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

## Installation Means and Methods

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## Introduction

Telecommunications systems inherently cover large distances and varied terrain in order to provide connectivity between distant locations. Novel and creative methods for increasing availability and reducing the cost of construction and operation represent a continuous challenge for network operators. This study approached the Kuskokwim River project with the primary objective of identifying and documenting the costs, methods and risks associated with construction of a fiber cable within the Kuskokwim River corridor.

The in-river methods of deployment explored were evaluated relative to traditional overland construction and permitting methods. This relative comparison approach provides a baseline using a well-known and understood benchmark to establish the feasibility of construction. Recommended construction methods utilize established river-based and submarine installation techniques adapted for longitudinal river installation. Construction emphasis is placed on reliability and habitat protection. Installation recommendations are established on a reach-by-reach basis and incorporate changing bathymetry, river bank conditions, and community proximity.

## River system constructability considerations

The construction techniques evaluated for use in the placement of a fiber-optic cable in the Kuskokwim River are limited to direct-lay methods. Water jet and underwater plow installation methods were considered but the cost, logistical complexity and impact on wildlife habitat were deemed too great. For the purposes of the study, only direct-lay cable placement is explored. Placement of a fiber-optic cable within the Kuskokwim River presents unique challenges. Arctic rivers experience increased seasonal flow variation, ice formation and flooding events that impact the project team’s ability to both construct and operate a cable. Some of the challenges are discussed below.

### Seasonal flow variation in the Kuskokwim River

The Kuskokwim River experiences strong seasonality in its flow due to snowmelt. Each season has its own behavior characteristics. The river experiences its minimum flow levels in winter (November to April) while the river is under ice cover. Groundwater dominates the flow during the winter season, flow channels are stable and water is at its lowest level. During the spring break-up season (May to early June) rapid snowmelt across the river basin causes the flow to increase dramatically, with levels rising to the point of flooding as ice jams and channel scour occur. Summer months (June to August) see increased flow levels due to continued melt and rainfall. Sediment transport and bank erosion typically occur during summer months. Fall (September to October) flows are primarily driven by rainfall events and the rate of flow declines between September and October until it reaches winter levels.

### Ice formation and break-up behaviors

The formation and break-up of river ice represent the single largest risk to a river-placed cable. This ice action can lead to cable breakage during ice active months (ice formation in the fall and ice melt in the spring). In addition to direct ice scouring impacts on the cable, the formation of ice jams can lead to bottom scour and boulder field formation as ice bonds with objects in the water columns and moves them downstream. The dynamic nature of the river and seasonality of the changes observed require careful review and consideration when selecting a cable deployment method.

### Transport of river sediment

Sediment transport in the Kuskokwim River is an area of concern with regard to the effectiveness of cable placement. As discussed above, the seasonal river flow variation leads to seasonal sediment transport within the river corridor. The most significant transport is observed during the spring break-up season. During the spring and summer seasons the river sees the movement of sediment, active channel migration and potential cable exposure or movement.

### Shallow and braided channel morphologies

The Kuskokwim River is predominantly a shallow, sand-bed, braided river across the majority of its reaches between Aniak and McGrath. This leads to high seasonal stage variation, high sand-bed mobility and a wide active channel belt. Annual ice jam behaviors and localized flooding events frequently reorganize the braidplain and can move the thalweg or induce new areas of high flow not previously observed.

### Fish habitat and seasonal spawning

The river corridor is habitat for all five Pacific salmon species as well as several other important fish species. The sand-bed bottom of the main river corridor and the tributaries that feed the river are spawning grounds for fish in the region. Disruption of the sediment layer during the spawning season should be minimized to the extent that it is possible during construction. Each salmon species observes a slight variation in its spawning season with Chinook salmon beginning in early to mid-July and Coho salmon extending through October.

## Fiber optic cable installation overview

The tools, materials and methods used to enter, exit and transit the river draw upon a combination of accepted river and marine installation techniques. A combination of riverine and adapted submarine fiber installation techniques are proposed. These methods are refined to emphasize reliability, environmental and habitat protection, and constructability within Alaska's adverse remote conditions. The recommended installation method is defined on a reach-by-reach basis based on river bathymetry, bank conditions and composition, and proximity to communities. These factors are taken into consideration in order to produce a cost-effective construction plan. Broadband FOC installation projects may involve one or more of the following installation methods:

