Kuskokwim River Middle Mile Fiber Technical Feasibility Study
RD-RU-COOP-25-09

River Route Selection, Self-Burial Assessment and Ice Jam Risk

Prepared for:
United States Department of Agriculture
Rural Utility Service

Prepared by:
Mark Ayers, PE
Ayers Telecom Consulting, LLC
Anchorage, Alaska

and
Dave Tucker, Barb Combs
Meridian Management Inc.
Anchorage, Alaska

and
John Seigle, Zach Huff
ABR, Inc. – Environmental Research & Services
Anchorage, Alaska

April 2026

Table of Contents

List of Tables

List of Figures

Introduction

The recommended route for a river-laid fiber optic cable in the Kuskokwim River from Aniak to McGrath is analyzed to identify the best option(s). The route selected is informed by academic study and consultation with industry experts. An attempt to quantify the risk of ice jam occurrence is performed in tandem with the route selection in order to demonstrate the areas of the river most likely to experience cable breakage. Determination of the river route is based on the assumption that the fiber cable is surface-laid on the river bottom in the deepest channel. This constraint is imposed by construction cost and technical challenge and the deepest channel's ability to facilitate self-burial. Placement of the cable in the river thalweg is the only realistic design that is constructable and achieves the cost savings required to justify river placement instead of traditional overland terrestrial placement.

It is assumed that one of the primary mechanisms leading to fiber-optic cable failure in the Kuskokwim River is the formation of ice jams. Ice jams, once formed, can lead to bottom scouring which in turn can lead to cable damage. The ice jam model developed in this section is used to simulate achievable reliability and availability performance expectations for the installed cable. Other river-based failure risks include frazil ice, which attaches itself to the cable, causing it to float, and external aggression from vessels or anchors in the river. It is shown that, even in the absence of frazil ice and vessel strike risks, a cable installation is challenged to achieve standard telecommunications system availability levels. As discussed in the executive summary, further refinement of the ice jam model and empirical data collection are highly recommended in order increase confidence in a river-laid cable's ability to provide the desired long-term system performance.

Characterization of the Kuskokwim River thalweg

The first step in determining the river route and assessing the cable failure risk is the determination of the best location to place the cable within the river corridor. As a result of conversations with industry experts, reviewing marine environment best practices, evaluating available river data and imposing construction and permitting limitations, it is determined that the fiber should be placed in the deepest river channel (the thalweg). The primary reason for thalweg selection is that the most active river channel is contained within it and as such, it has the highest likelihood of leading to cable self-burial. Self-burial occurs when the active flow channel of the river interacts with the cable itself to erode the sediment beneath and around the cable. As the sediment is eroded the cable settles and ultimately, over time, becomes buried in the sediment itself. A number of factors influence self-burial behavior. These factors include flow velocity, sediment size, bottom composition, cable diameter and occurrence of flooding events. Conditions leading to the most rapid self-burial involve areas of high flow with fine silt sediment composition. Larger diameter cables tend to create stronger local burial scour and reduce the time for self-burial to occur.

Three different methods were explored as part of the study to identify the thalweg of the river in a manner that is consistent with the feasibility analysis technical requirements.

- Method 1 – Watershed analysis using digital elevation models (DEMs)
  Thalweg determination using GIS watershed DEM analysis methods was attempted using publicly available data sets. After several attempts using a variety of data sources the results were deemed inconclusive using the public domain data[1]. The primary issue with watershed GIS methods is the lack of confidence in the resultant paths, particularly in areas of braided and confluence behavior.

- Method 2 – Empirical data from vessel transits

[1] Even with purpose collected DEM data, confidence is low that the watershed analysis method will result in a practical thalweg model acceptable for use in fiber cable system desktop analysis.

Historic river vessel path tracks are used to determine the most likely thalweg location. This data, obtained from the Marine Exchange[2], represents the main channel of the river to a level adequate for the purposes of the feasibility analysis. Many vessels transit the river annually during ice-free periods and the collection of that data shows what operators use in practice as the deepest, most active river channel. In addition to the best estimate of the main river channel path, a view of the historic movement of the thalweg is also possible as the Marine Exchange data spans a 9 year time period. Automated methods were considered for the determination of the thalweg using vessel route data but ultimately the route was drawn manually in GIS software as the presence of extraneous data points and judgement decisions were required. The route shown in the GIS figures is preliminary and any attempt to place a cable in the river should rely on sonar sounding data to definitively identify the thalweg.

- Method 3 – Sonar sounding and empirical data capture
  The river thalweg can be empirically determined through the use of modern sonar equipment. This method, although highly accurate and precise, is not recommended as part of the feasibility analysis. Collection of sonar data without a clear construction schedule provides limited value in the context of the overall fiber optic cable feasibility analysis. The analysis performed here is focused on identifying span lengths and ice jam risk. A highly accurate characterization of the thalweg does not increase the inherent precision or accuracy of those deliverables. The results of the data collection have a relatively short lifespan of 1-2 seasons. Seasonal ice jams, flooding and storm flows cause the thalweg and braided river conditions to change annually and even within a single season. Because the thalweg is not a static river metric and changes with seasonal conditions, a data capture for cable placement collected one year will very likely be incorrect in future years. It is recommended, based on the advice of industry experts, that the sonar collection of river thalweg location be conducted no more than 6 months before the actual placement of the fiber in the river itself. This would imply that the sonar data is collected the same year as the placement occurs. Emerging techniques, as discussed on the construction methods section of this study, suggest that the use of commercially available “fish finder” side scan sonar systems may be adequate for the purpose of thalweg identification. This has the potential to decrease planning and preliminary engineering costs significantly.

Sample images of the thalweg path are provided in the geographic areas surrounding the communities of Aniak, Chuathbaluk and McGrath. The images show both the inferred path as well as the historic tracks from Marine Exchange of Alaska.

[2] Marine Exchange of Alaska: https://www.mxak.org/

Figure 1. Aniak and Chuathbaluk region Marine Exchange vessel data points and inferred thalweg path

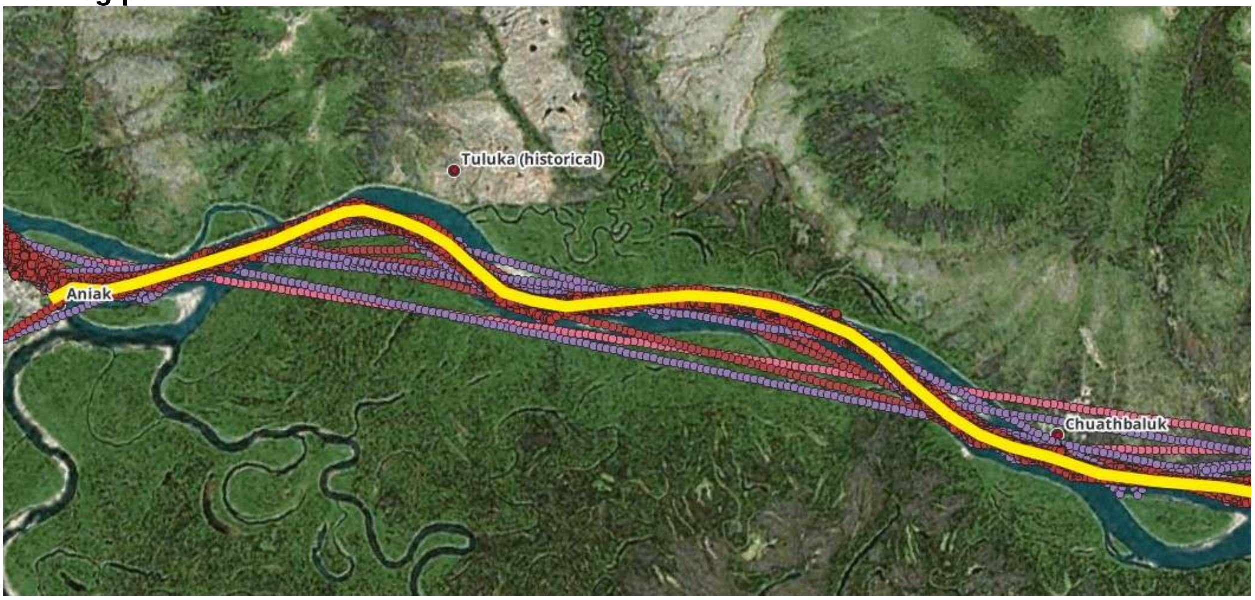
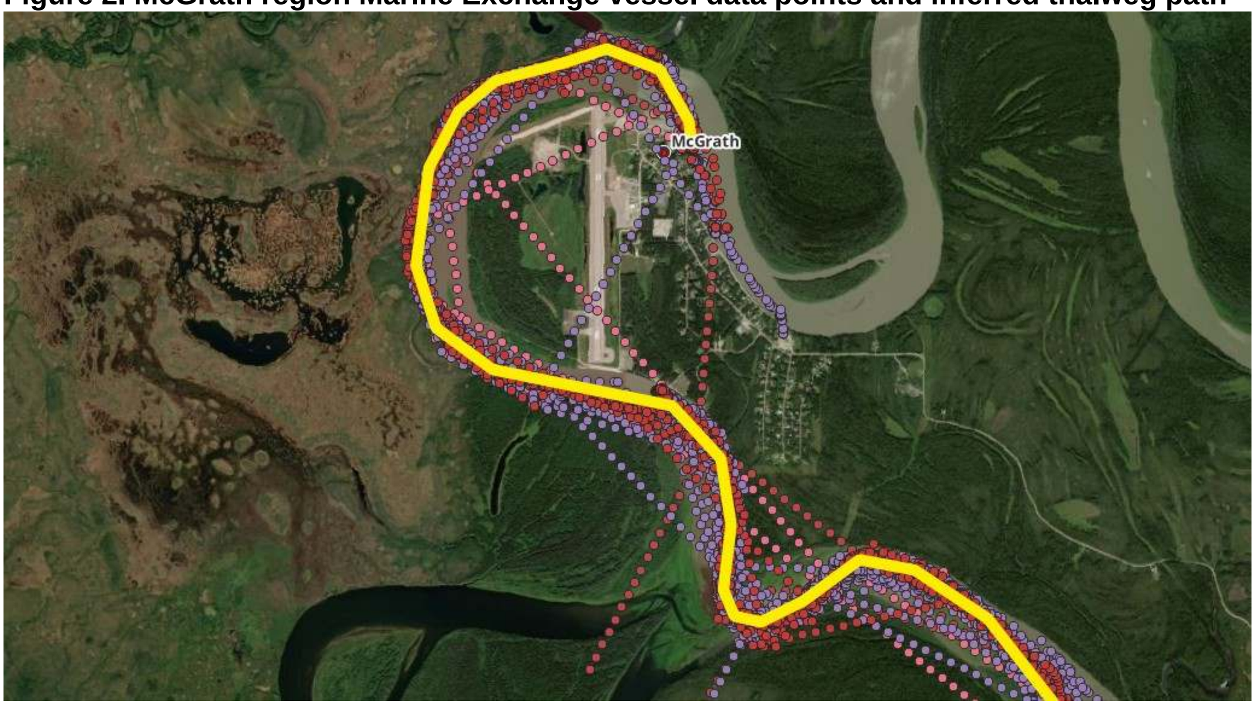


