The status of environmental monitoring in shared Alaska-British Columbia watersheds

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Purpose and scope

Click on the map for a higher resolution web image

In this data brief, I provide high-level summaries of recent environmental monitoring efforts related to mining operations in watersheds shared by Alaska and British Columbia (AK-BC transboundary region). My primary objective was to concisely describe and reference recently collected government data and identify potential information gaps.

Many legacy, exploration, and currently operating mining projects are present in the AK-BC transboundary region, which is rich in natural resources. I focus on the Taku, Stikine, Unuk, and Nass Rivers. While the Nass is not transboundary, it is included because it is adjacent to the Unuk River, shares similar potential for mining impacts, and—like the other transboundary rivers—is home to critically important salmon populations. The ecological, social, and cultural importance of these rivers has prompted government entities to pursue environmental monitoring activities with the intent of characterizing their current condition in case of future change resulting from mining impacts. Effective monitoring for environmental change relies upon defensible scientific data, standardized protocols, and sustained program support. Community members, agency regulators, and legislators rely on quality information to advocate for, enact, and enforce meaningful laws and regulations. Industrial operators also rely on this information to measure compliance with regulations. At the end of this document, I provide long-term monitoring program considerations that may be valuable for designing future programmatic efforts. Throughout the document, hyperlinks lead to more detailed information.

Acknowledgements

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Contemporary monitoring efforts in transboundary watersheds

Many entities are responsible for various aspects of past and ongoing data collection in Alaska-BC shared watersheds. Below, I review six current monitoring efforts that vary in spatial scope and length of time. Table 1 at the end of this section provides a brief summary of the temporal and spatial resolution of each effort.

Joint effort of the British Columbia Ministry of Environment and Climate Change Strategy (ENV) and Alaska Department of Environmental Conservation (DEC)

In response to the Memorandum of Understanding (November 25, 2015) and Statement of Cooperation (October 6, 2016) signed between Alaska and British Columbia, ENV began in August 2017 a two-year aquatic field survey on the BC portions of the Taku, Stikine, and Unuk Rivers. Bi-lateral working group meeting notes can be found here. A report completed March 2020 (Torunski et al. 2020) combines data collected by DEC during their 2018 Southeast Rivers survey, and data collected by ENV from 2017 through 2019. A final joint report is expected during autumn 2020.

Appendix Table A1 at the end of this document summarizes sampling effort by both agencies. Preliminary results from the DEC effort were originally published at the AKMAP website, but a final report has not yet been released. The preliminary DEC report states that surveyors measured physical habitat and collected water, sediment, benthic macroinvertebrates (small but visible aquatic animals), and periphyton (freshwater organisms clinging to bottom sediments) for chemical analyses (mainly, metal concentrations).

While the sampling summarized in Table A1 represents a significant and important data collection effort, some biological components known to be more sensitive to pollution were only collected at a small subset of the 43 listed sites (benthic macroinvertebrates collected at 28% of sites and fish at 21%). Additional periphyton and fish collections will be summarized in the upcoming final joint report. After reviewing existing reporting, it does not appear that any single site was sampled for all aquatic components across most or all of the field sampling events.

Historical water quality data collected as part of DEC's Southeast Data Mining Project are visually represented on Alaska's Water Quality Map. When the website was reviewed in August 2020, there were 11 data points from the Taku River watershed, approximately 75 data points from the Stikine River watershed, and 11 data points from the Unuk River watershed. As of September 2020, data were not available to download from the map viewer.

Taku River Tlingit First Nation (TRTFN)

During summer and fall 2019, staff from the TRTFN Lands, Resources and Fisheries Department and Flathead Lake Biological Station created pilot monitoring protocols to assess ecological condition of the Tulsequah River up and downstream of Tulsequah Chief Mine, for which a reclamation plan is currently under development. The Tulsequah River is a large tributary to the Taku River. Field work was conducted from 8-10 October 2019 across 13 sites and had two primary objectives: 1) increase the temporal and spatial resolution of environmental monitoring by TRTFN and BC; and 2) begin to track long-term changes to the aquatic macroinvertebrate community.

Sampling sites represented pairs of mainstem and side channel locations spaced at varying distances from Tulsequah Chief Mine. Sediment chemistry samples were collected at 8 sites, water across all 13 sites, sculpin at 6 sites, and aquatic macroinvertebrates at 12 sites. Aquatic macroinvertebrate community data have not yet been analyzed. Spatial trends in metal concentrations moving from upstream to downstream were not consistent across matrices, underscoring the need for continued monitoring to clarify the environmental mechanisms driving observed trends. All 13 sites from 2019 and several additional tributary sites were re-sampled during September 2020, and analyses are underway.

