	Model	Accuracy	Remarks
Hydro	Water Level	HOBO U20	± 0.6 cm	Absolute pressure, barometric correction required
Hydro	Current Velocity Meter	AA		0.03 to 6 m/s range
Hydro	ADCP	RDI RiverPro		20 cm to 25 m range
Hydro	ADCP GPS Reference and Datum Survey	Hemisphere S321 DGPS	WASS ± 30 mm (H) and ± 60 mm (V), RTK ± 8 mm (H) and ± 16 mm (V), Static ± 3 mm (H) and ± 6 mm (V)	H – horizontal V – vertical
Hydro	ADCP Mannered Boat	Aire Force		Kayak
Met	Barometric Pressure	Vaisala PTB110	± 1.5 mb @ -40° to +60°C	

CHAPTER 3.0 – RESULTS AND DISCUSSION

3.1 Results

3.1.1 Water Level

3.1.1.1 Upper Ivishak River

A HOBO water elevation sensor was deployed at the Upper Ivishak HOBO 1 site on December 7, 2016, in an open-water section of the Upper Ivishak River (Fig. 3.1a). This channel stretch had the potential for a long-term gauging station, as all the flow was concentrated in one channel and open winter flow had been observed previously. During the February 19 site visit the channel was completely covered with ice (Fig. 3.1b), approximately 1 m thick. A second HOBO was deployed at a new site, Upper Ivishak HOBO 2, located in an open-water channel 1.5 km downstream of the Upper Ivishak HOBO 1 site. The channel at the Upper Ivishak HOBO 2 site contains only a part of the water flow from the Upper Ivishak; however, it was the only open-water channel in that area. Narrow sections of open water were observed at the Upper Ivishak HOBO 1 site during the site visit on April 17. Upon closer inspection, we noticed that the ice at this site had dropped approximately 1 m (Fig. 3.1c) and had snapped the cable holding the HOBO sensor. The water was approximately 1.5 m deep, and the sensor could not be recovered then due to unsafe ice and snow conditions. The sensor may be recoverable during low summer flows. On August 2, 2017, discharge was measured with a RiverPro ADCP paired with a Hemisphere S321 DGPS (Fig. 3.1d).

Water level data were recorded at the Upper Ivishak HOBO 2 site from February 19 to July 6, 2017 (Fig. 3.2). During this period, the water elevation varied from 0.00 m above the water sensor to 0.75 m, representing a total gauge height change of 0.75 m.

