Water and Environmental Research Center Annual Technical Report FY 2012

Introduction

Research Program Introduction

The UAF Water and Environmental Research Center continues to be a vibrant, relevant, and expanding research center in the State of Alaska. The Center hired one additional research faculty member during the period from March 2012 through February 2013, bringing the total number of affiliated faculty members to 21. Moreover, the Center retained its contingent of approximately 10 support staff and 20 graduate students. WERC was awarded $3.7M in research funding during the reporting period. 47% of this originated from federal research grants, 43% originated from state sources, and 10% originated from foreign or private interests. An additional $0.5M was received from state sources for operation and maintenance of the Center. A portion of these operating funds were used as matching funds for the 104(b) grants. The 104(b) grants we received for the funding period were instrumental in allowing a group of WERC-affiliated students to pursue research projects important to the State of Alaska. The topics covered were broad, and included studies related to community drinking water resources, glacial runoff in the context of climate change, the use of strontium isotopes for tracking salmon migrations, the role of meltwaters in the mass movement of frozen subsurface formations, and the potential use of willow plantations for reducing the impact of petroleum-contaminated soils upon surface and ground water resources.

Evaluating the treatability of soil contaminated with diesel and 1-chloro-octadecane via bioremediation

Basic Information

Title:	Evaluating the treatability of soil contaminated with diesel and 1-chloro-octadecane via bioremediation
Project Number:	2012AK105B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Engineering
Focus Category:	Treatment, Toxic Substances, None
Descriptors:	None
Principal Investigators:	Silke Schiewer, Mary Beth Leigh

Publication

1. • Starsman, J.; Schiewer, S.; Schnabel, W.; Leigh, Mary Beth: Assessing the Potential for Rhizoremediation with Native Willows for Soils Contaminated with Diesel and 1-Chlorooctadecane in an Alaskan Village. 2012 AWRA Alaska Section Annual Conference, Anchorage, AK, March 4-7 2013.

USGS Annual Report

Title: Evaluating the treatability of soil contaminated with diesel and 1-chloro-octadecane via bioremediation

Start Date: March 1 2012

End Date: Feb. 28 2013

An extension of this project till Feb. 28 2014 is requested to complete the project

Focus Category: **Treatment (TRT), Toxic Substances (TS)**

Key Words: bioremediation, phytoremediation, contaminated soil, groundwater, remote communities, contaminants in cold regions, soil microbiology

PI: Silke Schiewer, Associate Professor, WERC, UAF, sschiewer@alaska.edu, (907) 474 2620
Co-PI: Mary Beth Leigh, Assoc. Professor, IAB, UAF, mbleigh@alaska.edu, (907) 474-6656

Products of Project

Conference Poster:

- Starsman, J.; Schiewer, S.; Schnabel, W.; Leigh, Mary Beth: Assessing the Potential for Rhizoremediation with Native Willows for Soils Contaminated with Diesel and 1-Chlorooctadecane in an Alaskan Village. *2012 AWRA Alaska Section Annual Conference*, Anchorage, AK, March 4-7 2013.

Student Support

The MS student Jessica Starsman is supported by this project.

Introduction: problem, objectives, and relevance

Critical Water Quality Problem

Spills of diesel fuel and other contaminants occurring in remote Alaskan villages pose a particular challenge due to the logistical difficulties associated with removal and treatment of contaminated soil. In small villages, risks of exposure are high due to a close spatial proximity between fuel storage/distribution facilities (and thereby contaminated sites) and residences, schools, wells, or surface waters. Sometimes, contaminated soil is simply stockpiled or placed in dumps, which are not necessarily managed as a modern landfill. Good options for treatment of contaminated soil in such locations are microbial bioremediation in lined cells and phytoremediation, due to their low maintenance approach, which does not require many outside resources.

In this project, the village of Kaltag is used as a typical example, where several diesel spills (historic as well as recent) have contaminated soil around the local school, adjacent to the Yukon River. Diesel concentrations of up to 75,000 mg/kg were documented in a report commissioned by the Alaska Department of Environmental Conservation (ADEC), with multiple locations reporting in excess of 10,000 mg/kg (Shannon and Wilson, 2011). These diesel spills originated at an Alaska Village Electric Cooperative (AVEC) tank farm, a Yukon Kuskokwim School District (YKSD) tank farm, from an YKSD heating-oil transfer tank, and a fuel line leak (Figure 1). In addition to diesel, 1-chloro-octadecane (1-COD) of unknown origin has been detected. Unfortunately, little is known about the environmental and health effects of this compound. Teacher housing has been constructed on one of the main contaminated sites, between the school and the Yukon River. The contaminated area is open to and used by the public, including children of the directly adjacent school. Potential exposure routes identified are soil ingestion, groundwater ingestion, dermal absorption from soil, surface- or groundwater, and inhalation (Shannon and Wilson, 2011).

To prevent potential contamination of the Yukon River, the shallow groundwater in the active layer above the permafrost, and exposure of children at the school surrounded by these spill sites, ADEC is considering excavation of the contaminated site and treatment in lined biocells. This could be combined with phytoremediation by planting willow saplings on the surface, with involvement of the local community. The present study evaluates the feasibility of bioremediation and phytoremediation of such contaminated sites.

<u>Nature & Scope:</u>
A laboratory investigation is undertaken by MS student Jessica Bay using soil microcosms to study the biodegradation of diesel and 1-chloro-octadecane under different conditions.

<u>Hypotheses:</u>

- Indigenous microbes in the contaminated soil have the capacity for biodegradation of diesel and 1-COD, and will most readily biodegrade the labile fractions of freshly spiked, unweathered contaminants.
- Biodegradation is temperature limited, such that higher (summer) temperatures will be associated with the greatest degradation rates, although the microbes present in this cold region soil will also show continued biodegradative activity at lower (shoulder season) temperatures.
- Because of the high hydrocarbon concentration, biodegradation will be nutrient limited and thus addition of nutrients will increase microbial numbers and contaminant degradation.
- Willow roots will promote accelerated contaminant biodegradation through biostimulation of degradative microbes, as evidenced by increased numbers of degraders and contaminant degradation rates when root turnover is simulated by the addition of crushed roots or the willow phytochemical, salicylate.

<u>Objectives:</u>
To test the above hypotheses, the effect of the following factors is studied in soil microcosms:

- Contaminant type and level: original contaminated soil from Kaltag is compared to soil spiked with diesel and 1-COD.
- Temperature: Since microbial activity is strongly temperature dependent, experiments are performed at 20 °C and 6 °C, which are typical for the summer and shoulder seasons, respectively.
- Nutrients: To evaluate how fertilizer addition can enhance bioremediation in field applications, experiments without fertilization will be compared to experiments with inorganic nutrient amendments (N-P-K).
- Crushed willow roots or salicylic acid: Since prior research has shown that addition of crushed roots, which simulate natural root death, or the phytochemical salicylate, a

compound released from willow roots, can promote the growth of soil bacteria able to degrade contaminants such as PAH (McFarlin, 2010), addition of the above is investigated to evaluate whether phytoremediation using willow trees may be a viable remediation strategy.

Project Relevance

This study will investigate options for accelerating degradation of diesel and 1-COD by naturally occurring microbes in a laboratory setting. ADEC supports the project which lays the groundwork for ADEC remediation plans to be implemented. The results of this laboratory study could lead to implementation in a field setting in the village of Kaltag, where local residents amy be involved in implementing a phytoremediation study plot planted with willow samplings grown by school children. Through simple methods such as fertilization and planting of native willow trees, which can easily be implemented in villages across Alaska, contamination of ground- and surface water and exposure of residents to toxic substances can be prevented.

Methods

Laboratory incubation studies are conducted to assess the intrinsic rate of biodegradation of diesel and 1-COD in contaminated and spiked Kaltag soils, and to assess the effects of willow roots, salicylic acid, and fertilization on biodegradation rates at 20°C (room temperature) and at 4°C.
Bioremediation microcosm experiments were set up varying the following parameters, whereby all experiments were performed in duplicate.
Soil Types:

- Contaminated soil from Kaltag
- Clean Kaltag soil spiked with diesel (3000 mg/kg) and 1-COD (2.58 mg/kg)
- Clean Kaltag soil (uncontaminated control)
- Sterilized clean Kaltag soil spiked with diesel and/or 1-COD (sterile control)

Temperature: 6 °C vs. 20 °C
Treatments:

- Control
- Fertilizer: 300 mg/kg of fertilizer type 20-20-20 ($N\text{-}P_2O_5\text{-}K_2O$)
- Salicylic acid: 100 mg/kg
- Willow Root: 100 mg/kg
- Fertilizer and Salicylic Acid
- Fertilizer and Willow Root

The microcosms are being incubated for periods of several months. The effectiveness of biodegradation is determined by measuring the following variables:

- Biotic and abiotic fluxes in carbon dioxide are determined using a LI-COR 6262 near-infrared detector (Figure 4) to establish the time course of microbial respiration.
- Diesel range organics remaining in the soil are determined by gas chromatography mass spectrometry (GC-MS) after extraction from samples sacrificed after one or more weeks, following a method based on AK102. The GC/MS analysis was performed using Agilent Technologies 6890N Network GC System coupled to a 5873 mass selective detector.
- 1-COD extracted from the soil is determined by GC-ECD for sacrificed samples.

- Microbial numbers are determined via most probable number (MPN) of diesel degraders, using samples sacrificed after one or more weeks.
- DNA fingerprinting of the microbial community with terminal restriction fragment length polymorphism (T-RFLP) of 16S rRNA genes is performed at beginning and end of experiment to detect shifts in the microbial community structure. The FastDNA SPIN kit is used to collect DNA for analysis. The T-RFLP protocol will be followed and samples then submitted to the Core Lab for DNA fingerprinting

Principal Results

Soil samples were collected from Kaltag on June 27, 2012 and June 28, 2012 during a field visit. Contaminated soil was collected from N 64° 19.590' W 158° 43.379', next to the Yukon Koyukuk School District Shop heating oil transfer tank (Figure 2). The sampling location was selected based on the Shannon & Wilson Inc. December 2011 site characterization report (Figure 1). Uncontaminated soil was collected from the playground at N 64° 19.590' W 158° 43.714'.

Salix alaxensis cuttings were taken from various locations around Kaltag and brought back for verification by plant taxonomist, Amy Breen (International Arctic Research Center).

Dionex Ion Chromatography was used to calculate nitrite and nitrate levels in the soil to determine if nutrients already present in the soil would influence the microcosms. Results showed that there was no measurable amount of nitrate and nitrite present in contaminated soil samples collected from Kaltag; the peaks shown were less than 3 times the background noise.

Gravimetric analysis results from clean soil samples collected from Kaltag showed the average soil moisture content was 44.2%.

Prior to sieving the contaminated soil samples collected from Kaltag total DRO based on GC/MS analysis; were determined to be 68,500 mg/kg. After sieving the contaminated Kaltag soil (Figure 3) total DRO was 95,000 mg/kg. This spike is most likely attributed to the removal of larger particles and rocks, resulting in an increase of surface area to mass ratio in remaining soil and perhaps also freeing of diesel trapped in micropores.

An analytical standard mixture was prepared that included: Benzo[a]pyrene, Napthalene, Napthalene D8 (deuterated Napthalene), and 1-Chlorooctadecane. This was used to determine retention time of these specific compounds to aid in properly identifying compounds. Chromatograms produced with the GC/MS from soil extracts were examined for 1-Chlorooctadecane, and none was detected.

Initial respiration data show that contaminated Kaltag soil clearly had a higher CO_2 production than the other soil types (Figure 4), which can be explained by the much higher contamination level. Respiration was lowest for the sterile spiked soil.
Among the different treatments, the best results, i.e. highest respiration, were obtained for addition of fertilizer combined with salicylic acid (Figure 5).

Experiments are ongoing to determine the time course of respiration for different microcosms as well as the chemical and biological analyses.

