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

Project Plan and Budgetary Cost Estimate

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Quantifying project feasibility

Determining the feasibility of constructing a fiber-cable in the Kuskokwim River is, ultimately, a subjective assessment of many different factors. In order to provide a more objective measure of feasibility a set of criteria is evaluated for each community passed. Scores are based on three metrics. The metrics represent areas of focus for broadband systems; cost, construction and operations. Each of the feasibility criteria is scored on a scale of 1-3 with (Lowest, Moderate and Highest). The individual scores are tabulated and a recommended action is provided as a result.

Cost effectiveness of in-river construction

Each community is evaluated to determine whether the cable can be constructed and operated at a cost that justifies the identified risks to deliver broadband service in that location. Cost effectiveness is established by comparing the river deployment cost with traditional ground lay methods to provide a frame of reference against which the estimated cost can be scored.

For the purposes of comparison, the ROM (rough order of magnitude) cost to construct an overland route to each community is estimated using a fully loaded cost of $160,000 / mile with a cost of $350 / foot to bore under the river in locations where this is required. GIS is used to estimate the distance between communities along the riverbank. River crossings are assumed only where necessary to access the opposite side of the river for community termination. Standalone equipment shelters are assumed to be identical in both cases.

Table 1. Kuskokwim River overland route ROM cost estimate

Community A	Community B	Overland distance	River crossings	Cost
Aniak	Chuathbaluk	17.9 km	3200 ft.	$2.9MM
Chuathbaluk	Napaimute	34.2 km	N/A	$3.4MM
Napaimute	Crooked Creek	57.5 km	N/A	$5.8MM
Crooked Creek	Red Devil	58.7 km	1500 ft.	$6.4MM
Red Devil	Sleetmute	10.9 km	1400 ft.	$1.6MM
Sleetmute	Stony River	44.9 km	1000 ft.	$4.8MM
			Phase 1	**$2.9MM**
			Phase 2	**$22.0MM**

Ease of construction

Constructability is defined as the ease with which a cable can be deployed and commissioned to each passed community. Construction includes logistics, installation and labor. Scoring is established by comparing the permitting, construction speed, labor efficiency of a river route with the terrestrial overland route.

Long-term stability of network operations

Operation of the constructed fiber-optic cable is a critical component of feasibility analysis. Network stability is scored by quantifying the modeled failure risk and downtime to establish relative reliability and availability scores. It is stated in the reliability analysis section of this report that none of the named communities achieve carrier-grade availability.

Table 2. Kuskokwim River community feasibility scoring model

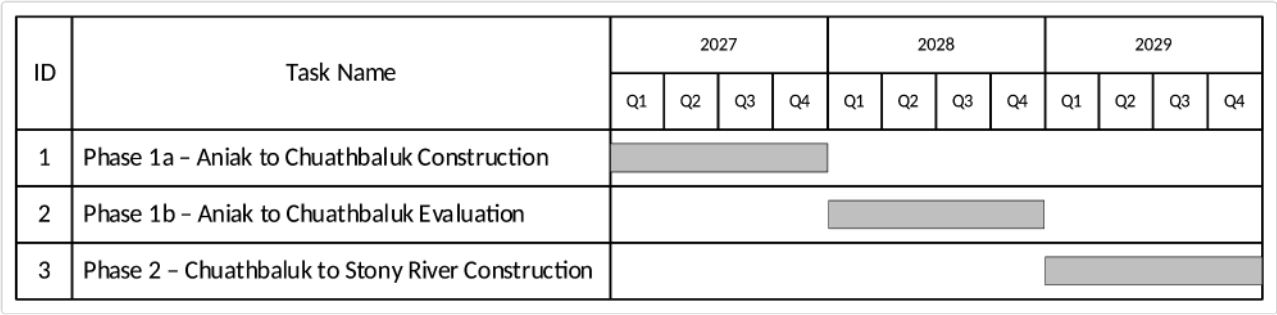
Community	Cost Effectiveness	Constructability	Operational Stability	Project Phase

Chuathbaluk	Lowest	Highest	Moderate	Phase 1 Experiment
Napaimute	Moderate	Highest	Moderate	Phase 2
Crooked Creek	Moderate	Highest	Moderate	Phase 2
Red Devil	Moderate	Moderate	Lowest	Phase 2
Sleetmute	Moderate	Moderate	Lowest	Phase 2
Stony River	Moderate	Moderate	Lowest	Phase 2
McGrath	Lowest	Lowest	Lowest	Not recommended