Figure 2. McGrath region Marine Exchange vessel data points and inferred thalweg path



Cable self-burial likelihood estimation

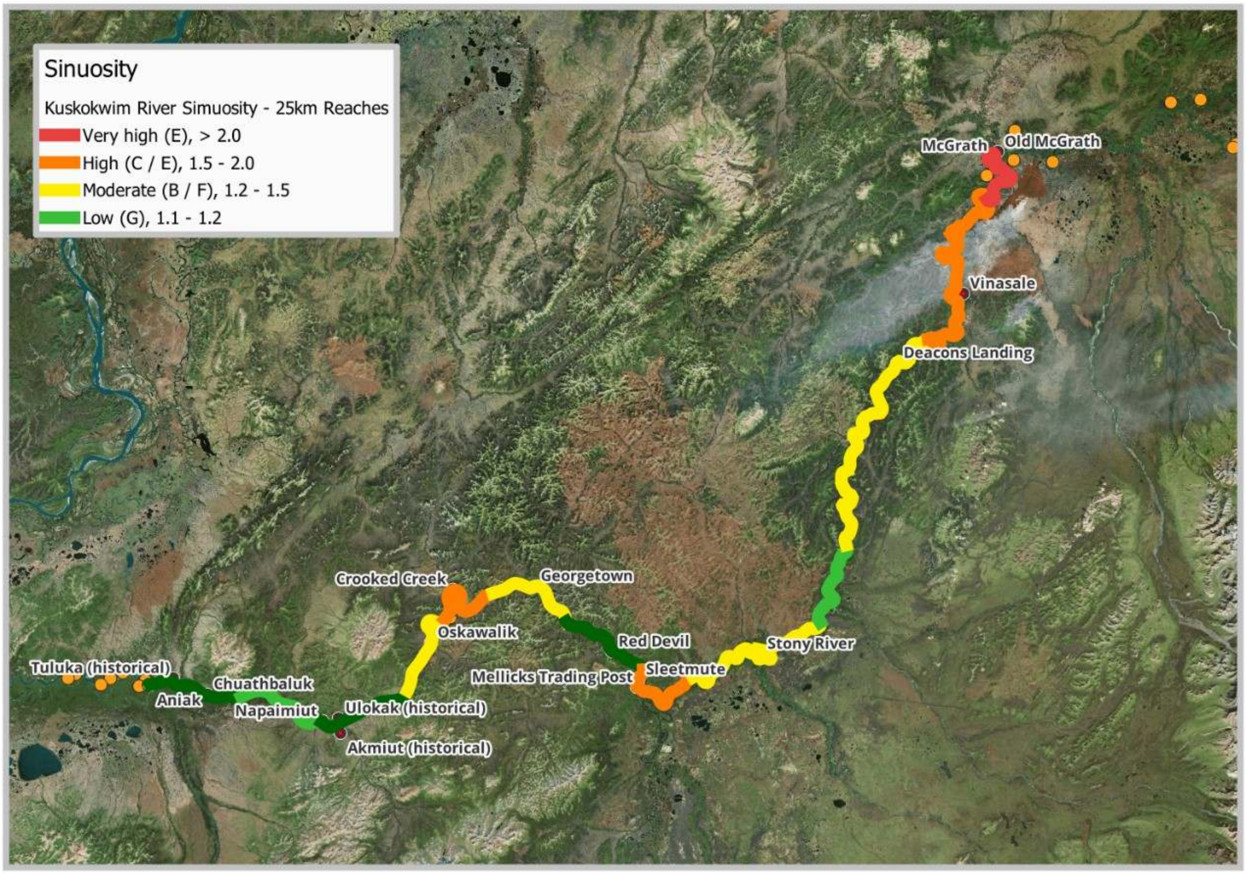
Following the identification of the thalweg using vessel transit data, a model is developed to estimate the relative likelihood of self-burial behavior along the river path. The likelihood of the cable self-burying in the river bottom substrate is estimated by considering four primary factors; sinuosity, slope, braiding of the river path, and inferred geological composition of the river bottom.

River sinuosity

Sinuosity is a measure of the curviness of the river and is strong geomorphic signal for cable self-burial potential. It is computed as the ratio of centerline channel length to the straightline length between the beginning and ending points of a reach. Longer centerline lengths relative to a straightline between the endpoints follow a more meandering path and have a higher sinuosity. Sinuosity impacts how active the flowing waters are and whether relative water speeds are present differentially on river banks. Qualitatively, higher values of sinuosity increase the likelihood of increased energy in a particular river reach versus a lower sinuosity values. Areas of the river with higher sinuosity equate to a higher likelihood of self-burial on inside bends of the river[3]. Intuitively, higher energy river reaches are more likely to self-bury the cable due to turbulent flow presence. Figure 3 shows the varying sinuosity of the Kuskokwim River between Aniak and McGrath. The legend in Figure 3 shows the relative ranges of sinuosity as identified by Rosgen, along with the typical river classifications associated with those values of sinuosity. These values are computed across 25 km reaches, resulting in 18 separate river reaches.

[3] The increase in self-burial likelihood also increases the potential for ice scour and cable damage.

Figure 3. Kuskokwim River sinuosity between Aniak and McGrath, 25 km reaches



Calculation of river slope

The slope of the river between two points impacts the flow rate between those points. Slope can, to some limited extent, be used as a proxy for actual flow measurements in analytical determination of likely areas active or dynamic river conditions when evaluating self-burial probability.

Reach slope for the project was determined by evaluating the elevation at the two ends of reach using USGS IFSAR DEM datasets that cover the Kuskokwim River. This data was collected in 2017 and is publicly available. Slope calculations along the river path result in a determination that the slope of the Kuskokwim River is largely very low and relatively invariant.

River reaches with higher slope values tend to lead to more active regions and higher turbulence values. Several different stream classification schemes exist. For the purposes of this analysis, the Rosgen Stream Classification model[4] is used to classify river reaches into an alphanumeric-based model using both slope and stream geographic behavior (sinuosity and braidedness).