Alaska Department of Fish and Game (ADFG)

To examine the potential impact of acid mine drainage from the Tulsequah Chief Mine on the Tulsequah River, ADFG collected water quality data and Dolly Varden tissue for chemical analysis at three sites during June 2011, August 2014, June and September 2015, and April 2016. Over those time periods, 29 Dolly Varden samples were collected and analyzed from the upper Tulsequah River (above Tulsequah Chief Mine), 52 from downstream of Tulsequah Chief Mine, and 20 from the mainstem Taku River at the AK-BC border. The analysis concluded that Dolly Varden, "…captured near acid drainage in the Tulsequah River are similar to samples we took upstream and downstream of mine drainage influence." Field crews also captured juvenile coho salmon, Chinook salmon, and sculpin (unidentified species) at all sites, but these species were not analyzed. Even as juveniles, Dolly Varden are highly mobile species that may use many different parts of a watershed before maturing and becoming anadromous. On the other hand, sculpin species are very sedentary and do not move far, often less than 1 km from where they were born. Therefore, metal concentrations in sculpin would be more representative of their immediate surroundings, which is an important consideration for future mining impact studies.

Water Survey of Canada (WSC)

The WSC is the federal entity responsible for collecting, interpreting, and disseminating streamflow data from Canada's rivers. Based on the online mapping tool, no streamflow gages currently exist in the BC portions of the Taku or Unuk River watersheds, but three exist within the BC portion of the Stikine River watershed at Tuya River, Telegraph Creek along the mainstem Stikine River, and the Iskut River near the confluence with the Stikine. Continuous data for these sites exist as far back as 1965, but some data gaps exist. All three stations are far downstream of the currently operating Red Chris Mine and not able to shed light on whether operations have an impact on Stikine River or tributary flow patterns. To better understand the future potential impacts of Red Chris Mine on water quantity patterns, there is a need to install gauges higher in the mainstem Stikine and Iskut watersheds. Streamflow data for the Tulsequah River will also be critical for determining the volume of water available for diluting treated or untreated runoff from Tulsequah Chief Mine.

Central Council Tlingit and Haida Indian Tribes of Alaska (CCTHITA)

Since 2015, CCTHITA has been conducting approximately monthly water sampling at two sites per river on the Stikine and Taku Rivers. At each site, all downstream of the AK-BC border, CCTHITA samples water at the surface, and five and ten foot depths. Standard water quality measurements such as pH and turbidity are collected with field sensors, while additional laboratory samples include dissolved metals and organic compounds. As of December 2019, 34 samples have been collected for the Stikine River, and 32 for the Taku River, but the effort is ongoing.

United States Geological Survey (USGS)

USGS is actively monitoring streamflow, water quality, and metals in fish tissue and sediment. Super gages, which measure streamflow and water quality every fifteen minutes at a fixed location, have been in place since November 2017 in the Unuk River and since May 2019 in the Taku and Stikine Rivers. All three super gages are placed in the Alaska portion of each watershed. Water quality parameters include water temperature, conductivity, dissolved oxygen, pH, fluorescent dissolved organic matter, and turbidity. USGS also collects additional water samples in the immediate vicinity of the gages. From 2017 to 2019, 8 samples have been collected in the Taku, 7 in the Stikine, and 19 in the Unuk. These samples have been analyzed in USGS labs for nutrients, carbon, major ions, total and dissolved metals, and alkalinity.

Multiple species of fish have been collected near each gage site for muscle, liver, or whole-body tissue analysis. Triplicates of riverbed sediment samples have been collected from areas approximately 100 meters up and downstream of each gage site. Results for both are pending. While the transboundary super gage sites are close to the border and assumed to be representative of surrounding conditions, this assumption will be tested by collecting additional biological and sediment samples from areas surrounding the gages. This effort began in federal fiscal year 2019, when additional biological and sediment samples were collected throughout the Alaska portion of the Taku River watershed.

The USGS monitoring efforts described here are part of a broader 5-year plan that includes (1) surveys to assess the geology, geochemistry, and potential for mining-induced impacts to the watersheds, (2) retrospective analysis and new data collection to characterize the water quality, sediment quality, and biological condition of the rivers, and (3) establishing partnerships with Tribes and other agencies to ensure that assessments meet the needs of Tribes and local stakeholders.

