Water and Environmental Research Center
Annual Technical Report
FY 2011

Introduction

WERC continued its growth during the period from March 2011 through February 2012. The Center hired two new research faculty members during the reporting period, bringing the total number of affiliated faculty members to 20. We retained our 10-member research support staff, and mentored approximately 20 graduate students. The Center was successful in obtaining research funds, winning $4.7M in new research awards over the reporting period. The 35 individual grants initiated during the reporting period ranged from $1,000 to $800,000, and had a median value of $45,000.

Research Program Introduction

WERC research activities are driven primarily by issues related to resource development, municipal supplies, ecosystem management, and climate change. In many instances, two or more of these broad categories inform the rationale behind a specific research effort. Alaska is a vast state with a comparatively sparse population and limited infrastructure. Consequently, much of the research is dedicated to understanding hydrologic processes in regions that are understudied and/or undeveloped. Moreover, the arctic and subarctic climate experienced in much of Alaska presents hydrologic conditions not found elsewhere in the US, and requires dedicated expertise and study.

Although hydrologic research in Alaska is technically and logistically challenging, it is crucial not only for the benefit of the state, but also for the benefit of the nation. Alaska represents the nation's single toehold in the Arctic, with coastlines along the Beaufort, Chukchi, and Bering Seas. With the reduction in Arctic Ocean sea ice accompanying a warming climate, shipping activity as well as resource development in the Arctic Ocean are certain to increase. The United States has a stake in this development, and Alaska is the base from which US arctic activities will be conducted. Gaining a better understanding of lake water availability, river discharge, permafrost-groundwater interactions, remote water/wastewater treatment options, climate-related transformations, and a host of related issues is a necessary precursor to increased development in America's Arctic.

The WERC is an interdisciplinary team with the expertise and the inclination to take on a wide variety of research topics in order to meet the needs of the State and the Nation. While the research performed under the WRRA 104(b) program is an important component of our research portfolio, this work represents only a fraction of the varied topics investigated at our Center. Nonetheless, the 104(b) projects elicit 2:1 matching funds from the State, which constitute a significant portion of the WERC's base funding. Consequently, while the topics studied in our 104(b) projects represent only a small sampling of the topics studied at WERC, these projects are crucial to the continued functioning of the Center.

Integrating Remote Sensing and Local Knowledge to Monitor Seasonal River Ice Dynamics

Basic Information

Title:	Integrating Remote Sensing and Local Knowledge to Monitor Seasonal River Ice Dynamics
Project Number:	2011AK100B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Ecology, Hydrology
Descriptors:	
Principal Investigators:	Knut Kielland

Publications

1. Jones, C., L.D. Hinzman, K. Kielland, W. Schneider. In prep. Using local knowledge, hydrology, and climate data to develop a driftwood harvest model in interior Alaska.
2. Jones, C., K. Kielland, L.D. Hinzman, D. Kane. In prep. Quantifying the heat dynamics of ground water flux into the Tanana River, Alaska.
3. Jones, C.E., L.D. Hinzman, and K. Kielland. 2012. Characterizing seasonal and spatial variability of groundwater in the Middle Tanana Valley. Alaska EPSCoR Annual Meeting. May 24-25, 2012.
4. Jones, C., L.D. Hinzman, K. Kielland. 2011. Using local knowledge, hydrology, and climate data to develop a driftwood harvest model in interior Alaska. 2011 American Geophysical Union Meeting, San Francisco, CA. December 5–9, 2011.
5. Jones, C., L.D. Hinzman, K. Kielland. 2011. Integrating remote sensing and traditional knowledge to assess hazardous river conditions. 2011 AWRA Alaska Section Annual Conference, Fairbanks, AK. April 4–6, 2011.
6. Jones, C., L.D. Hinzman, K. Kielland. 2011. Integrating remote sensing and traditional knowledge to assess hazardous river conditions. 2011 4-IGERT Workshop. “Understanding rapid environmental and social change in the Arctic: Bridging traditional knowledge and interdisciplinary science across IGERTs, Juneau, AK. March 22–24, 2011.

INTEGRATING REMOTE SENSING AND LOCAL KNOWLEDGE TO MONITOR SEASONAL RIVER ICE DYNAMICS

PROBLEM STATEMENT

This research uses scientific collaborations and knowledge exchange to gain a comprehensive understanding of hazardous river conditions facing subsistence users in rural Alaskan communities. River conditions in interior Alaska are projected to become less predictable due to climate change. Because Alaskan rivers are integral to subsistence activities for many rural Alaskans year round, increased variability in river conditions (e.g. timing of break-up and freeze-up, flood magnitude and frequency, ice conditions) may have adverse impacts on many rural Alaskan residents. Our research plan proposes to combine remote sensing, field studies, and local knowledge to examine the seasonal nature of river conditions from freeze-up through break-up on the Tanana River. This research is of significant interest to rural residents, academics, and government agencies as it seeks a comprehensive understanding of physical processes that have substantial impacts in communities across Alaska. The integration of observational and scientific data to examine hazardous river conditions will represent an important step towards a comprehensive understanding of how global changes may impact Alaskan rivers and the rural Alaskan residents that rely upon rivers for subsistence activities.

Since 2006, we have worked collaboratively with rural Alaskans to study social-ecological linkages to dangerous river ice on the Tanana River. The blending of information based upon scientific instrumentation and remote sensing to those based on local human observations of weather, flora, and fauna have yielded synergistic understanding of a variety of physical and biological phenomena (Huntington 1998, Krupnik and Jolly 2002, Schneider et al. 2005, Chapin 2006). Through our project, we have sought to build partnerships among scientific disciplines (social and natural science) and local peoples with a long tradition of environmental observations.

While traveling rivers by boat in the summer poses obvious risks, winter river travel in interior Alaska also is notoriously dangerous because of thin, intermittent, or unpredictable ice cover, which can be prevalent even at very cold (-40ºC) temperatures. Despite these dangers, frozen rivers provide the easiest way for travel to subsistence sites or between Alaskan villages in the winter. In some cases, portages are cut around notoriously dangerous places in the rivers. Though tale signs such as fog banks and frost on riparian vegetation may alert travelers of open water, in many cases it is not possible to determine poor conditions until one is actually in trouble.

In Alaska, the period referred to as the “shoulder season” relates to ice formation in early winter or spring break-up at the end of winter. These times are very important to Alaskan communities as they represent a transition period during which rivers cannot be used for travel or to support subsistence activities. Observational information has indicated that ice conditions during the shoulder periods have changed during the last seventy-five years. Recently, ice has been reported as degrading in place as break-up approaches, while historical observations note that ice degradation associated with break-up was typically a more sudden, episodic event.

The rationale for this proposal rests on several important observations. First, seasonal ice conditions are reported to be changing and have become less predictable over the last 100 years. Second, frozen waterways are a primary mechanism for subsistence-related travel in rural interior Alaska, because of a very limited and often non-existent road system. Third, ice degradation associated with spring break-up is reported to be less predictable in recent years. Fourth, ice jams and associated flooding can have major detrimental impacts on riverside communities during spring break-up, which is why improved monitoring methods (i.e. systematic remote sensing analyses) could greatly assist federal agencies with their commitment to public service.

Our proposed project will strengthen relationships between local experts, academic scientists, and federal agencies. The research plan proposes to combine remote sensing, field studies, and local knowledge to examine the seasonal nature of river conditions from freeze-up through break-up on the Tanana River. Our collaborative effort will draw upon the skills and background of each participant to encourage the exchange of knowledge through integrated scientific collaboration. Our methodological integration of observational and scientific data to examine hazardous river conditions represents an important step towards a comprehensive understanding of how global changes will impact Alaskan rivers and the rural residents that rely upon rivers for subsistence activities.

RESEARCH OBJECTIVES

This research complements and expands research conducted previously in the Dangerous Ice project. We examine the seasonal nature of river conditions from freeze-up through break-up on the Tanana River by addressing two primary research questions.

Q_1) What physical factors influence seasonal ice dynamics on the Tanana River?

Q_2) What is the magnitude of spatial and temporal changes in seasonal river ice dynamics (distribution, surface texture and morphology) on the Tanana River?

Objectives:

1. Collaborate with local experts in each community to identify field sites and collect field data
2. Knowledge exchange with rural communities/individuals in Alaska
3. Use field data to determine the mechanisms controlling ice cover associated with field sites determined to be “hazardous” by local experts;

4. Monitor changes in climatic and hydrologic variables on an appropriate temporal scale at each field site
5. Develop a numerical model of ice degradation as a function of groundwater upwelling rates; channel depth and velocity; air temperature; ice thickness; and snow depth
6. Monitor spatial and temporal changes in river ice cover using airborne infrared and optical imagery

METHODOLOGY

We have addressed our research questions by integrating various approaches to characterize ice dynamics from freeze-up through spring break-up on the Tanana River near Fairbanks and near the village of Tanana, Alaska in Hay Slough. The project builds upon collaborative relationships and outreach activities initiated by the Dangerous Ice project. We worked with local river experts (Athabascan natives and university scientists with long-term experience traveling the rivers for research or in support of subsistence activities - hunting, fishing, and trapping) in each community to establish our field sites. We have various types of field sites that include sites identified by our local experts as hazardous for river travel (thin, unpredictable, or intermittent ice cover) and sites more typical of winter river conditions. Figure 1 shows a map of our field sites near Fairbanks. We collect field data to characterize river conditions during winter, spring break-up, and ice-free river conditions in collaboration. We visit our field sites regularly, including trips following break-up, before freeze-up, and during frozen winter conditions. Data collected at our field site include hydraulic conductivity, air temperature (hourly), water temperature (hourly), specific conductivity (groundwater, river water, snow, and ice), cross-section profile (including channel width, water depth, ice thickness, snow depth, and water velocity), and daily time-lapse photography of changing site conditions. GPS is used to mark site locations and delineate open water areas and other features of interest.

A series of “thermistor boards” were installed at four field sites to monitor the vertical temperature profile through the water column from the groundwater in the river sediment, into the water column, through the ice and snow, and into the air. The thermistor boards were constructed by our researchers and recorded to Campbell CR-10X dataloggers.

Remote sensing is being used to monitor river conditions. Airborne infrared and optical images were collected over our study reach near Fairbanks on three dates (November 8, 2011, February 22, 2012, and April 22, 2012) to study spatial and temporal changes in seasonal river ice distribution. Flight elevation of 2500 ft AGL was used for each flight. We are planning a fourth and final data collection effort in October 2012 to compare low flow, ice-free conditions to winter conditions.

PRINCIPAL FINDINGS

Complimentary datasets have been collected over the last 2 winter field seasons. Time-lapse photography allowed us to explore anomalous data such as an unexpected increase in water stage on November 1, 2011 (Figure 2). These images were used to explore hydrological anomalies at some field sites and to monitor changes in river stage and snow depth.

The vertical temperature profiles have been used to better understand how seasonal changes in stage and groundwater upwelling affect the water column temperature and the degradation of ice. Figure 3 illustrates an example dataset from the thermistor boards.

A series of five groundwater wells and five sets of nested piezometers were instrumented with dataloggers that monitored water level and temperature. Some also monitored specific conductivity which is used as a proxy to monitor changes in the relative contributions of groundwater and surface water. Water samples have also been taken, which will be analyzed using stable isotope analyses which will help distinguish seasonal changes in the relative proportion of water sources. Saturated hydraulic conductivity (K_{sat}) was measured using the slug test method at Hot Cake Slough (Figure 4) and ranged between 1.7 and 3.8 m/day. Water level data from a pair of nested piezometers in Hot Cake Slough were used to calculate groundwater upwelling rates (K_{sat} assumed to be 2.5 m/day)(Figure 5).

Using the calculated upwelling rates and groundwater temperature, the potential ice melt rate was modeled based upon the heat energy of the groundwater (Figure 6). This calculation assumes that no surface water is present and that all of the heat in the groundwater is being used to melt ice (0 °C). Figure 7 illustrates the heat energy present in the changing groundwater upwelling rates relative to a theoretical shallow channel in the winter (d = 0.05 m; velocity = 0.04 m/s). This figure illustrates the relative difference in magnitude of the heat energy in the groundwater compared to water in the channel. Figure 8 shows the estimated heat energy that would dissipate through a layer of snow (5 mm thick) and ice (1 mm thick). The equations used to generate Figures 7 and 8 will be incorporated into a model that estimates potential ice melt rates.

While we have collected airborne remote sensing data, we have yet to analyze the data and are unable to discuss any findings related to our remote sensing efforts.

SIGNIFICANCE

Despite over 150 years of exploration and scientific investigation, many aspects of the Arctic remain poorly understood. This is true for both the physical environment and the ways that local, long term river travelers know about their environment, the considerations they bring to bear in discussing conditions, and their explanations of ice processes. The proposed research takes an innovative approach to understand river conditions, while collaborating and exchanging knowledge with rural Alaskan communities.

Two big issues facing researchers in Alaska are: 1) changes in the environment and climate; and 2) determining how to draw upon scientific and other ways of knowing to understand the changes that are observed and to plan for successful adaptation by people who live and work in the Alaska. This research is based on an approach that begins with local knowledge to identify hazardous ice and then draws upon scientific understanding of ice processes to gain a comprehensive understanding of a particular phenomenon (Schneider 2002). In previous projects, participants described their experience with dangerous ice conditions, which laid the foundation for the scientific explanation of intermittent ice cover in particular areas. There could be scientific explanation without the description of past experience at these places, but the local experience adds a richness and depth of understanding and the perspective of observations over time (years and throughout the entire ice season). Of course, the experience-based observations were not sufficient alone, but in this case, the scientific explanation is also dependent on the information provided by the local experts (i.e. location of reliably poor ice conditions that occur late in the winter each year and observation of decreased water flow at the site as the ice season progresses).