- *Overland*. Fiber optic cable routes through or over inland environments, including upland areas as well as inland wetlands, rivers, and lakes. Overland routes terminate at a connection vault, where the FOC transitions to a last-mile delivery method (e.g., aerial cable on a utility pole).
- *Submarine*. Submarine routes describe any in-water FOC deployment, including in rivers and lakes and offshore or nearshore areas (i.e., below mean lower low water) for FOC deployment. Submarine fiber optic cable is either laid directly on the substrate or trenched, depending on the bottom composition, local fishing and shipping activity, practical limitations and water flow conditions.
- *Landfall*. Fiber optic cables laid between the mean lower low water and a point of connection above the high tide line, such as a beach manhole or a connection vault. This installation method is used to transition submarine routes to onshore routes and includes FOCs placed in rivers that transition to uplands.
- *Fiber to the premise*. The last-mile segment of fiber optic cable infrastructure connects to a community's residential or commercial premises. The last-mile route uses new or existing underground or aerial utility infrastructure (e.g., conduits, utility poles) to provide connectivity to customers or system end-users.

### Installation features common to all fiber optic cable installation projects

FOC installations require some typical equipment or installation standards, regardless of where the project is located. These requirements include:

- *Cable splices*. FOC comes on spools of varying length, partly dependent on the size of the cable and the cable's selected armoring system, which impacts the cable's external diameter and subsequently how much cable can be placed on a single reel or spool. When two cables are joined, a weatherized splicing compartment is used to protect the cable splice. Splice points contained in environmentally sealed cases are used in aerial, underground, and submarine installations.
- *Slack loops*. Once FOC is placed, it cannot be readily relocated to provide for maintenance or other disturbances. One of the methods used to address this is to provide slack loops for new FOC

placement, which provide an additional length of cable that can be used to support future facility relocation or aid in cable repair operations. Slack loops can be placed on aerial spans or in vaults for buried cable installations.

- *Communication huts*. Communication huts are used to provide both periodic signal recovery and last-mile network interconnection points. Communication huts frequently implement multiple power systems, such as a combination of commercial and/or on-site generated power (e.g., diesel-fuel powered generator). Huts are typically placed in easily accessible locations and often have diverse, redundant FOC entry points.
- *Vegetation clearing*. All FOC utility construction may result in the need to clear vegetation to facilitate the movement of construction equipment or provide access to existing or proposed facilities.

## In-Water fiber optic cable installation

Cables may be placed in water (marine or freshwater) for short spans (e.g., crossing a river perpendicularly) or long lengths (e.g., marine placement, longitudinal river placement). Submarine FOCs are designed with appropriate armoring and waterproofing systems to provide system protection. These cables may be placed directly on the seafloor or riverbed, or they may be buried using cable plows or jet sleds. Submarine cable installation may include the use of pre-lay grapnel runs. Submarine cable can be placed from large, ocean-going vessels to river-navigable barges; operationally, vessels should use a dynamic positioning system to ensure the installation remains within specification as vessels traverse marine waters or rivers.

- *Pre-lay grapnel run*. This is an in-water operation that is intended to clear submerged debris out of the path of submarine FOCs before the cable is placed. The operation is completed by pulling a grapnel train across the submerged surface with a vessel. The grapnel train is typically made up of a series of grapnel anchors that hook into debris and allow it to be pulled to the surface. This process ensures that any obstacles that could obstruct the placement of the FOC on the riverbed or seabed surface are cleared from the FOC path.
- *Jet sled*. Burying submarine FOCs is frequently accomplished using high-pressure water jets to liquify or displace sedimentary substrates along the cable alignment. These systems use the water jets to create a temporary trench that the cable can be placed directly into and then naturally backfills. The jetting operation typically employees a towed skid or sled that includes the high-pressure water jet nozzles and a cable feeding system that places the cable into the jetted trench.
- *Cable plow.* Plowing is largely considered one of the most efficient methods for burying submarine cables, which is frequently required to protect the asset in shallow waters from damage by fishing or ship anchors. Cable plows (also known as “scratch plows”) are often recommended for installation in areas with higher river velocities as these fast-moving currents can lift the cable from the bottom of the riverbed. The cable plow, often mounted on a skid or wheeled chassis, is towed along the bottom on the riverbed or seafloor by the cable laying vessel or barge. The cable passes through the plow which lifts a wedge of sediment so the cable can be inserted below, minimizing the disturbance to a narrow corridor.
- *Trenching (intertidal zone)*. FOC is typically buried in intertidal zones to provide cable and environmental protection. The cable is frequently buried at low tide using excavators operating from the beach. FOC burial in the intertidal zone is similar to terrestrial cable burying operations.
- *Surface lay (submarine)*. In deep marine waters or areas with nominal risk of FOC dislodgement, frazil ice formation, or anchor damage, FOC may be directly laid on the ocean floor or riverbed. This is feasible when water depths are great enough that ship anchors or commercial fishing operations will not damage exposed cables, river velocities are low, and the risk of frazil ice formation is reduced. Cables laid directly on the seafloor or riverbed may include additional armoring for added protection or be installed with external weights to reduce the likelihood of

floating or FOC migration. Directly laying the FOC on the waterbody floor has the least direct impacts to fish or fish habitat.

