Willow to Atqasuk Route Study
Arctic Strategic Transportation and Resources Project
North Slope, Alaska

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Prepared for

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ACRONYMS

ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
AES Alaska	ASRC Energy Services Alaska, Inc.
ANCSA	Alaska Native Claims Settlement Act
ASRC	Arctic Slope Regional Corporation
ASTAR	Arctic Strategic Transportation and Resources
BLM	United States Bureau of Land Management
BMP	Best Management Practice(s)
BT	Bear Tooth
CFR	Code of Federal Regulations
CPAI	ConocoPhillips Alaska, Inc.
CWAT	Community Winter Access Trail(s)
EA	Environmental Assessment
EIS	Environmental Impact Statement
EO	Executive Order
GIS	Geographic Information System
IAP	Integrated Activity Plan
Kuukpik	Kuukpik Corporation
LIDAR	Light Detection and Ranging
MP	milepost
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NPR-A	National Petroleum Reserve – Alaska
NSB	North Slope Borough
ROD	Record of Decision
ROW	right-of-way
Section 106	Section 106 of the National Historic Preservation Act
Section 401/404	Sections 401 and 404 of the Clean Water Act
SME	subject matter expert
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service

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EXECUTIVE SUMMARY

This report found presents results of a desktop analysis for an all-season gravel access road connecting ConocoPhillips Alaska Inc.'s proposed Willow Development to the northern Alaskan community of Atqasuk. It builds off the Colville River Crossing Route study which terminated at Willow and the Atqasuk to Utqiaġvik All-Season Access Road study which originated at Atqasuk. Including the Road Network for Utqiaġvik, Atqasuk, and Wainwright, these projects would provide a year-round road network connecting the northern Alaskan communities of Deadhorse, Nuiqsut, Atqasuk, Utqiaġvik, and Wainwright and would broaden and diversify the region's transportation system and create economic, cultural, and subsistence opportunities for local residents of these communities.

The objective of this desktop analysis was to provide Arctic Strategic Transportation and Resources stakeholders with a better understanding of potential benefits that could influence future development of the proposed road, as well as important engineering, environmental, regulatory, and stakeholder inputs that may affect routing. Additionally, this desktop study can assist stakeholders in identifying and filling potential data gaps necessary to support future phases of the project.

This desktop analysis leverages results of previous studies titled *Road Network for Utqiaġvik, Atqasuk, and Wainwright* (ASRC Energy Services Alaska [AES Alaska] 2020) and *Colville River Crossing Route Study* (AES Alaska 2019a). The *Colville River Crossing Route Study* proposed four crossings connecting the Tarn-Meltwater Road on the east side of the Colville River with existing or proposed infrastructure on the west side of the river. A strong favorite was not determined due to uncertainty around Nuiqsut's preferences. In all cases the routes provide access to ConocoPhillips Alaska Inc.'s proposed Willow Development, which is where the Willow to Atqasuk study starts. The *Road Network for Utqiaġvik, Atqasuk, and Wainwright* study concluded that Corridor A – Coastal Route and Corridor D – Coastal Route Extension appeared to be the most favorable alignments, offering greater benefits than other options. The study also pointed out that linking together the three communities could open opportunities for development of a regional port for freight and fuel deliveries. With a route established from Atqasuk to Utqiaġvik and from oil field roads east of the Colville River to proposed development west of the river, this study focused on the remaining approximately 150-mile stretch through the National Petroleum Reserve–Alaska (NPR-A).

Year-round road access offers the potential for increased economic opportunities, increased social and cultural connections, lower costs for goods and services, enhanced subsistence traditions, improved health and safety, greater access to education opportunities, and greater opportunities for training and workforce development.