The participants in this project have been asked to learn from each other and to recognize different ways of explaining and knowing by documenting the cross-fertilization of information between groups or individuals. This approach is valuable at a time when our climate and environment are undergoing big changes and different ways of learning are critical to understanding and adapting to the changes. In Alaska, it is appropriate that an emphasis is placed on interdisciplinary approaches to serve as models for collaboration and advancement of knowledge.

Few projects have been identified that examine the physical controls on river ice mechanics in interior Alaska. South's (2010) mentions the role of groundwater influx in maintaining river polynas on the Tanana River, but field studies were not performed to gain a detailed understanding of the process. This research project seeks to develop a mechanistic understanding of the hydrologic and thermal processes that retain open water areas in the backwater sloughs of the Tanana River. The modeling results are promising and when compared to other models, we will have a good understanding the strengths and weaknesses of our model.

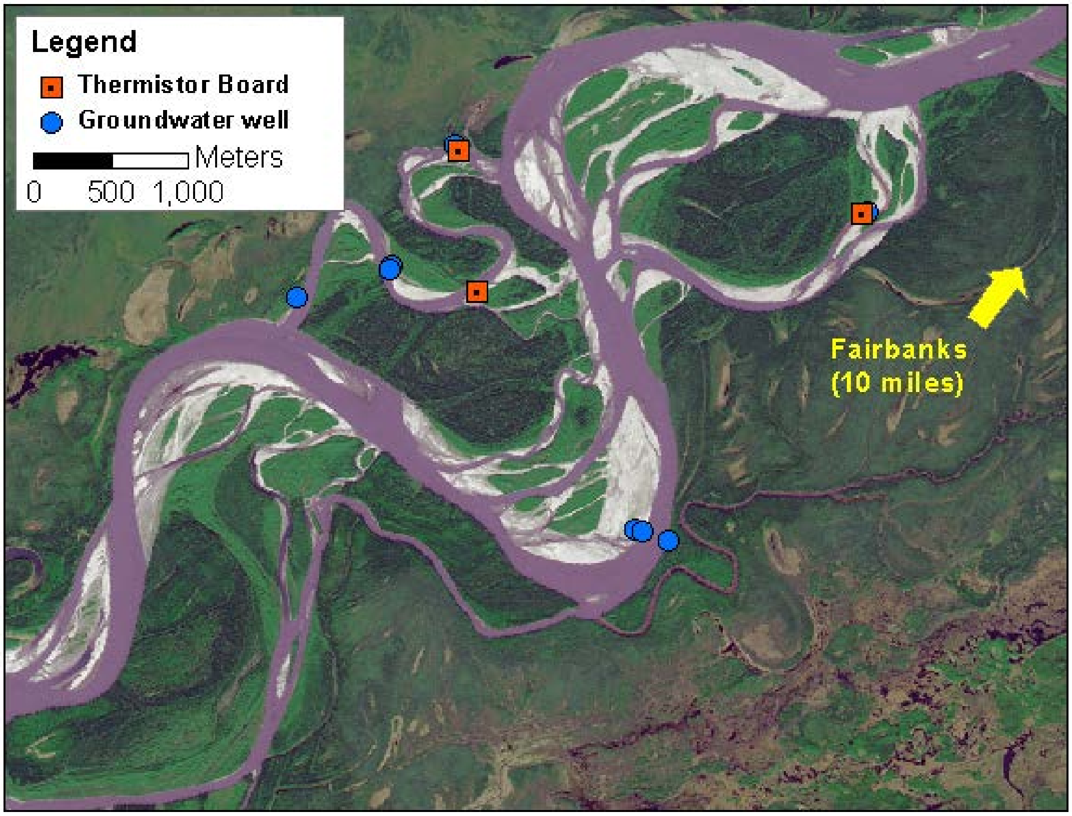


Figure 1. Field sites near Fairbanks.

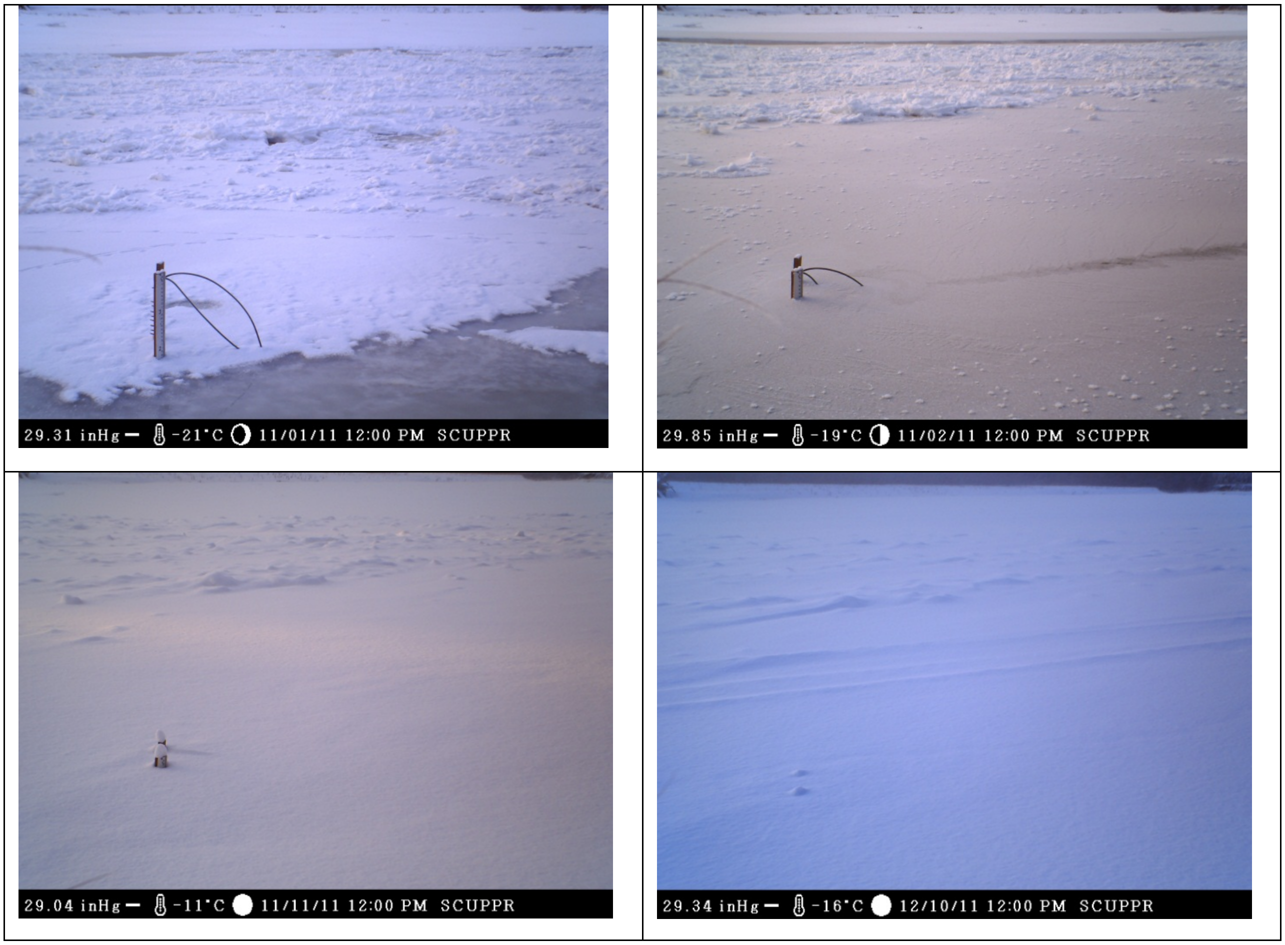


Figure 2. This photo series was taken in Upper Sam Charley Slough shows that the water level changed by over 1.5 ft in 24 hours and then became covered in a layer of snow on December 10, 2011. The instrument remained embedded in ice and snow until April 2012.

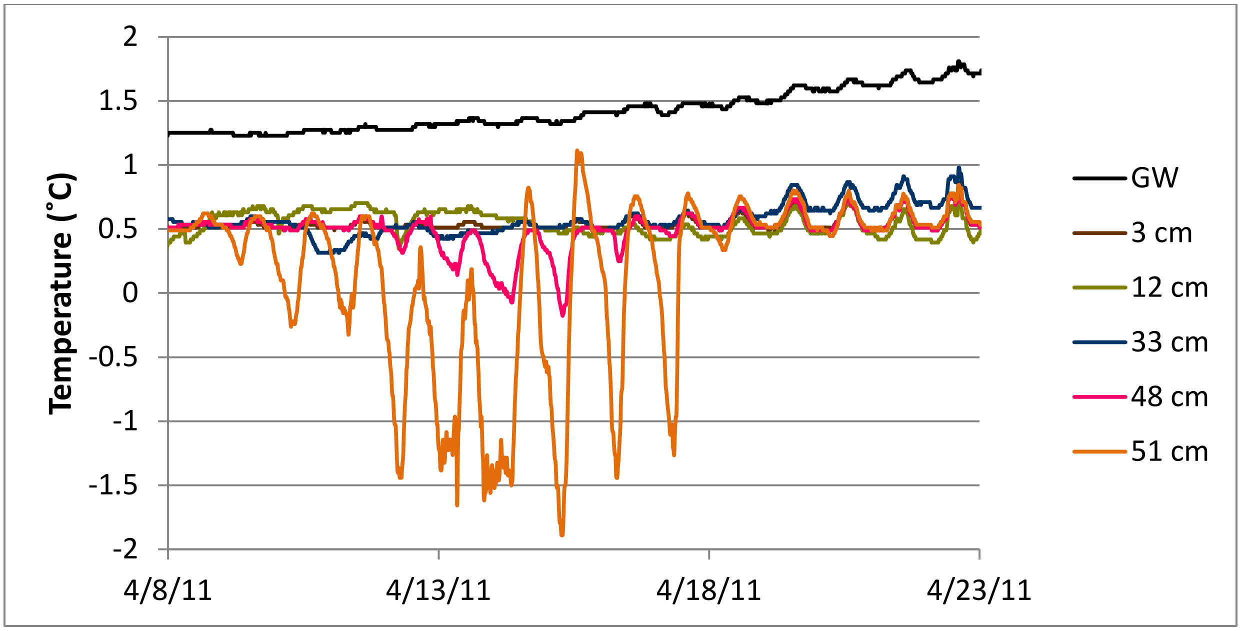


Figure 3. A series of temperature loggers monitored the vertical temperature profile from the groundwater, through the water column, ice, snow and into the air at Sam Charley Slough in 2011. The distances in the legend correspond to distance from the channel bottom. The thermistor at 51 cm was in the air until April 18.

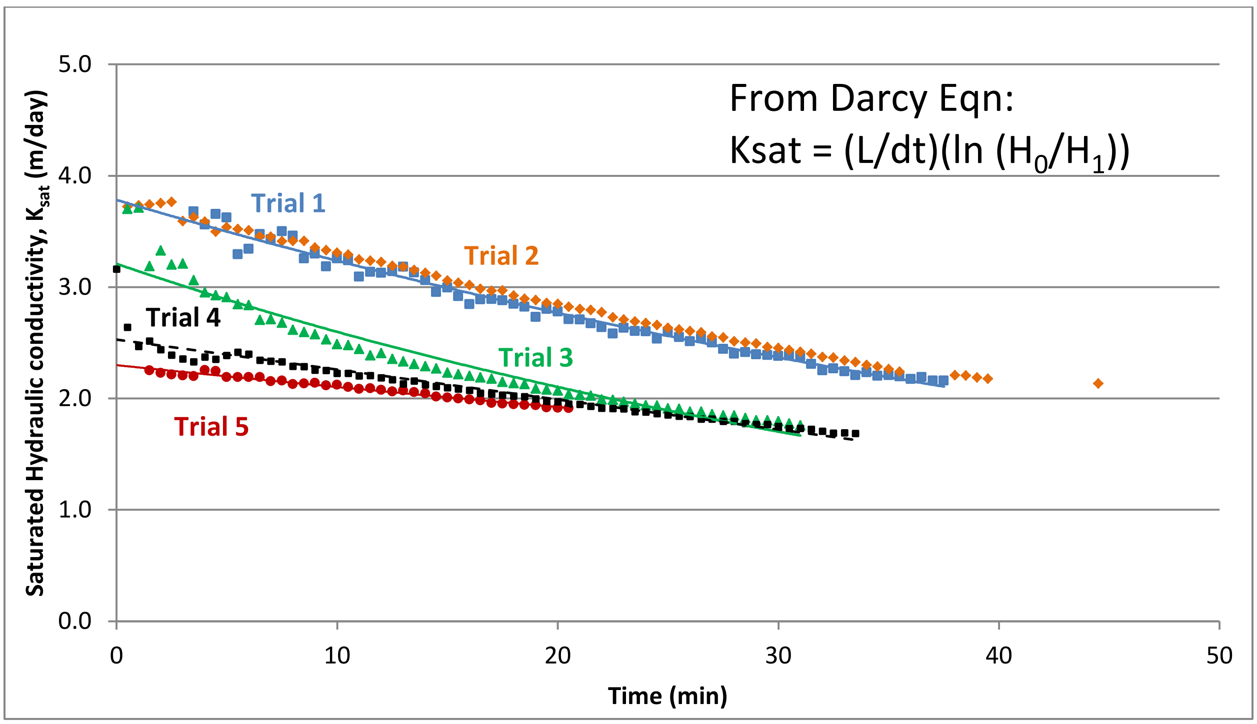


Figure 4. In-situ measurements of saturated hydraulic conductivity in the water channel of Hot Cake Slough were measured over five different trials across two dates.