Conclusions

This synthesis finds that monitoring efforts tend to be concentrated in small areas of each watershed or relatively short-term in effort. The need for long-term data is recognized across many different entities. For example, Section 7 of the Alaska Highway Drainage Manual recognizes the importance of surface water variability when designing infrastructure [e.g. bridges and culverts] and states, "A complete [discharge] record is usually defined as one having at least 10 years of continuous record. Twenty-five years of record is considered optimal." Hydropower licenses granted by the US Federal Energy Regulatory Commission typically last 30-50 years and involve many monitoring programs spanning the life of each license. The National Park Service's Inventory and Monitoring Program creates long-term monitoring protocols assuming that data collection will last 50 to 100 years. Therefore, monitoring the environmental health of the AK-BC transboundary region will require a commitment to longer term data collection across a broader number of sites than currently exists.

Table 1. Summary of the spatial and temporal resolution of each monitoring effort presented in this document. The types of samples collected are described in each section above.

Monitoring entity	Spatial resolution	Temporal resolution	Continued sampling expected?
DEC	20 sites across the AK portions of the Taku, Stikine, and Unuk Rivers	Single samples from every site during June or July 2018	No
ENV	23 sites across the BC portions of the Taku, Stikine, and Unuk Rivers chosen for proximity to existing or proposed mines	Repeat sampling for most sites across: - 2017: August - 2018: September, November - 2019: February, June, August, September	No
TRTFN	Up to 17 sites in the Tulsequah River	2019: October 2020: September	Yes
ADFG	3 sites spanning the upper Tulsequah River, lower Tulsequah River, and mainstem Taku River	2011: June 2014: August 2015: June, September 2016: April	No
WSC	3 sites in Stikine River watershed	Continuous streamflow data since 1965 with some gaps	Yes
CCTHITA	2 sites on the AK portions of the Taku and Stikine Rivers	Approximately monthly sampling since 2015	Yes
USGS	1 site each on the AK portions of the Taku, Stikine, and Unuk Rivers	Streamflow and water quality samples collected every 15 minutes; Unuk River since November 2017; Taku and Stikine Rivers since May 2019; additional grab samples periodically collected in vicinity of gages	Yes

Extended reading on long-term monitoring program considerations

The purpose of this section is to provide interested readers with more in-depth information related to important considerations for designing long-term future monitoring programs in AK-BC transboundary watersheds.

Key monitoring concepts: watershed, status/baseline, trend, and statistical power

Environmental monitoring is fraught with jargon, so in order to aid future conversations on ecological monitoring in the AK-BC transboundary region, I provide a definition for some of the terms used in this data brief to ensure readers have a common understanding.

Watershed refers to much more than just a flowing river channel. The United States Geological Survey defines a watershed as, "…an area of land that drains all the streams and rainfall to a common outlet…" For the Taku, Stikine, and Unuk Rivers, the common outlet for each watershed is the Inside Passage waters of Southeast Alaska. Each of the colored shapes in the map on the first page represent a watershed. Watersheds are sometimes also called drainage basins or catchments.

The **status** or **baseline** of a watershed characterizes the physical, chemical, and/or biological attributes (measurements) across the entire drainage area. Status and baseline are often used interchangeably. Examples of attributes include:

- Physical: maximum streamflow or sediment composition of the riverbed
- Chemical: pH or total phosphates in river water
- Biological: selenium concentration in fish tissue or abundance of an aquatic insect species

A change in physical, chemical, or biological measurements over a period of time is called a **trend**. To detect a trend, monitoring programs must be designed with **statistical power** in mind. Statistical power is the likelihood that a set of measurements will detect a trend (or effect) when there is actually a trend to be detected. A study with high statistical power has a better chance to detect a trend. Larger trends (for example, a 1° Celsius increase in water temperature per year) are easier to detect than smaller trends (0.1° Celsius increase in water temperature per year), and a ***greater number of consistently collected measurements over time increases the chance a trend will be detected***.