To assist in identifying feasible routes, a group of subject matter experts was convened to research, gather, and analyze available information characterizing the project area and describing features and benefits of the project. Both spatial and non-spatial data and background information were gathered. Spatial data captured in a Geographuc Information System (GIS) database included:

- GIS Raster Analysis
- Land Status
- River Hydrology
- Geology/Geotechnical
- Existing and Proposed Infrastructure
- Roadway Engineering
- Vehicle Bridges
- Cultural Resources
- Paleontological Resources
- Subsistence Patterns
- Wetlands
- Threatened and Endangered Species
- Terrestrial Mammals
- Fish and Fish Habitat
- Avian Resources and Habitat
- Environmental Compliance & Permitting
- Construction Cost

Spatial data were incorporated into a GIS cost-weighted raster analysis. The analysis was used to identify potential route alternatives that align with likely river crossings and account for features and constraints identified in the other technical memoranda. The following corridors were identified as preliminary route alternatives:

- Corridor G – Northern Route
- Corridor H – Middle Route
- Corridor I – Southern Route

Using information in the technical memoranda, the features and benefits of each route alternative were summarized, and the corridors were compared in a matrix with scoring based on degree of favorability. The scoring matrix was weighted by considering eight different stakeholder viewpoints: Federal Government, State Government, Local Government, community residents, village corporations (Ukpeaġvik Iñupiat Corporation; Olgoonik Corporation; Atqasuk Corporation; Kuukpik Corporation), regional corporation (Arctic Slope Regional Corporation), environmental non-governmental organizations (NGOs), and pro-development NGOs. The weighted scores were then summed to identify favorable route alternatives.

All three routes scored similarly, and it was difficult to determine a strong favorite. Out of a possible score of 400, Corridors G, H, and I scored 297, 307, and 313, respectively. Based on the outcome of the preliminary analysis and comparison, Corridor I – Southern Route is the most favorable alternative for connecting to Atqasuk, followed by Corridor G – Northern Route and Corridor H – Middle Route in descending order. While Corridor I is the longest route, it has more favorable river crossings. Material source potential across the project area remains largely untested, and route favorability may change upon location of suitable material sites. All corridors traverse a vast area of eolian sand, however, Corridor G traverses an ancient beach deposit that has higher potential to provide suitable materials for road construction. Other differentiators include Corridor I having access to the existing airstrip at Inigok, and Corridor G arrives north of Atqasuk whereas Corridors H and I arrive from the south and route through the village.

The road corridors and analysis presented in this report were developed without the benefit of stakeholder engagement. Before advancing the project further, a stakeholder engagement plan should be implemented to solicit specific input for refining the project description and evaluation. Despite the preliminary information presented in this desktop study, the stakeholder's preferences could significantly alter the study outcome and preferred routing.

In addition, the new Integrated Activity Plan for the NPR-A should be reviewed when it is finalized by the Bureau of Land Management to assess whether any changes to stipulations or best management practices affect the proposed route alternatives. The study concludes by recommending follow-on studies and activities to fill data gaps and advance the project.

1.0 Introduction

This report presents the results of a desktop analysis for a proposed all-season gravel access road connecting ConocoPhillips Alaska Inc. (CPAI) proposed Willow Development roads to the northern Alaskan community of Atqasuk. A year-round road would broaden and diversify the region's transportation system and create economic, cultural, and subsistence opportunities for local residents of Atqasuk and Nuiqsut. This study was completed by ASRC Energy Services Alaska, Inc. (AES Alaska) and PND Engineers for the Arctic Strategic Transportation and Resources (ASTAR) project.

This project was evaluated using a cumulative benefits analysis process developed specifically for ASTAR. This evaluation found the proposed project provides numerous regional benefits, enhances community connectivity, and receives a measure of local support. The process for selecting and evaluating this project follows that set forth in the *Assessment of Potential Tools for Cumulative Benefits Analysis* (AES Alaska 2018) prepared for ASTAR. Specifically, the methods presented here fall under Stage 3 of the process where selected projects are given a more rigorous desktop analysis by subject matter experts (SMEs) to characterize the scope; describe or quantify expected benefits; and identify feasible alternatives, important constraints, data gaps, and other key factors affecting project success.

1.1 Objective

The objective of this desktop analysis is to provide ASTAR stakeholders with a better understanding of potential benefits that could influence future development of the proposed road, as well as important engineering, environmental, regulatory, and stakeholder inputs that affect routing. Additionally, this desktop study will assist the stakeholders in identifying and filling potential data gaps necessary to support future phases of the project.