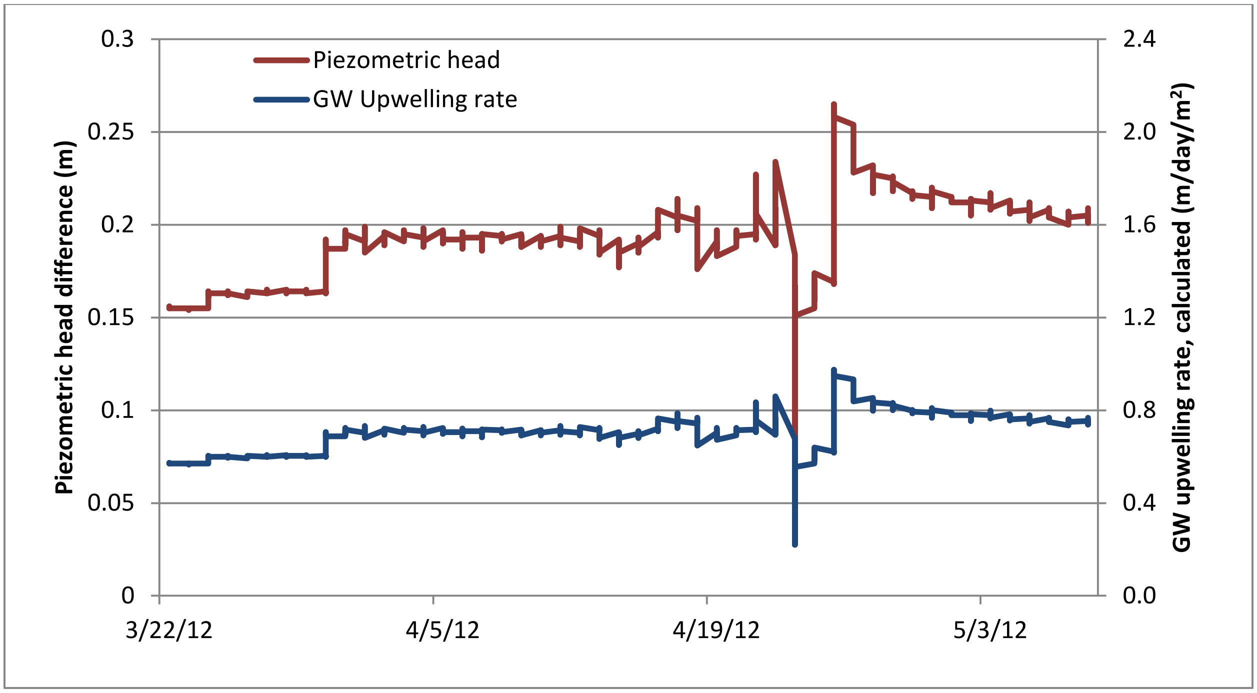


Figure 5. Nested piezometers were instrumented with data loggers to monitor head differences that were used to calculate changes in groundwater upwelling rates over time (K_{sat} = 2.5 m/day).

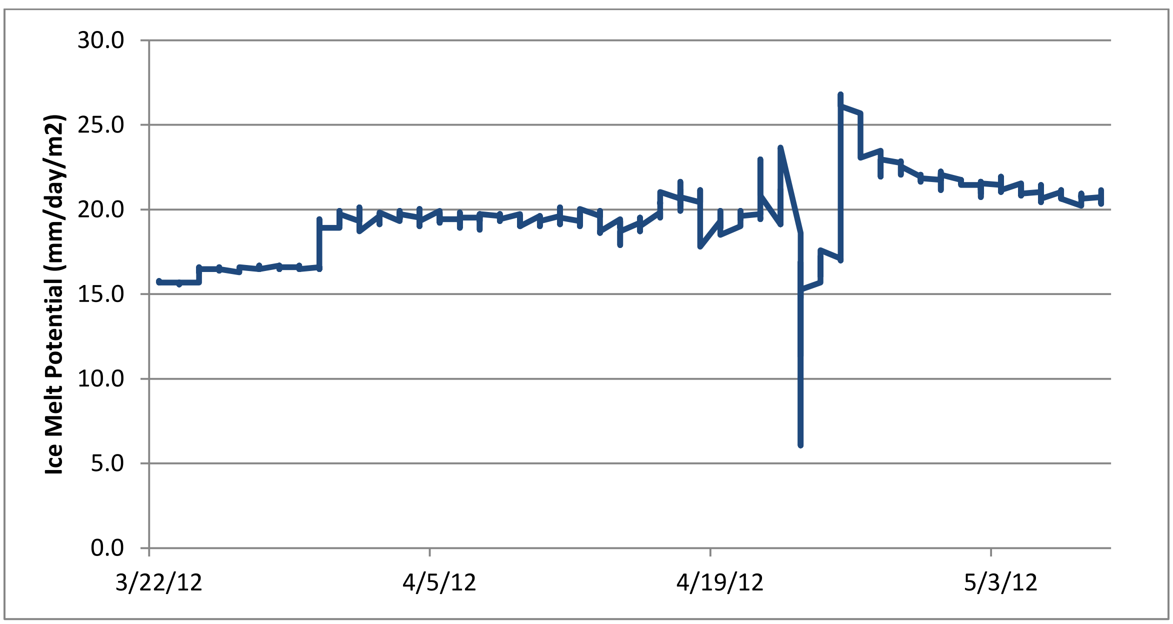


Figure 6. Using the calculated groundwater upwelling rates, the ice melt potential was calculated based upon the amount of heat in the groundwater (assumes that there is no water in the water column above the groundwater inflow.

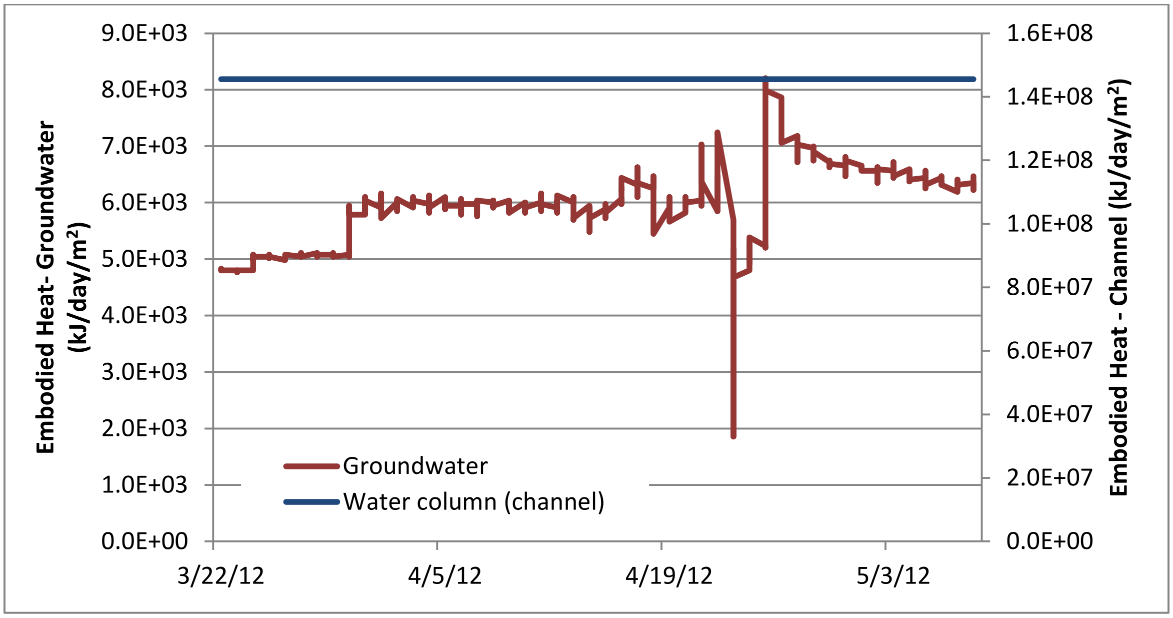


Figure 7. Based upon the calculated groundwater upwelling rate and the channel discharge, the amount of heat in the groundwater and water column was calculated. This will be used to model the ice melt potential in a channel with groundwater input.

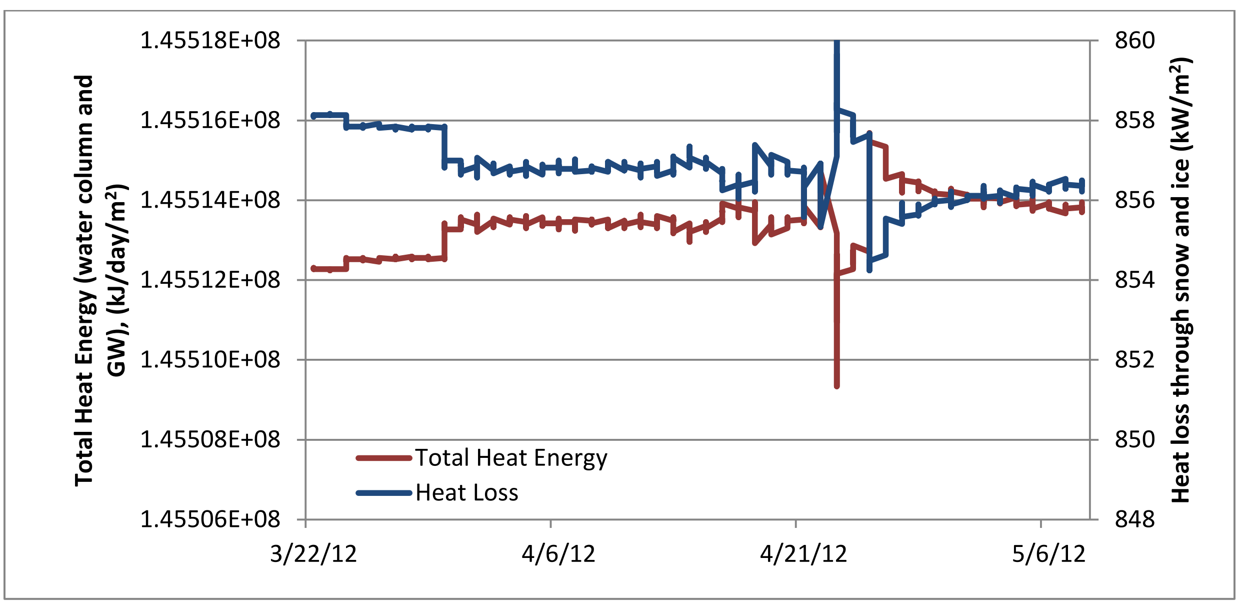


Figure 8. The total heat energy in the water column and groundwater was calculated and the total heat loss through a layer of ice and snow was estimated. This will be used to model effect groundwater on a channel with ice and snow cover.

LITERATURE CITED

Huntington, H., Brower, H. and Norton, D. (2001) The Barrow Symposium on Sea Ice, 2000: Evaluation of One Means of Exchanging Information between Subsistence Whalers and Scientists. Arctic, vol 54, no.2. June, 201-204.

Krupnik, I. (2002) “Watching Ice and Weather Our Way: Some Lessons from Yupik Observations of Sea Ice and Weather on St. Lawrence Island, Alaska” in The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change, edited by Krupnik and Jolly. Fairbanks, Arctic Research Consortium of the United States, 156-199.

Schneider, W. (2002) So they Understand: Cultural Issues in Oral History. Logan, Utah State University Press.

South, L. (2010) A remote sensing-GIS based approach to identify spawning habitat for fall chum salmon in a sub-arctic glacially-fed river. Master's thesis. School of Fisheries and Ocean Sciences. University of Alaska Fairbanks. 76 pp.

Developing high-resolution strontium isotope maps of Alaska Rivers to track pacific salmon migrations: The Nushagak River as a case study to evaluate spatial and seasonal variability.

Basic Information

Title:	Developing high-resolution strontium isotope maps of Alaska Rivers to track pacific salmon migrations: The Nushagak River as a case study to evaluate spatial and seasonal variability.
Project Number:	2011AK114B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Not Applicable
Focus Category:	Hydrogeochemistry, Water Use, Ecology
Descriptors:	Western Alaskan Rivers, salmon migration, strontium isotopes, biodiversity, conservation
Principal Investigators:	, Matthew John Wooller

Publications

1. Conference Poster and Abstract: Brennan et al. (2011). Strontium (Sr) isotopic (87Sr/86Sr) variation of Alaskan Rivers: implications on tracking movement patterns and natal origins of fish. Poster Presentation. American Fisheries Society – Alaska Chapter, Girdwood, AK.
2. Brennan, S., Wooller, M.J., et al. (2011). The Trans-Alaska Strontium Isotope Survey (TASIS) – geochemically characterizing Alaskan watersheds to track salmon migrations. Oral Presentation American Water Resources Association, Fairbanks, Alaska.
3. Brennan, S., Wooller, M.J., et al. (2011). Tracking natal sources of salmon using strontium isotopes (87Sr/86Sr) in Otoliths in the Nushagak River. Oral Presentation New Stuyahok High School, New Stuyahok, AK.
4. Brennan, S., Wooller, M.J., et al. (in prep.) The Trans-Alaska Strontium Isotope Survey: characterizing watersheds of Alaska using 87Sr/86Sr.

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 Nushagak River. Geochemical measurements of fish otoliths and river 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 provide an accurate and economical method for tracking natal and rearing habitat use of salmon breeding populations in the Nushagak River. This map will depict potential salmon natal sources of the Nushagak, which can be used to help resolve mixed stock fisheries conducted in the Nushagak Fishing District. This project focuses mainly on Chinook salmon (*Oncorhynchus tshawytscha*) as returns back to the Nushagak River, like other Western Alaskan Rivers, has seen marked declines in runs during the last decade. $^{87}Sr/^{86}Sr$ 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. We will use these natural markers in Chinook salmon otoliths to identify population structure and migration patterns, which can be used to source natal origins of Chinook salmon caught as by-catch during the Bristol Bay sockeye fishery in the Nushagak Fishing district. This will help current management efforts to conserve salmon biodiversity and sustain salmon productivity.

Objectives

The objectives of this study were:

1) To spatially and temporally geochemically characterize waters and breeding salmon populations of the Nushagak River and its major tributaries.

2) To continue to develop and evaluate a model in Arc Global Information Systems (GIS) which predicts inter- and intra-watershed variation using rock geochemistry data and geologic maps.