Table 1. Rosgen stream classification model for stream slopes

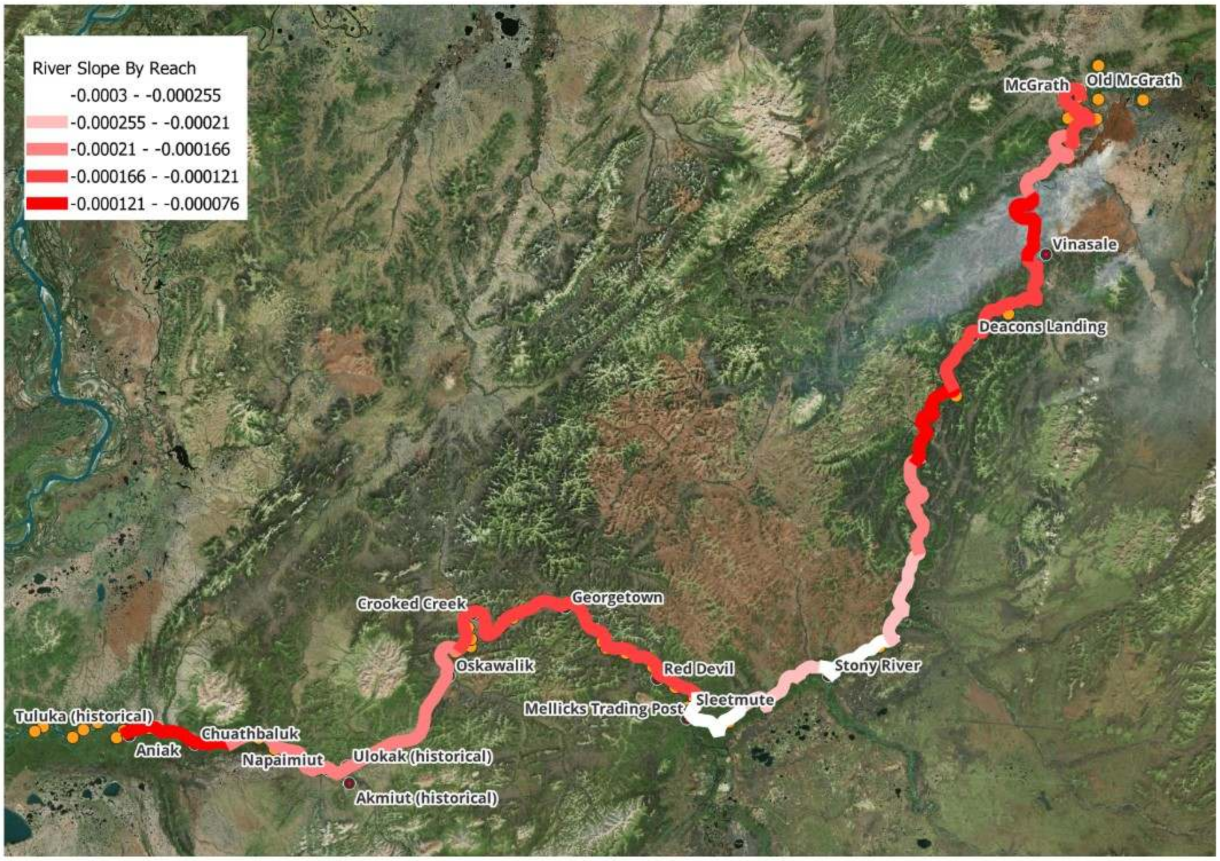
Rosgen Class	Description	Typical Slope Range	Sinuosity
A	Steep, entrenched, step-pool channels	0.04 – 0.10 (4–10%)	1.0 – 1.1
B	Moderate gradient, riffle-pool/plane-bed	0.02 – 0.039 (2–3.9%)	1.2 – 1.5

[4] See Rosgen, D.L (1994) A Classification of Natural Rivers and (1996) Applied River Morphology

C	Low gradient, meandering	0.001 – 0.02 (0.1–2%)	> 1.5
D	Braided channels	0.0005 – 0.02 (0.05–2%)	Variable, often <1.5
E	Very low gradient, highly sinuous	0.0002 – 0.02 (0.02–2%)	> 1.5, often > 2.0
F	Entrenched meanders, wide/shallow	0.002 – 0.02 (0.2–2%)	> 1.2
G	Incised/gully, entrenched	0.02 – 0.039 (2–3.9%)	1.0 – 1.2

The elevation gradient of the river as it flows from Mcgrath to Aniak is relatively constant and low in value. The maximum slope that occurs is approximately 0.03% while the minimum is three orders of magnitude smaller. Figure 4 shows the slope of the river by reach with the thalweg line colored to indicate the associated river slope value. This leads to an analytical conclusion that river slope has a comparatively small contribution to self-burial behavior.

Figure 4. Kuskokwim River slope by reach



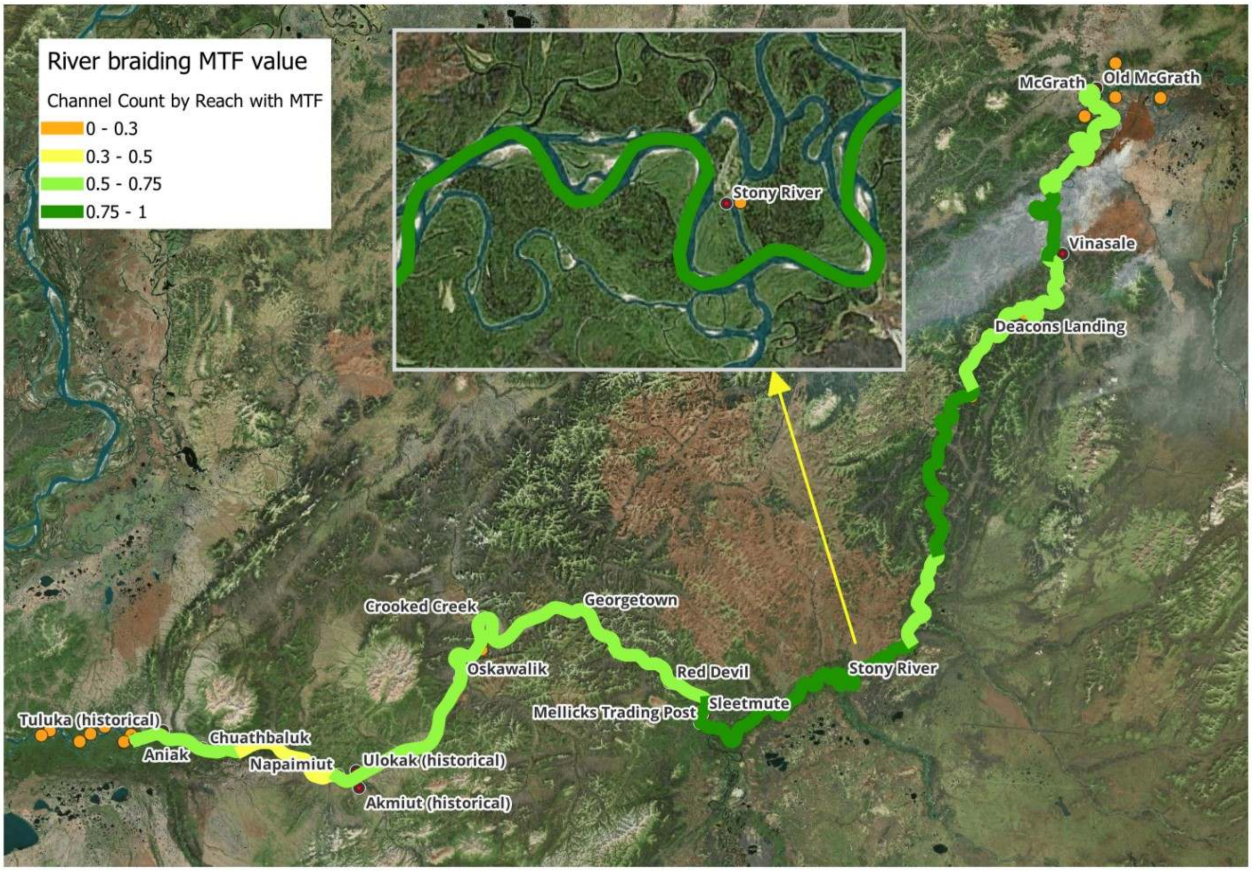
River braiding estimation

Another measure impacting how likely a cable is to become self-buried is braiding. Braiding refers to sections of the river where the main channel splits into multiple threads that diverge and rejoin around bars or islands, creating a network of interconnected channels. Braided rivers are often characterized by sediment-rich glacial meltwater or sand bed river conditions. These bottom substrate conditions lead to highly productive fish habitat and large biomass. Braided conditions also cause significant channel migration and bar deposition. The migration of channels and presence of bars often also lead to ice scour. Rosgen's classification model uses class D to identify braided rivers reaches.