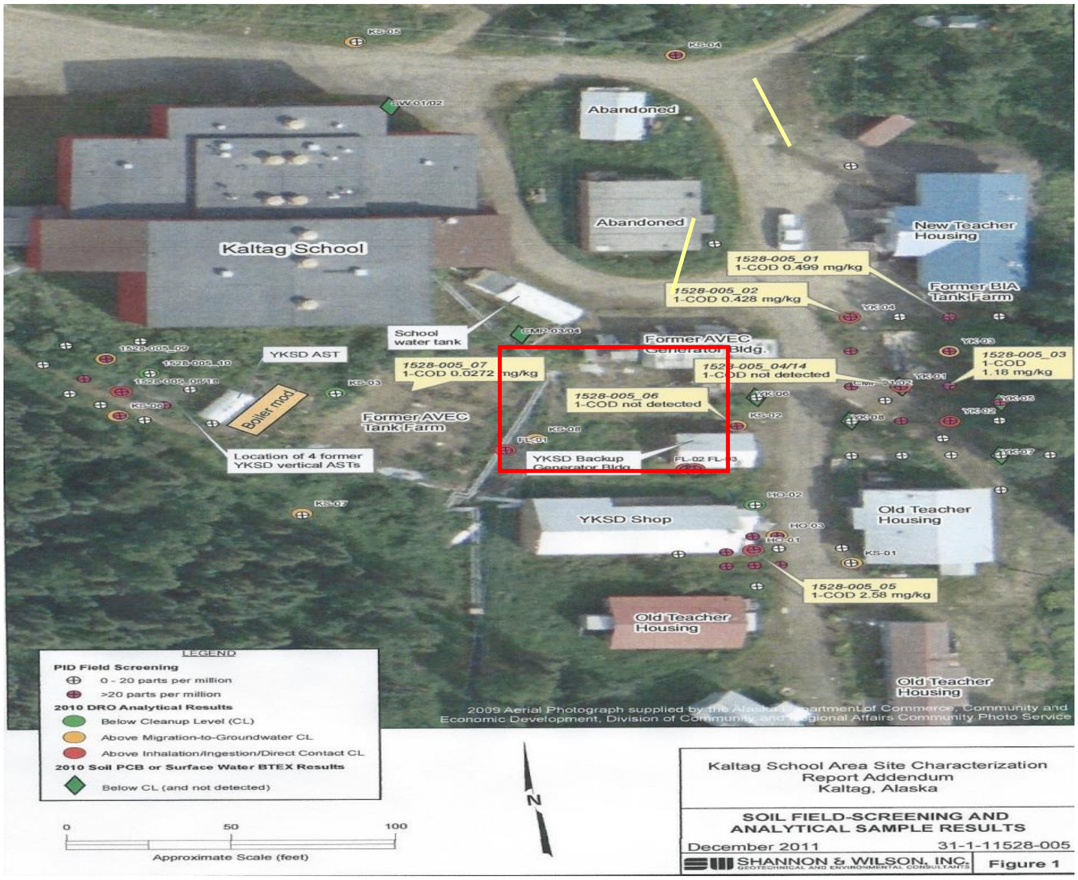


Figure 1: Contaminated sites in the Village of Kaltag.

Figure 2: Sampling at YKSD Tank where highest contamination was present.

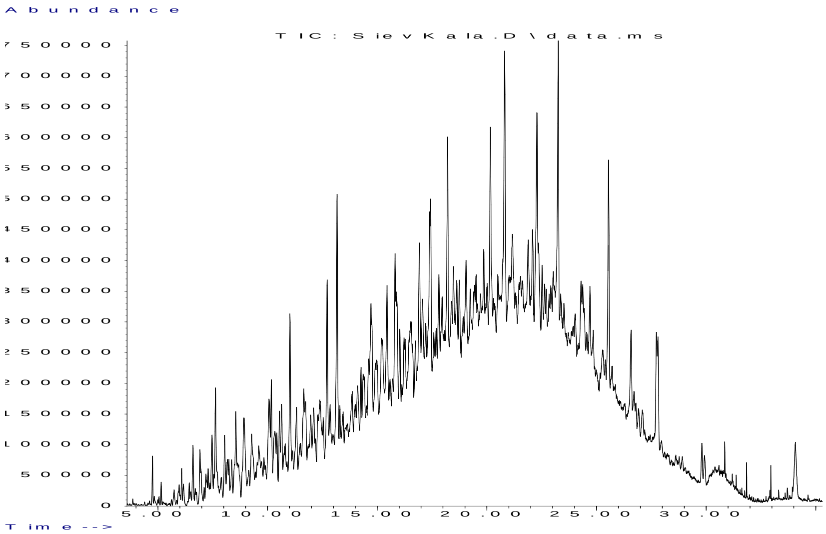


Figure 3: GC/MS Results for sieved contaminated Kaltag soil

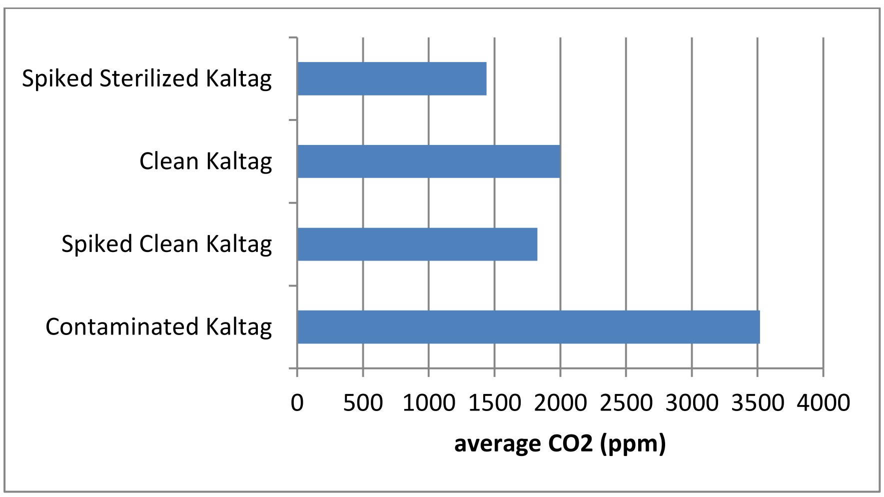


Figure 4: Respiration averages for different soil types at 20 C

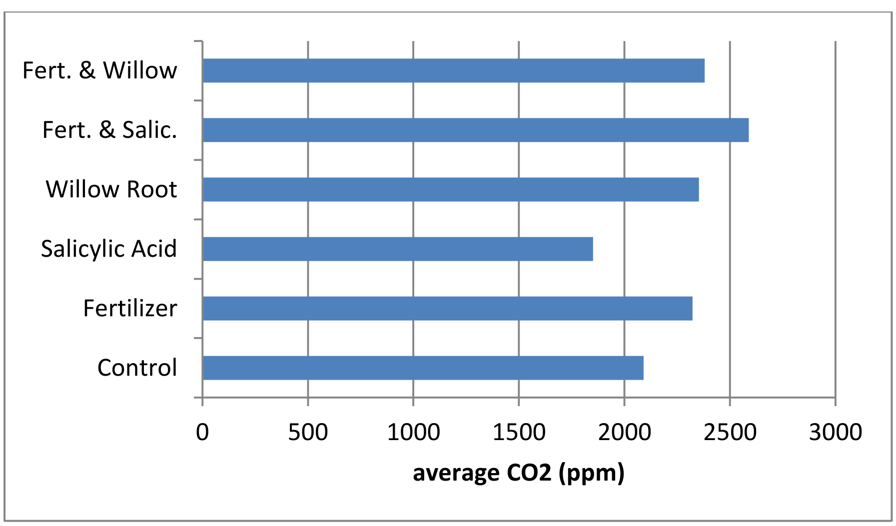


Figure 5: Respiration averages for different treatments at 20 C

Response of Water Supply Lakes to Climate Change in Western Alaska: a Case Study of Past, Present, and Future Thermal Regimes in Kotzebue

Basic Information

Title:	Response of Water Supply Lakes to Climate Change in Western Alaska: a Case Study of Past, Present, and Future Thermal Regimes in Kotzebue
Project Number:	2012AK106B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Quality, Climatological Processes, Water Quantity
Descriptors:	None
Principal Investigators:	Christopher Douglas Arp

Publication

1. Oral Conference Presentation: Benlova, T., C.D. Arp, B.M. Jones. (2012). Investigation of hydrologic and thermal regimes of lakes used for water supply in Kotzebue, Alaska. Oral Presentation American Water Resources Association, Fairbanks, Alaska. Master's Thesis: Bendlova, T. (2012). Investigation Of Thermal Regimes Of Lakes Used For Water Supply And Examination Of Drinking Water System In Kotzebue, Alaska. M.S. Thesis in Department of Civil and Environmental Engineering, University of Alaska Fairbanks, Fairbanks, AK, 66 p.

NIWR Progress Report

Title: Response of Water Supply Lakes to Climate Change in Western Alaska: a Case Study of Past, Present, and Future Thermal Regimes in Kotzebue

Start date: Feb, 2012

End date: Feb, 2013

Focus Category: Water Supply –WS, Climate Processes – CP, Water Quality – WQL

Descriptors: Arctic, lakes, water supply, thermal regime, climate change

PI: Dr. Christopher D. Arp

Products of Project:

Oral Conference Presentation:

Benlova, T., C.D. Arp, B.M. Jones. (2012). Investigation of hydrologic and thermal regimes of lakes used for water supply in Kotzebue, Alaska. *Oral Presentation* American Water Resources Association, Fairbanks, Alaska.

Master's Thesis:
Bendlova, T. (2012). Investigation Of Thermal Regimes Of Lakes Used For Water Supply And Examination Of Drinking Water System In Kotzebue, Alaska. M.S. Thesis in Department of Civil and Environmental Engineering, University of Alaska Fairbanks, Fairbanks, AK, 66 p.

Introduction: problem, objectives, and relevance

Problem

Arctic coastal plain in northwestern Alaska is studded by hydrological features with thousands of lakes dominating this picturesque landscape. These unique and very important ecosystems store large amounts of water, affect regional hydrological patterns and climate, as well as adjacent ground including permafrost. Lakes are also important components of the water and biogeochemical cycling. Because lakes are abundant throughout large portions of the Arctic, they have an enormous regional influence on landscapes and ecosystems. They can moderate local climate by absorbing heat in hot weather and releasing heat during cooler conditions, and also help ease impacts of both floods by storing large amounts of water and droughts by providing water previously accumulated. Therefore, lakes represent a key landscape component in the Arctic because they provide habitat for many aquatic organisms, and are part of food web that also supports many terrestrial species.

Not only do fish, birds and other animals rely on the services that lakes offer, but people also are highly attached to and dependent on freshwater lakes. Near many towns and villages, Arctic lakes provide a valuable and stable supply of water for drinking, washing, and other municipal uses. Lakes are an important municipal water source, especially in many areas where fresh groundwater is not accessible. Fifty four Alaskan villages, over 4,000 people, rely on lakes or reservoirs as their drinking water source and even a larger number of small villages rely on lakes for subsistence resources. Unfortunately, problems with source lakes have been recently observed in Arctic Alaska. Increase in incidence of algal blooms in a water supply tundra lake for Point Hope was noticed causing economic and labor problems in water treatment procedure. The increase in severity of algal blooms and related diminishing drinking water quality is believed to be due to warming water induced by climate change observed in the area. Additionally, it was concluded that Point Hope is susceptible to hydrologic changes including water shortages influenced by alterations to annual precipitation and temperature. Because Kotzebue, area of this study, uses two thermokarst lakes for their drinking water supply, and local air temperatures have raised at a similar rate as in Point Hope, there is a common concern.

Water temperature is a significant factor largely defining lake ecosystems as it has a great influence on hydrology by being one of the driving forces of the hydrologic cycling, on water quality, and productivity and sustainability of ecosystems. Thermal stratification, presence of ice-cover, concentration of dissolved oxygen, respiration and metabolism of fauna and flora, and also toxicity of pollutants are all substantially affected by a lake's water temperature. Although Arctic lake temperatures have been studied by limnologists since the 1950s; there is still a lot of unknown and to be discovered, such as lake thermal regimes. Due to large area of the Arctic and its low human population, only relatively a few, and usually just the large, lakes have been examined for their thermal regimes. As early as in the 1950s, water temperature variations of as much as 4°C change in one day were described and quite high surface temperatures of about 13°C were noticed in northern Alaska in summertime.

In recent years, rapid surface water warming has been described worldwide with stronger trends in high latitudes. Air temperatures in many parts of the Arctic show increasing trends and the surface water temperature have been affected. The climate of the Arctic has changed much more rapidly than it has globally and this trend is anticipated to continue. A wide range of lake responses in discontinuous and continuous permafrost to environmental phenomena has been observed in the Arctic. In analysis conducted by Smith et al. (2005) regionally variable shifts in lake surface area changes were revealed. Increases in surface areas and new emerging lakes were observed in regions with continuous permafrost and decreases in surface areas and disappearance of lakes were observed in regions with discontinuous permafrost. The boundary between the two regions seemed to be shifting northward. Generally, predicting lake thermal regimes is quite difficult because of the amount and variety of predictor variables coupled with the high heat capacity of water, latent heat associated with phase change, and a strong seasonality of ice cover.

Objectives

This project reveals information on summertime thermal regimes of four studied water-bodies located in north-western Alaska near Kotzebue. Such information is useful purely on its own as a new experiment giving knowledge about daily and yearly thermal variations of selected Arctic lakes. Above all, here, this knowledge is particularly useful because the lakes are vital to the Kotzebue community of over 3,200 people. However, I have not discovered any studies that would integrate investigations of lake thermal regimes related to climate change and their function as community drinking water source.

I hypothesized that the summer surface water temperatures in lakes near Kotzebue were generally higher than air temperatures. I also hypothesized that the water supply lakes respond to changing air temperatures and solar radiation in a similar manner as the un-managed thermokarst lake. This research is a coupled monitoring and modeling project, so the objective was to use the relationship of monitored surface water temperatures to air temperature and solar radiation and use it for hindcasting of past thermal regimes. An arising question was whether the man-managed water supply lakes significantly differ in their thermal regimes from a tundra lake with natural water-balance. Therefore, besides the two source lakes, I have also chosen to monitor Mosquito Lake and Kotzebue Lagoon (later just Lagoon) for reference. In order for us to better understand the local drinking water supply situation, especially with regard to the challenging Arctic conditions and the remote area, I have looked at the drinking water system and treatment plant and learned about its operations.