1.2 About this Report

This report is a condensed version of the content provided in previous ASTAR routing studies. Due to budget and schedule constraints it does not include most of the supporting technical memoranda that normally are appended to the report. The purpose of the memoranda was to expound on key topics considered during development of route alternatives for the proposed road. The following is a list of the key topics normally addressed by the memoranda, and although SMEs from each topic were consulted, only the River Hydrology memorandum is included in Appendix A.

- Geographic Information System (GIS) Raster Analysis
- Land Status
- River Hydrology
- Geology/Geotechnical
- Existing and Potential Infrastructure
- Roadway Engineering
- Vehicle Bridges
- Cultural Resources
- Paleontological Resources
- Subsistence Patterns
- Wetlands
- Threatened and Endangered Species
- Terrestrial Mammal
- Fish and Fish Habitat
- Avian Resources and Habitat
- Environmental Compliance & Permitting
- Construction Cost

Despite omitting narratives for many of the supporting memoranda, spatial data associated with each of these topics was captured in a GIS and was considered during our route analysis. In this analysis, close consultation with SMEs for route development, analysis, and evaluation was relied upon in the absence of information typically captured in the technical memos.

2.0 Project Description

2.1 Project Setting

The Project area is on Alaska's North Slope within the Arctic Coastal Plain physiographic province. Permafrost soils underlie almost the entire region. Terrain is characterized by arctic tundra with numerous lakes and meandering streams and rivers. The topography is relatively flat, although terraces and steep riverbanks are found adjacent to the major rivers; ground surface elevation within the project area varies from near zero to about 300 feet above sea level. The project area is shown on Figure 2.1-1 along with potential route alternatives. The project area is within the borders of the National Petroleum Reserve – Alaska (NPR-A), a vast 23 million acre reserve set aside for oil and gas leasing.

The project lies within the Arctic Climate Zone, an area characterized by long, very cold winters, and cool summers. Average monthly temperatures are below freezing for eight months of the year. The sun does not rise during 9-1/2 weeks of winter (mid-November to late January), and does not set for 7-1/2 weeks of summer (early May through early August). Despite 24 hours of daylight in the summer, the average low temperature is only a few degrees above freezing in July, and snow may fall in any month of the year. Although the terrain is wet in summer, the amount of precipitation is low – less than 5 inches. Hydrology is derived primarily from the freeze/thaw cycle of the permafrost active layer. Despite the proximity of the offshore ice pack to land for many months of the year, the Arctic Ocean has a moderating effect on coastal temperatures. Surface winds are strong at the coast but weaken and become more variable further inland. In recent years, the area has experienced rapid climate change with rising air and water temperatures, and diminishing sea ice.

Nuiqsut is located on the eastern edge of the project area along the west bank of the Colville River's Nechelik (Nigliq) Channel. Nuiqsut was settled in 1973 with 145 people in 27 families, after passage of the Alaska Native Claims Settlement Act (ANCSA). Nuiqsut has a population around 447 residents (North Slope Borough [NSB] 2016). A new U.S. census is being conducted in 2020; however, the population is not anticipated to change significantly. Under ANCSA, title for more than 200,000 acres of surface lands surrounding the village was transferred to the local village corporation, Kuukpik Corporation (Kuukpik). Kuukpik lands are bordered by federal lands on the west and south (i.e., the NPR-A), State lands on the east and south, and the Beaufort Sea to the North. Nuiqsut is affected by industry development more than any other community in the North Slope Borough (NSB). This comes with the benefits of access to infrastructure and natural gas but requires close management to maintain the community's cultural heritage (AES Alaska 2019a. Nuiqsut is connected to the Alpine and Alpine Satellite oil field via the Nuiqsut Spur Road. During the winter, the Nuiqsut Spur Road (a private restricted access road) facilitates access to the Spine Road and ultimately the Dalton Highway via CPAI's seasonal ice road which crosses the Colville River. With the exception of the access provided by the Community Winter Access Trail (CWAT) snow road, Nuiqsut the only village in the NSB with seasonal overland access to Alaska's contiguous road network.