## Fiber optic cable construction methods summary

Table 1 summarizes the installation methodologies for FOCs in terrestrial and submarine environments.

**Table 1. Summary of fiber optic cable installation methodologies**

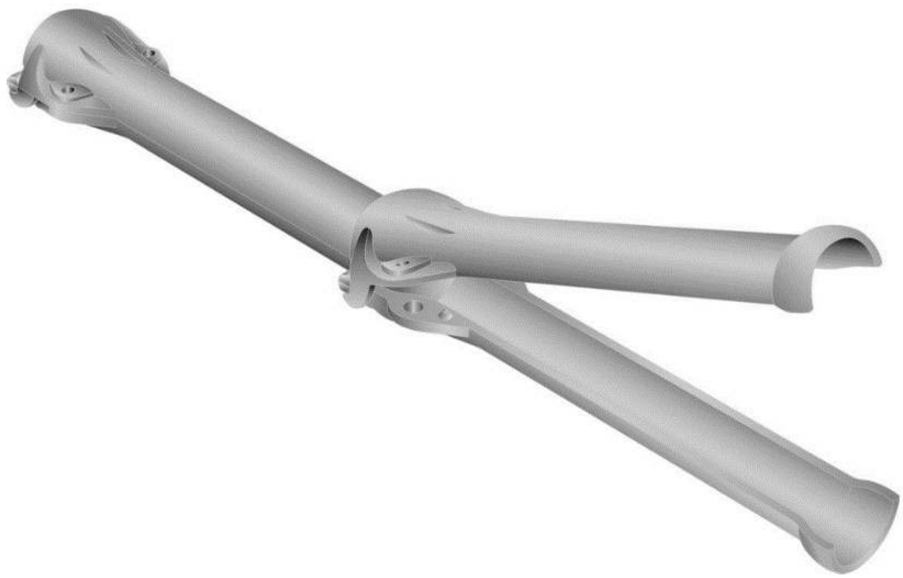
| Deployment Type | Deployment Methodology Description |
|---|---|
| Pre-lay grapnel run | This is generally performed prior to laying submarine fiber optic cable. The purpose is to clear the proposed fiber optic cable path of any potential obstacles (e.g., debris) which might be located on the waterbody floor in the path of the proposed cable. |
| Jet sled | Jet sleds are used to bury fiber optic cables in aquatic environments (e.g., oceans, lakes, rivers) to avoid interference from ground fishing operations, anchor setting, and natural hydrologic processes. Jet sleds are mounted with a high-powered hose that excavates trenches by liquefying the substrate and allowing the cable to settle into the trench. The cable then self-buries as the sediment resettles around it. This technique creates a temporary narrow trench and requires not sidecasting of material. |
| Cable plow | Where soft substrate (e.g., sandy, silty) exists, a cable plow is used to create a shallow trench that the fiber optic cable is placed into and buried. A cable plow operates in a similar manner to a vibratory plow by using a metal plow blade to create a temporary trench into which the fiber optic cable is directly fed. The trench then backfills immediately behind the blade. This technique creates a temporary narrow trench that requires material sidecasting. |
| Trenching (intertidal zones) | Traditional trenching using an excavator or similar machinery is used to lay buried fiber optic cable within the intertidal zone, between the mean lower low water mark and the high tide line. |
| Surface lay (submarine) | Laying cable directly on the seafloor. This is typically performed only in waters sufficiently deep enough to avoid environmental conditions or where necessary due to a hard or rocky substrate. |

## Riverine controlled direct-lay with armored cable

The primary method for cable placement between communities is the “controlled direct-lay” payout technique. The installation of the cable follows the GPS track set by the sonar-based river bottom survey. An HDPE (High-Density Polyethylene) jacket is recommended for use on the underwater sections of cable to minimize the potential for frazil ice bonding to the cable. Frazil ice formation on the cable can cause the cable to float in the water column and increases the likelihood of damage substantially. The cable selected for use is, in general, single armored with double armor recommended in areas of high scouring risk and / or low self-burial likelihood. Much of the Kuskokwim River is characterized as being highly braided with significant multi-threading of flows. Placement of the cable in the main river thalweg increases the likelihood of self-burial while simultaneously minimizing the requirement for double-armored cable.