Braiding is computed as part of the desktop study by utilizing GIS data from National Hydrography dataset. The number of channels present for a series of transects spaced at 500m between Aniak and McGrath is determined for each river reach. The average channel count is determined using the transect calculations. Additionally the Multi-Thread Fraction (MTF) can also be used to characterize the river (in addition to per reach average channel count). MTF measures the ratio of the number of transects for a given set of samples that have 2 or more active channels relative to the total number of transects. MTF ranges from zero to 1 and indicates the "braidedness" of a given reach of river.

Any value of MTF greater than a value of 0.5 indicates a highly braided river reach. As can be observed in Figure 5, with one small segment exception, the entire path from Aniak to McGrath on the Kuskokwim River is considered highly braided. Some sections, as can be seen in the legend are extremely braided.

Figure 5. Kuskokwim River braiding Multi-thread Fraction



Geologic composition of the Kuskokwim River bed

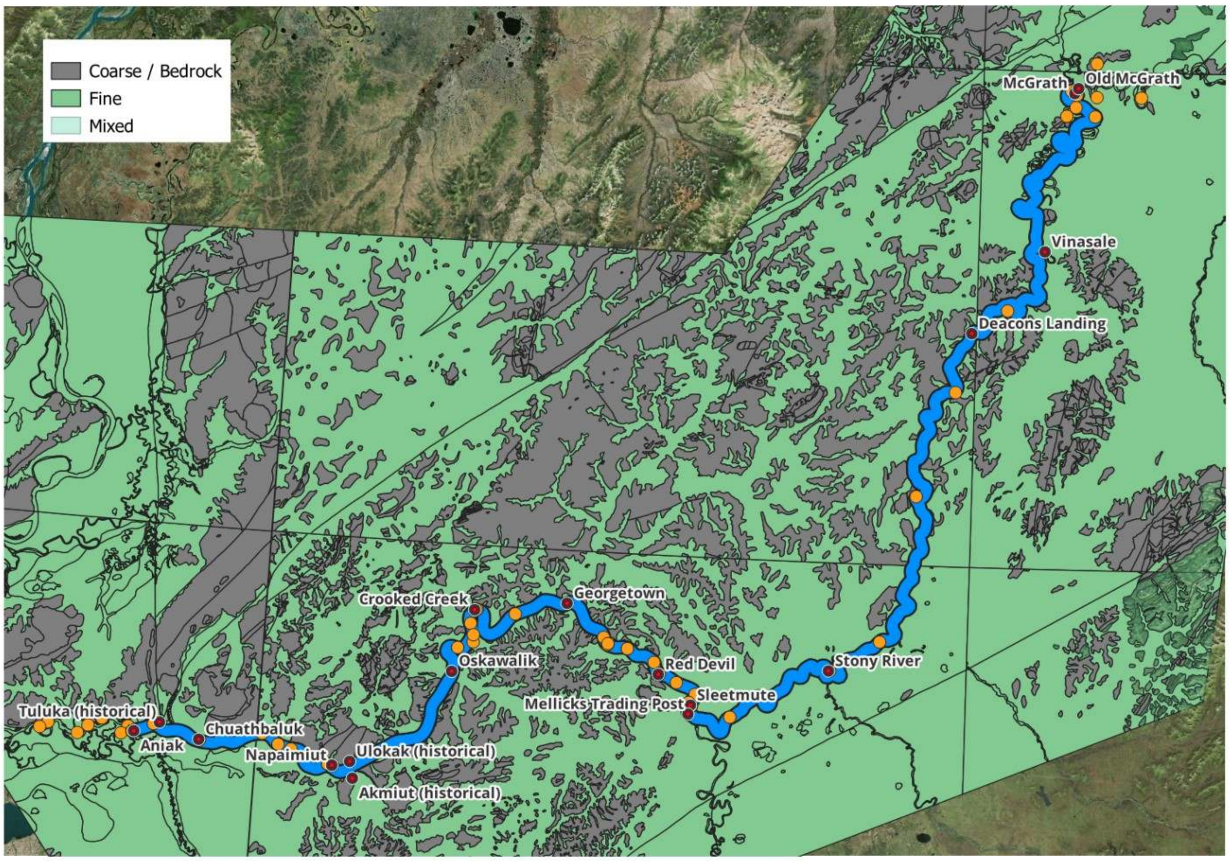
The final factor incorporated into the self-burial model is the geological composition of the around surrounding the river. The analysis presented here uses available data characterizing the soil adjacent to the river as a proxy for river bottom composition. This inferred bottom composition acts a guideline, not a definitive determination of the composition of the river bottom.

The argument for inferred bottom composition using adjacent soil composition is reinforced by the fact that the results of the sinuosity, slope and braiding behavior clearly show that the Kuskokwim River between Aniak and McGrath can definitively be classified as Rosgen D (braided). This is true for all but a few reaches near Aniak where the braiding is less and the sinuosity is much lower. This finding can be extended by examining Rosgen's geomorphic comments related to D classified rivers. Namely, that bars and river banks are often made up of the same sand and gravel mix because the bars are reworked frequently and the river banks in braided areas are just reconstituted bars. This leads to the conclusion that the bank and the bed are more likely to be consistent in our section of the river.

The overall fine categorization of much of the river bottom should be evaluated against the fact that sediment transport and rock migration due to ice are significant factors that must be considered using other methods. Boulder fields can occur due to ice that attaches itself to large rocks, floats the rocks and then deposits them somewhere downstream. This sediment and rock

transport often results in an increased likelihood of future ice jam events in areas where historic ice jams behavior has been observed.
The project used USGS geologic map data for Alaska to broadly characterize the river bank composition for each reach. The region surrounding the river was evaluated on either side of the river to determine the majority constituent substrate. Figure 7 shows the geological makeup of the area surrounding the river after consolidating the constituent geomorphic types into one of three categories (coarse / bedrock, fine and mixed). The categories are used as one of the factors when making an assessment of self-burial likelihood.

Figure 7. Geological makeup of areas surrounding the Kuskokwim River between Aniak and McGrath



Cable self-burial model

The likelihood of self-burial is modeled based on existing data, scientific evidence gleaned from GIS data, and engineering insight. The self-burial model is intended to provide guidance on whether the cable will experience low, moderate or high probability of self-burial and thus, lead to a higher likelihood that construction of a fiber optic cable is feasible and will sustain long-term, uninterrupted operation. A model was built using weights that are applied to each of the self-burial factors. The factors are computed for each of the 18 river reaches lying between Aniak and McGrath.

Table 2. Self-burial model factor weighting in per reach self-burial likelihood determination

Factor	Weight	Notes
Braiding	0.5	Braided systems (D-type) are primary drivers for repeated self-burial behavior.
Sinuosity	0.3	Inside-bend accretion is the second most prevalent self-burial marker behind braiding.
Geological Makeup	0.2	The availability of appropriate sediment to provide burial increases the chances of self-burial.
Slope	0.0	Slope is removed because their uniformity and low value are more likely to introduce noise errors than insight.

The model uses the simple weighted product of each normalized factor to obtain an overall three level likelihood model where each reach is assigned a low, moderate or high probability of self-burial.

Uncertainty in depth-of-burial

The actual, observed depth of self-burial that occurs needs more research and should be experimentally evaluated and quantified. There are a variety of opinions about how deeply a cable will bury itself when the conditions of the river lead to self-burial. This project is explicitly restricted from constructing test fiber sections (and has insufficient funds for any substantial field work) to evaluate the self-burial behaviors under different river flow, substrate and cable conditions. It is recommended that further work be performed to quantify and document these behaviors for use in both the Kuskokwim River and other applications.

The purpose of the self-burial model is to establish a high-level sense of whether the cable is likely to self-bury over time within each river reach. Figure 8 shows the modeled likelihood of self-burial behavior per reach and Table 3 provides the per reach self-burial likelihood in one of the three categories (low, moderate, high). By reviewing Figure 8 (and Table 3) it is apparent that, with the exception of two 25 km reaches outside of Aniak, the remainder of the river route is moderately to highly likely to self-bury a cable placed on the river bottom. The combination of ice scouring likelihood and probability of self-burying provides a semi-quantitative result from which feasibility of construction can be discussed with some level of objective basis. Having established a determination of feasibility, future experimental results can be used to increase confidence in the constructability and operational stability of a cable system.