Kuskokwim River fiber cable project phasing

Any project to deploy fiber in the Kuskokwim River should utilize a multi-year, phased approach with the results and findings from phase 1 informing a phase 2 go / no go decision. Several construction and operational risks exist that cannot be completely resolved or understood through a desktop analysis. The proposed multi-phase project is segmented by year with the complete project taking a minimum of 3 years to complete. Figure 5 shows a GANTT chart with a hypothetical start date of January 1st, 2027. In addition to the details called out below, it is recommended that an annual cumulative report be prepared to document findings, limitations and continued risks once the project is started. These annual reports serve as the basis for decisions about how to proceed with Phase 2 of the project.

Figure 1. Kuskokwim River fiber project phasing schedule by year



Experimental validation of design and feasibility

The river-laid fiber path between Aniak and Chuathbaluk is tentatively feasible based on the results of the desktop analysis. Tentative feasibility is due to the lack of empirical data supporting some of the desktop study assumptions. The project treats the first phase of construction as an experimental validation used to confirm the desktop analysis results. This contrasts with a traditional telecommunications deployment that assumes full operational stability is achievable in the first phase of deployment. The initial phase of the project carries both more risk and more cost than Phase 2 due to logistics ramp up and the relatively short distance between Aniak and Chuathbaluk. Phase 1 of the project is contained entirely within the first reach of the river[1]. This reach carries a moderate ice jam likelihood with historic ice jams recorded near both Aniak and Chuathbaluk. The short span length (less than 10% of the Phase 2 length) drives cost effectiveness down due to the high mobilization and logistics costs relative to the distance covered. Validation of the desktop study assumptions is critical to establishing confidence in long-term operational success. If the experimental phase proves that the remainder of the route is not feasible, the funds used in this validation are well spent in the

[1] The river is evaluated across eighteen (18) reaches, each spanning 20 km. The distance between Aniak and Chuathbaluk is 18 km.

avoidance of additional cost and poor service. Successful construction and ultimately, survival during the first two winter seasons allows the project to gather important empirical data. The capture of empirical data related to ice jams, ice scouring, armor effectiveness, strain instrumentation, repair method effectiveness and self-burial depth are all critical to the decision about whether to proceed further up-river to other communities in Phase 2. Construction methods used allow full commissioning and broadband service delivery to Chuathbaluk following empirical data collection and successful operations validation.

Timeline to construct initial project phase, Aniak to Chuathbaluk

Initial construction and validation of a Kuskokwim River fiber system is expected to require 2 years to complete. The first year is associated with construction and commissioning of the experimental system. Following successful deployment of the cable(s), instrumentation, shelters, and transmission equipment, the cables are monitored for approximately 18 months to validate the design parameters meet performance expectations and align with modeled reliability and failure predictions.

Budgetary estimate of phase 1 costs

The cost to construct the initial phase of the Kuskokwim River fiber system is approximately $7.1MM. This cost is fully loaded and includes the logistics, labor and materials required to complete the experimental phase as well as provide continued long-term operation should the experiment prove successful. The estimated costs to construct the system between Aniak and Chuathbaluk are detailed in the tables below. The tables are broken in materials, labor and travel / equipment rental sections and are summarized in a separate table which rolls up the total system cost.

Table 3. Aniak to Chuathbaluk materials cost estimate

Category	Description	Quantity[2]	Unit Cost	Extended
Materials	Ciena 6500 long haul transport equipment	2 x 1	$125,000.00	$250,000.00
Materials	Juniper MX304 w/ 400 GbE interface	2 x 2	$100,000.00	$400,000.00
Materials	Eltek Flatpack2 DC rectifier with 3 kW modules	2 x 1	$6,500.00	$13,000.00
Materials	Liebert PX011U 3-ton precision CRAC unit	2 x 2	$12,500.00	$50,000.00
Materials	Shelter pre-integrated with lighting and AC power	2 x 1	$150,000.00	$300,000.00
Materials	LiFePO4 battery system, 200 Ah	2 x 2	$6,000.00	$24,000.00
Materials	Cummins / Onan backup diesel generator w/ 100 gal fuel tank	2 x 1	$25,000.00	$50,000.00
Materials	NavePoint 42RU 23" relay rack	2 x 3	$300.00	$1,800.00
Materials	Commscope 2RU fiber distribution panel	2 x 2	$500.00	$2,000.00
Materials	Leviton 2RU Cat6 patch panel	2 x 1	$300.00	$600.00
Materials	Newmar -48VDC distribution panel, 2RU	2 x 3	$1,000.00	$6,000.00
Materials	OZ Optics BOTDR system	1	$150,000.00	$150,000.00
Cable	Single-armored 48 count fiber	62,040 ft.	$5.66 / ft.	$351,146.40
Cable	Submarine splice cases	2	$1,995.00	$3,990.00