Sections of the river that have hard bottom characteristics, poor self-burial, historical evidence of repeated ice jam events, or increased anchor drag occurrence should use modifications of subsea installation methods. Installations in these conditions should use armored, weighted articulated pipe segments suitable for underwater installation. These segments should be HDPE coated variety to avoid ice formation and build-up. Articulated armoring contributes to weight of the cable and is installed in 18 – 24 inch segments over the length single armored cable. Additional weight added to the cable to assists in forcing the cable to sink and encourages self-burial. Segments of articulated pipe are bolted onto the cable at a ratio of one 10 foot section per 100 feet of cable length. Phase 1 of the project plan should be used to optimize this cable weight ratio as free silt content and other factors can contribute to buoyancy factors of the cable. Areas identified as holding an extremely high risk of scouring or the cable exposure due to seasonally shallow water or braided river morphology changes should use continuous armoring.

**Figure 1. Articulating pipe cable armor**



Deep channel river segments where self-burial is assumed should use direct-laid, weighted, single-armored cable. Sediment movement in the thalweg tends to homogenize bottom conditions and are conducive cable self-burial.

**Figure 2. Single-armor cable construction**

## Cable pay-out and placement

Placement of the cable is managed by moving the barge vessel upstream into the river's current flow. This allows the barge to maintain maximum control of cable laying speed and position. Tension-controlled cable pay-out and rectification utilize cable payout methods with either tires or tracks that allow the operator to adjust the payout speed to match barge speed. Figures 3 and 4 show sample equipment used in the payout and rectification of the cable. The CEMAC linear cable engine and offshore track tensioner are available in a variety of configurations. The cable-laying barge turntable pays out the cable through a feed system that straightens the cable and maintains tension levels within the required cable specifications. This system allows the operator to maintain the 5% slack allowance and avoid dragging or causing the cable to go taut. Care should be taken to optimize payout speed and tension to accommodate for river current and boat speed. Sufficient slack should be maintained on deck to allow for rapid pay out in the event of locomotive power loss of the barge until anchors can be dropped and barge secured.

The cable reels proposed for use in the river installation weigh approximately 25 tons. In order to manage cable reels of this size, cable reel handling systems are required. The reel handling systems are used to place and handle the multiple lengths and types of cable used in each river reach. In addition to reel handlers; dollies and other modular equipment such as operator stations, generators, pumps, compressors, and handling booms should be available on the barge deck for use during installation. A cable turntable is used to ensure that minimum bending radius and tension limits are observed during installation. The turntable required for cable placement in the Kuskokwim River must be sized to match the barge vessel and have a minimum capacity of 15 miles. If more than one cable must be loaded to the turntable to reach between landing points,  Cable lengths should be pre-spliced to minimize re-load and labor specialization requirements. The turntable and tensioning equipment are used in tandem with the rectifying system which alleviates cable memory and reduces corkscrewing of the cable as it is laid.

**Figure 3. CEMAC linear cable engine used to perform cable payout during direct-lay operations**


**Figure 4. CEMAC cable offshore track tensioner used to cable tension with specification limits**

## Slack management

Cable slack is included during installation to accommodate the dynamic nature of riverbed. Slack is provided using serpentine routing during cable placement. The serpentine routing provides a minimum of 5 feet of slack per 100 feet of laid cable (5%). Additional slack placement is recommended upstream of particularly high flowing areas of the river.

## Sonar-based route survey

The desktop study identified thalweg route must be refined by commissioning a riverbed sonar survey to exactly locate the current thalweg (deepest channel) position prior to cable placement. This survey should be performed the same season that the installation is scheduled to occur. A survey operator with both marine and riverine experience should be engaged to ensure that river bottom survey best practices are observed.

Academic literature[1] tentatively suggests that commercially available recreational grade side-scan sonar systems might be adequate (fish finders) to map the channel depth of the river and bottom 'texture'. Furthermore, off-the-shelf software packages are available to facilitate the processing of collected field data into digital elevation models or pixel cloud files. This approach is the most cost-effective and efficient alternative to identify the river thalweg for cable placement. Use of this approach minimizes logistical effort and can be accomplished in tandem with the support vessel. With proper training and experience the collected bathymetry enables rapid field decisions that inform cable routing and dictate areas where additional weighting and armoring are appropriate.