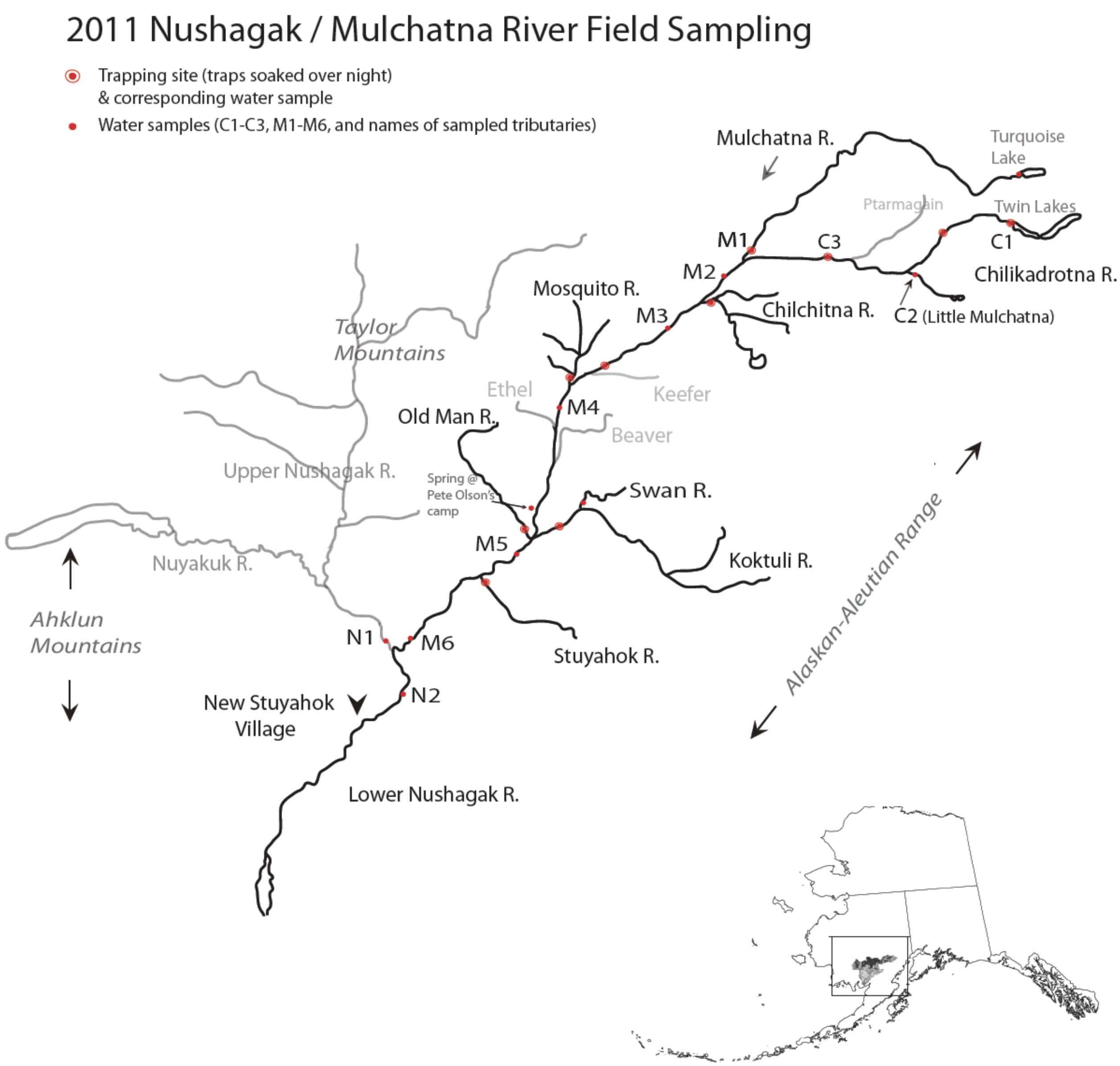
Relevance

This study is the first thorough investigation and evaluation in Alaska of whether $^{87}Sr/^{86}Sr$ variation of a watershed can be used to track natal sources of Pacific salmon using otoliths 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 Nushagak River salmon.

Methods

Water sample collection in the field:
Water samples from major tributaries of the Nushagak River were collected for $^{87}Sr/^{86}Sr$, $\delta^{2}H$ and $\delta^{18}O$, anions and major and trace elemental analyses. Additionally, alkalinity, pH and temperature were measured at each sampling site. Sample sites are pictured in Figure 1, and listed in Table 1. At about every fifth sample site three field replicates were collected to evaluate reproducibility of field collection and subsequent filtration methods. Also at every fifth site, a blank was collected and filtered in the same manner as samples to account for any field-derived contamination. 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. Samples were acidified with Ultrapure concentrated nitric acid within 16 days of collection and stored cool until analysis.

Figure 1: Fish trapping and water sampling sites completed during the 2011 field season on the Nushagak River.



Water isotopic and elemental analyses:
Sr isotopic compositions of waters are determined using a Thermo Scientific NEPTUNE High Resolution multi-collector inductively coupled mass spectrometer (MC-ICP-MS) at the University of Utah ICP-MS Laboratory. Elemental analyses are 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.

For isotopic analyses the Utah ICPMS lab has developed an automated sampling system to purify the Sr present in aqueous solutions using an inline chromatographic column packed with a crown ether resin (Eichrom's Sr Resin ®). The column is repeatedly used throughout each run (and also multiple runs). A total of two columns were used during the analyses presented in this report. The initial column was replaced with a new column when signal intensities for ^{88}Sr attenuated consistently below ~ 8 volts. Each sample (and standard) is bracketed with two 4M blanks (one before sample; one after), which act to purge the column of any residual Sr present from the prior analysis. The voltage of Sr measured in the blanks is used to correct the corresponding following sample or standard analysis. The residual voltage of Sr measured in blanks attenuates exponentially, such that our sample to blank signal ratio is consistently ~ 250:1 Volts.

Samples are analyzed in a series of runs consisting of about 10-15 samples per run. Prior to isotopic analysis a small sample from each river is analyzed to determine its elemental strontium concentration. For both elemental and isotopic analyses samples are prepared as a 4 molar acid solution using trace metal grade HNO_3. Run sequences are ordered starting with samples containing lowest concentrations of Sr to progressively higher concentrations. By not running a particular sample with a low Sr concentration directly after a sample with high Sr concentration we minimize potential memory effects of the column. All samples will lie between Sr concentration range of 40 – 290 ppb. 10 ppb is the minimum concentration, while 290 ppb is the max concentration (based off concentration of NIST SRM987 $SrCO_3$ standard) used to generate consistently accurate results for isotopic measurements using this method.

Otolith collections and strontium isotopic analyses:
Otoliths from fish representing three different life history patterns (anadromy - salmon, seasonally migratory - grayling, and sedentary - sculpin) were collected from the Nushagak River during the 2011 field season supported by funds from NIWR (see inventory in Table 1). These species of fish were selected to evaluate spatial and temporal variation in hydro-geochemistry and fish movement. Sculpin, an obligatory freshwater fish, which are sedentary, have been selected to evaluate potential seasonal variations in river water geochemistry. $^{87}Sr/^{86}Sr$ time-series of sculpin otoliths are hypothesized to reveal seasonal patterns if they exist in a particular river. Arctic grayling, a seasonally migratory fish have been selected to evaluate if otolith laser ablation methods can detect seasonal movement patterns of fish. These two different time-series address two important issues regarding the ability of the Sr-isotope method to track natal sources of fish caught in mixed stock fisheries: seasonal variation in a) hydro-geochemistry, and b) potential movement of juvenile salmon species from natal streams to rearing streams, respectively.

Analyses of $^{87}Sr/^{86}Sr$ ratios in otoliths are being done using multicollector-inductively coupled plasma mass-spectrometry (MC-ICP-MS) by Sean Brennan and Co-PIs Drs. Cerling and Fernandez at the University of Utah ICP-MS Laboratory using established laser ablation methods. Otolith analyses will target a) the region accreted during a salmon's freshwater stage (~250 μm distal of primordia – after yolk absorption, but before outmigration), and the region accreted during the marine stage; and b) produced $^{87}Sr/^{86}Sr$ time-series of individuals.

ArcGIS modeling of strontium isotopic variation in a watershed:

This model uses high- resolution geologic maps and available rock geochemistry data in the literature and databases (e.g., GEOROC - georoc.mpch-mainz.gwdg.de/georoc) to predict spatial variation of $^{87}Sr/^{86}Sr$ values of Nushagak river waters. Figure 2 is preliminary modeling conducted by Sean Brennan (the PhD student supported by this project) with Dr. Vanlaningham (Co-PI) (2010). For this preliminary work we compiled all available rock geochemistry data ($^{87}Sr/^{86}Sr$ and Sr ppm) available for each geologic unit in the Nushagak River basin and predicted the $^{87}Sr/^{86}Sr$ ratio of water at the mouth of the river based on the weighted contribution of each geological units respective area and average concentration of Sr in the rocks. Using the water samples collected during the 2011 field season for geochemical analyses we will ground truth this model and evaluate its accuracy.

Results

The $^{87}Sr/^{86}Sr$ range in samples collected this field season from tributaries of the Nushagak Watershed range from 0.70420 - 0.70778. As shown in Figure 1 the samples were collected from the Mulchatna River branch, which constitutes approximately half of the watershed area and drains a geologically diverse landscape (see Figure 2). As predicted by our model the tributaries draining out of the Taylor Mtn. are more radiogenic (higher $^{87}Sr/^{86}Sr$ ratios), than tributaries draining the Alaskan-Aleutian Range. However, the observed range is markedly less than our predicted range. Nonetheless, there are significantly different isotopic compositions between distinct tributaries of the Mulchatna-Nushagak River, which make it likely that this range can be used to distinguish distinct 'isotopic stocks' of respective salmon populations.

All adult and juvenile coho and Chinook salmon, and resident arctic grayling and sculpin collected during the 2011 field season (listed in Table 1) have been prepared for laser ablation ICPMS analyses. These analyses are currently taking place in Utah by Sean Brennan. Isotopic values from these fish otoliths will be correlated with water sample values to evaluate whether distinct 'isotopic stocks' exist in the Mulchatna-Nushagak tributaries sampled during the 2011 field season.

In addition to the Nushagak samples and analyses, we have also completed Sr-isotopic and elemental analyses of 14 Alaska Rivers (Table 3). These data add significantly to prior and ongoing data collected from Alaska Rivers during the 2009/2010 NIWR award, which was used to conduct the first Trans-Alaska Strontium Isotope Survey (TASIS). As is reported in Table 3, the $^{87}Sr/^{86}Sr$ range for Alaska Rivers has more than doubled with these additional 14 river samples. The range reported here is 0.70420 – 0.74041. This large range is likely to provide valuable data for water resource management projects and goals (incl. salmon) across Alaska by providing important baseline data, which geochemically characterizes watersheds and sub-watersheds. All of these water data are being prepared in a manuscript for submission to a peer-reviewed journal (Brennan, Wooller et al. in prep.).

Table 1: Water samples collected during the 2011 field season from tributaries of the Nushagak River.

2011 NUSHAGAK / MULCHATNA RIVER -- Water collections						
Site	**Temperature (^oC)**	**pH**	**ORP**	**Alkalinity ($CaCO3$ mg/L)**	**$^{87}Sr/^{86}Sr$, major and trace elements (100 ml)**	**δ^2H, $\delta^{18}O$**
Turquoise Lake	-	-	-	-	x	x
C1	11.38	7.16	186	36	x	x
C2	9.21	7.07	140	26	x	x
C3	9.17	7.13	138	42	x	x
M1	9.08	6.69	138	44	x	x
M2	9.29	6.89	125	39	x	x
Chilchitna	7.78	6.61	137	32	x	x
M3	10.02	6.81	146	38	x	x
Mosquito	8.08	6.69	130	32	x	x
M4	8.81	6.86	130	34	x	x
Old Man	9.33	6.35	134	22	x	x
Spring @ Pete Olson's	-	-	-	-	x	-
Swan	11.35	6.29	114	31	x	x
Koktuli	10.87	6.57	143	26	x	x
M5	11.08	6.75	173	34	x	x
Stuyahok	10.94	6.48	122	19	x	x
M6	11.94	6.36	146	28	x	x
N1	11.68	6.67	149	27	x	x
N2	11.36	-	-	26	x	x

Table 2: Otolith collections from different species from tributaries of the Nushagak River. Juvenile fish and sculpin were captured via minnow traps, while adult coho salmon and grayling were captured via angling. Otoliths from adult sockeye and Chinook were retrieved from spawned out carcasses found along the river.

