1. PROJECT INFORMATION

<table>
<thead>
<tr>
<th>Title:</th>
<th>Linking North Slope Climate, Hydrology, and Fish Migration</th>
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<tr>
<td>Report period</td>
<td>July 1 to December 31, 2012</td>
</tr>
<tr>
<td>Report submission date</td>
<td>February 6, 2013</td>
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<tr>
<td>Author of Report</td>
<td>Erica Betts</td>
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2. PROJECT OVERVIEW

a. Briefly (4-5 sentences) describe both the research purpose and the underlying need for this research.

The purpose of this research is to assess whether a changing hydrologic regime on the North Slope of Alaska may impact fish migration. Figure 1 below highlights the relationship between Arctic grayling migration and the typical hydrologic regime found in the Kuparuk River basin.

Figure 1. Relationship between timing of grayling migrations and typical hydrologic flow regime in non-glacial fed arctic rivers.
This hydrograph is typical of non-glacial fed arctic streams in that the highest flows occur during spring melt. Grayling migrate to spawning grounds during these high flows. High spring flows can quickly dissipate as low precipitation rates and high evapotranspiration rates occur in early summer. This drying of the landscape can lead to a fragmented hydrologic landscape for fish as lakes and ponds become disconnected from rivers and rivers themselves become fragmented by low water levels. Grayling must migrate back to safe overwintering sites before freeze-up occurs. Changing precipitation patterns, higher temperatures and longer open water seasons may result in magnified drying across the Arctic landscape. The purpose of this research is to assess the possibility of increased hydrologic fragmentation along the Kuparuk River in response to climate change and its impact on Arctic grayling.

b. **List the objective(s) of the project, exactly as described in your Statement of Work.**
Specific project goals are to:
1) Identify “critical” river reaches based on previous occurrence of minimal flow depth along known conveyances between seasonal fish habitats;
2) Establish the relationship between measured stream flow and depth of surface flow (as opposed to subsurface flow beneath the river bed) within the critical reaches;
3) Quantify the frequency, timing, duration, and magnitude of low flow periods over the historical record.

3. **PROGRESS SUMMARY**

a. **Describe report period progress.**

The summer of 2012 was the final field season for this project. Instrumentation was placed along critical reaches in May and collected in September. Discharge was measured along these reaches and a dye tracer test was performed at three intervals over the summer. Water samples were taken from critical stream reaches as well as associated springs and aufeis fields for use in isotope analysis.

b. **Describe preliminary results.**

Figure 2 below shows the project location as well as the location of equipment installed.
Figure 2. Research location: Kuparuk watershed, North Slope of Alaska. Image shows location of pressure transducers, temperature loggers, and meteorological stations. Research was conducted at three sites: Upper Kuparuk (UK), Lower Kuparuk, (KUP) and Oksrukuyik Creek (OX).

The following photos show the critical reaches in the Upper and Lower Kuparuk during dry periods as well as periods with stream flow.
Photo 1. Example of a dry event on the Lower Kuparuk River (KUP PT station).

Photo 2. Same reach on the Lower Kuparuk but with 6 ft. of water.
Photo 3. Example of a dry event on the Upper Kuparuk River (UK PT station).

Photo 4. Same reach as photo 3, but with low flow.
The image below was taken just downstream of the reach shown in Photo 3 and 4 during a dry spell. Hundreds of Arctic grayling were stranded below the “dry” reach. Heavy bird predation was witnessed at the site and a nearly 75% loss in accumulated biomass was measured in tagged fish.\(^1\) It will be very interesting to see how or if these fish survive the long winter.

![Arctic grayling](image)

Photo 5. Arctic grayling (*Thymallus arcticus*) congregating just North of the UK PT station during a dry spell, waiting to migrate south to their overwintering site. *Image courtesy of Linda Deegan, MBL*

In order to measure flow within these critical reaches, pressure transducers were placed within each reach, and just upstream and downstream. A piezometer was installed during the summer of 2011 which allowed for the measurement of below stream water levels. Figure 3 shows the resulting hydrograph measured at the Upper Kuparuk site for the summer of 2011. One pressure transducer is placed on the bottom of the stream and another inside the piezometer. The stage heights are displayed with the summer rainfall. A large dry spell is shown in August as a result of little to no rainfall. That same dry spell resulted in the photograph shown in Photo 5. The hydrograph shows how water levels continue to drop below the stream bottom, signified by negative values, until rain falls again and connectivity is reestablished in late August. Fish passage through this reach stops whenever the surface pressure transducer reads less than 0.2 ft. Therefore the reach is considered “dry” when stage measures less than 0.2 ft.

Figure 3. River stage and rainfall measurements collected during the summer of 2011. The yellow dashed line shows the stage below which fish become stranded.
Discharge measurements were collected periodically along the critical reaches. Figure 4 shows some of the results. The x-axis depicts distance downstream from the headwaters of the Kuparuk, Green Cabin Lake. For the Upper Kuparuk reach, 5 km is in the middle of the “dry” reach with 4 and 6 km being just upstream and downstream of the “dry” reach.

![Upper Kuparuk Discharge](image)

**Figure 4.** Discharge measurements taken along the Upper Kuparuk research location. The distance downstream indicates distance from the headwater lake. The “dry” reach begins just after the 4 km measurement and ends just before the 6 km measurement.

Discharge measurements taken within the dry reach during periods of flow compared with measurements taken just up and downstream show that nearly half the flow through this reach is flowing sub-surface. The discrepancy between upstream and downstream discharge on 7/23/12 is the result of a side channel which opens up during high flows.