Oil field developments at Greater Moose's Tooth and proposed developments at Willow were incorporated into the *Colville River Crossing Route Study* (AES Alaska 2019a). This current study picks up where that study left off – with proposed routes to Atqasuk originating at the proposed Willow Development as shown in Figure 2.1-2.. CPAI's proposed Willow development would include typical oil field gravel infrastructure that includes gravel roads, pads, and pipelines supported on Vertical Support Members, and a new gravel mine. Willow will extend from CPAI's Greater Moose's Tooth 2/Moose's Tooth 7 development that provides a direct all season surface connection to the Nuiqsut via the Nuiqsut Spur Road discussed above.

Figure 2.1-1. Project Area Map

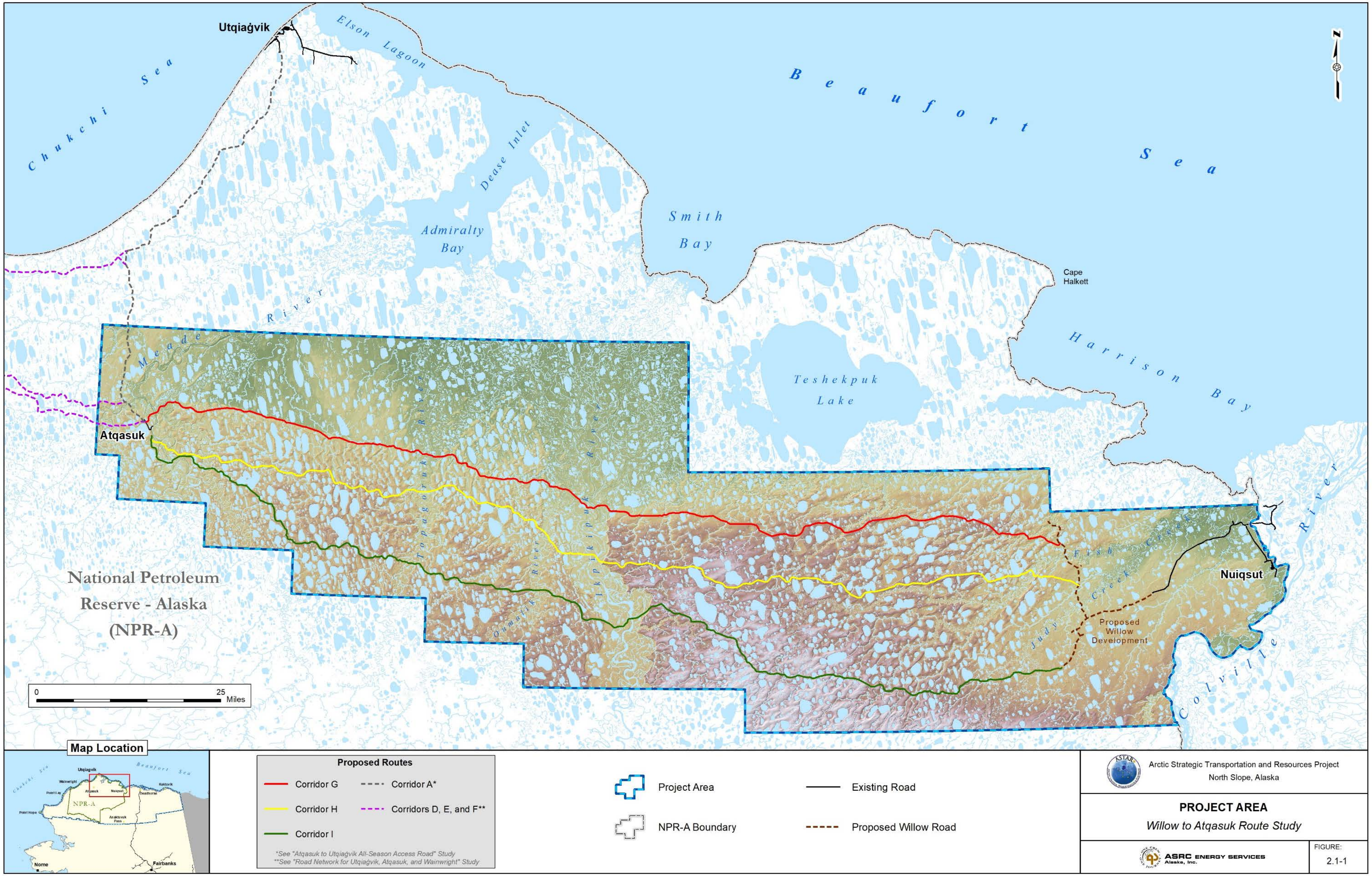

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Figure 2.1-2. Willow Area Map