The main purpose of this study was to establish a baseline of interannual variability, a modeled record, a point of reference of water temperature data, for lakes near Kotzebue including two water supply lakes. Because the biological, physical and chemical characteristics are closely related to a lake's thermal regime, information from this study on lake water temperature responses to seasonal weather patterns and interannual climate variability should assist the water treatment plant management and the City with planning and future vulnerability/resilience assessment. In Kotzebue, I met people highly committed to providing healthy drinking water to the City, deeply caring about their service to the community; and that motivated us even more in our efforts of helping with providing them with scientific information on lake thermal regimes.

Methods

Generally, to accomplish our project goals I began investigating two lakes being used for water supply by the City of Kotzebue and two adjacent reference water-bodies on the Baldwin Peninsula during the summer of 2011 (Figure 1.1). At each lake, I monitored surface and bed water temperatures, water levels, and water pressure, along with weather parameters that overlap with meteorological data collected long-term (since 1950s) at the Ralph Wien Memorial Airport in Kotzebue. Data collected during this period were used to develop mathematical models for each water-body to simulate lake temperature regimes using an empirical approach based on air temperature and solar radiation.

Figure Error! No text of specified style in document.**.1** Satellite image of the study area showing positions of Devil's Lake (D), Vortac Lake (V), Mosquito Lake (M), and Lagoon (L) in vicinity of

I used these models to hindcast summer lake thermal regimes from 1985-2010. Future validation of hindcasted values will be possible with use of the MODIS satellite surface water temperature measurements of Kotzebue Lagoon (monitored with sensors in summer 2011). Simulation of this time period will provide a reasonable baseline of thermal regimes of the water supply and reference water-bodies and their interannual variability. This dataset will also provide an opportunity to analyze if and how Arctic coastal lakes have changed during the past quarter of century.

Results

Thermal regimes of the studied water-bodies over the monitoring period

The surface (T_{ws}) and bed (T_{wb}) water temperatures in all four studied water-bodies were monitored during the time period of June 22nd- August 28th, 2011. We have observed the mean T_{ws} to be very similar for all water-bodies and range between 14.4 and 14.6°C with the lowest for Devil's Lake and the highest for Mosquito Lake (Table 1.1). The highest maximum daily average T_{ws} of 19.5°C was recorded on June 29th in Mosquito Lake. The lowest maximum daily average T_{ws} of 18.2°C was recorded also on June 29th in Vortac Lake. The monitored maximum daily averages gave a range of 1.3°C for the four water-bodies. The maximum daily average T_{ws} also occurred on June 29th in Devil's Lake (18.6°C) and on June 28th in Lagoon (18.9°C). The lowest minimum daily average T_{ws} of 10.7°C was recorded on July 4th in Mosquito Lake. The highest minimum daily average T_{ws} of 11.6°C was recorded on August 25th in Vortac Lake. The monitored minimum daily averages gave a range of 0.9°C for the four water bodies. The minimum daily average T_{ws} also occurred on August 25th in Lagoon (11.5°C) and on July 4th in Devil's Lake (10.9°C).

Table 1.1 Summary of the mean, maximum and minimum daily averages of surface water temperatures monitored in the four studied-water bodies during the time period of June 22nd- August 28th, 2011.

Water-body	Depth m	Area km²	Mean Tws °C	Max Tws °C	Min Tws °C
Devil's Lake	3.64	1.01	14.4	18.6	10.9
Vortac Lake	2.28	0.41	14.5	18.2	11.6
Mosquito Lake	1.56	1.48	14.6	19.5	10.7
Lagoon	1.99	3.88	14.5	18.9	11.5

Hindcasting

The models for hindcasting had to be based on data which were available for conducting the past estimates; therefore, I used historical data on air temperature measured at the Kotzebue airport weather station since 1985 and I kept TCSR constant for all years. I used lake specific model parameters which I determined during the model development phase of this study.

The hindcasted thermal regimes for each of the four water-bodies during the summer time period of July 1st – August 15th for years 1985 – 2010. Then I have calculated mean surface water temperature for each lake and year, and extracted annual maximum and minimum daily mean values during that time period. I compared these values in following graphs. The mean surface water temperatures ranged between 12.2°C (Devil's Lake in 2000) and 19.7°C (Mosquito Lake in

2004) (Figure 2.1). The three coldest years were 2000, 2006 and 2003 with mean temperatures below 14°C for most of the water-bodies. The four warmest years were 2004, 1990, 2009 and 2007 with mean temperatures above 17°C. Individually, Devil's Lake's mean T_{ws} range was 12.2°C - 19.2°C (7°C), Vortac Lake's was 12.8°C - 18.6°C (5.8°C), Mosquito Lake's was 12.2°C – 19.7°C (7.5°C), and Lagoon's was 12.4°C – 19.1°C (6.7°C).

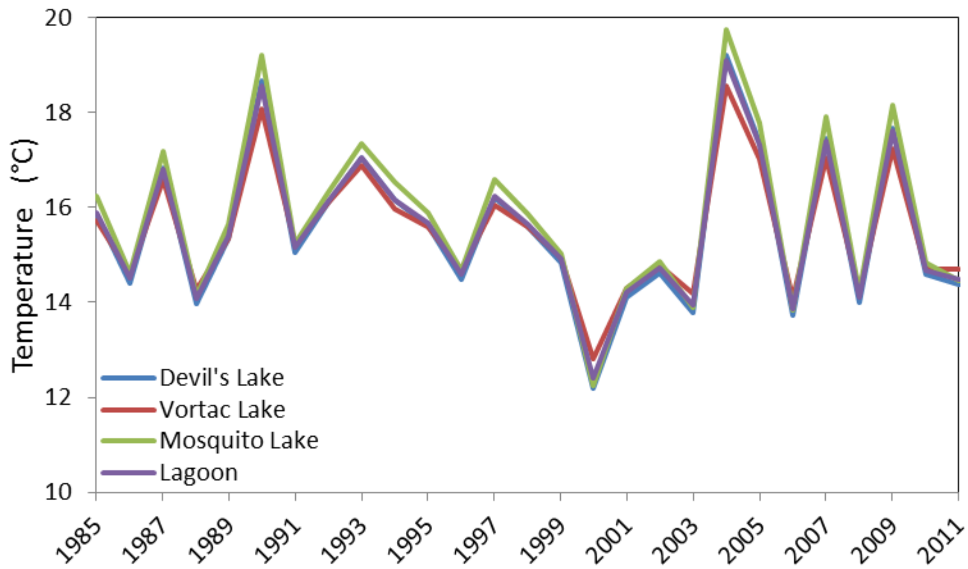


Figure 2.1 Hindcasted mean surface water temperatures of all studied water-bodies for each year since 1985 – 2010 and the time period of July 1st – August 15th.

Conclusions

Climate in Kotzebue (66°54'N 162°35'W) has been changing as shown by increases in the mean annual air temperature by 1.4°C in time period 1985-2011 and increases in summer mean temperature by 0.6°C over the same time. However, as p-values indicate, these trends are statistically insignificant. Because of the direct response of lake surface water temperature to air temperature and solar radiation in summer season, changes in thermal regimes of studied water-bodies are expected. Lakes used for municipal water supply in Kotzebue, Devil's and Vortac Lakes, responded to changes in air temperature and solar radiation in a very similar manner as an alike unmanaged water-body, Mosquito Lake. During the monitoring time period, June 22nd-August 28th 2011, the mean T_{ws} ranged from 14.4 to 14.6°C, the max daily average T_{ws} was 19.5°C and the min daily average was 10.7°C. Stratification and mixing were observed in all water-bodies for multiple times and various durations. Wind proved to be one of the factors. The max difference (T_{ws} - T_{wb}) recorded was 4.2°C in 3.6 m depth. T_{ws} was greater than T_a for most of the time and the mean difference was 3.2 – 3.5°C. This result is similar to the difference of 2.4 - 3.2°C observed in Arctic Lakes.

Interannual variation in lake thermal regimes was estimated based on models developed from T_a, TCSR, and monitored T_{ws} in each water-body (**α**=‹0.19, 0.30›; **a**=‹-4.88, -3.55›; **b**=‹1.00, 1.32›; **c**= ‹0.009, 0.014›). Although I have noticed significant fluctuation among years of the mean (12.2

– 19.7°C), minimum (6.6 – 16.7°C), and maximum (15.6 – 25.2°C), T_{ws} for time period July 1st – August 15th, I have not observed any emerging patterns showing increasing trends in surface water temperatures with time (1985 – 2011) which would confirm effects of climate change. A pattern I observed was that the minimum daily mean T_{ws} values fell either into first two weeks of July or last two weeks in August and the maximum values largely happened in July. The max T_{ws} in early July can be explained by warmer mean April-May-June T_a. Possible warming trend of surface water temperatures would likely alter quality and quantity of lake water used for drinking purposes for the City of Kotzebue, especially because the source lakes are of thermokarst origin. However, I am unable to predict from our baseline data, if such problem is to occur and if so, in what time frame. The most current problem regarding the municipal water system is possible contamination of source lakes from activities taking place in the area. I recommend that future scenarios are discussed and planned for the City of Kotzebue in regard to use of alternative source of water such as brackish ground water or seawater.

Monitoring runoff in glaciated watersheds to assess groundwater recharge and flooding risks

Basic Information

Title:	Monitoring runoff in glaciated watersheds to assess groundwater recharge and flooding risks
Project Number:	2012AK107B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Floods, Groundwater
Descriptors:	None
Principal Investigators:	Anna Liljedahl, Anthony Arendt

Publication

1. Conference Poster and Abstract: Davis, J., A. Arendt, G. Wolken, and A. Liljedahl, 2013. Assessment of flood hazard potential in Valdez Glacier watershed in future climate. Oral presentation, American Water Resources Association, Alaska Section Annual Conference. March 4-6, Anchorage, AK.

NIWR Progress Report 2013

Title: Monitoring runoff in glaciated watersheds to assess groundwater recharge and flooding risks

Start date: March, 2012

End date: Originally Feb, 2013. Extension granted.

Focus Category: HYDROL, FL, GW

Descriptors: Runoff, glacier, groundwater recharge, climate change

PI: Anna Liljedahl (WERC and IARC) and Co-PI Anthony Arendt (GI)

Products of Project:

Conference Poster and Abstract:
Davis, J., A. Arendt, G. Wolken, and A. Liljedahl, 2013. Assessment of flood hazard potential in Valdez Glacier watershed in future climate. Oral presentation, American Water Resources Association, Alaska Section Annual Conference. March 4-6, Anchorage, AK.

Abstract:
Few glaciological studies have addressed the effect of glacial runoff on watershed hydrology. Glaciers in Alaska's Prince William Sound region are losing volume in response to recent changes in climate. Valdez Glacier is one of the most rapidly thinning and retreating alpine glaciers in the Western Chugach Mountains of the Prince William Sound region. Melt water from glaciers contribute to runoff in lower elevations, which in combination with heavy precipitation events, can result in dramatic flooding. Downstream of the Valdez Glacier is the Valdez Airport and popular recreational and gravel mining areas - all which could be threatened in a large flooding event of the Valdez Glacier Stream. The hydrology of the Valdez Glacier watershed is less known, and it is challenging to predict how the watershed will respond as the glacier continues to lose volume. The study utilizes field measurements of meteorological, glacier mass balance, streamflow, and lake water level to inform and refine hydrologic simulations using the physically-based Water Balance Simulation Model (WaSiM). Computational simulations in combination with our field measurements can help identify areas that may be subject to flooding and provide guidance to the City of Valdez on decisions about infrastructure development and recreation.

Measurements from the 2012 field season indicate stream water level fluctuations between 16.1 m and 17.3 m above sea level, with maximums occurring during the last week of June and last week of September, and minimums occurring in mid-July and mid-September. The water level of Valdez Glacier Lake throughout the summer season ranged between 115.0 m to 118.2 m above sea level. The maximum and minimum water levels of the lake coincide with the maximum and mimimum levels observed in the stream. A lag time of approximately 30 minutes between the lake response and stream response was observed during the September peak.

Introduction: problem, objectives, and relevance

Problem

In Alaska, local and regional water resources management affected by glacier wastage include flood forecasting, groundwater supply, and operation, planning and design of water related facilities such as hydropower plants. Effective state and borough leadership in water resource issues depends upon a good understanding of the hydrologic fluxes and stores, and how these factors differ for watersheds with differing climate and glacier coverage. Although few studies have been conducted in Alaska, research in other locations has shown that glaciers tend to moderate streamflow, providing a baseline of runoff during summer seasons even in the absence of significant precipitation inputs, and even for basins with low percentages of ice cover. For example, glacier-melt discharge is estimated to comprise 35 to 54 % of the Tanana River discharge in spite of the 5.6% glacierized area (Chikita et al., 2007). A warming climate will increase glacier wastage, which will cause an initial increase in water exported to the lower portions of the watershed. However, as glacier surface areas decrease, so too will the glacier runoff. Given these factors, different management considerations are necessary when making water resource management decisions in glaciated versus non-glaciated basins.

Despite their important role in the hydrological cycle, glaciers in Alaska are poorly monitored, and tend to be only crudely represented in hydrologic analyses. Present hydrologic models employed by federal agencies include crude representation of glacier runoff, and have little capacity for predicting hazards associated elevated glacier melt. This limits our understanding of environmental and hydrologic responses to climate change, and therefore, our ability to successfully mitigate and adapt to an altered water cycle.