## Field engineering and installation method enhancements

Installation of the fiber cable requires the collection of as-built construction data for long-term operational sustainability. The location of the placed cable should be documented and collected digitally using differential GPS methods to ensure accurate cable location data is available for future repairs or maintenance. Daily installation logs detailing sonar, design variance and raw data should be collected, cataloged and archived. Physical depth of river checks should be collected every 300 feet to ensure that the sonar depth soundings remain calibrated with physical river depth.

Early installation efforts of the project will likely encounter challenges using the proposed cable placement methods due to the lack of empirical data supporting the methods. Field engineering and additional research and development effort will be required to enhance or resolve difficulties experienced due to localized flow variations, debris and other unknowns. Any improvements developed in Phase 1 of the project should be extended into Phase 2 to reduce the time to deployment and any technical difficulties that might be mitigated. Extension of these improvements is more likely if the crew compliment, equipment selection and design methods are maintained, to the extent possible, across both phases of the project.

## Shore approach and cable landing

Cable entry and exit from the river requires care to protect the cable from river bank erosion, debris, and vessel traffic. Shore landings are segmented into three main components, the bank to river conduit, the beach manhole and the cable landing station (CLS).

*Shore to river conduit installation methods*

Shore landings are completed through the use of horizontal directional drill (HDD) equipment that bores places conduit underground. The equipment selected for use in this project should have a capability of drilling 700 feet in total length and 250 feet from the high-water mark on the shore side. The conduit should emerge in the river within the thalweg to maximize protection from external aggression risks such as anchor drag.

The HDD equipment is used to bore an 8-inch pilot hole from the beach manhole location into the river thalweg. The drill head is captured in the river by the support vessel and the drill head is pulled to surface. Sections of 4 or 6-inch HDPE conduit are pulled back through the pilot hole, taking care to match pulling speeds to ground conditions and handling of the conduit on the support vessel. HDD locator equipment provide a bore log that accurately displays GPS coordinates and physical depths of the bore to within +/- 6-inch accuracy. These bore logs should be tabulated and documented for future using in repair and maintenance efforts. An EMS (Electronic Marker System) device will be attached to the river and shoreside ends of this conduit for future retrieval if necessary.

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[1] Hamill et al., "Bed Texture Mapping in Large Rivers.", Wilson, Singh, and Sethi, "Shallow Water Bathymetry Survey.", Pulido et al., "Time and Cost-Efficient Bathymetric Mapping."

**Figure 5. Vermeer horizontal directional drill (HDD) equipment used to place underground conduit**

### *Beach manhole placement*

The beach manhole should be placed as close to the bore entry pit as possible to minimize the pull back length from the river to the manhole. Conduit from the bore should is plumbed into the beach manhole vault and is grouted into the side wall leaving a minimum of 6 inches of tail inside the vault to secure the conduit against ground movement. This manhole should be placed on high ground to avoid the vault becoming swamped with water and crews should take care to minimize ground disturbance. Placement methods may vary based on local ground conditions, however the vault should be plumb, level and placed in the ground with sufficient bedding (such as 6 – 12 inches of compacted gravel) to avoid settling. Backfill of the manhole should be compacted to 95% compaction to avoid shifting of the vault during cable pull in operations. The fiber-optic cable is then pulled into the vault and anchored to the sidewall while leaving sufficient slack (approximately 100 feet) for splicing operations.

**Figure 6. Example beach manhole vault installation**

*Cable landing station shelter construction*

The beach manhole is connected to the cable landing station (CLS) shelter using traditional underground fiber trenching methods. The connection is accomplished using a minimum of two 4-inch conduits placed at a minimum depth of 42 inches. Conduits used can be either PVC or HDPE construction. Depending on the distance between the beach manhole and the cable landing station shelter, the fiber-optic cable may be able to be slack looped at the manhole and pulled through the cable landing station conduit to the shelter facility. This method eliminates a fiber splice (and potential failure) point in the beach manhole. Site selection for the cable landing station shelter should account for ease of access, proximity to commercial power and local fiber distribution network access. The shelter building should be set on a compacted gravel pad of an area at least 50 feet by 50 feet. This pad layout leaves room for the shelter, a generator, fuel tank, and parking for technicians.

**Figure 7. Cable landing station conduit entry example**

## Construction logistics

Successful rural Alaska telecommunications projects require careful planning in order to fit the required work into the short summer construction season. Project logistics is a critical element of any rural Alaska project. The discipline of logistics includes movement, staging and management of people and project materials. This section summarizes some of the more significant logistics considerations when considering the construction of a fiber-optic cable in the Kuskokwim River.