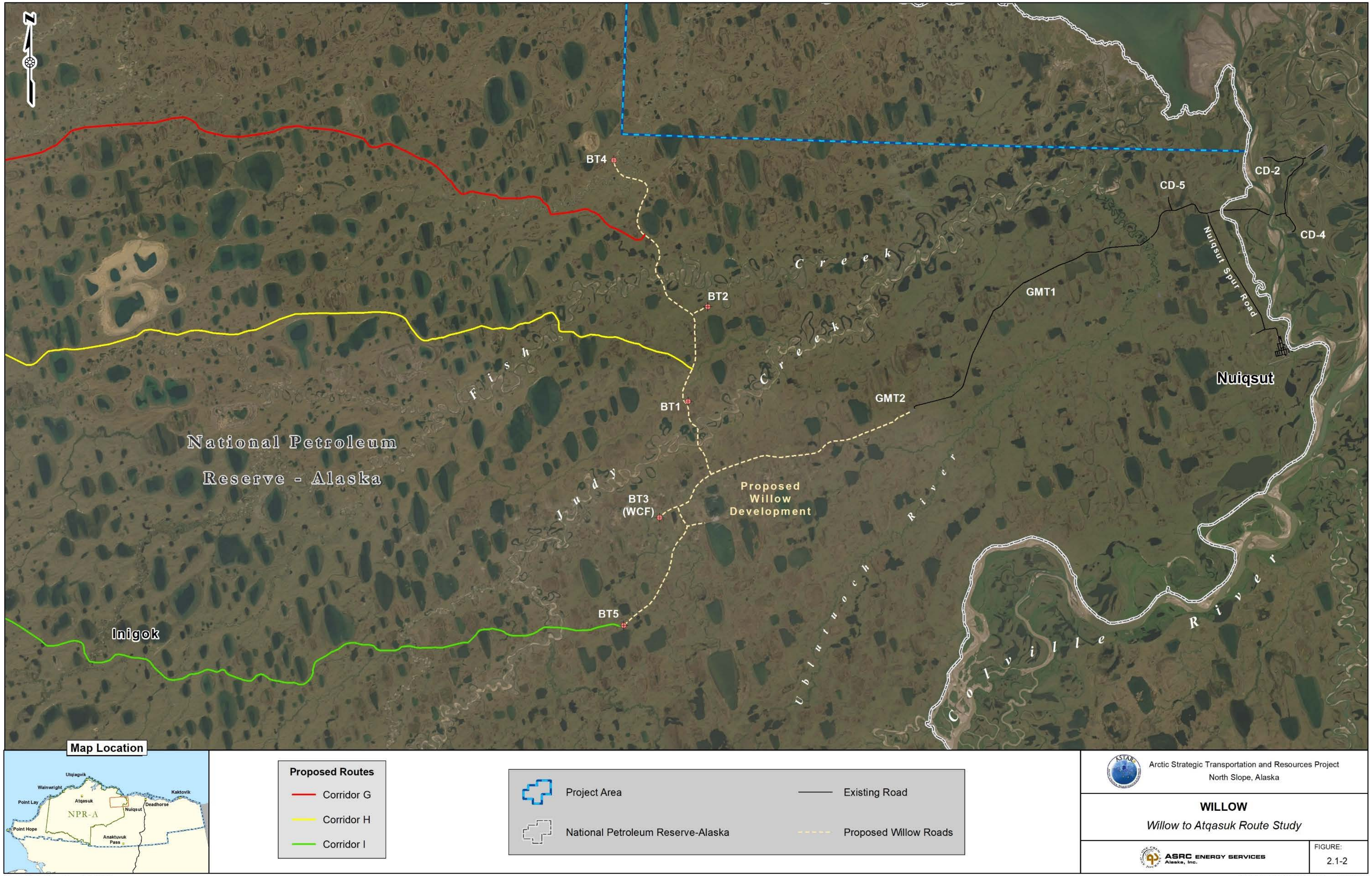

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Figure 2.1-3. Atqasuk Area Map