Goal

The overall goal of the proposed research is to integrate hydrologic and glacier mass balance monitoring to obtain a deeper understanding of the effect of glacier wastage on hydrologic processes in semi-arid and maritime landscapes under present (this proposal) and future climate regimes (supported by other funds). The work will be accomplished by combining glacier mass balance studies with continuous and distributed runoff measurements at glacial streams draining the study watersheds of Jarvis Creek and Valdez glacier. The ultimate deliverables of this work are to provide a range of decision-making tools focusing on aquifer recharge, runoff, and hazard maps that can be used to inform management of watersheds in the future.

Objectives

The objectives of this study are to:

1) Quantify low-land runoff in two glaciated watersheds; and through complementing funds, a) assess the stability of a proglacial hydrological environment with respect to flooding hazards; and b) develop a set of predictive modeling tools for simulating future runoff scenarios under a range of climate conditions.

Relevance

Quantifying the amount of runoff in glacier-fed streams has direct societal relevance to Alaska. For example, Alaska water resource issues related to glacier hydrology include small and large-scale hydropower exploration and consistent year-round supply of groundwater that is crucial for farming operations in an otherwise semi-arid climate. In addition, flooding events resulting from high rates of glacier discharge have the potential to limit access to extensive military training lands, causes disruptions in an already constrained road network, and results in extensive damage to homes or displacement of communities living near glacially-fed river systems. There are also less frequent but potentially more serious hazards associated with the breaching of moraine- and ice-dammed lakes currently impounding large volumes of water. Finally, changes in glacier runoff can alter the biogeochemistry of rivers and near-shore ocean ecosystems, with associated impacts on fisheries and other industries. Addressing these problems will require an expansion of glacier discharge monitoring and the development and improvement of physically-based watershed runoff models.

Methods

We conducted river discharge measurements at the Jarvis Creek watershed (634 km^2, Figure 1), south of Delta Junction, and the Valdez Glacier watershed (339 km^2, Figure 2) located northeast of the town of Valdez. These are located in semi-arid and maritime climate regimes respectively, providing information on distinctly different hydrological systems.

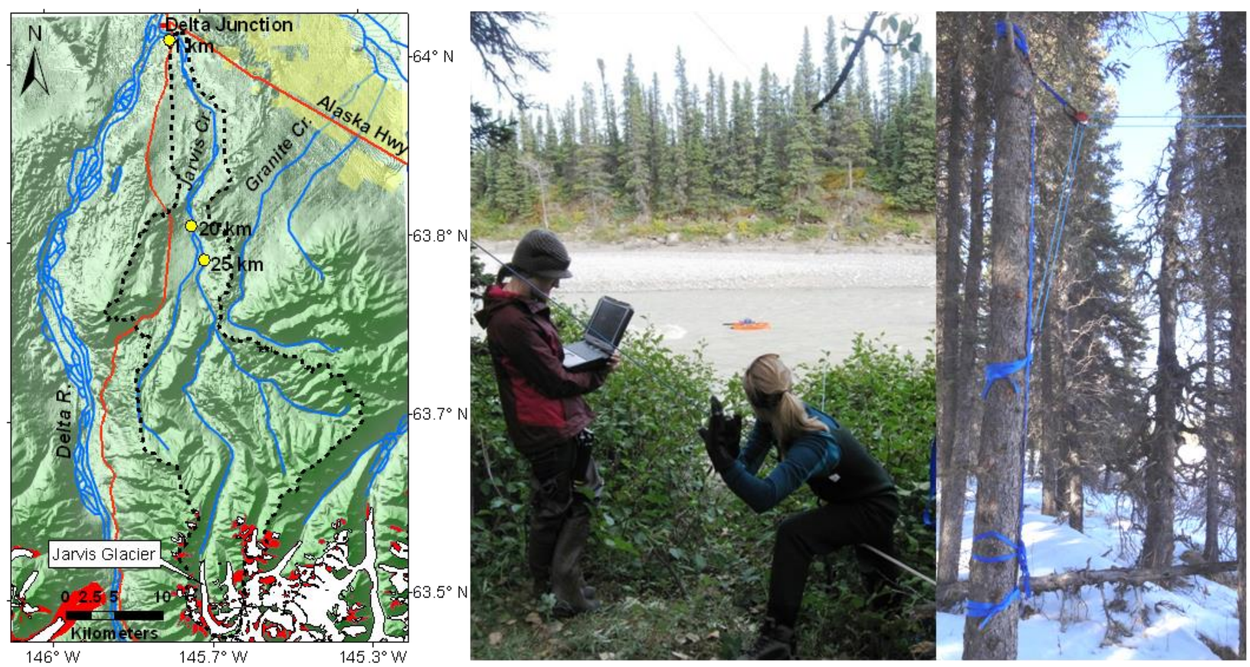


Fig. 1*. The Jarvis Creek watershed. Left: Runoff monitoring sites (yellow dots). Red shading is the 1950s glacier extent determined from USGS topogrpahic maps, and white shading is current (2000) glacier extent. Middle: Discharge measurement using the NIWR supported StreamPro Acoustic Doppler Current Profiler (ADCP) at the "25 km" site on August 29, 2012, by Jennifer Davis and Anna Liljedahl. Right: Close-up of left bank tag-line in a non-active measurement position.*

The NIWR award supported a purchase of a StreamPro Acoustic Doppler Current Profiler (ADCP), which was used to measure discharge at two locations at the Jarvis Creek (site “1-km” and “25-km” Fig. 1) and at one site representing the Valdez Glacier Stream, Richardson Highway bridge (Fig. 2). We deployed the ADCP sensor by erecting a static rope across the streams. Measurements performed near the bridges included one person at each bank holding a rope attached to the sensor. A tag-line system with multiple pulleys was installed in late spring 2012 across the upstream Jarvis Creek site (Fig. 1), which lacks a bridge crossing. The tag-line installation allowed discharge measurements using the StreamPro when Jarvis Creek flow conditions were too dangerous to wade. Pressure transducers (Onset) were installed near the runoff monitoring sites. Rating curves were established to describe the relationship between streamflow and stream water level to estimate continuous discharge.

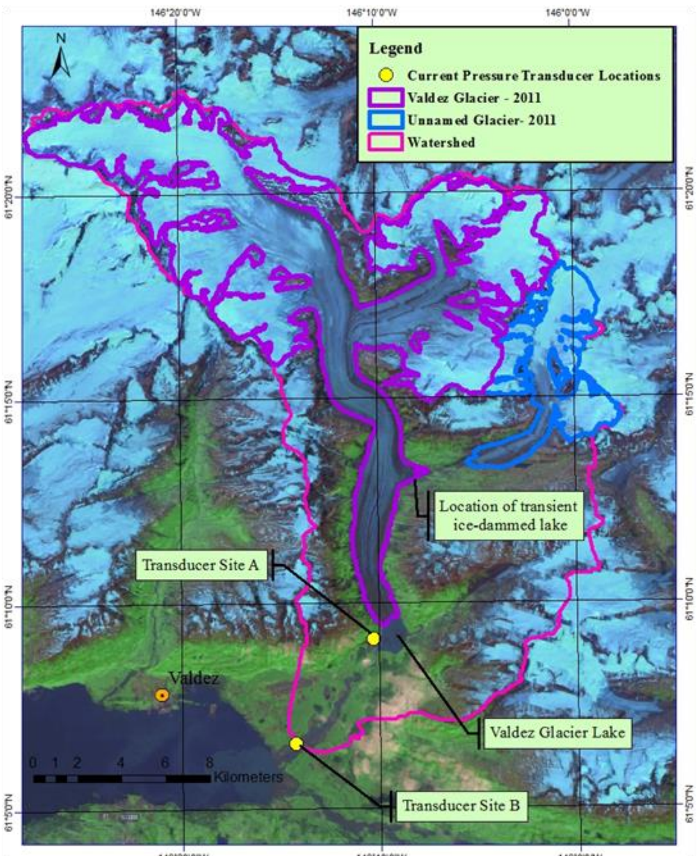


***Figure 2**. Left: The Valdez Glacier Stream watershed (pink outline), the 2012 extent of the Valdez Glacier and an unnamed glacier (purple/blue lines), stream and/or water level monitoring locations (yellow dot). Top: StreamPro ADCP measurement on May 31, 2012.*

Graduate student Jennifer Davis was given the lead in learning how to operate the StreamPro under supervision of research professionals at the WERC. This involved trouble shooting of the GPS system that informed the ADCP and post-processing of the velocity profile measurements using WinRiver II software (RD Instruments) to produce an overall discharge for each transect.

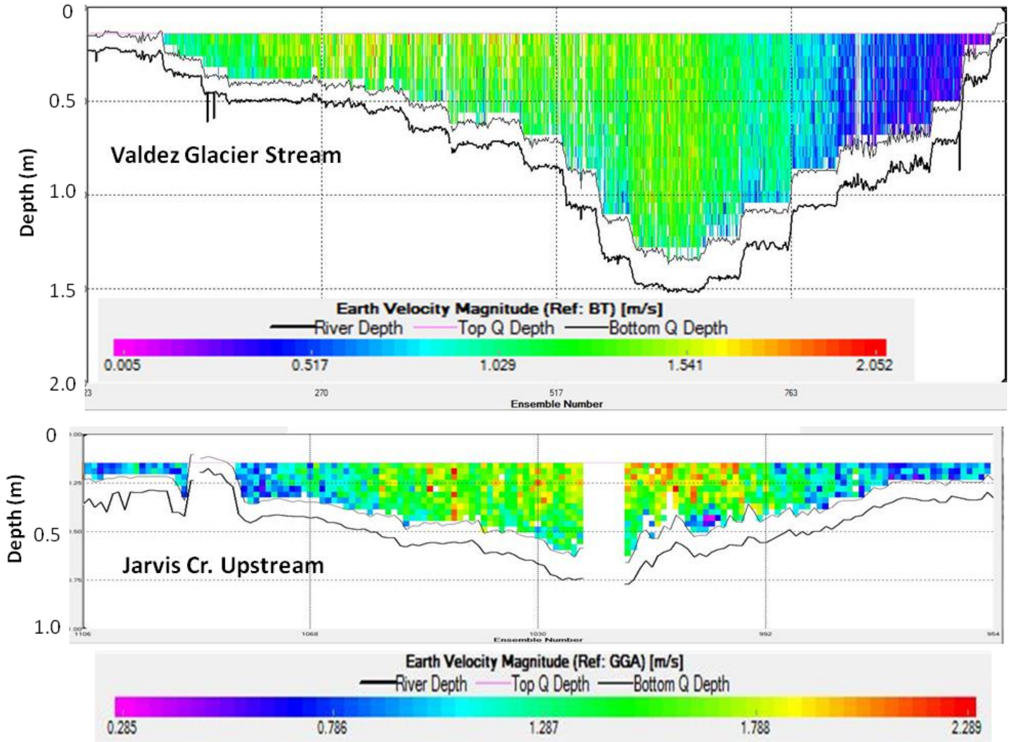


Fig. 3. *Velocity profile of Valdez Glacier Stream and Jarvis Creek generated from StreamPro ADCP data and processed using WinRiver II, from measurement conducted on May 31 and 29, respectively. The top profile is based on bottom tracking reference data. The bottom profile is based on GGA reference data. Holes in the discharge data are due to loss of GPS signal. A gap-filling algorithm is provided by the WinRiver software to estimate total runoff.*

Results

Multiple visits to the Valdez Glacier Stream and Jarvis Creek in May through September resulted in a series of discharge measurements (Table 1, 2, Fig. 3). Poor manufacturing of the StreamPro package resulted in GPS failure during the first field trip in late May. The GPS was discovered not water proofed, which resulted in battery failure. The distributor attached a small pelican case to protect the WAAS GPS system while attached to the float.

Table 1. *Discharge for Valdez Glacier Stream as measured using the StreamPro ADCP during summer 2012. Measurements were conducted at 3-4 hour intervals when possible, in order to capture diurnal variation in streamflow. *The average represents multiple measurements (>3 transects).*

Date	*Transect*	*Time*	*Average* (m^3/s)*
5/31/2012	1	1130	17.32
	2	1530	17.96
6/1/2012	1	1015	18.50
7/13/2012	1	2245	47.34
7/14/2012	1	1000	42.27
	2	1400	37.69
	3	1800	51.41
7/15/2012	1	930	58.73
9/15/2012	1	1200	19.89

Table 2. *Discharge for Jaris Creek as measured using the StreamPro ADCP during summer 2012. The downstream site is at the bridge of Richarson Hwy (site "1 km" in figure 1). The second site is about 24 km upstream.*

Site 1 – Downstream Jarvis Gauging Site			
Date	**Transect**	**Discharge (m^3/s)**	**Average**
8/29/2012	1	5.41	
	2	5.25	
	3	6.17	
	4	5.90	
	5	5.65	
	6	5.53	
			5.65
9/25/12	1	6.55	
	2	6.34	
	3	6.57	
	4	5.91	
			6.34
Site 2 - Upstream Jarvis Gauging Site			
Date	**Transect**	**Discharge (m^3/s)**	**Average**
5/29/2012	1	12.88	
	2	13.39	
			13.14
8/29/2012	1	6.32	
	2	7.27	
	3	6.40	
	4	6.09	
	5	6.70	
	6	7.93	
			6.79

Valdez Glacier Stream

The stage at the Valdez Glacier Stream varied between 16 to 17.2 masl (Fig. 4). Two major water level peaks were observed; June 26 ("Jun. event") and September 23 ("Sep. event"), respectively. Both events were preceded by heavy rainfall at Valdez airport. Summer 2013 had above average total summer precipitation (999 mm) compared to the long-term mean (586 mm, 1970-2000).