Figure 8. River laid fiber cable self-burial behavior likelihood

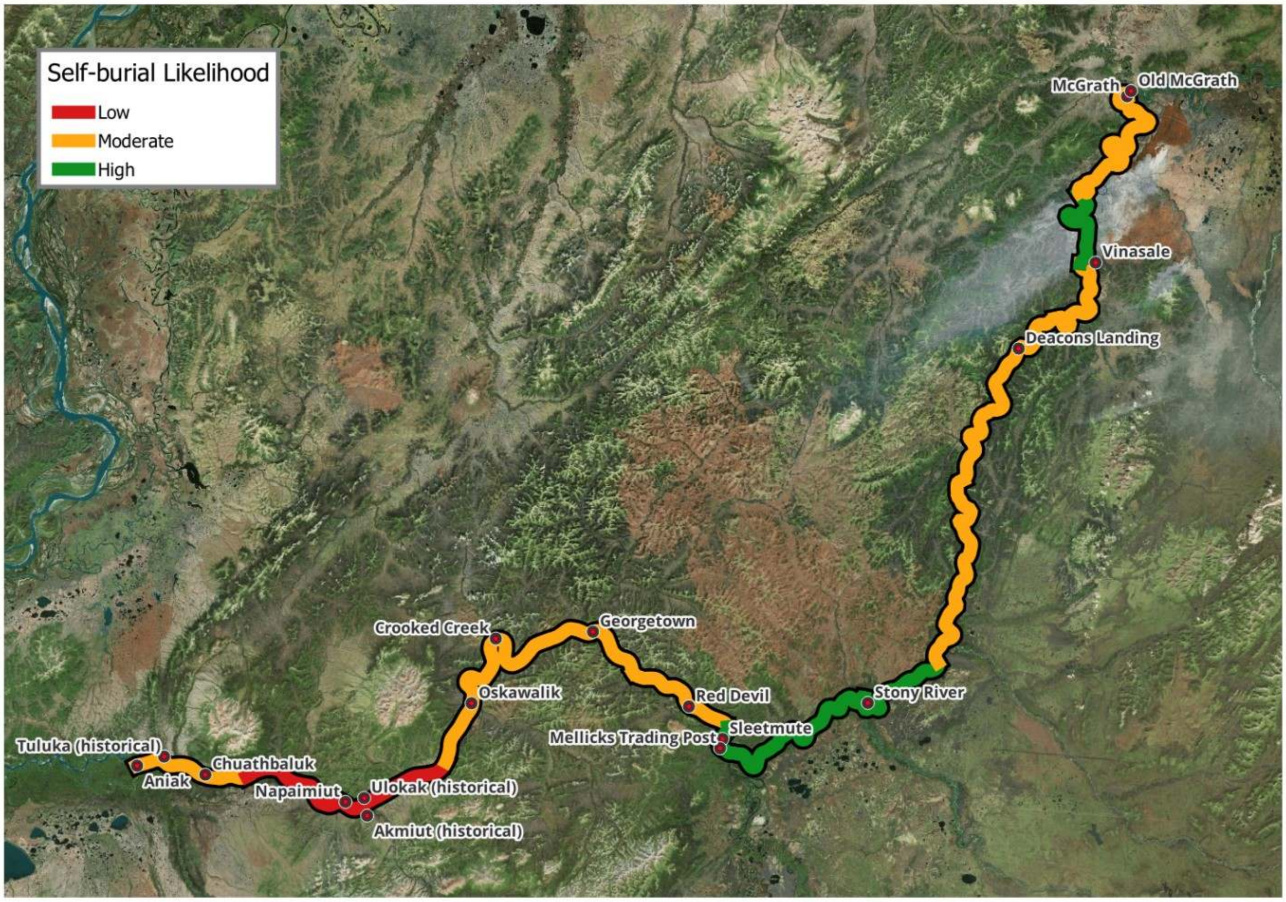


Table 3. Kuskokwim River self-burial model per reach classification

Reach ID	Cable Self-Burial Class
1	Moderate self-burial probability
2	Low self-burial probability
3	Low self-burial probability
4	Moderate self-burial probability
5	Moderate self-burial probability
6	Moderate self-burial probability
7	Moderate self-burial probability
8	High self-burial probability
9	High self-burial probability
10	High self-burial probability
11	Moderate self-burial probability
12	Moderate self-burial probability
13	Moderate self-burial probability
14	Moderate self-burial probability
15	Moderate self-burial probability
16	High self-burial probability
17	Moderate self-burial probability
18	Moderate self-burial probability

Modeling ice jams in the Kuskokwim River

A primary area of concern for placement of a fiber optic cable in flowing arctic waters is related to the formation of ice jams and the subsequent potential for ice scour of the river bottom that can occur as a result. A model for ice jam prediction is developed based on linear predictors and a log-odds probability function (linear regression). The predictor parameter, model training and the ice scouring probability results follow in the sections below.

Ice jam predictors

The likelihood of ice jam events is dependent on several contributing factors. Ice jamming occurs in arctic rivers during formation and break-up of ice. Jamming that occurs during freeze-up is typically caused by the formation of frazil or pancake ice which drifts until it reaches a bend, shallow or confluence where is jams. Ice jams that form during break-up are caused by the ice cover being broken by rain or rapid warming. The floes run downstream until they impact other ice or a constriction that jams the ice. Jam releases can send a surge of ice downstream, resulting in a subsequent downstream jam. Ice jams that occur during the break-up season can produce a variety of different outcomes including flooding, overflow, and scouring. The placement of the cable on the river floor causes the analysis to primarily focus on modeling ice jam formation and scouring.

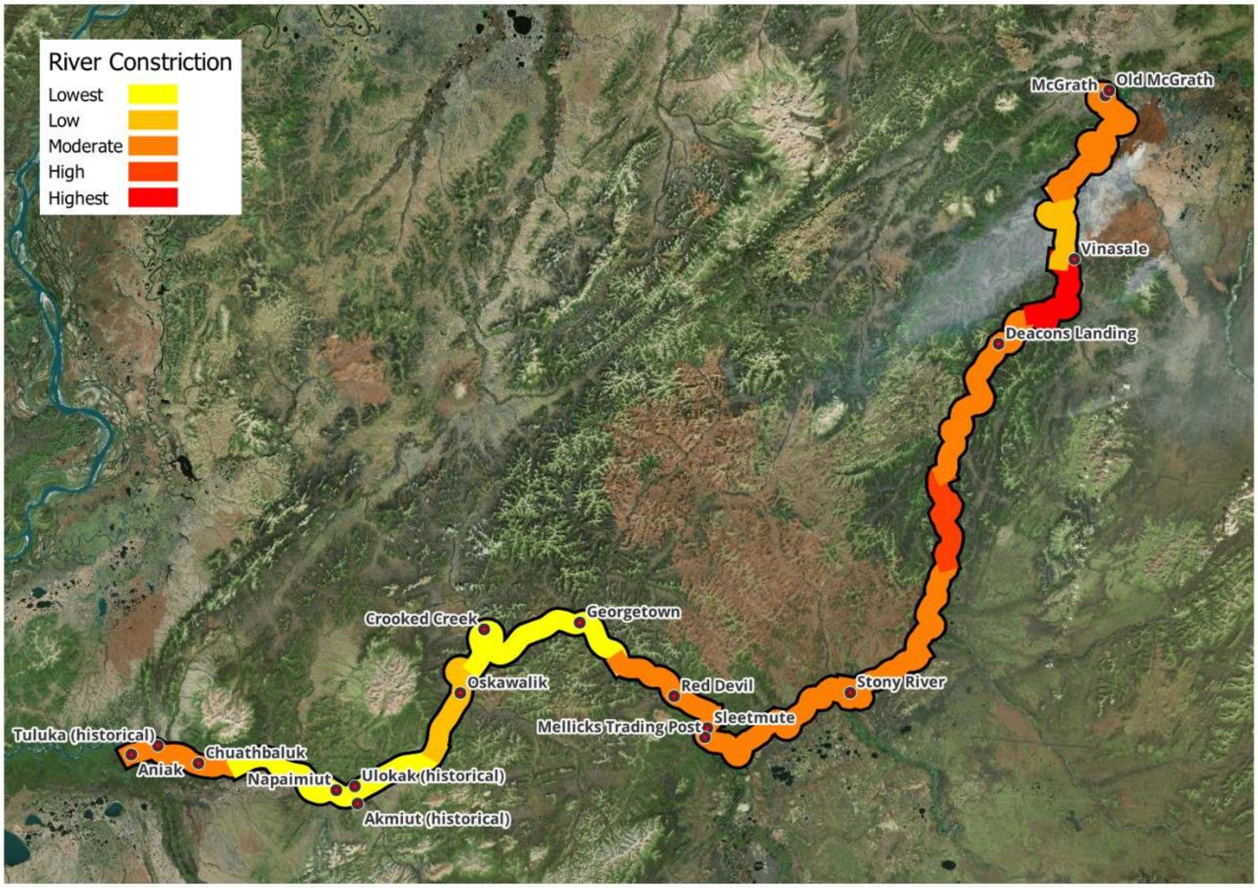
Ice jams become more likely in the river when certain river features exist. These features include chokepoints (sharp bends, islands and bars, and confluences), geometry changes such as rapid river constriction, shallows or slope changes, and structures in the river (such as boulder fields or foliage biomass). The model developed assesses a number of different characteristics that are predictors of jamming behavior. These predictors are similar to those used in the self-burial model.