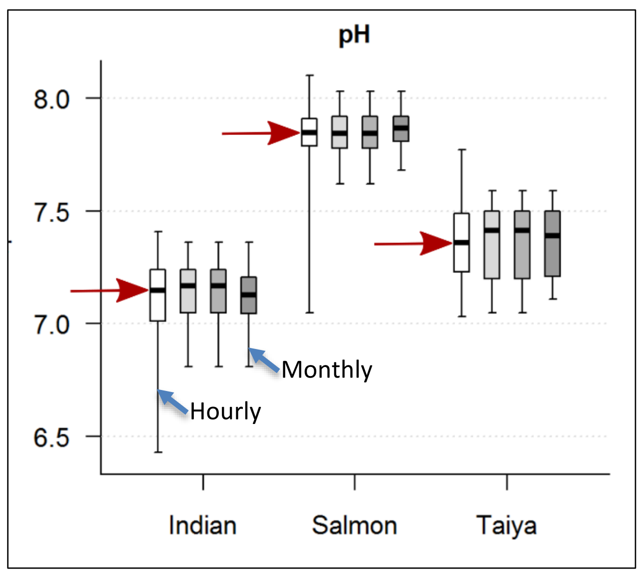
Monitoring consistency is essential

Rivers are dynamic environments, constantly shifting in character across space and time. For example, we would not expect measurements of water temperature, pH, metal concentrations, or aquatic insect communities in the Stikine River to be similar between Telegraph Creek and the Alaska-British Columbia border, which are separated by over 100 miles of river channel. Therefore, when characterizing the status of a watershed—as opposed to the status of a single tributary or impacted site—any measurements of interest must be made throughout the drainage area, from the headwaters to the outlet, across various tributaries and elevations. This is an important consideration for science in the transboundary Alaska-British Columbia watersheds, where proposed mining projects are scattered throughout watersheds and it is difficult to prioritize one particular monitoring location.

When measuring the status of a watershed, many environmental factors also complicate the interpretation of measurements and must be accounted for during monitoring program design, including:

- Location in the watershed—headwaters, medium-sized tributaries, large mainstems
- Location in the stream channel—pools, riffles, runs
- Seasonality and weather patterns—wet, dry periods
- Time of day
- Flow level
- Climate change—glacier retreat, less precipitation falling as snow, warmer air temperature

Monitoring program design is a broad and complex topic, but two general approaches are often combined in aquatic environments:



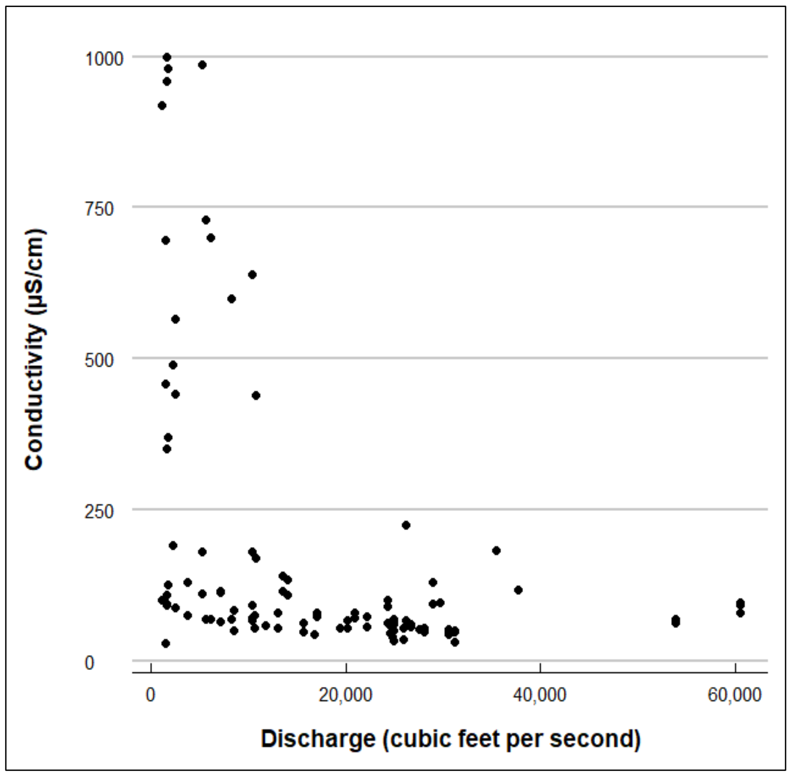
1) **Collect measurements at a high frequency under a variety of environmental conditions**. In this case, high frequency refers to measurements collected at the sub-hourly to daily time scales for five years or more. This is the ideal approach for characterizing watershed status and trends, but not always realistic in remote regions or for expensive analyses. The figure on the right (taken from Sergeant and Nagorski 2015), illustrates how various sampling frequencies impact our ability to discern the true range of pH values from three rivers in Southeast Alaska national parks. The red arrows point to data collected at hourly intervals. The bold lines represent the median pH value, while the ends of the bars represent the maximum and minimum observed values. As you move right for each river, the bars represent the same measurements but collected at weekly, biweekly, and monthly intervals (darkest gray). In each case, the true range of pH values, which vary by as much as 1 unit, would not be known without hourly monitoring. This phenomenon is consistent across many physical, chemical, and biological measurements. A Clark Fork River, Montana study by Brick and Moore (1996) demonstrated that dissolved metal concentrations rose to levels toxic to aquatic life only during nighttime hours, a time when sampling rarely occurs. In rivers, extreme high or low flow events are often short-lived, and it is within these small windows of time that water quality can change dramatically.