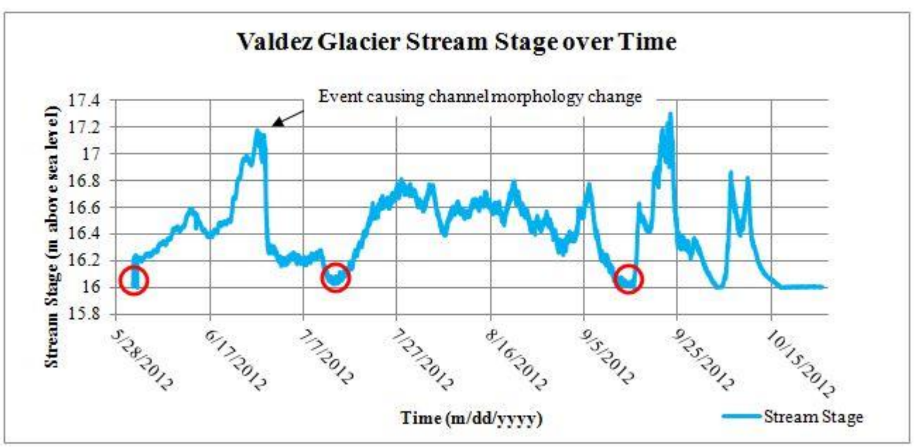


Fig. 4. *Continuous water level data in Valdez Glacier Stream as derived from a pressure transducer. Three field visits to obtain streamflow measurements were made (red circles). Additional streamflow measurements are needed to capture higher-flow events if continuous discharge is to be effectively characterized from water levels.*

The discharge measurements at the Valdez Glacier stream all represented low flow (red circles, Fig. 4), which was not intentional. However, results from the late May and mid-July field visits show differing stage-discharge relationships that produce two separate equations (Fig. 5). Despite a similar stage (16.1 and 16.2 masl, respectively, Fig. 4), discharge measured during the first (May 31-June 1) and second visit (July 13-15) was dramatically different (18 m^3 sec^{-1} and 48 m^3 sec^{-1}, respectively, Table 1). Accordingly, the June high water level event appears to have altered the stream channel morphology. This emphasizes the need to pre- and post high water event specific stage-discharge relationships.

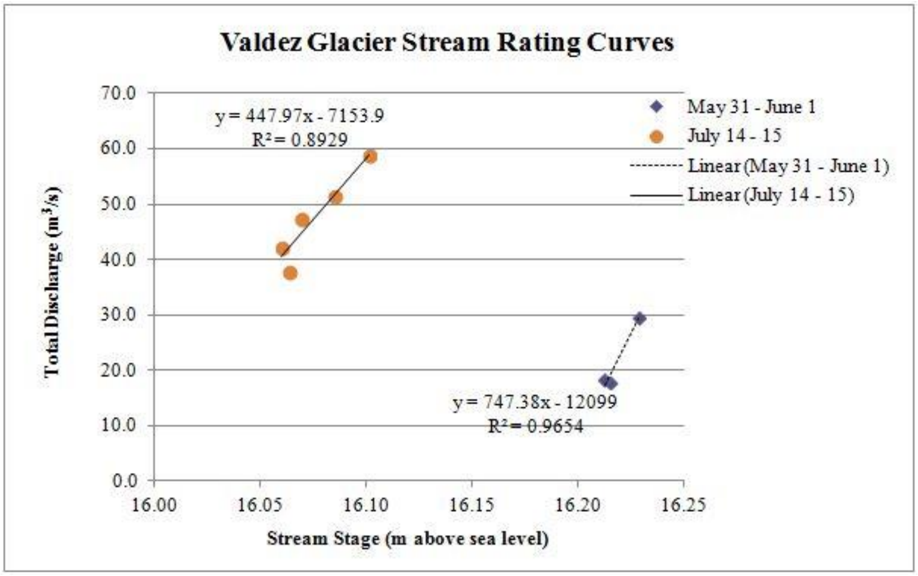


Fig. 5. *Total discharge is plotted against water level to produce a stage-discharge rating curve. Different streamflow was measured at similar water levels in May/June and mid-July, indicating a change in channel morphology. Thus, two separate equations describing the stage-discharge relationship.*

Jarvis Creek

Limited complementing funds for field travel in summer 2012 resulted in less than optimal number of runoff measurements at Jarvis Creek. Pressure transducer data at the downstream site (bridge crossing) show the seasonal peak in late September, which was related to heavy rainfall across the Alaska Range. The last site visit prior the winter was on October 10th at which time ice had started to form on the banks. The pressure transducer was frozen into the ice (Fig. 6), which prevented data retrieval. Therefore, the pressure transducer data from the upstream site has yet to be downloaded as of April 27, 2013. High water levels earlier in the season prevented safe crossing of the river to the pressure transducer. Detailed statistics of the ADCP measurements from Jarvis Creek on September 25th are found in Appendix A.

Fig. 6. *Photo of the pressure transducer well at the upstream Jarvis Creek site on Oct. 10, 2012.*

The ADCP discharge measurements from Valdez Creek Stream and Jarvis Creek watershed will continue and be expanded in summer 2013 thanks to new funding received from a student scholarship to Jennifer Davis (Center for Global Climate Change and Arctic System Research) and an award from the Alaska Department of Transportation and Public Services, respectively. The 2012 and upcoming 2013 field measurements are supporting hydrologic modeling efforts to predict the effect of climate change and increased glazier wastage on streamflow. The studies have high relevance to the local communities in respective watershed as flooding may disrupt transportation network (major highways and an airport) as well as US Army training lands and aquifer recharge in an agricultural setting that is dependent on irrigation. A website has been developed to provide general information and access to data for the Jarvis Creek hydrologic study (http://ine.uaf.edu/werc/projects/jarvis/Default.aspx).

Appendix A

Station Number: Meas. No: 0

Station Name: JarvisCr_bridge_25sept2012 Date: 09/25/2012

Party: ey, jb
Boat/Motor: tethered trimaran
Gage Height: 0.000 m

Width: 20.5 m
Area: 5.9 m²
G.H.Change: 0.000 m

Processed by: ey
Mean Velocity: 1.07 m/s
Discharge: 6.34 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (20.4°)
Depth Sounder: Not Used
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.060 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s Rating No.: 1
Adj.Mean Vel: 0.00 m/s Qm Rating: F
Rated Area: 0.000 m² Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: NO
BT Error Vel.: 0.10 m/s
WT Error Vel.: 0.60 m/s
BT Up Vel.: 0.30 m/s
WT Up Vel.: 2.50 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.09 m/s
Max. Depth: 0.490 m
Mean Depth: 0.288 m
% Meas.: 38.69
Water Temp.: None
ADCP Temp.: 7.6 °C

ADCP:
Type/Freq.: StreamPro / 2000 kHz
Serial #: 1302 Firmware: 31.12
Bin Size: 2 cm Blank: 50 cm
BT Mode: 0 BT Pings: 1
WT Mode: 12 WT Pings: 6

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: NO
Meas. Location: 50 yds ds

Project Name: jarvis_ck_bridge_25sept2012_(
Software: 2.10

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	7.20	1.00	237	2.36	2.59	0.899	0.651	0.051	6.55	20.8	6.0	17:09	17:14	0.07	1.09	1	1
001	R	7.50	1.00	171	2.29	2.45	0.900	0.658	0.047	6.34	20.6	6.0	17:14	17:17	0.08	1.06	1	1
002	L	7.50	1.00	113	2.32	2.59	0.921	0.664	0.075	6.57	20.9	6.3	17:18	17:20	0.11	1.04	1	0
003	*R*	*7.70*	*1.00*	*163*	*2.11*	*2.18*	*0.815*	*0.715*	*0.093*	*5.91*	*19.6*	*5.4*	*17:20*	*17:24*	*0.09*	*1.10*	*1*	*1*
Mean		7.48	1.00	171	2.27	2.45	0.884	0.672	0.067	6.34	20.5	5.9	**Total**	00:14	0.09	1.07	1	1
SDev		0.21	0.00	51	0.110	0.193	0.047	0.029	0.022	0.305	0.6	0.4			0.02	0.02		
SD/M		0.03	0.00	0.30	0.05	0.08	0.05	0.04	0.32	0.05	0.03	0.06			0.19	0.02		

Remarks: Stage reading 1.0
Streampro Trimaran tethered, 50 yards downstream of bridge.
Too few transects fro transect 000.
Poor moving bed test and transects due to loss of BT. Use GPS-GGA. Compass calibration good (less than 1 deg). High nur of satellite changes in GGA.
Changed magnetic declination from 20deg to 20.38 deg NOAA NGDC.
Measurement rated "Fair" (<8% uncertainty) due to COV, satellite changes, use of WAAS instead of RTK, and low number of ensembles in transect 000.

Discharge for transects in *italics* have a total Q more than 5% from the mean

Developing partnerships with rural high-schools along the Kvichak River, Alaska to map strontium (Sr) isotope (87Sr/86Sr) variation and aid tracking Pacific salmon migrations

Basic Information

Title:	Developing partnerships with rural high-schools along the Kvichak River, Alaska to map strontium (Sr) isotope (87Sr/86Sr) variation and aid tracking Pacific salmon migrations
Project Number:	2012AK108B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Biological Sciences
Focus Category:	Hydrogeochemistry, Water Use, Ecology
Descriptors:	None
Principal Investigators:	Matthew John Wooller

Publications

1. Oral Presentation: Brennan, S., Wooller, M., et al. Public Presentation. (May 2013). Sr isotopes in rivers of the Bristol Bay Region and their application to tracking population structure and movement patterns of Chinook salmon. University of Alaska, Fairbanks, Bristol Bay Campus. Dillingham, AK. Brennan, S. Presentation and demonstration. (April. 2013). Using Sr isotopes to tracking fish movements. Invited visiting lecture to MSL661 students, UAF. Brennan, S. Presentation and demonstration. (Sep. 2012). Using ear-bones (otoliths) of Chinook salmon to track movement patterns in the Nusahgak River. New Stuyahok School. New Stuyahok, AK. Brennan, S. Presentation. (Sep. 2012). Developing a high-resolution 87Sr/87Sr baseline map of the Nusahgak River to track Chinook salmon migration and population structure. Water and Environmental Research Center – Seminar. Fairbanks, AK. Brennan, S. Presentation and demonstration. (Sep. 2012) Using Sr isotopes to track salmon in Alaska and why it's important to conserve biodiversity. Salmon Workshop for Rural Alaskan Teachers. Center for Ocean Science Education Excellence (COSEE). Fairbanks, AK Wooller, M.J. Presentation and demonstration. (Sep. 2012) Using stable isotopes to track animal feeding and migration ecology. Salmon Workshop for Rural Alaskan Teachers. Center for Ocean Science Education Excellence (COSEE). Fairbanks, AK
2. Journal Publications and News Articles: "Salmon in the Classroom Teacher Training". Fishlines Newsletter. Alaska Sea Grant. Vol. 32, No. 10, October 2012. "You are what you eat and where you live" – INE-WERC introduces teachers to the fascinating world of stable isotope research. Water and Environmental Research Center - News. October 22, 2012. Link: http://ine.uaf.edu/werc/2012/10/22/you-are-what-you-eat-and-where-you-live-inewerc-introduces-teachers-to-t Brennan, S., Wooller, M.J., et al. (in prep.) ¬Mapping 87Sr/87Sr variations in bioavailable Sr across Alaska: implications for large-scale provenance studies.

NIWR Progress Report

Title: Developing partnerships with rural high schools along the Kvichak River, Alaska to map strontium (Sr) isotope ($^{87}Sr/^{86}Sr$) variation and aid tracking Pacific salmon migrations

Start date: March 1, 2012

End date: Feb 28, 2013

Focus Category: Hydro Geochemistry - HYDGEO, Water use - WU, Ecology - ECL.

Descriptors: Western Alaskan Rivers, salmon migration, strontium isotopes, biodiversity, conservation.

PI: Dr. Matthew John Wooller

Products of Project:

Oral Presentation:

Brennan, S., Wooller, M., et al. *Public Presentation.* (May 2013). Sr isotopes in rivers of the Bristol Bay Region and their application to tracking population structure and movement patterns of Chinook salmon. University of Alaska, Fairbanks, Bristol Bay Campus. Dillingham, AK.

Brennan, S. *Presentation and demonstration.* (April. 2013). Using Sr isotopes to tracking fish movements. Invited visiting lecture to MSL661 students, UAF.

Brennan, S. *Presentation and demonstration.* (Sep. 2012). Using ear-bones (otoliths) of Chinook salmon to track movement patterns in the Nusahgak River. New Stuyahok School. New Stuyahok, AK.

Brennan, S. *Presentation.* (Sep. 2012). Developing a high-resolution $^{87}Sr/^{87}Sr$ baseline map of the Nusahgak River to track Chinook salmon migration and population structure. Water and Environmental Research Center – Seminar. Fairbanks, AK.