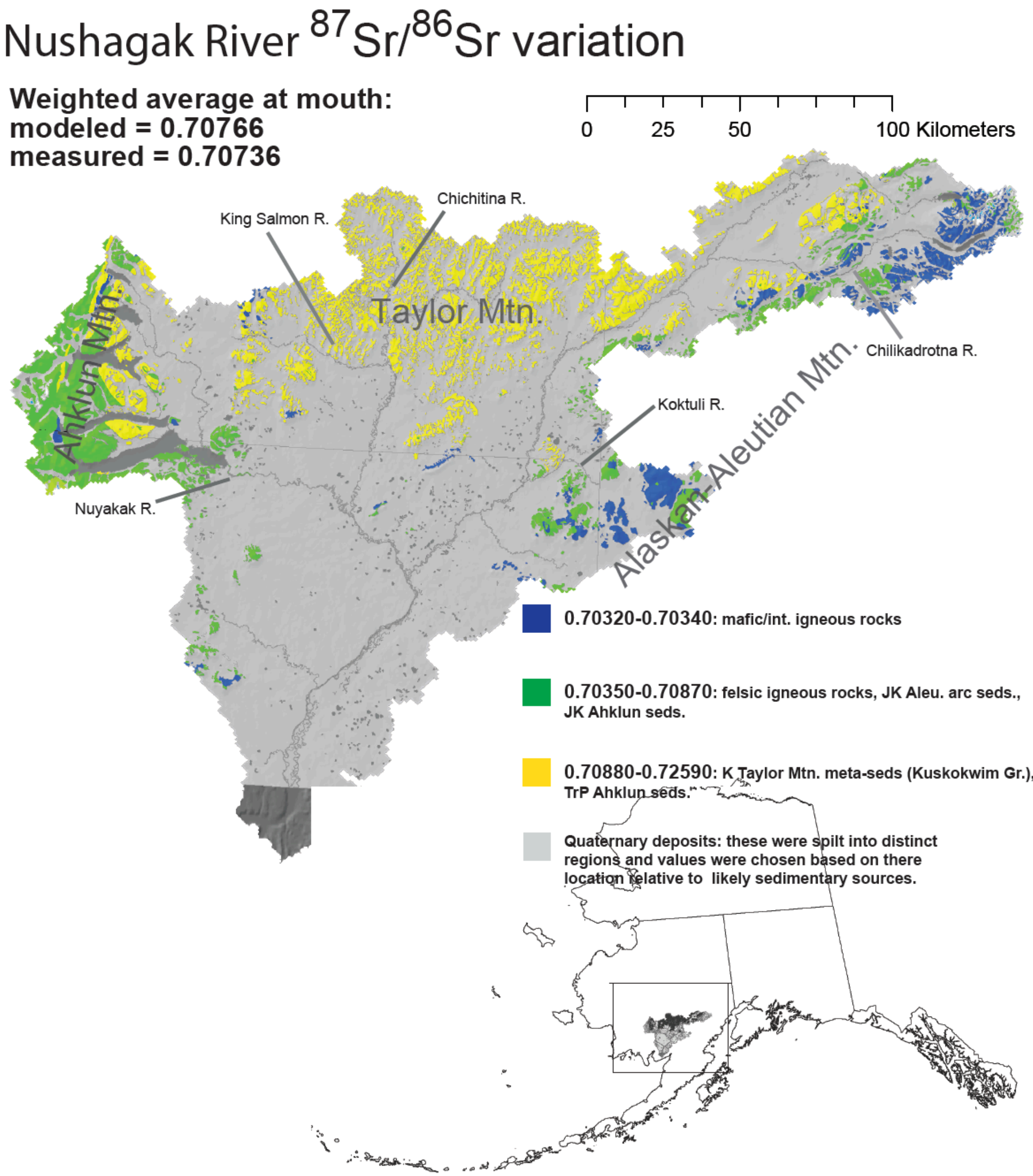
2011 NUSHAGAK / MULCHATNA RIVER -- Fish otolith collections

River	Juvenile King	Adult King	Juvenile Coho	Adult Coho	Adult Sockeye	Arctic Grayling	Sculpin
Chilikadrotna	5	3	9	0	0	1	4
Mulchatna	16	4	12	6	1	6	3
Chilchitna	1	1	10	0	0	1	0
Mosquito	0	0	10	0	0	1	0
Old Man	2	5	8	3	1	3	0
Koktuli	12	3	11	3	7	3	1
Stuyahok	12	1	10	3	0	3	2
Total	48	17	70	15	9	18	10

Table 3: Water results: Sr-isotope, major and trace element concentrations in Alaska Rivers.

Alaska River	Strontium isotope analyses complete
Nushagak Watershed	X
South Fork Koktuli 1	X
North Fork Koktuli	X
South Fork Koktuli 2	X
Stuyahok	X
Little Mulchatna	X
Koktuli 1	X
Koktuli 2	X
Koktuli 3	X
Chilikadrotna Outlet	X
Pete Olson's	X
C3	X
Swan	X
M2-1	X
M2-2	X
M2-3	X
Chilchitina	X
Turquoise Lake	X
M6-1	X
M6-2	X
M6-3	X
M4-1	X
M4-2	X
M4-3	X
M3	X
M5	X
Old Man Creek	X
M1	X
N2	X
Mosquito	X
N1	X
Other Alaska Rivers	X
Lake Amanka 1	X
Lake Amanka 2	X
Lake Amanka 3	X
Upper Talarik Creek	X
Snake Lake	X
Lake Aleknagik	X
Dulbi River	X
Hogatza River	X
Inoko	X

Figure 2: *A priori* modeling of the Nushagak River basin's predicted $^{87}Sr/^{86}Sr$ variation based on geologic maps and available rock geochemistry data. The 2011 field sampling (Figure 1) is being used to ground truth this modeling effort and evaluate its accuracy and effectiveness.


Nushagak River 87Sr/86Sr variation
Weighted average at mouth:
modeled = 0.70766
measured = 0.70736
0
25
50
100 Kilometers
King Salmon R.
Chichitina R.
Taylor Mtn.
Ahklun Mtn.
Chilikadrotna R.
Koktuli R.
Alaskan-Aleutian Mtn.
Nuyakak R.
0.70320-0.70340: mafic/int. igneous rocks
0.70350-0.70870: felsic igneous rocks, JK Aleu. arc seds., JK Ahklun seds.
0.70880-0.72590: K Taylor Mtn. meta-seds (Kuskokwim Gr.), TrP Ahklun seds.
Quaternary deposits: these were spilt into distinct regions and values were chosen based on there location relative to likely sedimentary sources.

UAA Wellfield: Research and Teaching Applications, Phase II

Basic Information

Title:	UAA Wellfield: Research and Teaching Applications, Phase II
Project Number:	2011AK97B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Water Quality, Education
Descriptors:	
Principal Investigators:	Bryce Willems, LeeAnn Munk

Publications

There are no publications.

UAA Wellfield: Research and Teaching Applications, Phase II

LeeAnn Munk, Department of Geological Sciences, University of Alaska Anchorage

Problem Statement

Water supply and water quality are critical environmental issues that face the Anchorage region as well as the State of Alaska. Continued population growth and land development in Anchorage has increased the demand for groundwater while potentially reducing water quality. According to the Alaska Department of Environmental Conservation (ADEC, 2005); "groundwater is a source of drinking water for about 50% of Alaska's population". Although ~80% of municipal drinking water in Anchorage is sourced from surface water (Eklutna Lake), groundwater is an important secondary source of the municipal water supply, especially during the summer months when demand is highest. Groundwater is also the primary drinking water source for over 12,000 households with private wells in the Anchorage area. In addition, there are numerous wells that tap into the Anchorage aquifers for nonresidential use. For example, buildings on the UAA campus use groundwater as a heat exchanger for purposes of building cooling. This water is discharged directly into streams or to the municipal drainage system and is not directly returned to the aquifer. The volume of water used for this purpose is unknown but is undoubtedly quite large particularly in the summer months. In terms of water quality, increased urbanization and changes in land use patterns have the potential to cause degradation of water quality by enriching both surface and ground water with common contaminants, such as nitrates, metals, hydrocarbons, and others. Arsenic has already been identified in the groundwater supply is exceed the EPA drinking water standard by up to an order of magnitude in some locations (USGS, 2004; Munk et al., in press). Clearly there are groundwater water supply and quality issues that are not well understood for the Anchorage aquifer system.

Research Objectives

The nature and scope of this research is focused on student learning and training. Undergraduate students and faculty from the Departments of Geological Sciences will utilize the results of this work in everyday classroom activities and in undergraduate research. **We proposed to install a 200 ft groundwater monitoring well at the UAA Wellfield.** The well will expand the capabilities of the wellfield and provide additional opportunities for undergraduate learning within the Department of Geological Sciences at UAA.

The specific objectives of this study are to:

1. Generate a detailed record of lithological and textural characteristics of the sediments immediately beneath the current depth of the wellfield.

2. Determine vertical groundwater flow characteristics through the analysis of time-drawdown data and static head measurements.

3. Examine deeper fluctuations of the groundwater table and the chemical variations in water quality as a function of seasonal changes.

Methodology

Well Installation/Geologic Sampling

The monitoring well will be installed using an air-rotary method by Discovery Drilling, which is the same company that successfully installed two monitoring wells and one pumping well at the wellfield this past year. During the drilling processes, drive samples will be collected at 20 ft intervals, or when a significant change in lithology is encountered. Additional samples of cuttings will be collected from the air discharge when drive samples are not collected. The well will be cased with PVC pipe, screened within aquifer material, and enclosed at the ground-surface with a lockable steal case to ensure well security. Samples will be used to produce a detailed stratigraphic model of the subsurface and to determine the physical attributes of the aquifer and any confining layers. Grain size analysis of the coarse-grained materials will be used to estimate porosity and hydraulic conductivity (Hazen, 1911). The bulk density of the fine-grained sediments will be used to determine porosity in the lab through an oven-drying process. Organic content of the sediments will also be measured in the lab, which is important in the characterization of water quality parameters. This will be done by standard gravimetric methods.

Aquifer Characteristics

Aquifer characteristics, such as hydraulic conductivity and transmissivity, will be determined from the analysis of time-drawdown data collected during pump tests and slug-tests. These characteristics are fundamental aquifer parameters that are routinely used to delineate potential groundwater resources (Fetter, 2001). The exact solution used in the analysis of the time-drawdown data will depend of the penetration of the well, well construction parameters, and unconfined versus confined conditions in the aquifer unit.

Principal Findings, and Significance

The proposed project will continue to build the foundation for groundwater research and education within the Department of Geological Sciences at UAA. One of our Departmental goals is to provide hands-on training for the next generation of environmental geologists and hydrogeologists for our State. The wellfield is also accessible to secondary and high school teachers and students, the Alaska Pacific University community, environmental consulting community in Anchorage, as well as any community groups interested in learning about groundwater resources/quality.

The Community Advisory Board to the Department of Geological Sciences at UAA and the environmental consulting and mining industries in the State have repeatedly indicated that our field-based education gives our students an edge when they compete for jobs and admission to graduate school. The wellfield allows us to continue the development of the long-term infrastructure needed for our environmental geology field-based curriculum.

Though the priority of this project is to provide educational opportunities and research projects for students while developing needed educational infrastructure, field data will be collected that will provide new information regarding aquifer composition/properties and groundwater chemistry and assist in furthering our understanding of groundwater flow in Anchorage.

Core description and sediment sampling will produce detailed stratigraphic record down to ~ 200 feet). This data will enhance our understanding of local aquifer heterogeneity, which is important when attempting to understanding local groundwater flow patterns. These data will supplement numerous, less detailed, well logs available (e.g. DNR, WELTS database) from the surrounding area (depositional environment, grain size distribution, organic content, etc.).

The characterization the aquifer units at a greater depth will help us understand the aquifer parameters, such as hydraulic conductivity and tranmissivity. In particular the addition of a deeper well will allow the delineation of a potential confining aquifer as well as the magnitude of vertical groundwater gradients at the wellfield. Such gradients could be important when considering recharge flow patterns and contamination potential. Aquifer characteristics and flow patterns will be determined through the analysis of time-drawdown data generated by pump and slug tests as well as static water levels.

The chemical characterization of the groundwater is important when examining water quality. In-situ measurements of temperature, pH, dissolved oxygen, oxidation reduction potential and specific conductivity will be collected from all wells. Measurements of nitrate, iron (II/III), alkalinity, major cations and anions, trace elements, TOC, and stable isotopes will also be obtained for modeling groundwater quality and composition to compliment ongoing surface and groundwater studies in the Anchorage area (Cardenas et al., 2009).

Regional Background and Significance

Extraction of groundwater in Alaska is largest in the municipalities of Anchorage and Fairbanks where population density is greatest, making the need to understand groundwater supply and quality imperative. Anthropogenic activities in urban environments are frequently the cause of degradation to both surface and groundwater quality. Often, a detailed understanding of groundwater and its relationship to surface water is necessary to properly maintain local water resources and acceptable water quality (Moran & Galloway, 2006). In this light, additional research is needed throughout the Anchorage area in order to comprehensively evaluate sustainable groundwater yields. Groundwater is locally derived from the glacifluvial Cook Inlet Aquifer System, which is composed of interbedded fine- and course-grained sediments (Miller & Whitehead, 1999). Such glacifluvial aquifers are the most productive aquifers in Alaska (Miller & Whitehead, 1999), yet are complex and often difficult to study comprehensively without a wide variety of geochemical, geophysical, and hydrological techniques.

Groundwater contamination issues in Anchorage are of concern. The most common pollutants in the Anchorage area are naturally occurring iron, manganese and arsenic and potential anthropogenic contaminants include nitrates and phosphates (Alaska Department of Environmental Conservation, 2005). Additionally it has been determined that lead, copper, and zinc are present in elevated concentration in both surface and groundwater as well as suspended and bed sediments in Chester Creek (Burich, 2007; Munk et al., in press).

Recent UAA Groundwater and Surface Water Studies

An investigation of arsenic in Anchorage groundwater by Munk et al. (in press) was undertaken because of the consistently elevated (greater than the EPA drinking water standard of 10 μg/L) levels of arsenic in the Anchorage groundwater. Their results indicate that over a four month period the groundwater levels and the concentration of arsenic and other constituents had the most variation in concentration in vicinity of the UAA campus versus any other well locations in the study area of Anchorage. This may be due to the close link between surface and ground water in the Chester Creek watershed. Additionally this work discovered that the bulk of the arsenic measured in all the wells occurs mainly in the reduced form of As (III), which is the most bioavailable form of this contaminant. One of the conclusions drawn from this work is that the reliance on groundwater for drinking water may not be sustainable in the Anchorage watershed without additional treatment systems.

A more recent and ongoing study of the linkages between surface and groundwater by Cardenas et al. (2009) indicates that based on bi-monthly sampling of stream water (Chester Creek) and shallow groundwater both sampled in the vicinity of the UAA campus are most similar in chemical composition during early summer (June). This is based on major and trace element composition as well as hydrogen and oxygen isotope signatures of the surface and groundwater. This is the first study to characterize the seasonal linkages between surface and groundwater in the Anchorage area.

Two undergraduate students will be responsible for the majority of the data collection and processing with assistance from other students in various geology courses. One student will focus on the physical characterization of the aquifer material and the hydrogeologic data from aquifer testing while the third will focus on the groundwater quality aspects. The students will write final reports and present their work at an undergraduate research seminar at UAA.