River width constriction

It is demonstrated[5] that river channel narrowing leads to ice jams. This predictor has the single biggest influence on the likelihood of ice jam formation. Constriction is computed in the model by creating river transects at 500m intervals. These transects are then intersected with a polygon which captures the river water extents, resulting in a series of transects which represented the “wetted” section of the river. Statistics (mean, standard deviation, minimum, maximum, etc.) are computed for each reach and the relative constriction of each river reach is determined using the ratio of the minimum river width to the mean river width. Figure 9 shows the per reach constriction of the Kuskokwim River, colorized into 5 categories.

[5] De Munck, S., Gauthier, Y., Bernier, M., Chokmani, K., & Légaré, S. (2017). *River predisposition to ice jams: a simplified geospatial model*. Natural Hazards and Earth System Sciences, **17**(7), 1033-1045. https://doi.org/10.5194/nhess-17-1033-2017

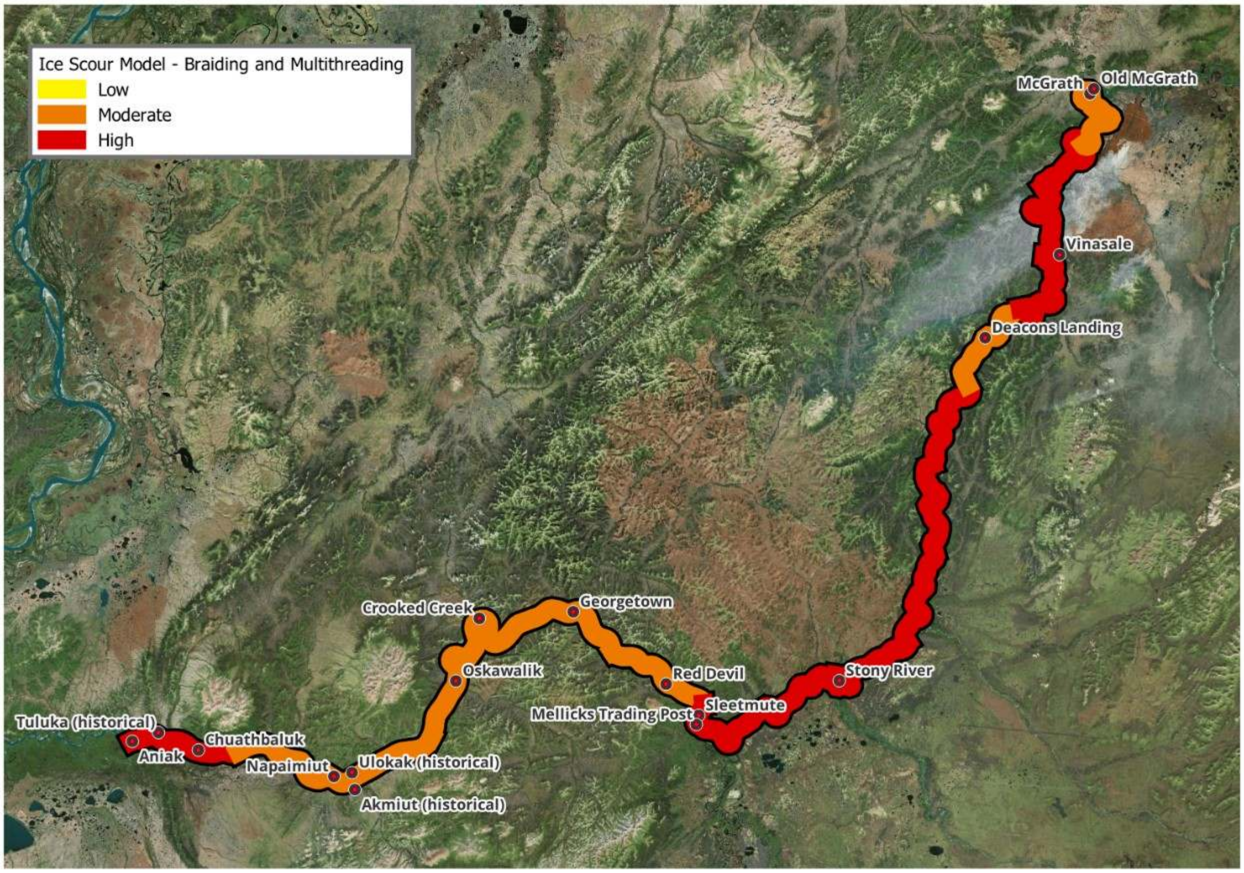
Figure 9. Relative Kuskokwim River constriction by 25 km reach.



Braiding and multi-threading

Braiding and multi-threading cause the river to meander, split and reform as it travels between two points. In river reaches where significant multi-threading occurs, the channels inherently constrict, which can lead to ice jams. This predictor is related to but not the same as the width constriction predictor. The braiding and multi-threading factor also contributes to increased ice jam probability in the model.

Figure 10. Kuskokwim River braiding and multi-treading index values



Sinuosity

Sinuosity, as discussed in the self-burial section, is a measure of the curviness of the river as it flows. Although sinuosity influences the formation of ice jams, it was found through analysis that this predictor was highly correlated with the braiding and multi-threading predictor and was therefore dropped from the model.

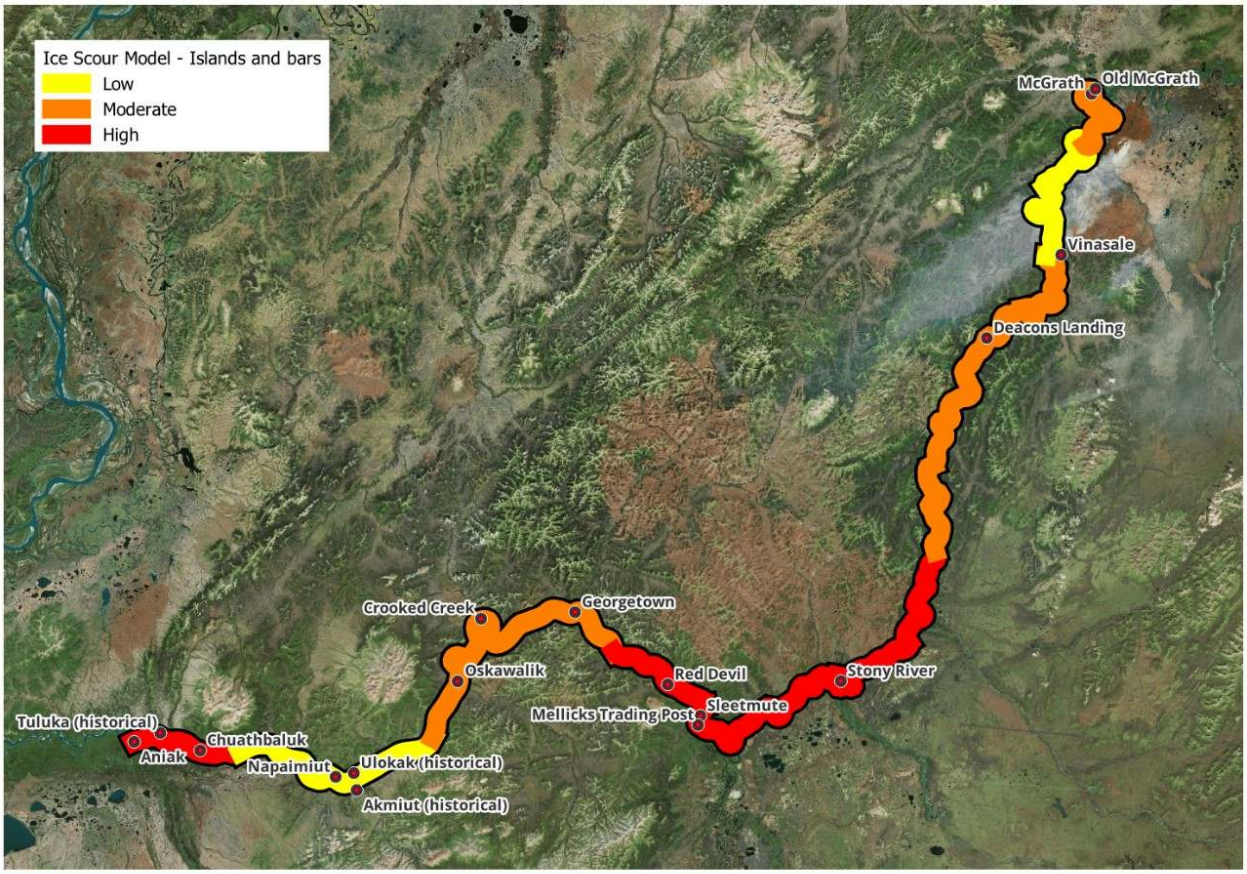
River Slope

River slope can influence ice jam formation when its value is large or the river has a large differential value over multiple reaches. Neither of those is the case on the Kuskokwim River, the slope of the river is relatively small and constant across the span considered. This predictor was not included in the model.