Brennan, S. *Presentation and demonstration.* (Sep. 2012) Using Sr isotopes to track salmon in Alaska and why it's important to conserve biodiversity. Salmon Workshop for Rural Alaskan Teachers. Center for Ocean Science Education Excellence (COSEE). Fairbanks, AK

Wooller, M.J. *Presentation and demonstration.* (Sep. 2012) Using stable isotopes to track animal feeding and migration ecology. Salmon Workshop for Rural Alaskan Teachers. Center for Ocean Science Education Excellence (COSEE). Fairbanks, AK

Journal Publications and News Articles:

"Salmon in the Classroom Teacher Training". Fishlines Newsletter. Alaska Sea Grant. Vol. 32, No. 10, October 2012.

"You are what you eat and where you live" – INE-WERC introduces teachers to the fascinating world of stable isotope research. Water and Environmental Research Center - News. October 22, 2012. Link: http://ine.uaf.edu/werc/2012/10/22/you-are-what-you-eat-and-where-you-live-inewerc-introduces-teachers-to-the-fascinating-world-of-stable-isotope-research/

Brennan, S., Wooller, M.J., et al. (in prep.) Mapping $^{87}Sr/^{87}Sr$ variations in bioavailable Sr across Alaska: implications for large-scale provenance studies.

Introduction: problem, objectives, and relevance

Problem

A challenging issue in freshwater ecological conservation is tracking population response to perturbations. This is especially difficult when studying population dynamics of anadromous fish such as, salmon of the North Pacific. Pacific salmon stocks (e.g., Chinook - *Oncorhynchus tshawytscha*) have shown dramatic changes in returns into Western Alaskan Rivers. Salmon not only maintain an important mechanism of nutrient transport between marine, aquatic and terrestrial ecosystems, but are also a valuable resource to humans. The population structure of salmon is hierarchical with a strong geographical relationship. Large-scale changes in the freshwater environment such as mineral development by humans pose real threats to the biodiversity and overall productivity of these species, and to human communities dependent upon sustainable returns of salmon year to year. Thus, there are large efforts to develop tools to track salmon natal sources and habitat use patterns to better conserve salmon biodiversity and productivity, and the natural resource they represent to human communities.

Goal

The goal of this research is to geochemically characterize salmon natal sources and habitats of a productive Western Alaska River – the Kvichak River – and to develop collaboration with High School students and teachers of the village schools within this watershed to collect water samples and learn how these techniques can be used to track salmon population structure and migration patterns. Geochemical measurements of river and lake waters collected during this project will be used to generate a map of strontium (Sr) isotope ratio ($^{87}Sr/^{86}Sr$) variation within this watershed to help develop an accurate and economical method for tracking natal and rearing habitat use of salmon breeding populations in the Kvichak River. This map will depict the $^{87}Sr/^{86}Sr$ composition of salmon natal sources of the Kvichak, which can be used to help resolve mixed stock fisheries conducted in Bristol Bay, AK region. This project focuses mainly on collection and analysis of water samples from the Kvichak River and education of students and teachers in the methods of using geochemical markers and otoliths to help conserve biodiversity in the Kvichak River. $^{87}Sr/^{86}Sr$ compositions of aqueous environments are recorded in the otoliths (the auditory structure of teleost fish) of salmon incrementally like tree rings, such that variations in the aquatic habitats used by salmon are recorded throughout an individual fish's life span. The water analyses generated from this project will be incorporated into ongoing work in Western Alaska and adjacent basins (e.g. the Nushagak River) to characterize the $^{87}Sr/^{86}Sr$ composition of freshwater environments. This baseline dataset can then be used to track population structure and migration patterns of salmon in the Bristol Bay Region. This will help current management efforts to conserve salmon biodiversity and sustain salmon productivity.

Objectives

The objectives of this study were:

1) To spatially characterize geochemical constituents, primarily $^{87}Sr/^{86}Sr$ ratios, in waters of the Kvichak River.

2) To develop collaborations with Kvichak River village schools to collect water samples so as to give teachers and students in the region hands-on experience in a scientific investigation taking place within their region and aimed at developing tools to help manage the natural resources in the region.

Relevance

This study is part of the first thorough investigation and evaluation in Alaska of whether $^{87}Sr/^{86}Sr$ variation between and within watersheds can be used to track natal sources of Pacific salmon using water and otolith geochemistry to help resolve mixed-stock fisheries. This will have implications on the sound management of Pacific salmon biodiversity and productivity by providing an accurate, high-resolution and economically sound tool to track harvests on different breeding populations of the Bristol Bay Region.

Methods

Water sample collection and development of sampling kits and protocols for village schools:

Six schools along the Kvichak Watershed agreed to participate in this water sampling campaign and each school participating received a complete sampling kit. Sample sites and participating village schools are pictured in Figure 1, and listed in Table 1. Detailed protocols for water sample collection and filtration were sent with kits, including background information on methods and applications so the teachers could provide context for the students during sampling events. Each school received a sampling kit containing supplies for four sampling events: three single sampling events and one triplicate sampling event. The kit also contained supplies for each school to collect a 'blank', whereby collection and filtration methods are mimicked in the field using ultra pure de-ionized water. The blank and triplicate sampling events are used to evaluate potential contamination (the blank) and consistency (the triplicate) at each school. Initially, water was collected into acid washed 250 ml LDPE bottles. Following collection, all samples, triplicates and blanks were filtered using 0.45 μm syringe filters within 48 hours of collection into acid washed 125 ml LDPE bottles. Following filtration samples were sent to Sean Brennan in Fairbanks to be acidified with Ultrapure concentrated nitric acid within 16 days of collection and stored cool until analysis. Water samples from major tributaries of the Kvichak River were collected for $^{87}Sr/^{86}Sr$ and major and trace elemental analyses.

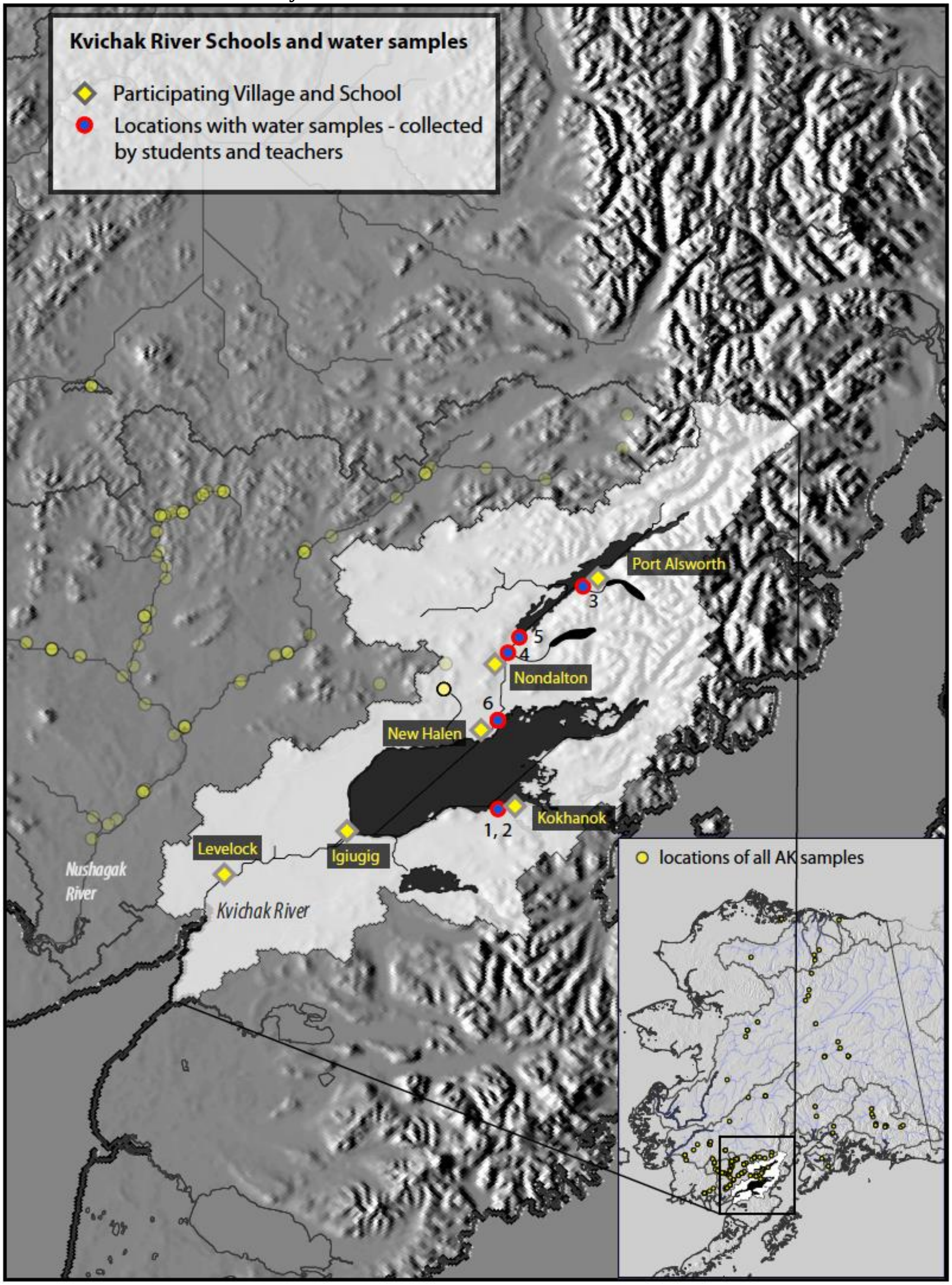
Water isotopic and elemental analyses:

Sr isotopic compositions of waters were determined using a Thermo Scientific NEPTUNE High Resolution multi-collector inductively coupled mass spectrometer (MC-ICPMS) at the University of Utah ICPMS Laboratory. Elemental analyses were determined using an Agilent 7500ce inductively coupled mass spectrometer. All samples prepared for elemental and strontium isotopic analysis are prepared in a clean laboratory in laminar flow hoods.

Table 1: Water samples collected during 2012 from the Kvichak watershed by teachers and students.

Village school	River / sampling site	Sample ID	Collection Date	Sample type	Blank	Elemental	$^{87}Sr/^{86}Sr$
Kokhanok	Gibraltar river Fall	1	10/1/12	single	-	x	x
	Gibraltar river Spring	2	4/16/12	single	-	x	x
Port Alsworth	Tanalian R.	3	4/24/12	single	-	x	x
Nondalton	Tazimina R.	4	11/5/12	single	-	x	x
	Outlet of Lake Clark	5	5/16/12	single	-	x	x
Newhalen	Newhalen River	6	9/27/12	triplicate	x	x	x
Igiugig	-		-	-	-	-	-
Levelock	-		-	-	-	-	-

Figure 1: Participating villages and schools and locations of water samples collected for $^{87}Sr/^{86}Sr$ and elemental analyses within the Kvichak watershed



Results

The Kvichak samples make up an important contribution to our Alaska-wide sampling campaign to characterize Sr isotopic compositions of Alaska Rivers. These data add significantly to prior and ongoing data collected during the 2009/2010, 2010/2011 NIWR awards, which were used to conduct the first Trans-Alaska Strontium Isotope Survey (TASIS) and to document variation within the Nushagak River, respectively. The total variation observed in Alaska is 0.70420 – 0.74041.

The $^{87}Sr/^{86}Sr$ range in samples collected from tributaries of the Kvichak Watershed range from 0.70432 - 0.70518. Four out of the six schools which participated collected and sent samples thus far. Samples are still being collected and sent to Sean Brennan for analysis. One school (New Halen) executed a triplicate sampling event, which indicated that the collection methods for isotope analysis and elemental abundance estimates were sufficient to produce high precision (± 0.000025 standard error of mean $^{87}Sr/^{86}Sr$ ratio, and 2.0% total analytical error of mean Sr umol/L, respectively). Additionally, the same school executed a field blank collection, which indicated that all elements were below the limit of determination (LOD) (e.g. for Sr LOD=0.000044 Sr mg/L). This suggests that the collection methods employed by the New Halen School, as instructed via the sampling protocol and plan developed by our team, was sufficient in avoiding contamination during field collection and filtration. As shown in Figure 1 the samples were collected from the Tanalian River, Tazimina River, outlet of Lake Clark, New Halen and Gibraltar Rivers. Compared to the adjacent basin, the Nushagak River, this is a relatively small observed range in Sr isotope compositions. This is an important finding in and of itself, indicating smaller within watershed variation in the Kvichak relative to the Nushagak. This is largely driven by the differences in geology between these two basins. Namely, the Kvichak water shed drains the young mafic to intermediate mantel derived plutonic and volcanic rocks associated with the Alaskan-Aleutian Range. While the Nushagak drains both the rocks of the Alaskan-Aleutian Range and the older more felsic, continentally derived rocks of the Kuskokwim group associated with the Nushagak Hills and Taylor Mountains, which lie north of the Alaskan-Aleutian Range. The variation that we do see within the Kvichak is likely driven primarily by compositional differences (e.g. felsic vs. mafic) between different rock groups within this watershed. For example within in the Kvichak there are is both mafic volcanic rocks and felsic plutonic rocks.

During this study we have developed good working relationships with the teachers and students of the villages around the Kvichak Schools. Reports from teachers indicate that the students were interested and enjoyed conducting the water sampling events, learning about a currently developing technique to track their salmon resources, and participating in current ongoing research within the watershed in which they live. The teachers have communicated interest in continuing the water sampling, which will be particularly useful for research questions regarding seasonal and inter-annual changes in the Sr isotopic composition of river and lake waters. Collaborations such as the ones developed via this project are mutually beneficial for both us as researchers and for the teachers and students. As researchers, we get access to samples in a remote and often prohibitively expensive region and get to interact with the communities, which depend upon the organisms in which we study. The teachers and students benefit by getting experience with ‘real-life’ science and get to interact in a hands-on fashion with the types of research questions that are relevant to their home-region.