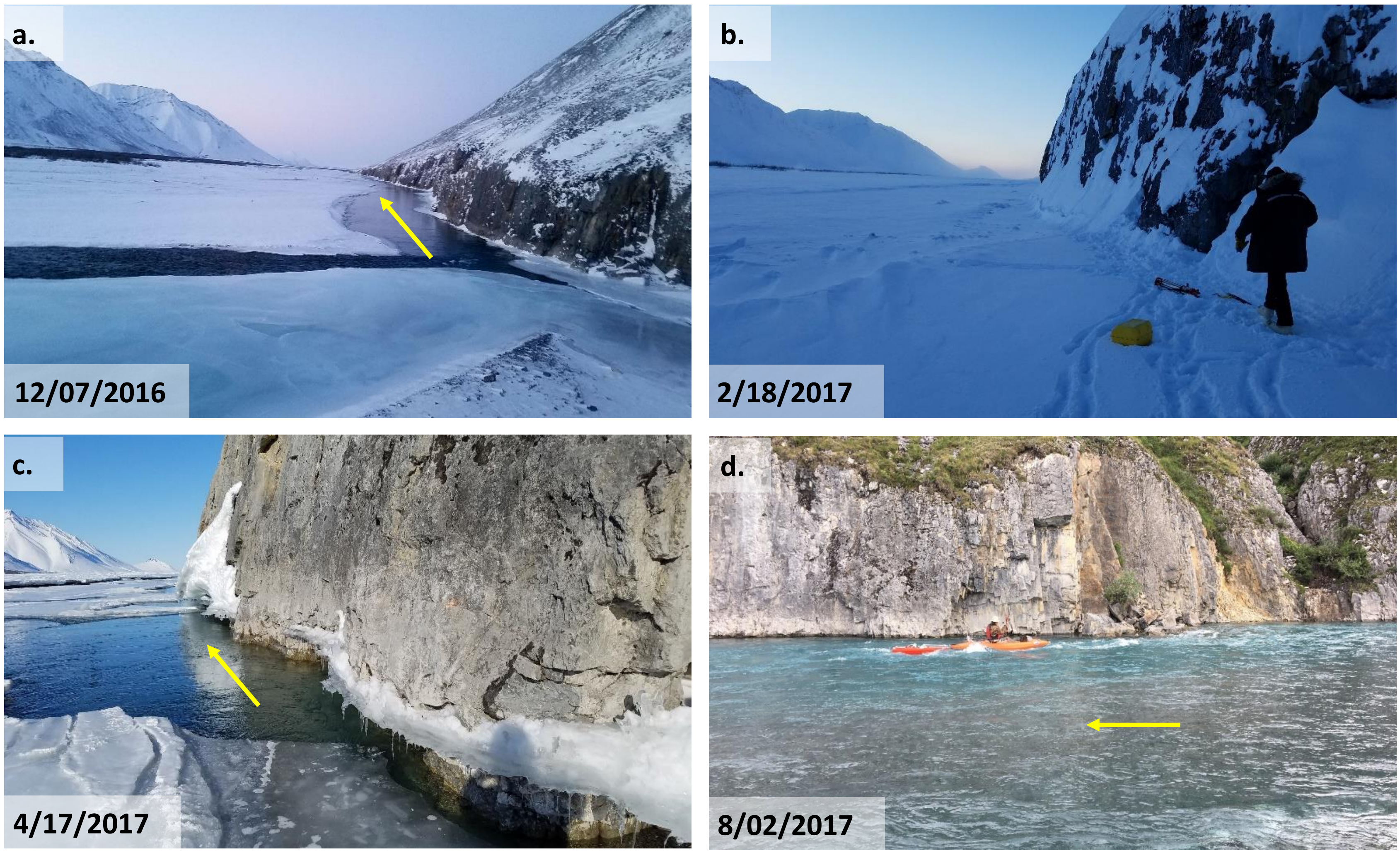


Figure 3.1 Upper Ivishak HOBO 1 site channel ice condition (a) on 12/7/2016, (b) on 2/18/2017, and (c) on 4/17/ 2017; (d) discharge was measured on 8/2/2017 with a RiverPro ADCP paired with a Hemisphere S321 DGPS. Yellow arrows indicate flow direction.

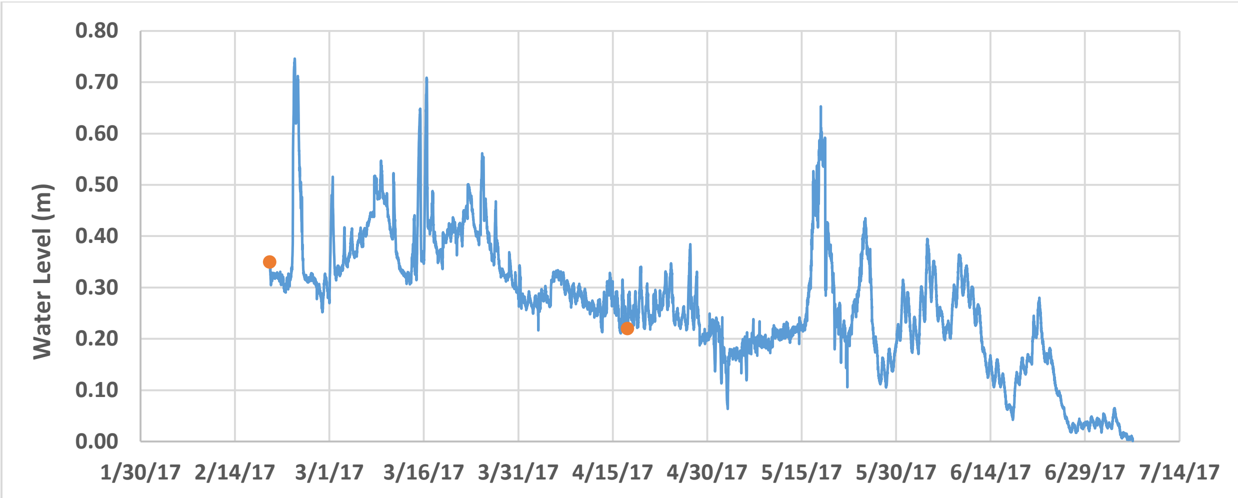
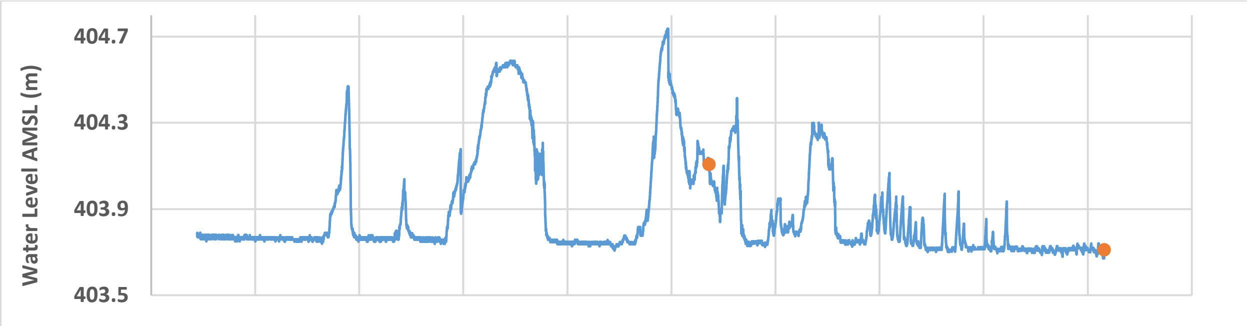