### Vessel selection

Installation of the fiber-optic cable within the river requires the use of a vessel capable of carrying the fiber cable and materials and installation equipment as well as enough remaining deck spacing to perform the cable laying operations safely. The cable is expected to be delivered in 12 mile reaches with a unit weight of 0.8 lbs / foot. This results in a total weight of of approximately 25 tons per reach. Installation should be performed using a shallow-draft river barge of the variety that frequently navigates the Kuskokwim River. The selected craft should be regionally available and have minimal draft such that shallow reaches do not present technical difficulties or limitations during cable laying operation. Bowhead Transport, a regional barge operator, has a barge in its fleet with the capability to accommodate these requirements. This barge, the Ace, is 121 feet in length and 35 feet wide. The Ace has a deadweight capacity of 600 tons. This capacity is sufficient to support the required materials for installation in the river.

**Figure 8. Bowhead Transport Ace shallow-draft barge**

## Material staging recommendations

Materials staging for both in-river and in-community equipment is an important element of the project logistics plan. Placement of project materials can be a challenging element of remote projects due to the limited availability of heavy equipment within communities. Flat, empty lots suitable for lay-down yards must be pre-arranged within each community. The project plan proposes to provide material staging in the communities of Aniak, Chuathbaluk, and Stony River. It is important to note that permitting requirements and land ownership issues must be resolved well ahead of project execution to ensure that the project schedule is not impacted.

### *Temporary riverside lay-down areas*

All of the communities suggested for use in materials staging have boat launch areas appropriate for use as lay-down yards. Conveniently, many of the candidate cable landing sites are either at these locations or in close proximity to them. Lay-down sites should be free of debris with a surface that is sufficient hard packed to support drive off equipment use. Significant space to off-load and temporarily stage equipment and materials will be necessary to provide effective storage and staging operations. A recommended pad size of 100 feet by 100 feet accommodates heavy equipment movement for loading and off-loading activities. Community outreach and permissions for these sites would is vital to ensure that their use and timing matches with owner and construction team expectations. If nearby but off-site lay-down yard permission cannot be obtained it may be necessary to use cable landing station shelter location as a lay-down area. This construction model is not recommended as it creates inefficiencies and congestion during placement of the shelter and beach manholes.

*Community rental spaces for environmentally controlled materials*

The transmission equipment, generator(s), battery systems and other sensitive equipment requires a secure, environmentally conditioned space. The rural nature of the communities in which these facilities are being installed limits the options available for housing equipment prior to commissioning. It is recommended that rental spaces be arranged well ahead of the deployment to ensure their availability and adequacy for the purposes of storing system components such as generators, batteries and other equipment. Options to be explored for rental spaces include local schools, town halls and community buildings.

*Strategies for barge loading and unloading*

Efficient loading and unloading of equipment and materials from the barge is an important element of minimizing labor costs and increase project speed. Strategies include the trailer loading of materials prior to river movement to ease loading and off-loading. Care must be taken to ensure that the fiber-optic cable is loaded in a ‘first-on, last-off’ manner to increase efficiency. Equipment needed for off-loading is generally available in larger communities. Pre-planning should be performed to ensure that required equipment is available in smaller or more remote communities. Each community has road maintenance equipment that may be utilized to shuttle equipment and trailers with prior coordination. Phase 1 of the project should have the fiber-optic cable pre-loaded at the dock facilities at point of embarkment (in Anchorage or Homer, Alaska). Pre-loading the cable allows Phase 1 to be completed with fewer in-region facilities and equipment. A front-end loader (Cat 966 or equivalent) capable of moving and placing the communications shelters will be shipped with the initial equipment from the point of embarkment. The loader is then moved from community to community using already coordinated barging services and in region resources.

*Methods for managing the supply chain*

Supply chain refers to the management of project resources from acquisition of the raw materials required to implementation of the final system commissioning. There are two basic supply chain management methods used in the Kuskokwim River project. The just-in-time supply chain model allows lay-down space requirements to be minimized by only staging materials immediately required on-site. Scheduling fiber shipments to align with project milestones allows trans-loading from shipping to cable-laying barge with little long or short term storage required. The trans-loading model also reduces the risk cable reel damage with the off-loading and re-loading of cumbersome 25-ton reels in less-than-ideal conditions at landing sites. Alternatively, for materials that have long lead times or require plan-ahead transport, pre-staging is used. Lay-down space in each community is used to accommodate shipments of materials where they are temporarily staged until ready for deployment. With proper local or municipal approval boat launch areas could make suitable staging areas. Lay-down space might also be accommodated by coordinating with local Department of Transportation or village airport resources. The village airport properties can sometimes be utilized for short durations to store heavy equipment prior to the start of construction.