Repeated aquifer testing is planned as part of the regular UAA curriculum and research which will allow students to gain first-hand experience collecting and interpreting time-drawdown data while providing additional information regarding the precision of the methods and any temporal changes in the aquifer, perhaps in response to changes in local groundwater consumption, climate, and/or other hydraulic dynamics.

References

Alaska Department of Environmental Conservation, 2005. Groundwater in Alaska. Anchorage, AK: ADEC.

Burich, B.E., 2008. Biogeochemical Pathways and Land Use Associations of Potentially Toxic Metals in the Anchorage Watershed, Alaska. MS thesis, UAA, 23p.

Cardenas, M.E., Munk, L.A., Munk, J., Hagedorn, B., 2009, Physical and Chemical Connections Between Surface and Ground Water in the Anchorage Watershed, Alaska, Geological Society of America Abstracts with Programs, Vol. 41, No. 7, p. 669

Fetter, C.W., 2001, Applied Hydrogeology, 4th Edition, Printice Hall, Upper Saddle River, NJ, 598p.

Hazen, A., 1911, Discussion: Dams on sand foundations. Transactions, American Society of Civil Engineers 73, 199.

Kane, D. L., Youcha, E. K., Billings, S. F. Gieck, R. E., 2008. Flow Patterns and Chemistry of Groundwater Aquifers in Southwest Anchorage, Alaska. Fairbanks, Alaska: University of Alaska Fairbanks, Water and Environmental Research Center.

Miller, J.A., and Whitehead, R.L., 1999. Ground Water Atlas of the United States: Alaska, Hawaii, Puerto Rico and the Virgin Islands, U.S. Geological Survey, HA 730-N, available online at http://capp.water.usgs.gov/gwa/ch_n/index.html.

Moran, E. H., and Galloway, D. L., 2006. Ground Water in the Anchorage Area, Alaska. Anchorage, AK: USGS, US Department of the Interior.

Munk, L.A., Hagedorn, B.H., Sjostrom, D., 2011. Seasonal Fluctuations and Mobility of Arsenic in Groundwater Resources, Anchorage, Alaska. Anchorage, AK. Journal of Applied Geochemistry.

United States Geological Survey, 2004. Arsenic in ground-water resources of the United States. Fact sheet FS-063-00, p1-4.

Developing high-resolution strontium isotope maps of Alaskan Rivers to track pacific salmon migrations: The Nushagak River as a case study to evaluate spatial and seasonal variability.

Basic Information

Title:	Developing high-resolution strontium isotope maps of Alaskan Rivers to track pacific salmon migrations: The Nushagak River as a case study to evaluate spatial and seasonal variability.
Project Number:	2011AK98B
Start Date:	3/1/2011
End Date:	1/29/2012
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrogeochemistry, Water Use, Ecology
Descriptors:	
Principal Investigators:	Matthew John Wooller

Publications

There are no publications.

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 Nushagak River. Geochemical measurements of fish otoliths and river 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 provide an accurate and economical method for tracking natal and rearing habitat use of salmon breeding populations in the Nushagak River. This map will depict potential salmon natal sources of the Nushagak, which can be used to help resolve mixed stock fisheries conducted in the Nushagak Fishing District. This project focuses mainly on Chinook salmon (*Oncorhynchus tshawytscha*) as returns back to the Nushagak River, like other Western Alaskan Rivers, has seen marked declines in runs during the last decade. $^{87}Sr/^{86}Sr$ 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. We will use these natural markers in Chinook salmon otoliths to identify population structure and migration patterns, which can be used to source natal origins of Chinook salmon caught as by-catch during the Bristol Bay sockeye fishery in the Nushagak Fishing district. This will help current management efforts to conserve salmon biodiversity and sustain salmon productivity.

Objectives

The objectives of this study were:

1) To spatially and temporally geochemically characterize waters and breeding salmon populations of the Nushagak River and its major tributaries.

2) To continue to develop and evaluate a model in Arc Global Information Systems (GIS) which predicts inter- and intra-watershed variation using rock geochemistry data and geologic maps.

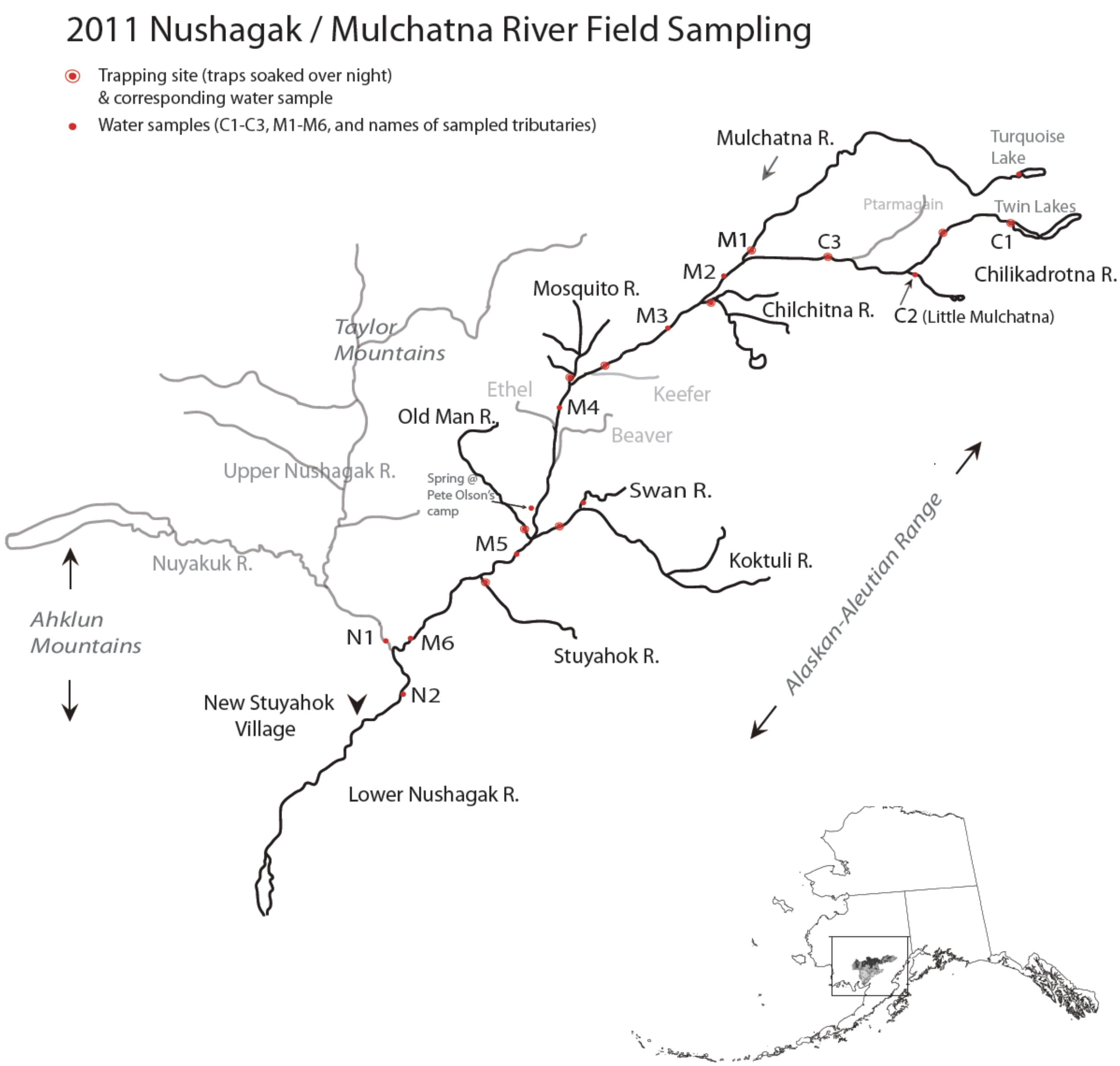
Relevance

This study is the first thorough investigation and evaluation in Alaska of whether $^{87}Sr/^{86}Sr$ variation of a watershed can be used to track natal sources of Pacific salmon using otoliths 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 Nushagak River salmon.

Methods

Water sample collection in the field:
Water samples from major tributaries of the Nushagak River were collected for $^{87}Sr/^{86}Sr$, δ^2H and $\delta^{18}O$, anions and major and trace elemental analyses. Additionally, alkalinity, pH and temperature were measured at each sampling site. Sample sites are pictured in Figure 1, and listed in Table 1. At about every fifth sample site three field replicates were collected to evaluate reproducibility of field collection and subsequent filtration methods. Also at every fifth site, a blank was collected and filtered in the same manner as samples to account for any field-derived contamination. 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. Samples were acidified with Ultrapure concentrated nitric acid within 16 days of collection and stored cool until analysis.

Figure 1: Fish trapping and water sampling sites completed during the 2011 field season on the Nushagak River.



Water isotopic and elemental analyses:
Sr isotopic compositions of waters are determined using a Thermo Scientific NEPTUNE High Resolution multi-collector inductively coupled mass spectrometer (MC-ICP-MS) at the University of Utah ICP-MS Laboratory. Elemental analyses are 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.

For isotopic analyses the Utah ICPMS lab has developed an automated sampling system to purify the Sr present in aqueous solutions using an inline chromatographic column packed with a crown ether resin (Eichrom's Sr Resin ®). The column is repeatedly used throughout each run (and also multiple runs). A total of two columns were used during the analyses presented in this report. The initial column was replaced with a new column when signal intensities for ^{88}Sr attenuated consistently below ~ 8 volts. Each sample (and standard) is bracketed with two 4M blanks (one before sample; one after), which act to purge the column of any residual Sr present from the prior analysis. The voltage of Sr measured in the blanks is used to correct the corresponding following sample or standard analysis. The residual voltage of Sr measured in blanks attenuates exponentially, such that our sample to blank signal ratio is consistently ~ 250:1 Volts.

Samples are analyzed in a series of runs consisting of about 10-15 samples per run. Prior to isotopic analysis a small sample from each river is analyzed to determine its elemental strontium concentration. For both elemental and isotopic analyses samples are prepared as a 4 molar acid solution using trace metal grade HNO_3. Run sequences are ordered starting with samples containing lowest concentrations of Sr to progressively higher concentrations. By not running a particular sample with a low Sr concentration directly after a sample with high Sr concentration we minimize potential memory effects of the column. All samples will lie between Sr concentration range of 40 – 290 ppb. 10 ppb is the minimum concentration, while 290 ppb is the max concentration (based off concentration of NIST SRM987 $SrCO_3$ standard) used to generate consistently accurate results for isotopic measurements using this method.

Otolith collections and strontium isotopic analyses:
Otoliths from fish representing three different life history patterns (anadromy - salmon, seasonally migratory - grayling, and sedentary - sculpin) were collected from the Nushagak River during the 2011 field season supported by funds from NIWR (see inventory in Table 1). These species of fish were selected to evaluate spatial and temporal variation in hydro-geochemistry and fish movement. Sculpin, an obligatory freshwater fish, which are sedentary, have been selected to evaluate potential seasonal variations in river water geochemistry. ^{87}Sr/^{86}Sr time-series of sculpin otoliths are hypothesized to reveal seasonal patterns if they exist in a particular river. Arctic grayling, a seasonally migratory fish have been selected to evaluate if otolith laser ablation methods can detect seasonal movement patterns of fish. These two different time-series address two important issues regarding the ability of the Sr-isotope method to track natal sources of fish caught in mixed stock fisheries: seasonal variation in a) hydro-geochemistry, and b) potential movement of juvenile salmon species from natal streams to rearing streams, respectively.

Analyses of ^{87}Sr/^{86}Sr ratios in otoliths are being done using multicollector-inductively coupled plasma mass-spectrometry (MC-ICP-MS) by Sean Brennan and Co-PIs Drs. Cerling and Fernandez at the University of Utah ICP-MS Laboratory using established laser ablation methods. Otolith analyses will target a) the region accreted during a salmon's freshwater stage (~250 μm distal of primordia – after yolk absorption, but before outmigration), and the region accreted during the marine stage; and b) produced ^{87}Sr/^{86}Sr time-series of individuals.

ArcGIS modeling of strontium isotopic variation in a watershed:

This model uses high- resolution geologic maps and available rock geochemistry data in the literature and databases (e.g., GEOROC - georoc.mpch-mainz.gwdg.de/georoc) to predict spatial variation of $^{87}Sr/^{86}Sr$ values of Nushagak river waters. Figure 2 is preliminary modeling conducted by Sean Brennan (the PhD student supported by this project) with Dr. Vanlaningham (Co-PI) (2010). For this preliminary work we compiled all available rock geochemistry data ($^{87}Sr/^{86}Sr$ and Sr ppm) available for each geologic unit in the Nushagak River basin and predicted the $^{87}Sr/^{86}Sr$ ratio of water at the mouth of the river based on the weighted contribution of each geological units respective area and average concentration of Sr in the rocks. Using the water samples collected during the 2011 field season for geochemical analyses we will ground truth this model and evaluate its accuracy.

Results

The $^{87}Sr/^{86}Sr$ range in samples collected this field season from tributaries of the Nushagak Watershed range from 0.70420 - 0.70778. As shown in Figure 1 the samples were collected from the Mulchatna River branch, which constitutes approximately half of the watershed area and drains a geologically diverse landscape (see Figure 2). As predicted by our model the tributaries draining out of the Taylor Mtn. are more radiogenic (higher $^{87}Sr/^{86}Sr$ ratios), than tributaries draining the Alaskan-Aleutian Range. However, the observed range is markedly less than our predicted range. Nonetheless, there are significantly different isotopic compositions between distinct tributaries of the Mulchatna-Nushagak River, which make it likely that this range can be used to distinguish distinct ‘isotopic stocks’ of respective salmon populations.