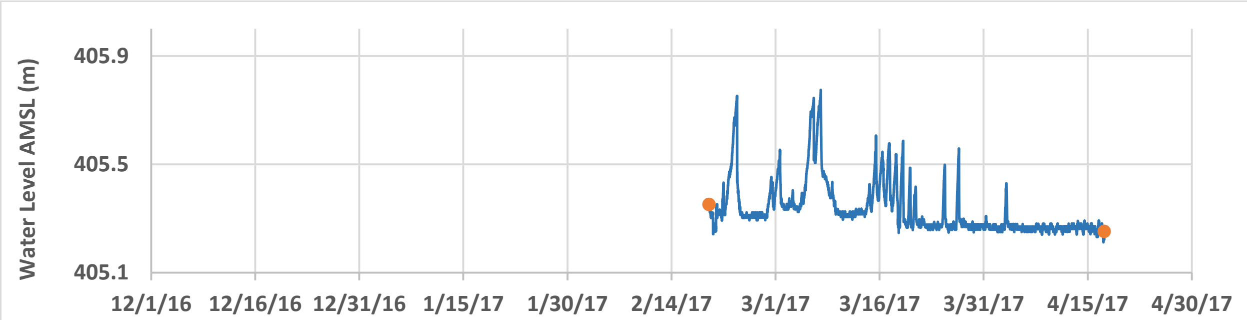
Figure 3.2 Water level above the sensor at the Upper Ivishak HOBO 2 site from 2/19/2017 to 7/6/2017 (orange dots indicate the discharge measurements made on 2/19/2017 and 4/17/2017).

3.1.1.2 Saviukviayak River

Water level data were collected at the Saviukviayak HOBO 1 site from December 7, 2016, to April 17, 2017 (Fig. 3.3a). During this period, the water elevation varied from 403.67 m to 404.74 m AMSL (above mean sea level), a total gauge height change of 1.07 m. Water level data were collected at the Saviukviayak HOBO 2 site (located approximately 100 m upstream of the Saviukviayak HOBO 1 site) from February 19 to April 17, 2017 (Fig. 3.3b). Water elevation varied from 405.21 m to 405.78 m AMSL, a total gauge height change of 0.57 m.



(a)



(b)

Figure 3.3 Water levels on the Saviukviayak River: (a) HOBO 1 site from 12//7/2016 to 4/17/2017 and (b) HOBO 2 site from 2/19/2017 to 4/17/2017. Orange dots indicate the discharge measurements made on 2/19/2017 and 4/17/2017.