*Modular mobilization*

Modular mobilization is utilized to pre-package each cable landing station shelter with its associated equipment, generators, batteries, HDPE conduit, and beach manhole materials into modules for deployment. As each module is offloaded on-site it can be correctly sequenced and made ready for efficient deployment. This modularity reduces the impact of having to verify the presence and completeness of materials by hand on-site prior to the start of work. The modules are then staged sequentially from the southern-most to northern-most location and can be efficiently staged in a single barge trip. For example, the barge for Phase 1 would be loaded such that all materials for Aniak are loaded on the barge last so that upon arrival in Aniak, those materials are first off of the barge. This approach increases project flexibility and allows for the use of standard, regularly available, shipping methods and in-region resources to distribute materials to the correct sites.

## Labor, staffing and resource allocation

Outside plant telecommunications construction projects are inherently labor intensive. Telecommunications systems are designed to span long distances in order to interconnect communities and users. In contrast with wireless middle-mile communication technologies such as microwave radio or satellite, fiber-optic cable systems require the placement of a physical transmission medium to facilitate connectivity. This construction requirement increases the cost relative to wireless transmission methods with the benefit of dramatically increased capacity. Planning for the right staffing levels and expertise as part of a large project such as placing fiber in the Kuskokwim River requires expertise, knowledge and planning.

### Staffing levels

In addition to the raw labor headcount, the construction team must also employ the right compliment of technical specializations. This river project requires a unique combination of technical expertise that spans vessel operations, fiber-optic technicians, electricians, HVAC technicians and drilling crew specialist.

Three discrete task sets must be addressed on the project:

- The river placement crew is responsible for placing the fiber cable in the river and terminating it in the beach manhole. This includes directional boring from the shore to the river thalweg.
- Outside plant fiber construction between the beach manhole and the transmission facility shelter is a specialized skill set that requires a dedicated team.
- Shelter integration, commissioning and power interconnection also requires specialized knowledge and expertise and is another separate crew.

Each of the crews listed above is unique and from a project planning perspective can be run as parallel separate project tracks until the system is ready to be commissioned. During the course of the project some overlap of resources is expected. This collaboration between crews creates efficiencies and reduces project cost. For example, the HDD construction crew could perform the dirt work portion of the beach landings and cable landing station shelters while on-site for HDD operations. These same crews might also be tasked with assisting with loading and off-loading of materials at landing sites. Fiber splicers could be moved from site-to-site to commission and test systems when not needed at intermediate splicing sites. The suggested crew compliment for each project phase is shown below.

**Table 2. River construction crew headcount**

| Crew Member | Headcount |
|---|---|
| Project manager | 1 |
| Project engineer (field verification, QA / QC) | 1 |
| Vessel operator (captain, mechanic, swamper) | 3 |
| Journeyman lineman (cable handling) | 2 |
| Apprentice (equipment maintenance) | 1 |
| Fiber cable splicer | 2 |
| Drill crew (foreman, support, mud tech) | 3 |

**Table 3. Outside plant crew headcount**

| Crew Member | Headcount |
|---|---|
| Journeyman Lineman | 1 |
| Apprentice | 1 |

**Table 4. Cable landing station crew headcount**

| Crew Member | Headcount |
|---|---|
| Apprentice | 1 |
| Fiber cable splicer | 1 |
| Inside Communications Technician | 1 |
| Wireman | 2 |

### Training and safety considerations

Safety is paramount on all telecommunications construction projects. Rural construction projects increase the consequence of accidents due to the remoteness of the locations. As a result, extensive and specialized training is required for all staff associated with a river construction project. All personnel receive training in the areas shown below as part of the project scope. In addition, tasks requiring licensure, certification or other professional credentials will be validated and kept on file as current for the duration of the project.