[2] In cases where “2 x 1, 2 x 2, 2 x 3” quantities are shown the intent is to indicate that two shelters are used and each shelter requires 1, 2 or 3 of those items.

Cable	HDPE conduit, 6-inch	1000 ft.	$9.98 / ft.	$9,980.00
Cable	Splice sleeves	100	$1.25.00	$125.00
		Contingency	10.0%	$161,264.14
		Misc.[3]	3.0%	$48,379.24
			Total	**$1.8MM**

Table 4. Aniak to Chuathbaluk labor cost estimate

Category	Description	Man hours	Rate ($ / hour)	Extended
Labor	Site survey	2 x 40	$125.00	$7,500.00
Labor	Integration & testing prior to field deployment	2 x 40	$184.09	$14,727.20
Labor	Installation crew travel to site	2 x 72	$184.09	$17,672.64
Labor	Installation and commissioning	2 x 252	$191.13	$96,329.52
Labor	Systems testing	2 x 50	$193.70	$19,370.00
Labor	Communications engineering	2 x 112	$225.00	$50,400.00
Labor	Facilities engineering	2 x 112	$175.00	$39,200.00
Labor	Logistics support	2 x 112	$129.65	$29,041.60
Labor	Prinicpal oversight	2 x 70	$225.00	$31,500.00
Labor	Project management	2 x 160	$175.00	$56,000.00
Labor	Project controls analyst	2 x 160	$90.00	$28,800.00
Labor	Technician supervisor	2 x 84	$185.54	$15,585.36
Labor	Drafting and documentation	2 x 40	$60.00	$4,800.00
Labor	In-River cable placement	3160	$176.84	$558,885.14
Labor	Lost time delays	95	$176.84	$16,799.80
Labor	Safety and planning	60	$176.84	$10,610.40
Labor	Mobilization	280	$176.84	$49,515.20
Labor	Project management	1010	$176.84	$178,608.40
Labor	Material handling and logistics	280	$176.84	$49,515.20
		Contingency	10.0%	$127,486.04
			Total	**$1.4MM**

Table 5. Aniak to Chuathbaluk travel and rental equipment cost estimate

Category	Description	Quantity	Unit Cost	Extended
Travel	Travel for site survey	2 x 1	$1,500.00	$3,000.00
Travel	Site survey meals & lodging	2 x 3	$175.00	$1,050.00
Travel	Site survey car rental / taxi	2 x 3	$500.00	$3,000.00
Travel	Travel for installation and commissioning	2 x 3	$1,500.00	$9,000.00
Travel	Installation meals & lodging	2 x 21	$150.00	$6,300.00
Travel	Installation car rental / taxi	2 x 7	$500.00	$7,000.00
Equipment[4]	30' landing craft	6	$53,200.00	$319,200.00
Equipment	Reel dollies	2	$320.00	$640.00
Equipment	Directional drill, Vermeer 40	3	$27,930.00	$83,790.00
Equipment	Drill crew support truck	3	$8,246.00	$24,738.00
Equipment	Drill crew mud truck	3	$13,100.00	$39,300.00

[3] Miscellaneous equipment is an allocation of cost associated with consumables such as wire, fiber optic jumpers, connectors, etc.
[4] Equipment category costs use a “monthly rental quantity” and their unit costs are per month.