This variance in water level was consistent with field observations of ice shelf formation at the Saviukviayak HOBO 1 site (Fig. 3.4). During the February 2, 2017, site visit the channel at the Saviukviayak HOBO 1 site was covered with a thin (less than 10 cm) layer of ice; however, open water was visible downstream and upstream of this site. A hole was open in the ice at the Saviukviayak HOBO 1 site, and no upward water pressure was noticed. A second HOBO sensor, Saviukviayak HOBO 2, was deployed on February 19, 2017, at a new open-water section of the channel, located approximately 100 m upstream of the first site.

Figure 3.4 Ice shelf formation at the Saviukviayak HOBO 1 site (photo taken 4/17/2017). Yellow arrow indicates flow direction.

3.1.2 Discharge Measurements

3.1.2.1 Upper Ivishak River

Winter discharge (Q) measurements were conducted on the Ivishak River in February and April 2017 at the Upper Ivishak HOBO 2 site. Even though the focus of the project was winter measurements, we conducted a summer measurement in August 2017 at the Upper Ivishak HOBO 1 site as well. During the February 18 site visit, the measured discharge was 2.5 m^3/s (Fig. 3.5a) with a gauge height of 0.35 m. During the April 17 site visit, the measured discharge was 1.1 m^3/s (Fig. 3.5b) with a gauge height of 0.22 m. During the August 2 site visit, the measured discharge was 31 m^3/s, (Fig. 3.5c), with a gauge height of 387.12 m AMSL.