Stage data collected at the Upper and Lower Kuparuk sites was compared with data from the Upper Kuparuk Stream Gauge. Data from 2010 - 2012 was used to establish a statistical relationship between the sites. Based on this relationship, a historical data set was created for the Upper and Lower Kuparuk sites. This dataset provided information regarding the timing and frequency of dry periods over the past 15 years. Field notes of observations from researchers working in this area of Alaska were used to confirm as many dates as possible. Figures 5-7 highlight some of the findings from this dataset.
Figure 5 displays the timing of “no flow” events at the Upper Kuparuk site as identified by the recreated dataset. The shaded area indicates the critical migration period for Arctic grayling. Dry spells occurring during this period would impede fish from migrating to their overwintering site.

Figure 5. The recreated dataset showing dry spells (horizontal bars) per year. The shaded region indicates the time period during which Arctic grayling migrate to their overwintering site.
Figure 6 shows the data in terms of total number of days with no flow. This gives a picture of how often such events occur on average in any given year. Notice the particularly high number of days in 2004, 2005 and 2007. The green triangles represent the actual measured values in the Upper Kuparuk while the blue diamonds represent the estimated values. The discrepancy between observed versus estimated values for 2011 and 2012 occurs because the historical relationship is based on two years of data. If the model is run on 2011 data only, the predicted and observed values for that year are much closer. The same is true for 2012 if only the data from that year is used.

![Figure 6. Estimated number of days per summer with no above surface stream flow based on 15 years of data. Observed values for 2011 and 2012 are also shown.](image-url)
Figure 7 shows the timing of dry events as a monthly average. It is interesting to note that there is no statistically significant difference in the likelihood of a dry event occurring in any given month during the summer.

![Average Number of Days with No Stream Flow](image)

Figure 7. Average number of days per month with no flow at Kuparuk dry site.
The long term summer surface water balance (P-ET) is estimated based on measurements made in Imnivait Creek from 1996-2008. Imnivait Creek basin is adjacent to the Upper Kuparuk. Data shows a strong seasonal trend with a surface water deficit occurring until August (Figure 8).

Figure 8. Monthly averaged values of surface water balance based on 11 years of data. Negative values indicate a water deficit, or drying conditions.
Figure 9 shows data collected by George Kling and represents thaw depths collected over a 7 year period at the Arctic LTER site located near the Upper Kuparuk research site. This data shows a strong seasonal trend as well with increased thawing of up to 30 cm over the course of the summer.

![Thaw Depths (2003-2009) with Standard Error](image)

Figure 9. Summer thaw depths collected over a 7 year period show an average increase in thaw depth of 30 cm from June 14 (Julian Day 165) through August 23 (Julian Day 235). Data source: George Kling, Arctic LTER database.

Figures 8 and 9 represent surface and subsurface controls on the hydrology of the critical reaches studied in this project. Figure 8 represents the surface controls of precipitation and evaporation. Figure 9 represents the subsurface controls of active layer depth. There is a strong seasonal trend to both of these drivers. Figure 7 showed that there was not a seasonal trend to the occurrence of “dry” events. The lack of any significant seasonal trend here indicates that surface and sub-surface controls may both be drivers of these dry spells. More dry spells early in the summer would indicate that surface drivers were the control because of low rainfall rates and high ET. More dry spells later in the summer would indicate a greater subsurface control as a result of greater thaw depths allowing for greater subsurface/hyporheic flow. I am trying to apportion the relative influence of these drivers in controlling above-ground flow, in order to project future conditions.

**c. Publications, conference papers, and presentations.**
- Poster presented Alaska section meeting of the American Water Resources Association, March 2012
- Poster presented at the Arctic LTER Spring meeting, March 2012
- Poster presented at the American Geophysical Union annual meeting, December 2012

**d. Education and outreach.**
- Nothing to Report

**e. Other products resulting from the project.**
Aerial imagery was collected along a 30 mile section of the Kuparuk River as well as a 20 mile section of Oksrukuyik (Ox) Creek. This imagery was collected during a “dry” spell and several reaches that ran dry were identified.

f. Describe any concerns you may have about your project’s progress.
High flows on the Lower Kuparuk during field expeditions prevented discharge measurements from being made and from installing a pressure transducer in the piezometer. Otherwise all data collection efforts were successful.

4. PROGRESS STATUS

All data for this project has been collected. Significant data analysis has also been completed. Remaining work involves statistical analysis and model development. The resulting conceptual/statistical model will link the hydrologic regime of the Kuparuk to physical drivers. Future impacts to fish migration as a result of changes in hydrologic connectivity will be assessed by determining the effect of climate change on these larger physical drivers such as surface temperature and precipitation.
Part 2: Detailed report on progress made towards deliverables specified in Statement of Work

List each deliverable specified in the Statement of Work and estimate the progress made towards completion of that deliverable. If no progress has been made on a deliverable, record that as '0'. Please limit entries into the “Progress (% completed)” column to integers only, it is not necessary to include text or symbols.

The information you provide in the table is for use by LCC staff and will not be posted on arcticlcc.org.

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<th>Deliverable</th>
<th>Progress (% completed)</th>
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<tr>
<td>Identify critical reaches</td>
<td>100</td>
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<tr>
<td>Establish relationship between streamflow and depth of flow in critical reaches</td>
<td>100</td>
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<tr>
<td>Quantify the frequency, timing, duration and magnitude of low flow periods over the historic period</td>
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