Equipment	Mini Excavator	3	$7,980.00	$23,940.00
Equipment	Larson trailer (Rectifier and feed)	6	$1,426.00	$8,556.00
Equipment	Turntables and tensioning equipment	6	$40,000.00	$240,000.00
Misc	Consumables	1	$14,630.00	$14,630.00
Misc	Small tools	1	$6,650.00	$6,650.00
Misc	Safety gear and training	9	$5,320.00	$47,880.00
Travel	Per diem	405	$232.75	$94,263.75
Misc	Bond	1	$19,950.00	$19,950.00
Misc	Permits	12	$5,054.00	$59,333.96
Travel	In-river team airfare	18	$1,330.00	$23,940.00
Misc	Lodging / lay down yards	73	$598.00	$43,654.00
Misc	Engineering support	12	$1,596.00	$18,737.04
Misc	Emergency support	1	$13,300.00	$13,300.00
Equipment	Bowhead barge	60	$19,457.00	$1,167,420.00
Misc	Divers	504	$399.00	$201,096.00
		Contingency	10.0%	$248,036.88
			Total	**$2.7MM**

Table 6. Aniak to Chuathbaluk (Phase 1) cost roll up and comparison with overland

Category	**Cost**
Materials	$1.8MM
Labor	$1.4MM
Travel, equipment rental and miscellaneous	$2.7MM
Experimental costs (cable alternative, self-burial assessment, etc.)	20%
In-river Total	**$7.1MM**
Phase 1 overland ROM estimate	**$5.1MM**
In-river to overland cost efficiency	**-28%**

The cost of constructing fiber between Aniak and Chuathbaluk is approximately 28% higher than the ROM overland route cost. This leads to the conclusion in Phase 1 has low cost effectiveness. As stated earlier, this is an expected result given that Phase 1 is intended be both experimental and operational (should the experiment be successful). The Phase 1 work increases confidence and to provides empirical evidence of sustainability in the presence of ice jams and repairability risk in the river. Lower cost efficiency is due to the mobilization and logistical inefficiencies associated with the short route between Aniak and Chuathbaluk. This relative inefficiency observed in Phase 1 is improved in Phase 2 where the route is much longer.

Experimental phase project deliverables

Ice jam to ice scour causality and armor effectiveness variables are modeled in the study using a sensitivity analysis approach. The experimental phase is used to collect empirical data to validate and refine and refine these assumptions. This increases confidence in the sustainability of long-term operations and increases the accuracy of failure and repair models. Tasks to be performed and documented during the experimental phase of the project include:

- *Ice jam validation.* Observation and documentation of ice jam to ice scour causality and correlation to improve model and increase confidence in predicted behaviors.
- *Cable armor effectiveness.* Quantification of cable armor effectiveness in the presence of ice scour. Ideally performed by placing multiple cable armor alternatives and observing survivability.

- *Cable sheath frazil ice resistance.* Demonstration of cable sheath coating resistance to frazil ice formation by placing multiple cables with different coatings to observe frazil ice formation propensity.
- *Self-burial depth.* Observation and documentation of self-burial depth and time to achieve self-burial relative to academic literature and expected behavior.
- *Constructability validation.* Analysis and demonstration of desktop analysis assumptions relative to construction, logistics and cost.
- *Cable placement.* Validate technique(s) for technical and cost effectiveness.
- *Instrumentation.* Demonstrate technical ability to measure fiber strand strain and correlate events with emerging or occurring faults
- *Repair.* Validate and demonstrate repair methods during ice-covered and ice-free conditions.

Successful completion of Phase 1 is measured by evaluating each individual deliverable against a set of confidence criteria that demonstrate budgetary and operational viability for continued deployment. An objective success criteria matrix be developed prior to deployment in Phase 1 in order to attempt to maintain objectivity during the experimental phase.

Full network construction, Chuathbaluk to Stony River

Construction of the fiber route between Chuathbaluk and Stony River is completed following the successful implementation of Phase 1. The path from Chuathbaluk and Stony River passes four intermediate communities and is approximately 215 km in length. Construction to Stony River effectively extends service half of the total distance to McGrath and spans 9 of the 18 river reaches. The cost to extend the cable from Chuathbaluk to Stony River is estimated to be approximately $19.6MM. Phase 2 moves the system from experimental status to a fully functional system capable of delivering broadband services at a telecommunications carrier-level reliability and availability performance. Following the construction of Phase 2, all of the communities between Aniak[5] and Stony River are provided with high-speed broadband connectivity. Cable landings are provided at all locations passed between Aniak and Stony River to maximize the number of subscribers passed and value of the construction project. Phase 2 increases the cost effectiveness of the system by reducing the per community logistics and construction costs. Completion of the project to Stony River delivers a telecommunications system capable of carrier-class service delivery with a standard operational model. Upon completion and commissioning of Phase 2, the system is capable of delivering high speed broadband access at gigabit+ speeds to all of the subscribers within the communities passed[6].