2) **Collect measurements at a low frequency but under nearly similar environmental conditions.** This complements the high frequency approach described above and is well-suited for analyses that require intense collection effort, large expense, and do not change quickly, such as metal concentrations in fish tissue. Typically, these would be collected at monthly, seasonal, or annual time scales, but it is extremely important to reduce the potential influence of external environmental variables. It is impossible to collect measurements under the same conditions every time monitoring occurs, but environmental factors should be controlled to the extent possible to allow data users to have the best chance to detect changes over time. For example, monitoring design should consider sampling at the same times of year, at similar flows, with the same methods, at the same location. Often, a dynamic sampling approach, which also allows practitioners to sample during extreme events provides more information on how and why observed trends are happening. Trends are important to detect, but sampling must also be created in a way that allows researchers to determine why trends are observed (e.g. chronic or acute pollution changing precipitation patterns, shifting soil chemistry, etc.).

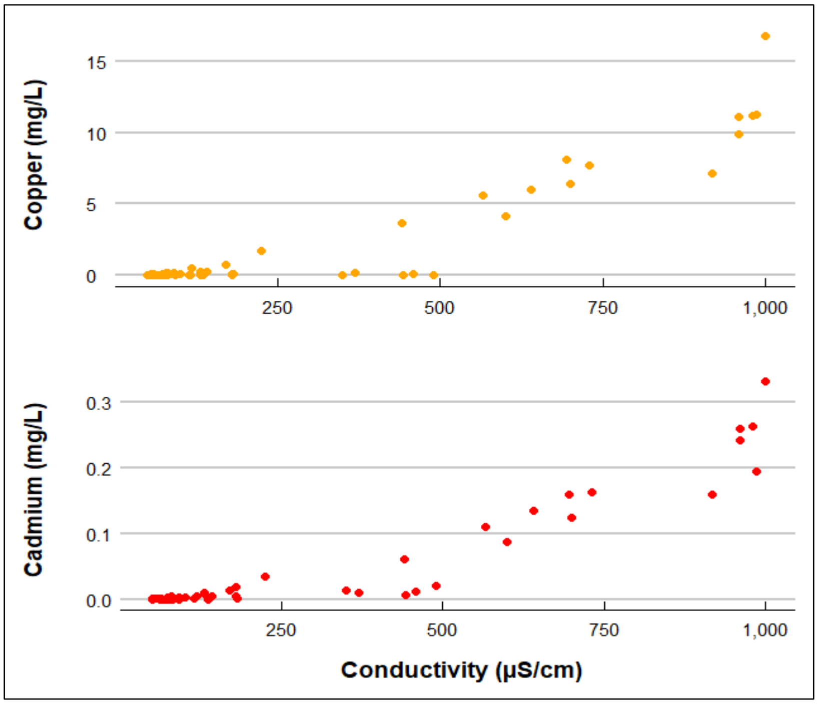
An example of why river conditions matter: metal concentrations change with flow

We can illustrate the importance of environmental factors on data collection and interpretation using streamflow, conductivity, copper, and cadmium data from water samples collected on the Tulsequah River, a large tributary of the Taku River that has been impacted by mining activities for more than 70 years.

Specific conductance—shortened here to conductivity—is an easily measured water quality parameter describing the ability of a water sample to conduct an electrical current. Increasing conductivity values are often indicative of elevated dissolved ions (resulting from, for example, surface soils entering a river channel from a floodplain) and often correlated with pollution events. In historical data collected from the Tulsequah River (Gartner Lee Limited 2007 and British Columbia Ministry of the Environment and Climate Change Strategy 2019), conductivity values downstream from Tulsequah Chief Mine are highly correlated with flow (discharge) in the Taku River[1]. Values are highest during low flow periods.