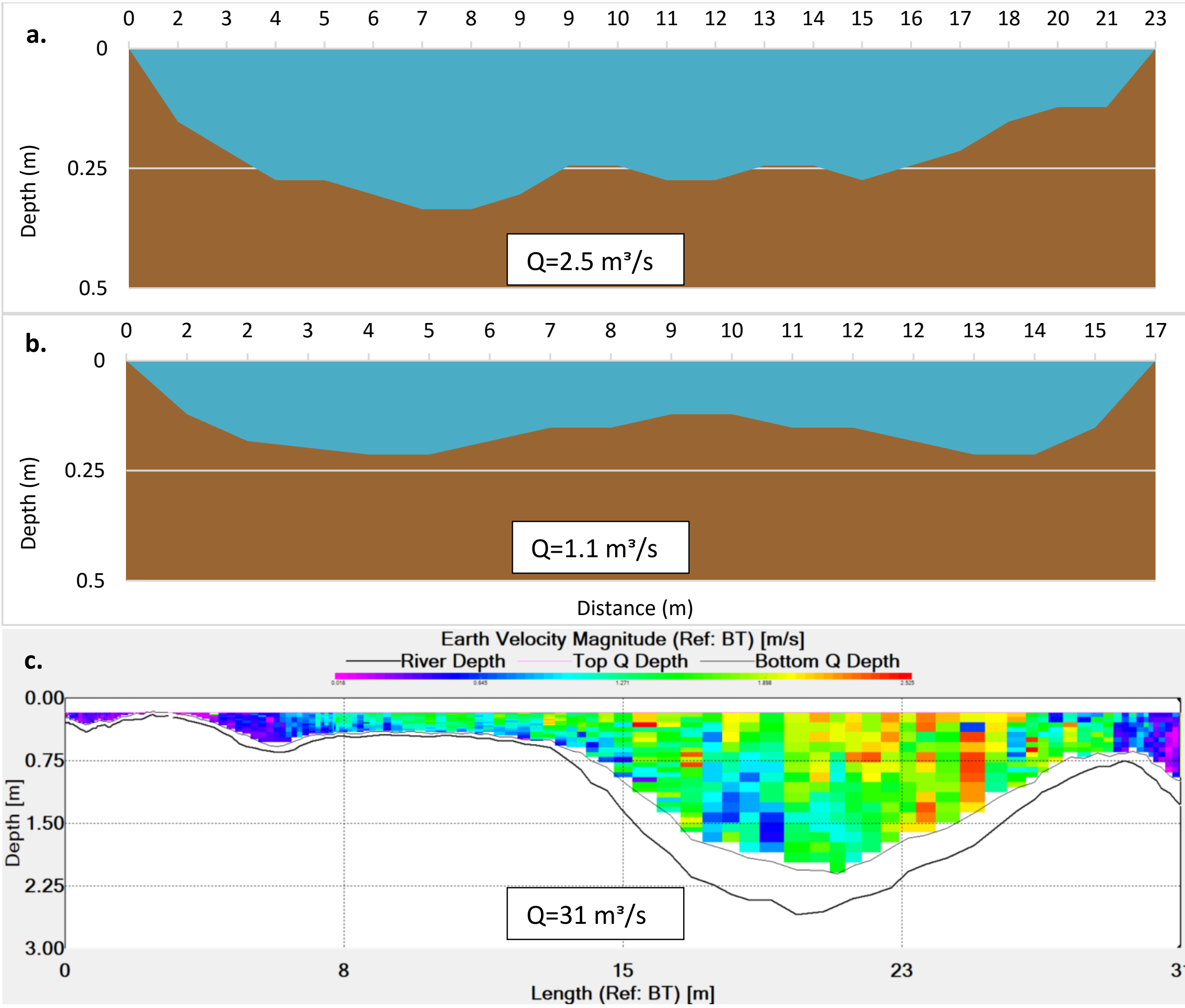


Figure 3.5 Channel profile of (a, b) Upper Ivishak HOBO 2 site on 2/18/2017 and 4/17/2017, and (c) Upper Ivishak HOBO 1 site on 8/2/2017.

3.1.2.2 Saviukviayak River

Winter discharge (Q) measurements were conducted on the Saviukviayak River in February and April 2017. The first measurement was made on February 19 at the Saviukviayak HOBO 2 site. Measured discharge was 3.2 m^3/s (Fig. 3.6a), with a gauge height of 405.35 m AMSL. The second measurement was made on April 17 at the Saviukviayak HOBO 1 site. Measured discharge was 2.7 m^3/s (Fig. 3.6b), with a gauge height of 403.71 m AMSL. The last measurement was made on August 1 at the Saviukviayak HOBO 1 site. Measured discharge was 11.8 m^3/s (Fig. 3.6c), with a gauge height of 404.00 m AMSL