Island and bar presence

The De Munck paper also indicates that the presence of islands in the river channel is generally correlated to the presence of ice jams. This predictor has the second largest influence on the overall probability of an ice jam. To model the presence of islands and bars in the river, the river is analyzed to determine the polygons that reside inside of the river extent polygon for that reach. Having determined the “inside polygons” for each river reach, the area of those island and bar polygons is computed and then compared with the river wetted area for that reach. This ratio of island / bar area to wetted area is used as a metric of how many islands and bars occur on a given reach of the river.

Figure 11. Kuskokwim River islands and bars per reach



Historic ice jam data

Historic data related to the presence of ice jams on the Kuskokwim River has been collected for many years. This data is publicly available on the Cold Regions Research and Engineering Lab (CRREL) home page[6]. The data was filtered over the Kuskokwim River between Aniak and McGrath by 25 km reach. The relevant details are provided in Table 4.

Table 4. CRREL historic ice jam data, filtered and aggregated by 25 km reach

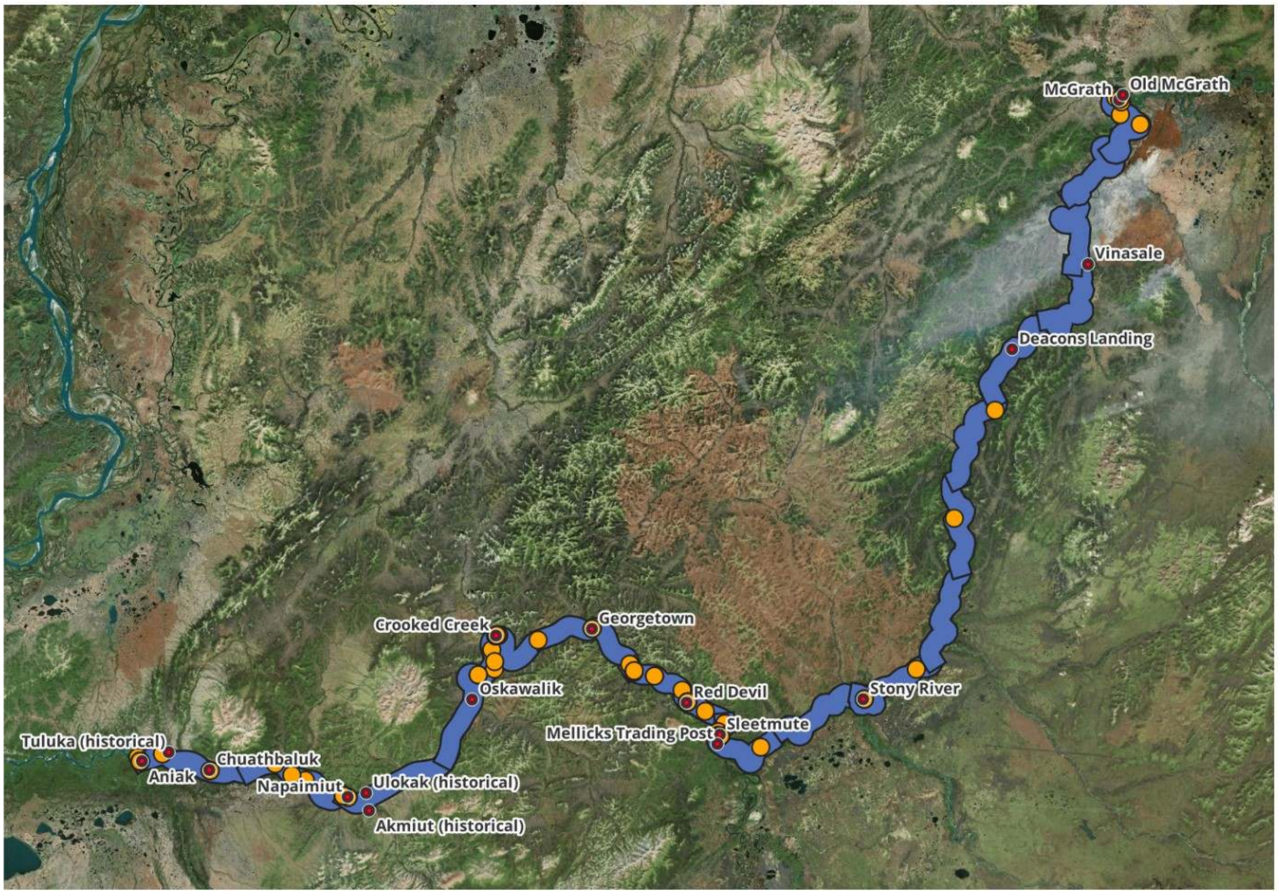
id	S_cons	S_mt	K_n	S_sub
1	0.466	0.688235	0.041	Fine
2	0.276	0.426	0.103	Mixed
3	0.233	0.546	0.045	Mixed
4	0.347	0.52549	0.142	Fine
5	0.279	0.562745	0.516	Fine
6	0.324	0.545098	0.163	Fine
7	0.489	0.608	0.051	Fine
8	0.453	0.960784	0.629	Fine
9	0.479	0.936	0.255	Fine
10	0.475	0.915686	0.291	Fine
11	0.461	0.854	0.133	Fine
12	0.578	0.937255	0.21	Mixed

[6] https://icejam.sec.usace.army.mil/ords/f?p=1001:7

13	0.479	0.760784	0.195	Mixed
14	0.514	0.646	0.147	Mixed
15	0.721	0.754	0.633	Mixed
16	0.374	0.854902	0.43	Fine
17	0.453	0.68	0.635	Fine
18	0.488	0.5875	0.716	Fine

The data in Table 4 are used to train the regression model and determine appropriate coefficients for the predictor variables.

Figure 12. Kuskokwim River historic ice jam locations



Linear regression ice jam prediction model

The probability of an ice jam occurring per reach for any given year is determined by applying a regression model to the predictors. The model is then trained using historic ice jam incidence data to tune the coefficients and minimize the error in the predicted ice jam probability. The equation below details the model.

$$\operatorname{logit}(p) = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 S_{\text{cons}} + \beta_2 S_{\text{mt}} + \beta_3 S_{\text{island}}$$

Where the value of β_0, $\beta_1, \beta_2, \beta_3$ are coefficients and the values of $s_{cons}, s_{mt}, s_{island}$ are the predictor variables for river width constriction, multi-threading and island / bar presence. The values for each of these predictors are estimated per 25 km reach as shown in the previous section. The values for beta are estimated using the linear regression logit function (shown above) to estimate the annual probability of ice jam occurrence per reach.

The analysis was iterated multiple times to optimize the model and reduce the error. A number of model performance metrics were computed as part of the analysis and are discussed below. The ice jam probability model has some behaviors that should be noted.

- The model overpredicts in low likelihood areas and underpredicts in high likelihood areas. These errors are likely correctable with more data in the areas of zero or very low observations. The end result of these prediction errors is a model which is inherently conservative when used to model availability and reliability of the cable system.

- The model is limited to three predictors in order to maintain simplicity and ease of interpretation. Additional or more sophisticated predictors might yield improved results but the absence of more robust training data limits inclusion of more predictors.

- The purpose of the model is to provide the study team with reasonable and objective guidance with regard to the likelihood of an ice jam and subsequent ice scouring event per 25 km reach. To that end, the absolute precision of the estimate is of less concern than the relative and macro level predictions about ice jam occurrence and its relative geographic intensity.

Kuskokwim River ice jam prediction model results

The likelihood of an ice jam occurring in one of the reaches between Aniak and McGrath is provided in Table 5 along with the predictor values for that reach.