[1] Regular flow measurements are not available for the Tulsequah River, so Taku River flow values downstream of the Tulsequah River were used here as a surrogate



In addition, conductivity is highly correlated with certain metal concentrations in Tulsequah River water collected downstream of Tulsequah Chief Mine. Therefore, to accurately characterize the range of metal concentrations found in Tulsequah River water samples, monitoring must be conducted at a range of high and low flows, or else the true range of cadmium and copper concentrations would be unknown. This example also demonstrates that measurements such as conductivity, which can be measured remotely with readily available instrumentation, can be used as surrogates for more expensive laboratory analyses of metals. It is important to note however, that surrogates such as conductivity cannot become the sole monitoring focus, because these relationships may not represent the same distribution of dissolved ions over time and some metal concentrations do not correlate with conductivity.

Supporting materials and further reading

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Appendix A: Summary of recent monitoring conducted by Alaska Department of Environmental Conservation (DEC) and British Columbia Ministry of Environment and Climate Change Strategy (ENV)

Table A1. Summary of DEC and ENV transboundary monitoring efforts conducted between August 2017 and June 2019. This table is copied directly from Torunski et al. 2020. Additional sites sampled in August and September of 2019 will be included in the final report. In addition to physical and chemical analyses of water and sediment, all aquatic components sampled were analyzed for a standard suite of metals.

Watershed	Site Name	River/Creek	DEC/ B.C.	Aquatic Components Sampled					Sampling						
				Water	Sediment	Benthic Inverts	Periphyton	Fish	Aug '17	Jun '18	Jul '18	Sep '18	Nov '18	Feb '19	Jun '19
Taku	Taku 1	Tulsequah	B.C.	X	X				X				X	X	X
	Taku 2	Tulsequah	B.C.	X	X				X				X	X	X
	Taku 3	Tulsequah	B.C.	X	X	X			X			X	X	X	X
	Taku 4	Taku	B.C.	X	X	X			X			X	X	X	X
	Taku 5	Taku	B.C.	X	X				X				X	X	X
	Taku 6	Whitewater	B.C.	X								X		X	X
	Taku 7	Whitewater	B.C.	X				X				X		X	X
	Taku 8	Tulsequah	B.C.	X		X						X			
	Taku 9	Tulsequah	B.C.					X				X			
	Taku 10	Tulsequah	B.C.	X	X			X				X			
	Taku 11	Taku	B.C.	X	X	X						X			
	NRS18-AK-10159	Taku	DEC	X						X					
	NRS18-AK-10160	Taku	DEC	X						X					
	NRS18-AK-10162	Taku	DEC	X						X					
	NRS18-AK-10165	Taku	DEC	X						X					
	NRS18-AK-10167	Taku	DEC	X	X					X					
	NRS18-AK-Taku1	Taku	DEC	X						X					
	NRS18-AK-Taku2	Taku	DEC	X	X					X					
Stikine	Stikine 1	Stikine	B.C.	X	X				X			X	X	X	X
	Stikine 2	Stikine	B.C.	X	X				X			X	X	X	X
	Stikine 3	Stikine	B.C.	X	X				X						X
	Stikine 4	Iskut	B.C.	X	X	X			X			X	X	X	X
	Stikine 5	Iskut	B.C.					X				X			
	Stikine 6	Christina	B.C.			X		X				X			
	Stikine 7	Stikine	B.C.	X		X		X				X	X	X	X
	NRS18-AK-10064	Stikine	DEC	X	X						X				
	NRS18-AK-10139	Stikine	DEC	X							X				
	NRS18-AK-10147	Stikine	DEC	X							X				
	NRS18-AK-10150	Stikine	DEC	X	X						X				
	NRS18-AK-Stik1	Stikine	DEC	X							X				
	NRS18-AK-Stik2	Stikine	DEC	X							X				
Unuk	Unuk 1	Unuk	B.C.	X	X	X						X	X	X	X
	Unuk 2	South Unuk	B.C.	X	X	X		X				X	X	X	X
	Unuk 3	Unuk	B.C.	X	X	X						X	X	X	X
	Unuk 4	Sulphurets	B.C.	X	X	X		X				X	X	X	X
	Unuk 5	Unuk	B.C.	X	X	X		X				X	X	X	X
	NRS18-AK-10177	Unuk	DEC	X							X				
	NRS18-AK-10178	Unuk	DEC	X							X				
	NRS18-AK-10180	Unuk	DEC	X							X				
	NRS18-AK-10181	Unuk	DEC	X							X				
	NRS18-AK-10182	Unuk	DEC	X							X				
	NRS18-AK-Unuk1	Unuk	DEC	X	X						X				
	NRS18-AK-Unuk2	Unuk	DEC	X	X						X				