All adult and juvenile coho and Chinook salmon, and resident arctic grayling and sculpin collected during the 2011 field season (listed in Table 1) have been prepared for laser ablation ICPMS analyses. These analyses are currently taking place in Utah by Sean Brennan. Isotopic values from these fish otoliths will be correlated with water sample values to evaluate whether distinct ‘isotopic stocks’ exist in the Mulchatna-Nushagak tributaries sampled during the 2011 field season.

In addition to the Nushagak samples and analyses, we have also completed Sr-isotopic and elemental analyses of 14 Alaska Rivers (Table 3). These data add significantly to prior and ongoing data collected from Alaska Rivers during the 2009/2010 NIWR award, which was used to conduct the first Trans-Alaska Strontium Isotope Survey (TASIS). As is reported in Table 3, the $^{87}Sr/^{86}Sr$ range for Alaska Rivers has more than doubled with these additional 14 river samples. The range reported here is 0.70420 – 0.74041. This large range is likely to provide valuable data for water resource management projects and goals (incl. salmon) across Alaska by providing important baseline data, which geochemically characterizes watersheds and sub-watersheds. All of these water data are being prepared in a manuscript for submission to a peer-reviewed journal (Brennan, Wooller et al. in prep.).

Table 1: Water samples collected during the 2011 field season from tributaries of the Nushagak River.

2011 NUSHAGAK / MULCHATNA RIVER -- Water collections						
Site	**Temperature (°C)**	**pH**	**ORP**	**Alkalinity (CaCO3 mg/L)**	**$^{87}Sr/^{86}Sr$, major and trace elements (100 ml)**	**δ^2H, $\delta^{18}O$**
Turquoise Lake	-	-	-	-	x	x
C1	11.38	7.16	186	36	x	x
C2	9.21	7.07	140	26	x	x
C3	9.17	7.13	138	42	x	x
M1	9.08	6.69	138	44	x	x
M2	9.29	6.89	125	39	x	x
Chilchitna	7.78	6.61	137	32	x	x
M3	10.02	6.81	146	38	x	x
Mosquito	8.08	6.69	130	32	x	x
M4	8.81	6.86	130	34	x	x
Old Man	9.33	6.35	134	22	x	x
Spring @ Pete Olson's	-	-	-	-	x	-
Swan	11.35	6.29	114	31	x	x
Koktuli	10.87	6.57	143	26	x	x
M5	11.08	6.75	173	34	x	x
Stuyahok	10.94	6.48	122	19	x	x
M6	11.94	6.36	146	28	x	x
N1	11.68	6.67	149	27	x	x
N2	11.36	-	-	26	x	x

Table 2: Otolith collections from different species from tributaries of the Nushagak River. Juvenile fish and sculpin were captured via minnow traps, while adult coho salmon and grayling were captured via angling. Otoliths from adult sockeye and Chinook were retrieved from spawned out carcasses found along the river.

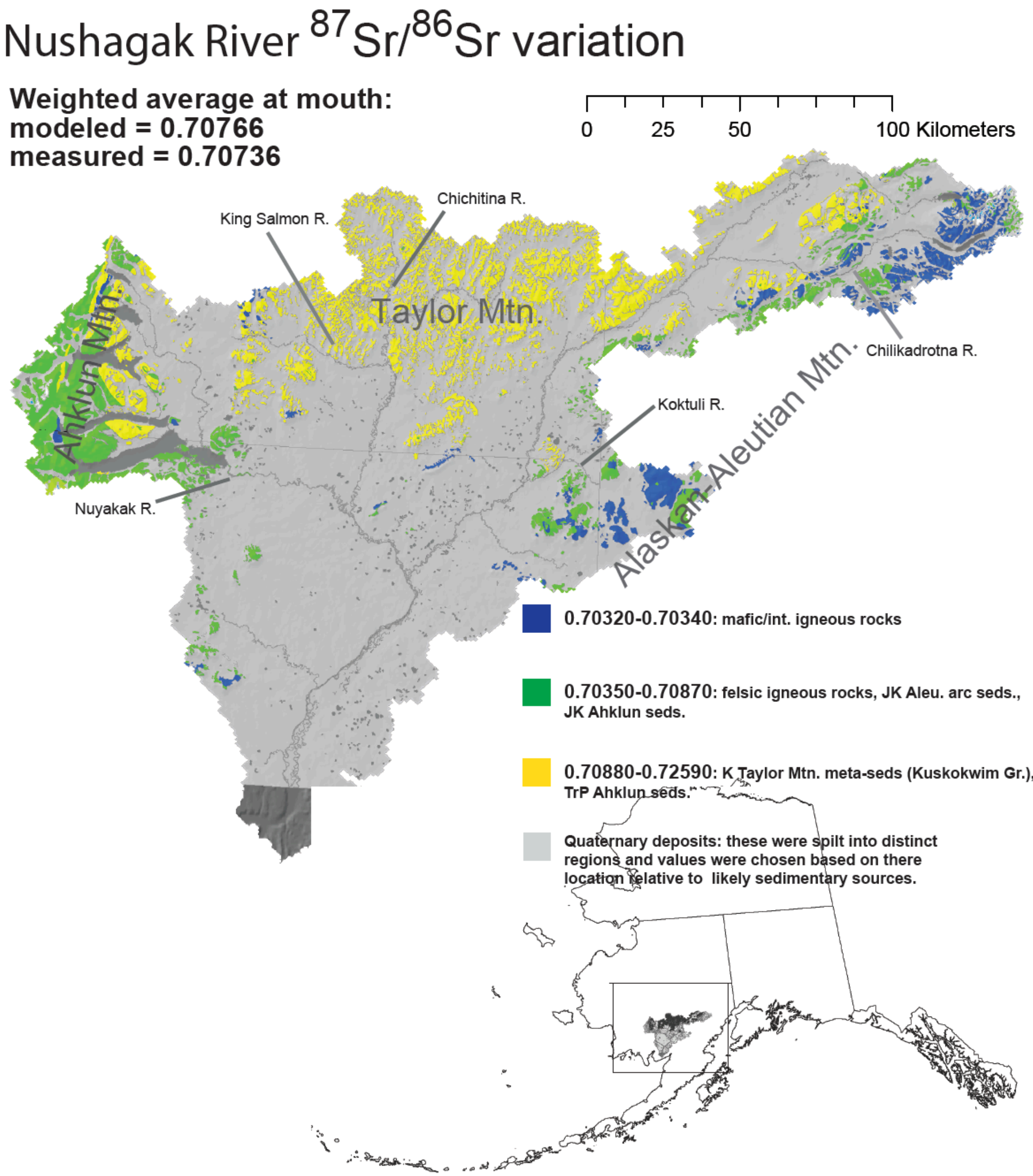
2011 NUSHAGAK / MULCHATNA RIVER -- Fish otolith collections

River	Juvenile King	Adult King	Juvenile Coho	Adult Coho	Adult Sockeye	Arctic Grayling	Sculpin
Chilikadrotna	5	3	9	0	0	1	4
Mulchatna	16	4	12	6	1	6	3
Chilchitna	1	1	10	0	0	1	0
Mosquito	0	0	10	0	0	1	0
Old Man	2	5	8	3	1	3	0
Koktuli	12	3	11	3	7	3	1
Stuyahok	12	1	10	3	0	3	2
Total	48	17	70	15	9	18	10

Table 3: Water results: Sr-isotope, major and trace element concentrations in Alaska Rivers.

Alaska River	Strontium isotope analyses complete
Nushagak Watershed	X
South Fork Koktuli 1	X
North Fork Koktuli	X
South Fork Koktuli 2	X
Stuyahok	X
Little Mulchatna	X
Koktuli 1	X
Koktuli 2	X
Koktuli 3	X
Chilikadrotna Outlet	X
Pete Olson's	X
C3	X
Swan	X
M2-1	X
M2-2	X
M2-3	X
Chilchitina	X
Turquoise Lake	X
M6-1	X
M6-2	X
M6-3	X
M4-1	X
M4-2	X
M4-3	X
M3	X
M5	X
Old Man Creek	X
M1	X
N2	X
Mosquito	X
N1	X
Other Alaska Rivers	X
Lake Amanka 1	X
Lake Amanka 2	X
Lake Amanka 3	X
Upper Talarik Creek	X
Snake Lake	X
Lake Aleknagik	X
Dulbi River	X
Hogatza River	X
Inoko	X

Figure 2: *A priori* modeling of the Nushagak River basin's predicted $^{87}Sr/^{86}Sr$ variation based on geologic maps and available rock geochemistry data. The 2011 field sampling (Figure 1) is being used to ground truth this modeling effort and evaluate its accuracy and effectiveness.


Nushagak River $^{87}Sr/^{86}Sr$ variation
Weighted average at mouth:
modeled = 0.70766
measured = 0.70736
0
25
50
100 Kilometers
Chichitina R.
King Salmon R.
Taylor Mtn.
Ahklun Mtn.
Chilikadrotna R.
Koktuli R.
Alaskan-Aleutian Mtn.
Nuyakak R.
0.70320-0.70340: mafic/int. igneous rocks
0.70350-0.70870: felsic igneous rocks, JK Aleu. arc seds., JK Ahklun seds.
0.70880-0.72590: K Taylor Mtn. meta-seds (Kuskokwim Gr.), TrP Ahklun seds.
Quaternary deposits: these were spilt into distinct regions and values were chosen based on there location relative to likely sedimentary sources.

Pharmaceutical Trace Study to Identify Microbial Pathogens Sources in and around Rural Alaskan Waste Sites

Basic Information

Title:	Pharmaceutical Trace Study to Identify Microbial Pathogens Sources in and around Rural Alaskan Waste Sites
Project Number:	2011AK99B
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Research Category:	Water Quality
Focus Category:	Solute Transport, Toxic Substances, Acid Deposition
Descriptors:	
Principal Investigators:	David L. Barnes

Publications

1. Mutter et al. (2012). Assessment of Rural Alaskan Solid Waste Leachate. Alaska Forum on Environment, Anchorage, 2012.
2. Mutter et al. (2011). Water Quality – Everyone's Topic. Alaska Tribal Conference on Environmental Management, Anchorage, 2011.
3. Mutter, E., and Schnabel, W., et al. (2011). Assessment of Rural Alaskan Solid and Wastewater Leachate. Biology Graduate Student Association Interdisciplinary Research Symposium, and at the Water Environmental Research Center Seminar, University of Alaska Fairbanks, 2011.
4. Mutter, E., and Schnabel, W., et al. (2012). Assessment of Contaminant Concentrations and Transport Pathways in Rural Alaskan Solid Waste Sites. American Water Resource Association Conference-Alaska Chapter, Juneau 2012.
5. Mutter, E., and Schnabel, W., et al. (2012). Assessment of Contaminant Concentrations and Transport Pathways in Rural Alaskan Solid Waste Sites. EPSCoR All-Hands Meeting, Fairbanks, 2012.

Introduction:

In rural Alaska, communities are highly sensitive to changes in the surrounding ecosystem and its effects upon subsistence activities. In turn, ecosystems themselves are highly sensitive to perturbations brought about by ineffective solid and sewage waste management practices. Due to the absence of regular monitoring, very little is known about chemical and microbial pollutants leaching from these solid waste dumps and sewage lagoons into nearby water resources. Moreover, these water resources often represent the environment that supports subsistence life in arctic and subarctic regions. In most instances, untreated waste material, including antifreeze, lead-acid batteries, detergents, medical, animal carcasses, and human waste is deposited into natural tundra ponds, unlined sewage lagoons or unlined dump sites. In rural Alaska, waste leachates and runoff can be caused by seasonal flooding and rain events, or through thawing of the active layer primarily during the warm season. In Alaskan communities underlain by permafrost, the spatial and/or hydrologic separation between water, wastewater, and solid waste facilities are often minimized due to a lack of adequate road systems and overly abundant surface water. For example, source water assessments recently conducted by the Alaska Department of Environmental Conservation (ADEC) rated the majority of public water systems utilizing surface sources in the Kuskokwim Delta region as being “highly” or “very highly” vulnerable to bacterial/viral impacts (ADEC 2008). Therefore, pathogenic microorganisms existing in the wastewater stream or in landfill leachate/runoff can pose a substantial threat to rural Alaskan drinking water resources. As a consequence, source water protection is an important component of community health maintenance wherever people treat drinking water. In areas such as rural Alaska with vulnerable water resources, source water protection is imperative. This study was conducted to investigate the interactions between rural Alaskan solid and wastewater sites upon the surrounding water resources, and to develop a new application to identify fecal pollution sources by using pharmaceutical tracers. Pharmaceuticals, such as anti-inflammatory; antibiotic, stimulant, and antidepressant drugs were selected for tracers to identify human fecal pollution.

Objectives:

In many of the 1,104 open dump sites located in rural Alaska, household waste chemicals and microorganisms are likely mobilized in the active layer during the warm season. However, due to the small size and relative inaccessibility of such communities, few waste disposal sites have been thoroughly evaluated. Consequently, there is limited information available to help planners better manage risks to human and environmental health. Specifically, the transport processes between dump sites, sewage lagoons, and nearby water resources in arctic or subarctic regions are not well understood. Moreover, these transport processes may be susceptible to changes resulting from human activity or warming climate.

The objective of this study is to 1) assess dump and sewage leachate to discriminate among different sources, human or nonhuman; 2) to use pharmaceutical tracers to identify and measure fecal pollution levels; 3) to use specific pharmaceutical traces to track human pathogenic organism sources from collected leachate/runoff in and around waste disposal sites; and 4) evaluate the existing pharmaceutical and microbial transport pathways between anthropogenic point sources and the surrounding surface resources.

These objectives were accomplished through surface and groundwater sample collection and analysis of pharmaceutical tracers and indicator bacteria in close proximity to four rural Alaskan solid waste and wastewater facilities. All analyses were conducted at the University of Alaska Fairbanks (UAF) Water Environmental Research Center (WERC), and the University of Alaska Anchorage (UAA) Applied Science Engineering and Technology (ASET) laboratory facilities. Field activities conducted for this project were coordinated with a team of researchers at the University of Alaska (UAF and UAA) in collaboration with the EPA Regional Applied Research Assessment (RARE) program, and the Rural Alaskan Community Action Program (Rural CAP). The study will result in at least one peer-reviewed publication describing the application of pharmaceutical tracer to identify human fecal pollution sources upon local water resources of waste disposal sites. Moreover, project results will be communicated directly to the communities.