Full system construction budget

The budget to complete Phase 2 of the project is approximately $19.9MM[7]. This budget is fully loaded and include the logistics, labor and materials required to complete the broadband deployment. The estimate to extend service from Chuathbaluk to Stony River includes a shelter

[5] Although not discussed here, construction of Phase 2 is not recommended unless middle mile connectivity has been extended from Bethel to Aniak. This connectivity does not exist as of the publication of this report.
[6] This assumes that in-community distribution using XGS-PON or equivalent is included in the project and that middle mile connectivity to Aniak is already in place.
[7] The budgetary estimate provided does not include community last-mile distribution costs. It is recommended that these costs be loaded into any project that proposes construction and that last mile distribution be provided using XGS-PON technology to maximize the value of the middle-mile fiber system.

and transmission equipment in Stony River, landing vaults in each intermediate community and the cable and installation labor costs. These costs are detailed in the tables that follow below.

Table 7. Chuathbaluk to Stony River materials cost estimate

Category	Description	Quantity[8]	Unit Cost	Extended
Materials	Ciena 6500 long haul transport equipment	1	$125,000.00	$125,000.00
Materials	Juniper MX304 w/ 400 GbE interface	2	$100,000.00	$200,000.00
Materials	Eltek Flatpack2 DC rectifier with 3 kW modules	1	$6,500.00	$6,500.00
Materials	Liebert PX011U 3-ton precision CRAC unit	2	$12,500.00	$25,000.00
Materials	Shelter pre-integrated with lighting and AC power	1	$150,000.00	$150,000.00
Materials	LiFePO4 battery system, 200 Ah	2	$6,000.00	$12,000.00
Materials	Cummins / Onan backup diesel generator w/ 100 gal fuel tank	1	$25,000.00	$25,000.00
Materials	NavePoint 42RU 23" relay rack	3	$300.00	$900.00
Materials	Commscope 2RU fiber distribution panel	2	$500.00	$1,000.00
Materials	Leviton 2RU Cat6 patch panel	1	$300.00	$300.00
Materials	Newmar -48VDC distribution panel, 2RU	3	$1,000.00	$3,000.00
Materials	OZ Optics BOTDR system	4	$150,000.00	$600,000.00
Cable	Single-armored 48 count fiber	716,285 ft.	$5.66 / ft.	$4,054,173.10
Cable	Submarine splice cases	5	$1,995.00	$9,975.00
Cable	HDPE conduit, 6-inch	5000 ft.	$9.98 / ft.	$49,900.00
Cable	Splice sleeves	250	$1.25.00	$312.50
		Contingency	10.0%	$526,306.06
		Misc.[9]	3.0%	$157,891.82
			Total	**$5.9MM**

Table 8. Chuathbaluk to Stony River labor cost estimate

Category	Description	Man hours	Rate ($ / hour)	Extended
Labor	Site survey	40	$125.00	$5,000.00
Labor	Integration & testing prior to field deployment	40	$184.09	$7,363.60
Labor	Installation crew travel to site	72	$184.09	$13,254.48
Labor	Installation and commissioning	252	$191.13	$48,164.76
Labor	Systems testing	50	$193.70	$9,685.00
Labor	Communications engineering	112	$225.00	$25,200.00
Labor	Facilities engineering	112	$175.00	$19,600.00
Labor	Logistics support	112	$129.65	$14,520.80
Labor	Prinicpal oversight	70	$225.00	$15,750.00
Labor	Project management	160	$175.00	$28,000.00
Labor	Project controls analyst	160	$90.00	$14,400.00
Labor	Technician supervisor	84	$185.54	$15,585.36
Labor	Drafting and documentation	40	$60.00	$2,400.00

[8] In cases where “2 x 1, 2 x 2, 2 x 3” quantities are shown the intent is to indicate that two shelters are used and each shelter requires 1, 2 or 3 of those items.
[9] Miscellaneous equipment is an allocation of cost associated with consumables such as wire, fiber optic jumpers, connectors, etc.