Rapid Moving Debris Lobes in the Brooks Range of Alaska

Basic Information

Title:	Rapid Moving Debris Lobes in the Brooks Range of Alaska
Project Number:	2012AK109B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	Alaska
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Groundwater, Geomorphological Processes
Descriptors:	None
Principal Investigators:	Ronald P. Daanen

Publications

1. Daanen, R.P., M.M. Darrow, G. Grosse, B. Jones, 2012, Frozen debris lobes, permafrost slope instability, and a potential infrastructure hazard in the south-central Brooks Range of Alaska. Poster presentation AGU Fall Meeting, San Fransisco, CA.
2. Daanen, R.P., G. Grosse, M. Darrow, T.D. Hamilton, and B.M. Jones, 2012. Rapid movement of frozen debris-lobes: implications for permafrost degradation and slope instability in the south-central Brooks Range, Alaska. Natural Hazards and Earth System Sciences 12(5), 1521-1537.
3. Darrow, M., R.P. Daanen, J. M. Simpson, 2012. Monitoring and Analysis of Frozen Debris Lobes, Phase I, Alaska Department od Transportation & Public Facilities Report: FHWA-AK-RD-12-17. K. Hopkins, 2012. Frozen landslide threatens to devour Dalton Highway, Anchorage Daily News.

Title: Rapid debris lobes in the Brooks Range, Alaska
Start date: March 1, 2012

End date: Feb 28, 2013

Focus Category: Hydro Geochemistry – HYDGEO
Descriptors: Sediment movement, Brooks Range, Permafrost, Climate Change.

PI: Dr. Ronald Daanen

Products of Project:

Darrow, M., R.P. Daanen, J. M. Simpson, 2012. Monitoring and Analysis of Frozen Debris Lobes, Phase I, Alaska Department od Transportation & Public Facilities Report: FHWA-AK-RD-12-17.

Daanen, R.P., M.M. Darrow, G. Grosse, B. Jones, 2012, Frozen debris lobes, permafrost slope instability, and a potential infrastructure hazard in the south-central Brooks Range of Alaska. *Poster presentation* AGU Fall Meeting, San Fransisco, CA.

K. Hopkins, 2012. Frozen landslide threatens to devour Dalton Highway, Anchorage Daily News.

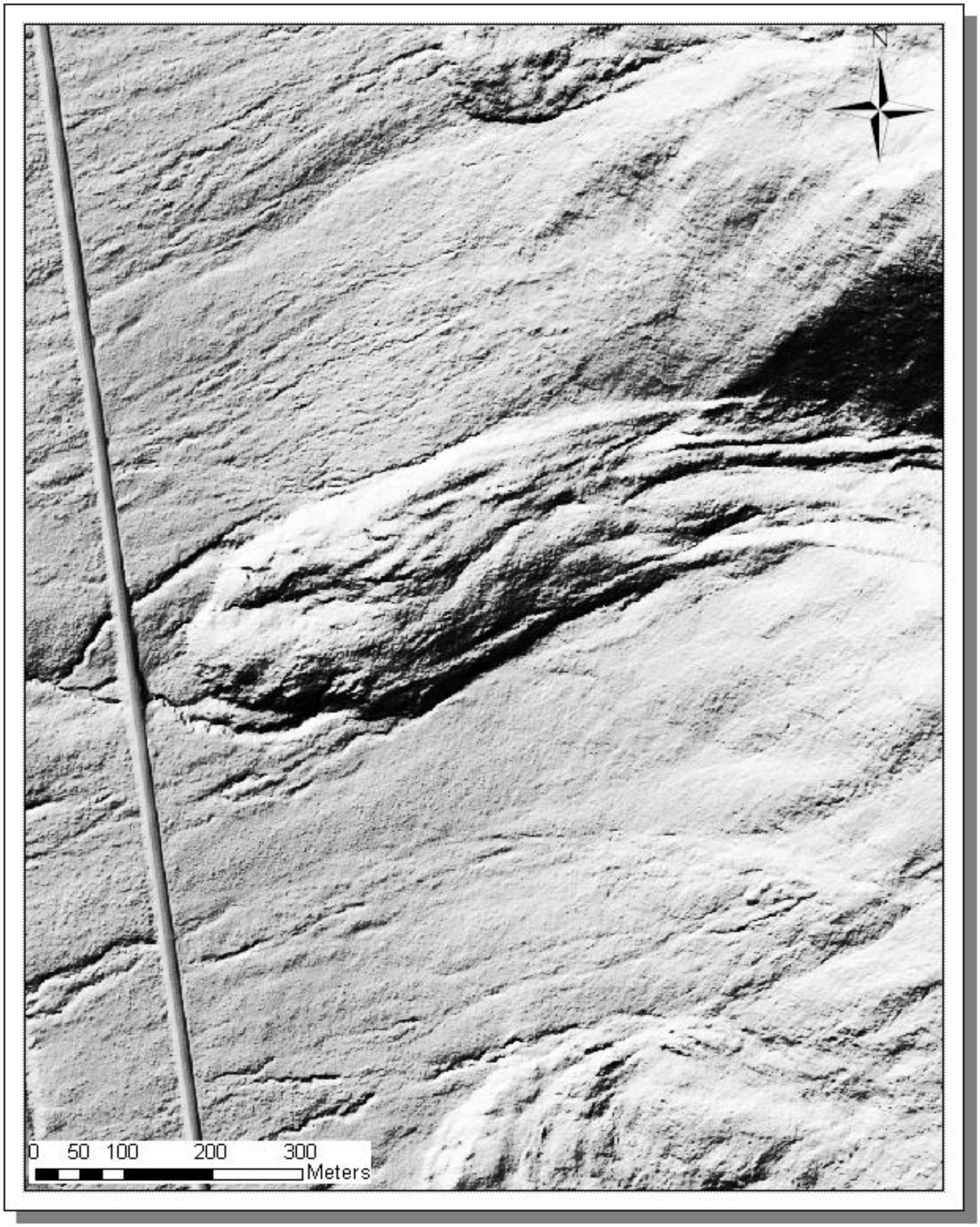
Daanen, R.P., G. Grosse, M. Darrow, T.D. Hamilton, and B.M. Jones, 2012. Rapid movement of frozen debris-lobes: implications for permafrost degradation and slope instability in the south-central Brooks Range, Alaska. Natural Hazards and Earth System Sciences 12(5), 1521-1537.

Summary of finding to date

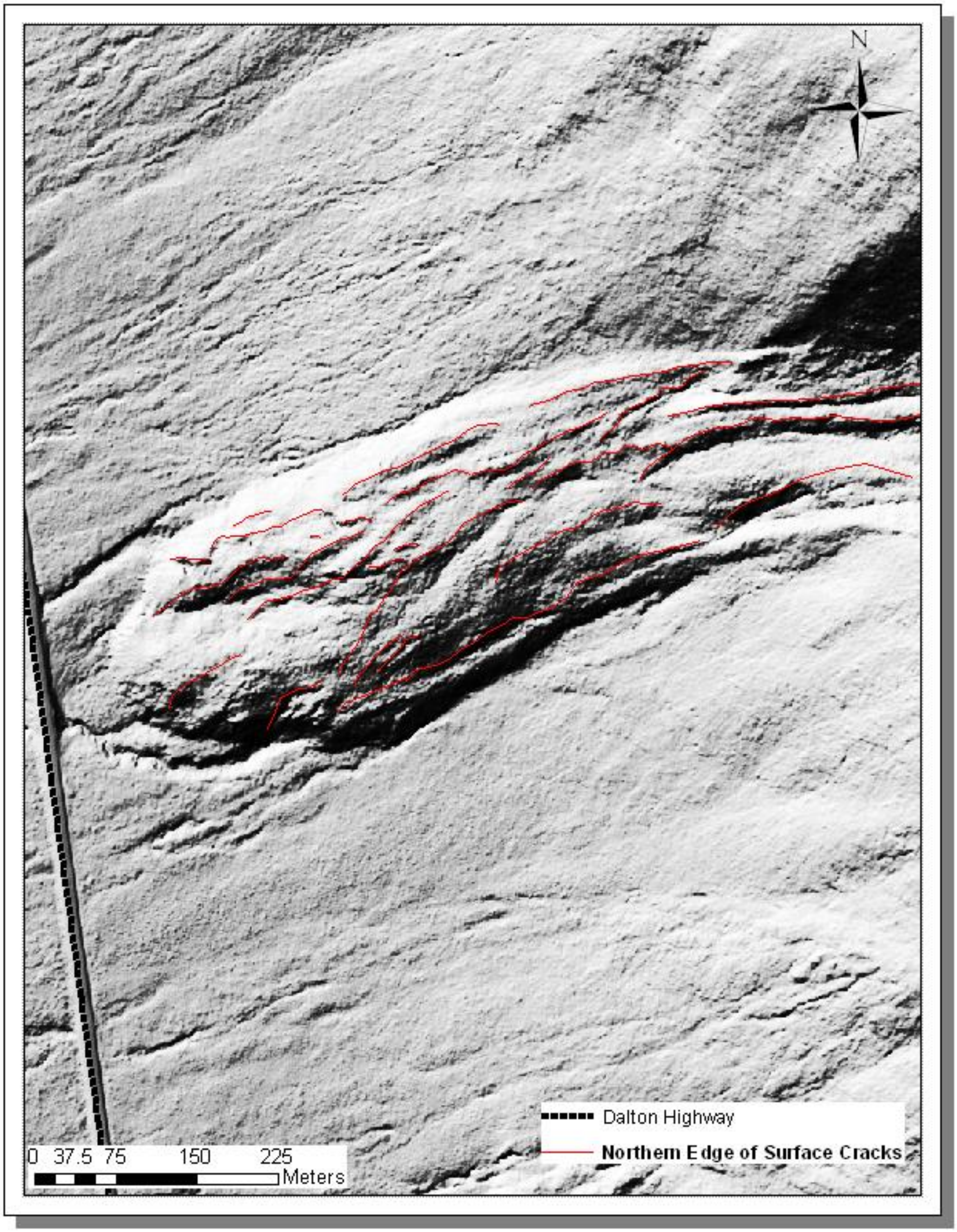
Frozen debris lobes are mass movement features on the slopes of mountain sides in the south central Brooks Range. These features are actively moving at rates up to multiple inches per hour. Current research focusses on the mechanisms of movement through the assessment of movement throughout the seasons and detailed surface analyses of these features. One character of the features is large cracks in the surface that appear to be very deep. These cracks allow snow melt infiltration and bypass frozen ground. It was observed that supper cooled water is present at a depth of 75 feet in these features with temperatures down to -1.2˚C. Super cooled water at this temperature needs to have a pressure of 480 feet water column to prevent freezing, This pressure can only be maintained through larger pathways up the hill along the sliding surface of these features at the same depth of 75 feet below the surface near the center of the lobe. The water cannot escape these conduits, because a release of pressure would instantly freeze the water and close the pathway out of the conduit.

NIWR funding has enabled us the support a student working on the crack analysis together of with the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys. Support from the Alaska department of Transportation & Public Facilities together with the Alaska University Transportation Center have provided funding to support a drilling campaign and instrument installation on the closest Frozen debris lobe to the Dalton Highway. These results are summarized in the report mentioned above. The following sections describe the latest results of the crack analysis and movement observations over the past ½ year.