Research Goals:

The goals of this research were to characterize the impacts of rural Alaskan solid waste dumps and sewage lagoons upon the surrounding water resources. In order to better manage the risk to human and environmental health, stakeholders need to more carefully evaluate the array of chemical and microbial risks imposed, and determine which ones pose the greatest threats. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, this study was designed to develop a new application for identifying and tracking fecal pollution sources, hence a more efficient method to assess rural Alaskan water resource quality. Furthermore, the obtained information evaluated the potential impacts of pharmaceuticals and microbial contaminants on human and ecosystem health. The project results will be leveraged with those of a parallel project being conducted by the U.S. EPA RARE program, and will therefore support a broader multi-agency effort. The study results are intended to assist rural communities, as well as the state and federal agencies in their attempts to find better solutions for rural waste disposal. Information collected in this project will be supplemented with data collected in a parallel study to form the basis for a peer-reviewed manuscript. This manuscript, along with associated conference presentations or other dissemination efforts, will begin the pro knowledge gap crucial to the State of Alaska.

Methods, Procedures, and Facilities

Geographic Extent:

Four rural Alaskan communities including Ekwok, Eek, Allakaket, and Fort Yukon are participating in the EPA sponsored Regional Applied Research Effort (RARE) project. These communities serve as models for other Artic and Subarctic regions. The following criteria were used for selection of the study sites:

1) Each community has a unique waste site situated in a different environmental setting (e.g., open tundra, ponded site, permafrost, and permafrost-impacted)

2) All open dumpsites are situated less than 1 mile from their respective communities, thereby constituting a proximal nuisance
3) Each community dumpsite is located less than 1,000 feet from a water resource;
4) each disposal site is reportedly impacted by seasonal flooding from rain or snowmelt runoff

Sample Collection:

Surface and subsurface water samples were collected in the vicinity of four rural Alaskan waste sites over the past year. Sampling sites were selected along hydrological pathways to enable monitoring and evaluation of contaminant transport via surface or subsurface waters throughout the warm season (including spring snowmelt). An elevation survey was performed for each site, and the distance between and and topographic gradient to source waters were derived from existing maps. Differences in aspect and inclination of surfaces were considered, and sampling sites were established to ensure the consideration of all individual pathways (e.g. slope-downhill, trough). A minimum of two control samples from undisturbed sites was obtained from each location.

Microbial Analysis:

Surface and subsurface water samples were collected at each waste site on two consecutive days in May and August 2011. Surface water samples were collected in the vicinity of the solid waste sites and sewage lagoons including: the waste site itself, 1 to 50 meters down gradient of the waste site, 50 to 5,000 meters down gradient of the waste site, and non-waste impacted sites (i.e., control sites). Subsurface water for microbial analysis was obtained from shallow groundwater wells (installed by RARE) when sufficient amount of water was present. Sampling techniques were consistent with EPA protocols for pathogen indicator organisms. Microbial indicator analysis was performed using IDEXX equipment available at the WERC (i.e., Colilert® for *E. coli*, and Enterolert® for *Enterococcus*). Statistical ANOVA analyses were performed to evaluate the significant difference between the Log MPN of the microbial indicators detected in the waste impacted surface and subsurface waters compared to the control samples. For each community collected surface and subsurface waters *E.coli* and *Enterococcus* microbial indictor density results were compared to EPA's recommended water quality criteria for these bacteria in recreational and fresh waters (EPA 2004). The recommended water quality criteria establish a geometric mean of 126 MPN/100 mL for *E. coli*, and a geometric mean of 35 MPN/100 mL for *Enterococci* (EPA Water Quality Criteria for Bacteria, 2004). Despite EPA recommendations, the State of Alaska sets its own criteria for fresh, recreational primary and secondary, groundwater, and marine water quality (18 AAC 70) for fecal coliform bacteria (ADEC 2011). The Alaska regulatory standards for secondary recreational water are set for a monthly period with a geometric mean of 200 FC/100mL, and not more than 10 percentage of the total sample may exceed 400 FC/100mL (ADEC 2011).

Pharmaceutical Analysis:

Surface water samples were collected at the vicinity of the solid waste sites and sewage lagoon on two consecutive days in May and August 2011. Water samples were collected in 250mL glass bottles (previously cleaned and baked at 400 ^{0}C), filtered through a Whatman GF/C 0.45 -1µm membrane filter, and acidified with hydrochloric acid to pH 2 within 48 hours. The samples were stored at 4 degree Celsius until solid phase extraction (SPE) was performed. Extraction and purification method was developed for identifying and quantifying pharmaceutical compounds in waste impacted surface waters samples. The Liquid Chromatograph (Agilent 1200) coupled to a Tandem Mass spectrometer (Agilent® 6140B), which is located in the ASET laboratory at UAA, was used for analysis. This instrument is specifically designed to study organic contaminants and drugs at low-level concentrations in a diversity of matrices. Table 1 illustrates all the tested pharmaceuticals in waste-impacted surface water samples.

Table 1: List of chemicals and their characteristics, which were tested in waste impacted surface water samples.

No.	Compound	formula	MW	typical use
1	Sulfamethoxazole	$C_{10}H_{11}N_3O_3S$	253.28	antibiotic
2	Trimethoprim	$C_{14}H_{18}N_4O_3$	290.32	antibiotic
3	Lincomycin	$C_{18}H_{34}N_2O_6S$	406.54	antibiotic
4	Enrofloxacin	$C_{19}H_{22}FN_3O_3$	359.40	antibiotic
5	Carbamazepine	$C_{15}H_{12}NO_2$	236.20	anticonvulsant
6	Venlafaxine	$C_{17}H_{27}NO_2$•HCl	313.86	antidepressant
7	Sertraline	$C_{17}H_{17}NCl$•HCl	342.69	antidepressant
8	Bupropion	$C_{13}H_{18}ClNO$•HCl	276.20	antidepressant
9	Ibuprophen	$C_{13}H_{18}O_2$	206.28	anti-inflammatory
10	Acetaminophen	$C_8H_9NO_2$	151.17	antipyretic
11	1,7Dimethylxanthine	$C_7H_8N_4O_2$	180.16	caffeine metabolite
12	Cotenine	$C_{10}H_{12}N_2O$	176.22	nicotine metabolite
13	Erythromecin-H_2O	$C_{37}H_{67}NO_{13}$•H_2O	751.93	Erythromecin metabolite
14	Caffeine	$C_8H_{10}N_4O_2$	194.19	stimulant

1) LC MS/MS methods for these compounds existed in ASET laboratory

Preliminary Results:

Preliminary Microbial Results:

The cumulative microbial results for each sampling event are presented in Tables 2 & 3. As indicated in the tables, *E.coli* and *Enterococci* indicator organisms were present in the vicinity of all the communities' waste-impacted water samples. A significant difference between samples collected from waste impacted samples compared to the control surface water samples was observed for all of the communities. The microbial indicator organisms samples, which exceeded EPA recommended geometric mean (*E.coli* of 126MPN/100mL and *Enterococci* of 33MPN/100mL) were observed with a range of 126 to 2512MPN/100mL for *E.coli* and 65 to 2512MPN/100mL for *Enterococci* (Tables 2&3). No evidence was detected indicating the migration of microbial indicator organisms into the subsurface waters or further than 50 meters downgradient from the waste sites.

Table 2: Summary table of E.coli microbial indicator samples exceeding EPA recommended bacterial geometric mean (*E.coli* of 126MPN/100mL) for water quality criteria 2004.

Sample Location:	**Ekwok**	**Eek**	**Fort Yukon**	**Allakaket**	**Totals**
Dump	4	3	--	1	8
Subsurface	1	0	0	0	1
<50 meters	2	0	1	0	3
50-5,000 meters	0	0	0	0	0
Sewage	4	4	N/A*	N/A*	8
Control	0	0	0	0	0
Totals	11	7	1	1	20

*N/A – no samples were collected

Table 3: Summary table of Enterococci microbial indicator samples exceeding EPA recommended bacterial geometric mean (*Enterococci* of 33MPN/100mL) for water quality criteria 2004

Sample Location:	**Ekwok**	**Eek**	**Fort Yukon**	**Allakaket**	**Totals**
Dump	4	5	--	2	11
Subsurface	1	0	0	1	2
<50 meters	3	0	2	1	6
50-5,000 meters	0	0	0	0	0
Sewage	4	4	N/A	N/A	8
Control	0	0	0	0	0
Totals	12	9	2	4	27

*N/A – no samples were collected

Preliminary Pharmaceutical Results:

Pharmaceuticals, such as anti-inflammatory; antibiotics, stimulant, and antidepressant drugs can serve as an excellent tracer to identify human fecal pollution sources due to the wide detection reported in raw sewage, treatment plant effluents, surface and groundwater, manure, and soils (Kuemmerer 2001), and have also been identified as emerging toxins in ground and surface water in the United States (Barnes et al. 2008; Focazio et al. 2008). Pharmaceuticals are primarily discharged into the environment through the route of human excretion of unmetabolized fraction following usage. Most rural Alaskan communities provide minimal or no treatment for their wastewater, it is therefore, likely that the concentration of pharmaceuticals in their sewage lagoons and/or solid waste sites is higher than the concentrations observed in modern treatment plant effluents. Moreover, outdated medication or their remnants are often disposed into household waste and eventually end up untreated in these open dumps. In addition, it is likely that pharmaceuticals present in rural Alaskan sewage lagoons and/or landfills will persist in the environment upon offsite migration due to low temperature and degradation rates. Pharmaceutical detected present in waste impacted surface waters are illustrated in Table 4. The data presented in this report are preliminary, and still require further evaluation prior to reporting concentration results.

Table 4: List of pharmaceutical detected present in waste impacted surface water samples.

No.	Compound	Sewage Lagoon	Dump Impacted Water
1	Sulfamethoxazole	X	X
2	Trimethoprim	X	X
3	Lincomycin	N/D	N/D
4	Enrofloxacin	N/D	N/D
5	Carbamazepine	N/D	N/D
6	Venlafaxine	X	X
7	Sertraline	X	X
8	Bupropion	N/D	N/D
9	Ibuprophen	N/D	N/D
10	Acetaminophen	X	X
11	1,7Dimethylxanthine	X	X
12	Cotenine	N/D	N/D
13	Erythromecin-H_2O	N/D	N/D
14	Caffeine	X	X

* X - Detected Pharmaceutical Compounds
* N/D - not detected or below HPLC-MS/MS detection limit

Discussion:

Figure 1&2: Rural Alaskan Open Dump during a Flooding Event and Rural Alaska Solid Waste Dump Pond

Developing proper disposal and management techniques for solid waste in rural Alaska is a difficult issue (Figure 1). Highway infrastructure is limited in most of rural Alaska, thereby limiting the utility of regional landfills. Barge traffic is often discontinued during the winter, thus diminishing transport options for river communities. Many communities import goods and materials via air freight, but the option of flying garbage out to distant landfills is not cost effective. Consequently, many villages are limited to disposing their solid waste (and wastewater) in swampy terrain relatively close to drinking and subsistence water resources (Figure 2). As a result, it is crucial to better understand the mobilization of contaminants such as pathogenic organisms from the waste sites to the surrounding environment. The study results have demonstrated that fecal indicator bacteria are prevalent and exceeding the recommended EPA water quality criteria for bacteria in the surface water samples surrounding waste sites in rural Alaska. Furthermore, the study demonstrated the presence of pharmaceutical compounds, such as Sulfamethoxazole, Trimethoprim, Venlafaxine, Sertraline, Acetaminophen, 1,7Dimethylxanthine, and Caffeine in waste impacted water samples. Based upon the preliminary data, we believe that caffeine represents the best suited, of the pharmaceutical tracers evaluated, to track human pathogen microorganism sources from collected leachate/runoff in and around waste disposal sites for cold regions. We will provide a final recommendation following further evaluation of our project results. However, caffeine does pose problems with respect to analytical matrix interference. Finally, we obtained no evidence to indicate that indicator organisms or pharmaceuticals migrated in detectable concentrations into the subsurface waters or further than 50 meters downgradient from the waste sites.

<u>Literature Cited:</u>

ADEC. (2008). "Drinking Water Program: Public Source Water Assessment Results." Alaska Department of Environmental Conservation.

ADEC. (2011). "Water Quality Standards". http://dec.alaska.gov/water/wqsar/wqs/pdfs/18_AAC_70_as_Amended_Through_May_26_2011.pdf

Barnes, K. K., Kolpin, D. W., Furlong, E. T., Zaugg, S. D., Meyer, M. T. and Barber, L. B. (2008). A national reconnaissance of pharmaceuticals and other organic wastewater contaminants in the United States -- I) Groundwater. *Science of The Total Environment* **402**(2-3): 192-200.

EPA. (2004). “Water Quality Standards for Coastal and Great Lakes Recreation Waters; 40 CFR Part 131Final Rule”. (http://www.epa.gov/fedrgstr/EPA-WATER/2004/November/Day-16/w25303.pd

Focazio, M. J., Kolpin, D. W., Barnes, K. K., Furlong, E. T., Meyer, M. T., Zaugg, S. D., Barber, L. B. and Thurman, M. E. (2008). A national reconnaissance for pharmaceuticals and other organic wastewater contaminants in the United States -- II) Untreated drinking water sources. *Science of The Total Environment* **402**(2-3): 201-216.

Kuemmerer K., (2001). Pharmaceuticals in the environment: Source, fate, effects and risks. Springer.

United State Geologcial Survey (USGS). Toxic Substances Hydrological Program. Available for download at http://toxic.usgs.gov.

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Notable Awards and Achievements