**Table 5. Kuskokwim River fiber optic cable project training plan**

| Training requirement | Provided training |
|---|---|
| River safety and cold-water | Alaska Marine Safety Education Association |
| Boat safety | Alaska Marine Safety Education Association |
| Remote work communications equipment | Starlink, Garmin In-reach, Satcom training |
| Wildlife safety | Learn to Return – Bear Guard Training |
| Equipment-specific operations | Manufacturer provided (Vermeer, Macton, Motive offshore) |
| Environmental protection and spill prevention | Alaska Safety Alliance |
| Alaska Certified Erosion and Sediment Control | Alaska Safety Alliance |

## Arctic river fiber cable repair methods

The single largest risk that the Kuskokwim River fiber-optic cable system carries in operation is failure within the river corridor. Failures during the open water season are repaired using standard diver recovery methods and can be resolved quickly. Ice formation or ice break-up seasonal failures present a much more challenging repair task. Failures are expected to be most likely during these seasons and, unfortunately, carry a much longer assumed downtime. The downtime associated with each of the scenarios discussed is discussed and modeled in the Reliability section of this report. Ice jamming, its probability and the likelihood of ice scouring are discussed in the Route Selection section of the report. This section of the report focuses on practical methods that might be used to retrieve, repair and place a damaged cable back into service.

### Ice-covered cable repair

The fall season in the Kuskokwim River produces reduced flow rates and decreasing temperatures. As the ambient temperatures fall, the river surface layer begins to freeze. As the initial ice forms three primary types of ice begin to emerge. Frazil ice are slushy crystals that occur primarily in turbulent waters, border ice forms along river banks and shallow sand bars, and surface skim ice forms in slow side channels. The Kuskokwim River is a wide, shallow and braided river which means that its extensive shallow bars, side channels and lower velocity margins freeze up first. As frazil and skim ice form and thicken, pieces will break loose and begin drifting downstream. This results in floating pan ice, slush rafts and border ice fragments. In a manner similar to sediment transport, this ice load continues moving until it encounters an obstruction which causes it to stop. The dynamic ice tends to accumulate in areas where river velocity drops or the depth of the river changes. Ice will continue to flow until it is jammed by ice transport capacity (ice not moving out of the way fast enough to accommodate incoming ice) or becomes lodged due to an obstruction. Once ice becomes lodged the jam grows quickly. This causes water levels upstream to rise and can lead to local flooding and ice scouring in some cases. The primary risks in fall ice formation lie in the frazil ice (which can cause the cable to float) and the likelihood of scouring.

The repair strategy following a fall season cable failure relies on both pre-emptive and reactive elements. It is important during the construction phase that the cable route be documented using GPS coordinates and that shallow water repair candidate locations be identified. Electronic Marking System (EMS) tags should be installed on the cable in locations that represent the best candidates for future recovery and repair. Following a failure the cable must be retrieved and a temporary segment inserted into the system to restore communications. No repair can take place until the river is safe for vehicle travel. Once safe ice thickness has been achieved, a bi-directional OTDR is used to pinpoint the location of the damage. Having noted the location of the damage, the team then uses the as-built route map to identify previously selected candidate locations for repair retrieval. The surface of the ice is then opened on both sides of the failure at a size sufficient to retrieve the cable from the river bottom through either riverbed jetting or cable fishing methods. The now surface-laid cable can be spliced with a temporary cable and service can be restored. The repair is temporary and should be flagged to avoid physical damage from snowmobiles or other vehicle traffic. It is expected that the temporary repair will fail in the spring during break-up and will require a second repair once the river is ice free.

If a failure occurs in a particularly shallow (6 feet deep or less) reach of the river, all methods should be explored to locate, extract and repair the actual damaged cable in order to avoid the dual outage scenario. This could include ice trenching to enable the cable to be lifted from the river, repaired and placed back into service with no above ice elements remaining.

## Open-water Cable Repair

Repair of the fiber cable following a spring ice scouring failure event uses open water repair methods instead of attempting a temporary repair. Spring break-up typical extends from April 20th to May 7th. It is assumed that the river will be open for boat travel by the 2nd week in May, at which time the fiber cable could be repaired. In addition to the repair of a failure caused by spring break-up ice scouring open-water repairs are possible as a result of debris transport during heavy rain (stumps, logs, etc.) and anchor drag or boat strike events during summer months.

Two distinct scenarios exist for open-water cable damage. The first scenario occurs when the cable is damaged adjacent to the beach approach. In this case it may be necessary to pull the cable out to the cable landing station, repair the damaged section and re-pull the cable back into the river. This repair requires a river support craft and divers. The second scenario involves a failure in the main channel of the river. In this case, bi-directional OTDR equipment is used to identify the location of the failure. The cable is retrieved both upstream and downstream from the break using a boat with divers or using the bottom drag / grapple method. The cable is repair and place back into the river thalweg with sufficient slack to allow self-burial to occur.