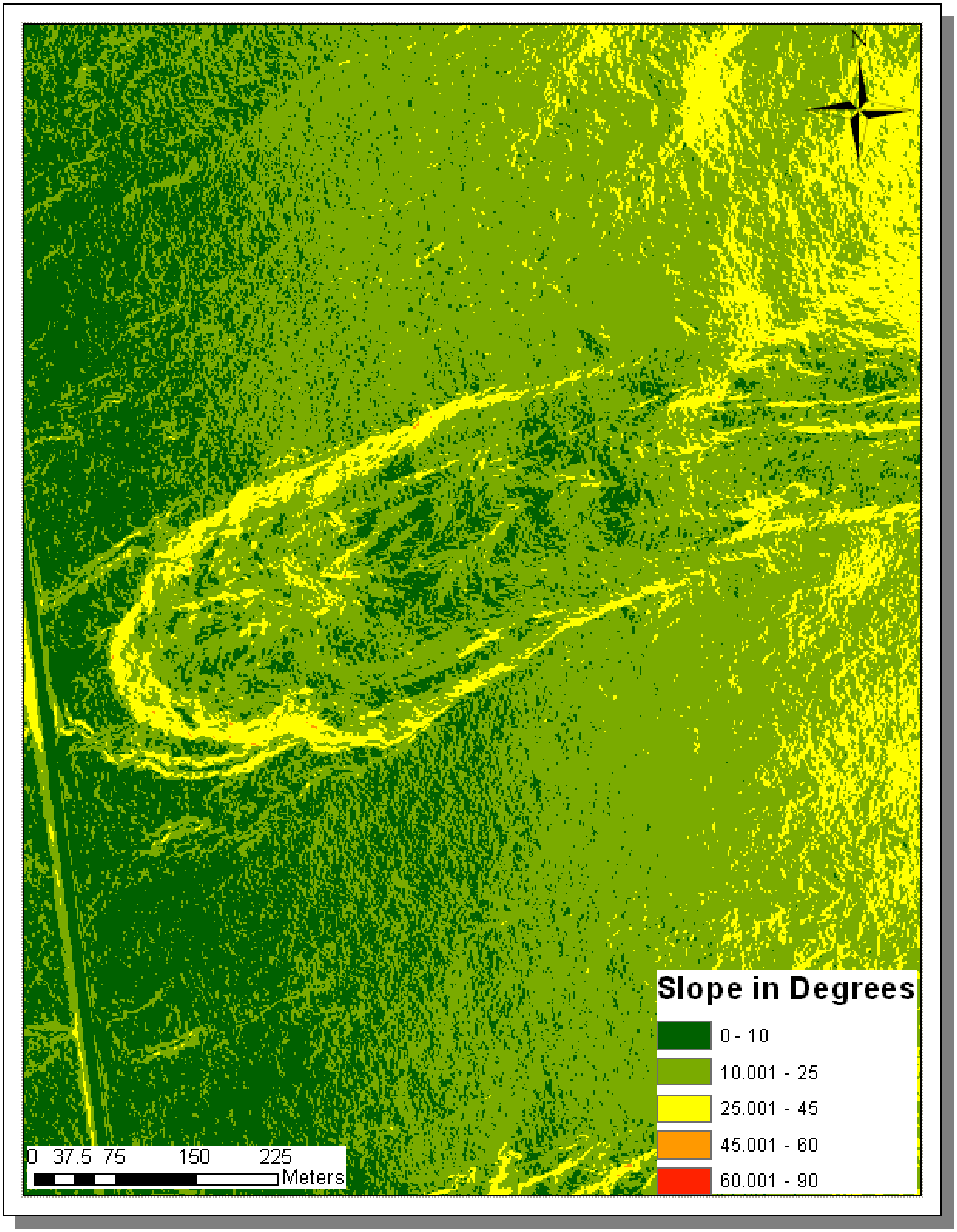
Crack analysis



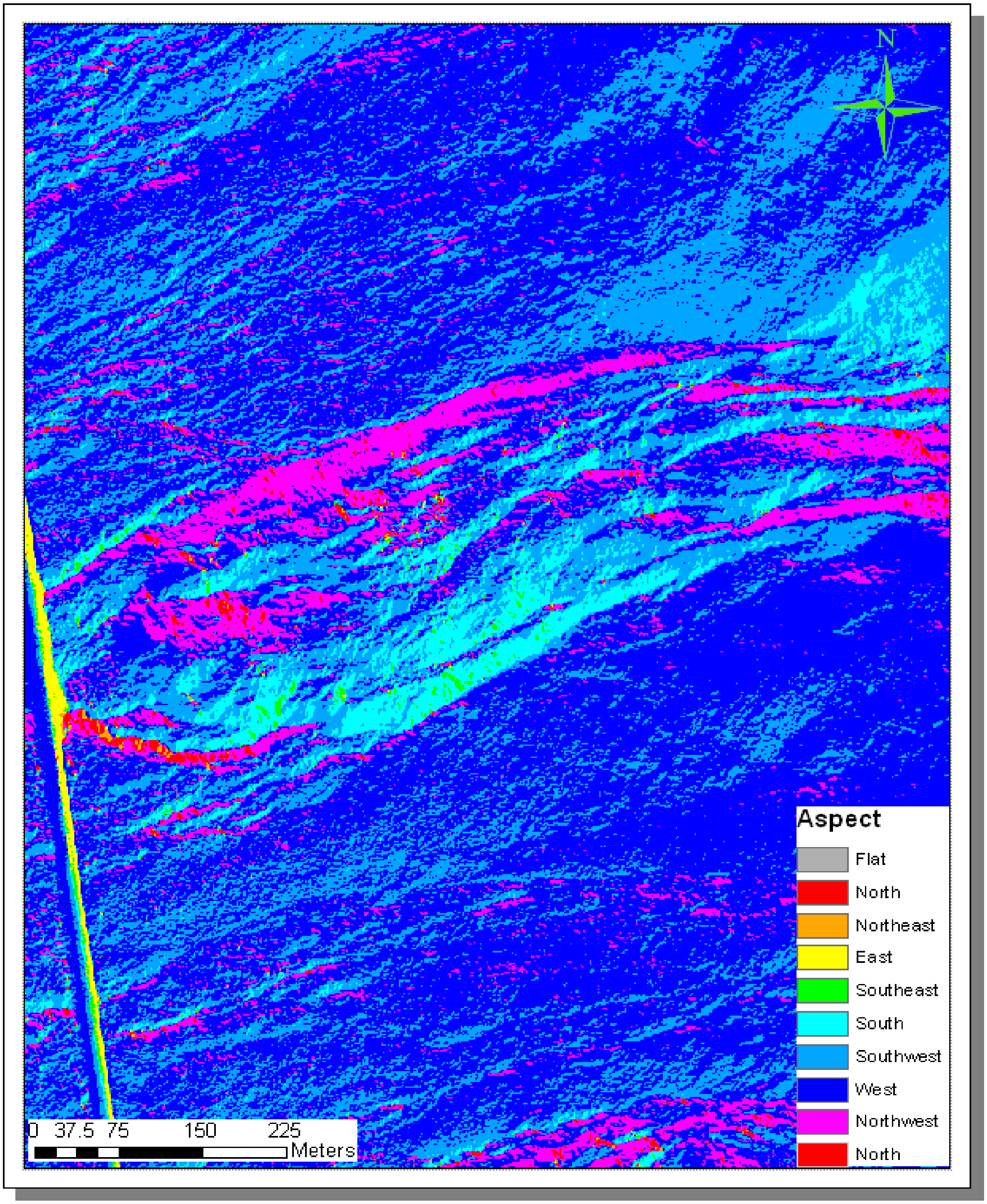
FDL-A hillshade (azimuth 315, angle 45) with histogram equalize stretching applied



same as above with northern edge of cracks traced



Degree Slope



Slope Aspect

LiDAR imagery obtained from the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys is currently being used to carry out the mapping of surface cracks on FDL-A. Several techniques are being applied in an attempt to find the most accurate way of defining these features on the lobe.

Multiple hillshade models, shaded relief rasters based off of elevation rasters, have been created in ArcMap using the bare earth LiDAR data. These models can be produced at varying sun azimuths and angles to generate images where the shadowing and contrast highlights the surface cracks. Slope and aspects models were also created and have aided in the identification of cracks through slope degree and position changes.

These methods have been useful in seeing the northern most sides of the cracks; however, it has been difficult identifying the full extent of them. The next methods that will be attempted are analysis of surface or topographical roughness and graphing elevation changes on the lobe using the digital elevation model. It is anticipated that this will give a better representation of these surface features on FDL-A.

Movement analysis

The following is a summary of surface measurements made of FDL-A on October 27 and November 23, 2012, and on April 13, 2013. The distribution of total surface movement measured between October 2012 and April 2013 is shown in feet in Figure 1. The upper portion of the lobe was moving faster than the toe, with nearly 8 feet of movement in the upper reaches and an average of just over 5 feet of movement closer to the toe.

Combined with the *in situ* measurements obtained in September and October, FDL-A moved at an average rate of 0.7 inches per day between September 2012 and April 2013. This value is two to three times larger than the historic rates of FDL-A movement based on aerial photograph analysis. Of more concern, this rate occurred during the fall and winter months when movement was anticipated to slow or stop due to frozen soils. Table 1 contains a summary of overall movement and average rates of movement in inches per day for the measurement period.

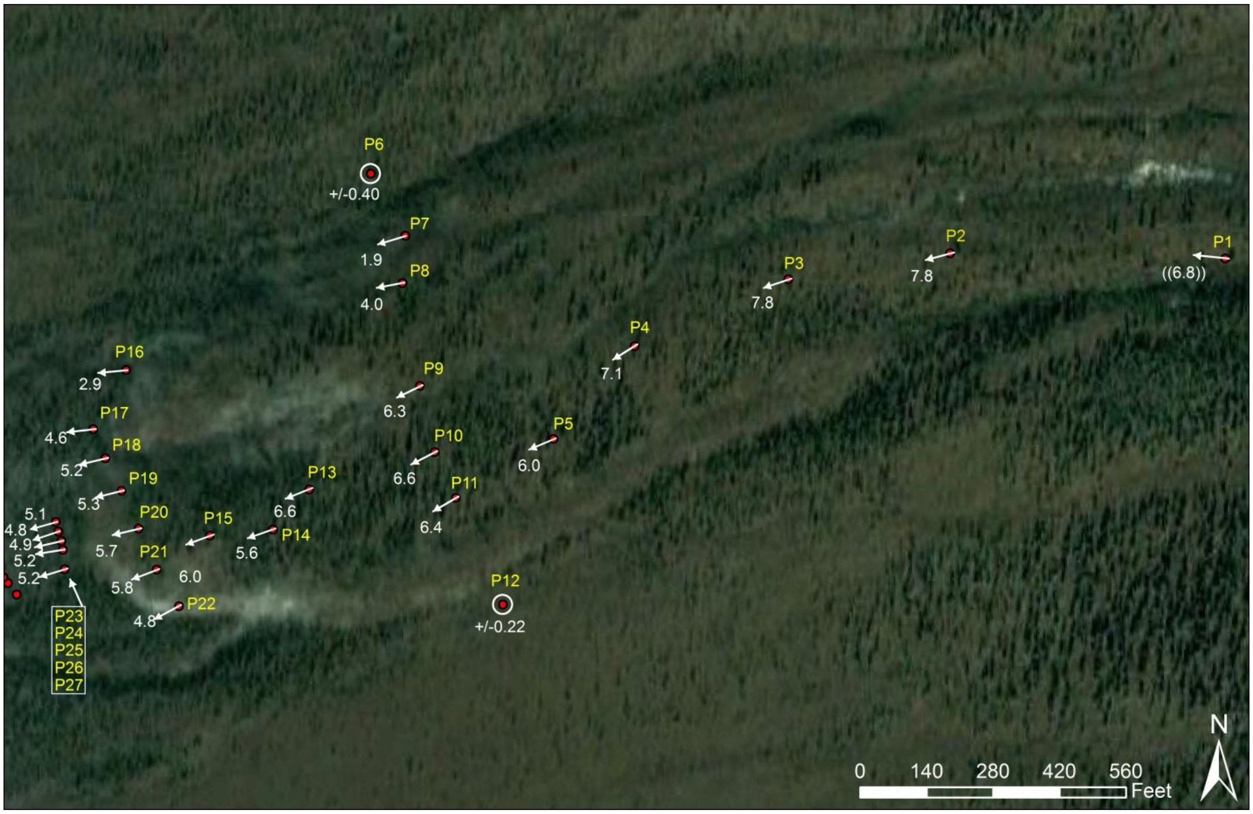


Figure 1: Surface measurement points on FDL-A. Point identifiers are shown in yellow. Total surface movement measured in feet from October 2012 until April 2013 are shown in white near the arrow heads. Arrows are not vectors; instead they show the relative reaction of movement. The reading shown in double parentheses for P1 reflects movement between November and

April, as an accurate reading was not obtained for October. The base image, which was imported from Google Earth, was acquired in 2002. It does not accurately represent the location of FDL-A, which has advanced since its acquisition. The current toe is indicated by the row of red dots that are at the extreme left of the image.

Table 1: Summary of surface movement measurements and average rates. Points P6 and P12 are located off of the lobe and act as control points to show overall error in measurements. The reading shown in double parentheses for P1 reflects movement between November and April, as an accurate reading was not obtained for October. The three asterisks for P18 indicate that no reading was obtained for this point in November.

POINT	Movement (feet)			Rate (inches/day)	
	10/27-11/23	11/23-4/13	TOTAL Oct - April	10/27-11/23	11/23-4/13
P1	---	6.8	((6.8))	---	0.6
P2	2.9	4.9	7.8	1.3	0.4
P3	3.2	4.6	7.8	1.4	0.4
P4	2.4	4.8	7.1	1.1	0.4
P5	2.0	4.0	6.0	0.9	0.3
P6 (control)	---	---	±0.4	---	---
P7	0.6	1.3	1.9	0.3	0.1
P8	0.9	3.1	4.0	0.4	0.3
P9	1.8	4.5	6.3	0.8	0.4
P10	2.2	4.4	6.6	1.0	0.4
P11	2.2	4.2	6.4	1.0	0.4
P12 (control)	---	---	±0.2	---	---
P13	2.5	4.1	6.6	1.1	0.4
P14	1.0	4.6	5.6	0.5	0.4
P15	1.8	4.2	6.0	0.8	0.4
P16	0.7	2.3	2.9	0.3	0.2
P17	0.9	3.7	4.6	0.4	0.3
P18	---	---	5.2***	---	
P19	1.2	4.1	5.3	0.5	0.3
P20	1.9	3.8	5.7	0.9	0.3
P21	1.6	4.1	5.8	0.7	0.4
P22	1.0	3.8	4.8	0.5	0.3
P23	1.5	3.7	5.1	0.7	0.3
P24	1.1	3.7	4.8	0.5	0.3
P25	1.4	3.5	4.9	0.6	0.3
P26	1.4	3.8	5.2	0.6	0.3
P27	1.5	3.7	5.2	0.7	0.3

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Notable Awards and Achievements