Table 5. Ice jam probability and predictor values by reach

Reach ID	S_cons	S_mtf	S_island	Jam probability
1	0.47	0.69	0.67	0.44
2	0.28	0.43	0.23	0.13
3	0.23	0.55	0.25	0.08
4	0.35	0.53	0.63	0.37
5	0.28	0.56	0.63	0.30
6	0.32	0.55	0.63	0.33
7	0.49	0.61	0.66	0.52
8	0.45	0.96	0.72	0.35
9	0.48	0.94	0.74	0.38
10	0.48	0.92	0.70	0.36
11	0.46	0.85	0.71	0.37
12	0.58	0.94	0.65	0.43
13	0.48	0.76	0.63	0.40
14	0.51	0.65	0.64	0.52
15	0.72	0.75	0.64	0.75
16	0.37	0.85	0.17	0.07
17	0.45	0.68	0.26	0.21
18	0.49	0.59	0.41	0.40

Figure 13. Kuskokwim River ice jam probability per reach

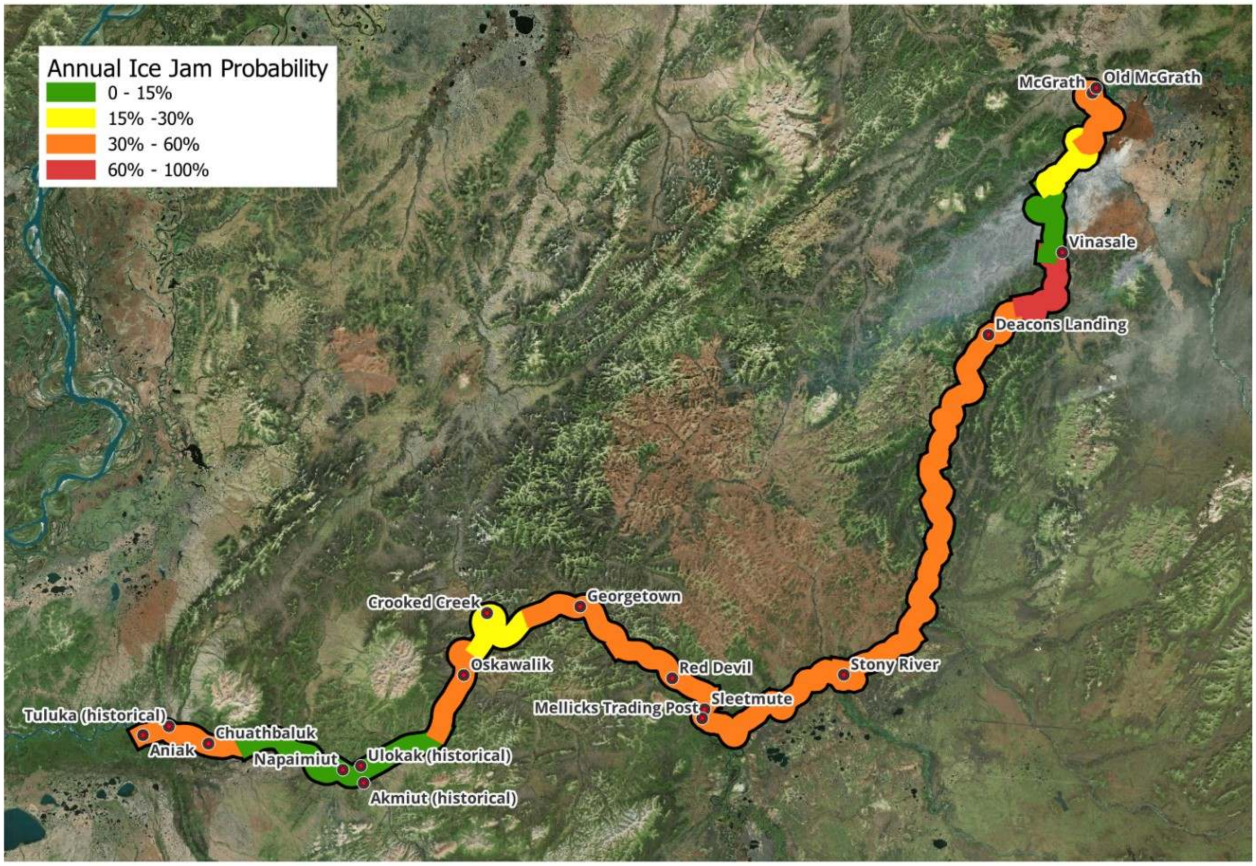


Figure 13 shows the route with the probability of ice jam categorized by color. In addition to the annual probability of ice jam occurrence per reach, additional metrics are computed as shown in Table 6.

Table 6. Kuskokwim River ice jam likelihood measures

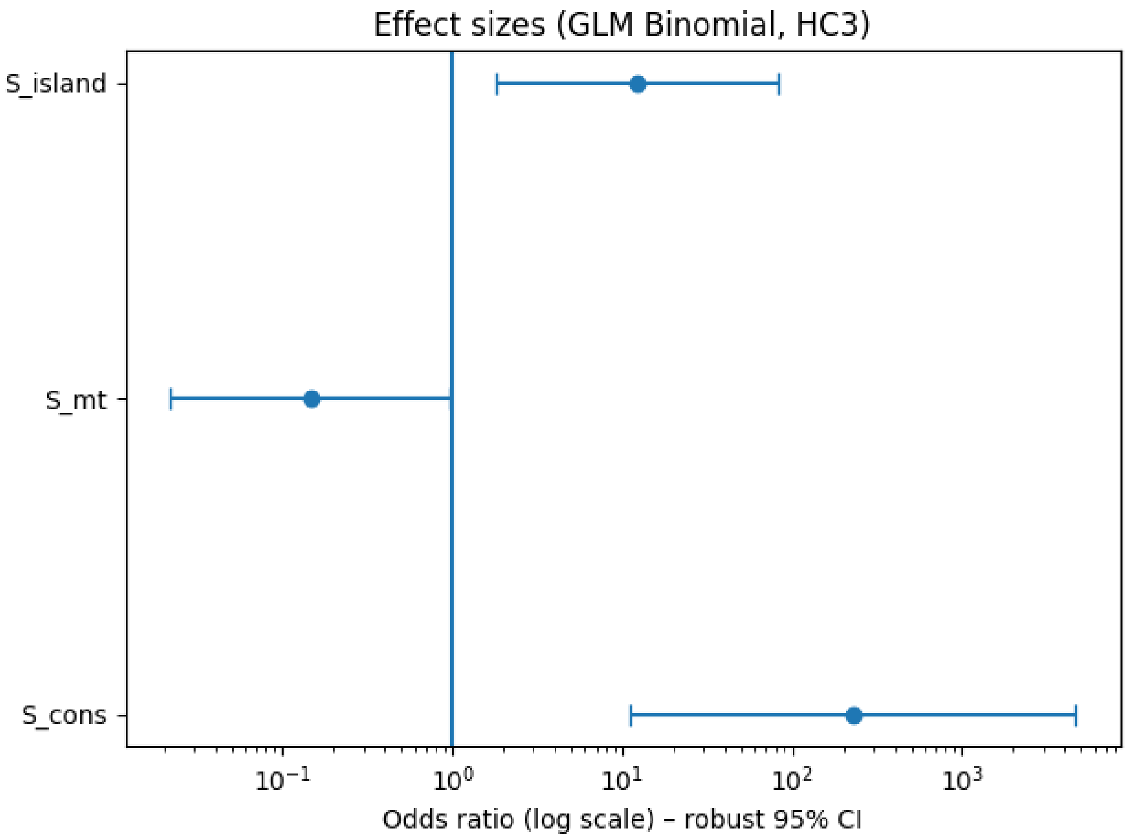
Metric	Value
P(any jam in system this year)	99.98%
Expected number of jammed reaches per year	6.5
Mean probability of jam per reach	36%

The predictions of the ice jam model, when viewed at a macro level, provide initial insight with regard to the operational feasibility of a fiber system placed in the river. First and foremost, it is almost certain that annually there will be multiple ice jam events between Aniak and McGrath. With the estimated mean value of 6.5 reaches experiencing a jam this implies that the system will be under substantial risk on an annual basis (>30% chance of a jam on an average basis). Although a number of reaches have low probability of jam occurrence, the majority of the reaches having a moderate to high likelihood of jam occurrence. The sections that follow discuss two ice jam model metrics related to predictor effect and model alignment with empirical data. Importantly, jam behavior has a cascading effect when viewed along the river corridor. Jams occurring upstream influence the occurrence of jams downstream. This compounding effect is not included in the model.

Regression model predictor effects size

The effects size for each predictor is a measure of the impact that each predictor has on the overall probability of ice jam occurrence. The figure shows (as discussed above) that the constriction and island factors provide the largest contribution to overall ice jam occurrence. The effect of braiding and multi-threading on the overall probability is orders of magnitude lower that of the construction and island factors.

Figure 13. Ice jam model effect sizes for jam predictors



Predicted vs. empirical ice jam model performance

The chart in Figure 14 shows the performance of the model against the empirical ice jam data collected from CRREL. Note that the majority of the samples (larger marker size) align with the linear regression model prediction.

Figure 14. Predicted vs. Empirical ice jam model performance