Labor	In-River cable placement	17316	$176.84	$3,062,161.44
Labor	Lost time delays	1040	$176.84	$183,913.60
Labor	Safety and planning	1300	$176.84	$229,892.00
Labor	Mobilization	1276	$176.84	$225,647.84
Labor	Project management	4040	$176.84	$714,433.60
Labor	Material handling and logistics	1010	$176.84	$178,608.40
		Contingency	10.0%	$481,358.09
			Total	**$5.3MM**

Table 9. Chuathbaluk to Stony River travel and rental equipment cost estimate

Category	Description	Quantity	Unit Cost	Extended
Travel	Travel for site survey	1	$1,500.00	$1,500.00
Travel	Site survey meals & lodging	3	$175.00	$525.00
Travel	Site survey car rental / taxi	3	$500.00	$1,500.00
Travel	Travel for installation and commissioning	3	$1,500.00	$4,500.00
Travel	Installation meals & lodging	21	$150.00	$3,150.00
Travel	Installation car rental / taxi	7	$500.00	$3,500.00
Equipment[10]	30' landing craft	8	$53,200.00	$425,600.00
Equipment	Reel dollies	8	$320.00	$2,560.00
Equipment	Directional drill, Vermeer 40	8	$27,930.00	$223,440.00
Equipment	Drill crew support truck	8	$8,246.00	$65,968.00
Equipment	Drill crew mud truck	8	$13,100.00	$104,800.00
Equipment	Mini Excavator	8	$7,980.00	$63,840.00
Equipment	Larson trailer (Rectifier and feed)	8	$1,426.00	$11,408.00
Equipment	Turntables and tensioning equipment	8	$53,200.00	$425,600.00
Equipment	Fuel surcharge	1	$80,000.00	$80,000.00
Misc	Consumables	1	$29,260.00	$29,260.00
Misc	Small tools	1	$13,300.00	$13,300.00
Misc	Safety gear and training	9	$7,980.00	$71,820.00
Travel	Per diem	1219	$232.75	$283,722.25
Misc	Bond	1	$50,437.59	$50,437.59
Misc	Permits	136	$5,054.00	$687,344.00
Travel	In-river team airfare	36	$1,330.00	$47,880.00
Misc	Lodging / lay down yards	210	$598.00	$125,580.00
Misc	Engineering support	136	$1,596.00	$217,056.00
Misc	Emergency support	3	$13,300.00	$39,900.00
Equipment	Bowhead barge	210	$19,457.00	$4,085,970.00
Misc	Divers	2016	$399.00	$804,384.00
		Contingency	10.0%	$787,454.48
			Total	**$8.7MM**

Table 10. Chuathbaluk to Stony River (Phase 2) cost roll up and comparison with overland

Category	Cost
Materials	$5.9MM
Labor	$5.3MM
Travel, equipment rental and miscellaneous	$8.7MM
In-river Total	**$19.9MM**

[10] Equipment category costs use a “monthly rental quantity” and their unit costs are per month.

Phase 2 overland ROM estimate	**$23.0MM**
In-river to overland cost efficiency	**17%**
Total project cost efficiency relative to overland	**5%**

Construction from Stony River to McGrath is not recommended

The results of the desktop analysis are pessimistic with regard to the feasibility of fiber construction between Stony River and McGrath. There are a number of risks that arise on the upper half of the river that lead to the recommendation of extreme caution when considering construction beyond Stony River. The absence of intermediate communities between Stony River and McGrath means that there are no year-round residents between Stony River and McGrath. This complicates staging, construction, and repair scenarios significantly. The ice jam model predicts a moderate to high ice jam likelihood for almost the entire span between Stony River and McGrath, increasing the chances of a failure event on those 9 reaches. Finally, the population of McGrath is 301, while the remainder of the communities passed have a cumulative population of approximately 915. The relative value of construction to Stony River is substantially higher than the economic value of McGrath when considering the cost per subscriber passed. Reaching the final 301 subscribers in McGrath is effectively twice as expensive as reach those between Aniak and Stony River since the distance between Aniak and Stony River and Stony River and McGrath is almost identical (~215 km). With the information currently available a route between Stony River and McGrath does not appear feasible or recommended for further study.