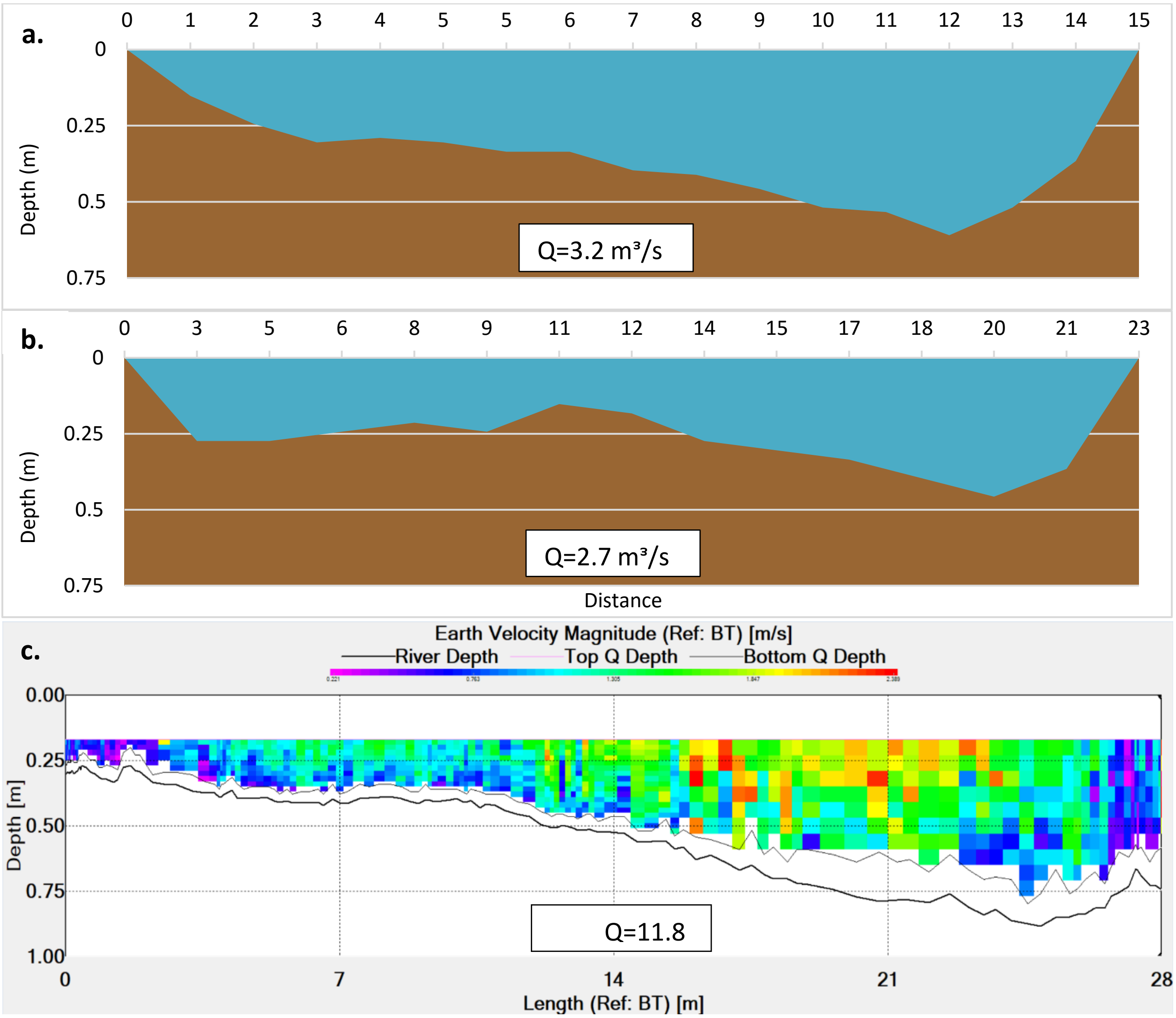


Figure 3.6 Channel profile of (a) Saviukviayak HOBO 2 site on 2/19/2017; (b) Saviukviayak HOBO 1 site on 4/17/2017; and (c) Saviukviayak HOBO 1 site on 8/1/2017.

3.2 Discussion

The Ivishak River and its tributaries are braided streams, which makes it difficult to find an ideal single channel location for a long-term gauging station. The Saviukviayak River HOBO 1 and HOBO 2 sites seem suitable for long-term gauging stations, as the channels remain ice-free for the most part. The Upper Ivishak HOBO 1 site showed promise as a long-term hydrological monitoring location. With flow concentrated in one channel, open water had been visible during previous winter surveillance missions. However, this site proved difficult for placing a gauging station. Thick ice cover (approximately 1 m) formed at this site from December 2016 to February 2017 and then collapsed sometime before April 2017. Additionally, a small avalanche shoot developed less than 10 m upstream of the Upper Ivishak HOBO 1 site, and an ice and snow overhang formed on the rock wall directly above the site. The Upper Ivishak HOBO 2 site was open during the entire period—from December 7, 2016, to April 17, 2017—but captured only part of the flow.

CHAPTER 4.0 – CONCLUSIONS

The goal of this study was to conduct preliminary monitoring of water levels in open water channels as well as to perform a limited number of discharge measurements on the main tributaries of the Ivishak River (i.e., Upper Ivishak and Saviukviayak rivers) during the 2016–2017 winter season.

Field logistics and fieldwork activities were extremely difficult due to harsh weather conditions in the area. Changes at the sites (i.e., growth and collapse of ice in the area where the sensors were deployed) caused the loss of several sensors. Sites with open water reported in previous winters were ice-covered in winter 2016–17. Water level data gathered from the sensors indicate a maximum water level change of 1.07 m during the winter months.

Winter discharge measurements at the Upper Ivishak HOBO 2 site indicate a reduction of 44% between February 18 and April 17, 2017. A summer discharge measurement at the Saviukviayak HOBO 1 site indicates an increase of approximately 430% from winter to summer.

While a suitable location for a long-term winter gauging station on the Upper Ivishak River was not found, the research team found an adequate site (identified as the Upper Ivishak HOBO 1 site in this report) for summer measurements. It is expected that measurements will be performed at this site in the future. Thus, the project was successful in terms of gaining critical knowledge of river conditions in the study area.

CHAPTER 5.0 – REFERENCES

National Wild and Scenic Rivers System. (n.d.) "Ivishak River, Alaska." Retrieved 1 May 2017: https://www.rivers.gov/rivers/ivishak.php

Toniolo, H., Youcha, E.K., Gieck, R.E., Tschetter, T., Engram, M., and Keech, J. (2015). Sagavanirktok River Spring Breakup 2015: Final Report. University of Alaska Fairbanks, Water and Environmental Research Center, Report INE/WERC 15.10, Fairbanks, Alaska.