UTM Zone 4N (NAD83)

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All proposed project route alternatives come through or just north of Atqasuk before heading to Utqiaġvik via a previously studied coastal route (see below). Atqasuk is located on the southern extent of the Arctic Coastal Plain, approximately 60 miles south of Utqiaġvik, and 58 miles east of the village of Wainwright. The community is entirely within the boundaries of the NPR-A, managed by the U.S Department of Interior, Bureau of Land Management (BLM). The village lies between Imaġruaq Lake and the Meade River as shown on Figure 2.1-3. The population of Atqasuk has grown steadily over recent years to approximately 261 residents (NSB 2019), with the majority being Iñupiat who practice a subsistence lifestyle. From Atqasuk, the routes are assumed to follow the Coastal Route as identified in the *Road Network for Utqiaġvik, Atqasuk, and Wainwright* (AES Alaska 2020) and the *Atqasuk to Utqiaġvik All Season Access Road* (AES Alaska 2019b).

Utqiaġvik (formerly Barrow) is the northernmost community in the United States, at the base of the Point Barrow, and bordered by the Chukchi and Beaufort Seas of the Arctic Ocean. The surrounding landscape is characterized by tundra with numerous lakes and permafrost soils underlying almost the entire region. The majority of residents are Iñupiat, an indigenous Inuit ethnic group. Utqiaġvik is the largest community on the North Slope with the 2018 population estimate of 5,286 people (NSB 2019). Utqiaġvik is the NSB seat of government where diverse issues converge, among them Native Iñupiat subsistence rights, oil and gas development activity, and the study of climate change in the Arctic (NSB 2015).

2.2 Previous Studies

AES Alaska completed a desktop analysis of an all-season road connection between Atqasuk and Utqiaġvik in July 2019, titled *Atqasuk to Utqiaġvik All Season Access Road* (AES Alaska 2019b). The study concluded that a coastal route appeared to be the most favorable alignment, offering greater benefits than other options (see Corridor A shown on Figure 2.1-1).

The study also concluded that because the alignment of the Coastal Route (Corridor A) essentially parallels the coastline, it sets the stage for a road extension to Wainwright, offering potential to link together the three local communities (Wainwright, Atqasuk, and Utqiaġvik). Connecting the three communities would further enhance the benefits listed in the 2019 study, and could open opportunities for development of a regional port for freight and fuel deliveries. The study also pointed out that simultaneously considering all three communities could result in minor adjustments to portions of the original alignment for Corridor A.

Information from the 2019 study was leveraged in the *Road Network for Utqiaġvik, Atqasuk, and Wainwright* to evaluate an extension of the road system to Wainwright to link the three communities (AES Alaska 2020). This study favored the Coastal Route (Corridor A) and the Coastal Route Extension (Corridor D) to connect the communities of Utqiaġvik, Atqasuk, and Wainwright.

The *Colville River Crossing Route Study* (AES 2019a) analyzed Colville River crossing locations connecting existing infrastructure on the east side of the Colville River with existing or proposed infrastructure on the west side of the river, effectively connecting Nuiqsut with the Alaska highway system. The favorable route in this study was Drill Site 2L to CD-4, effectively connecting two oil industry roads and providing a route near, but not through, Nuiqsut. Access along this road may require approval from Kuukpik. CPAI's oil field road network from CD-4 provides a direct connection to the proposed CPAI Willow Development.

These previous studies have helped simplify the analysis for routing between Nuiqsut and Utqiaġvik, effectively limiting the study from CPAI's proposed Willow Development to Atqasuk.

2.3 Project Description

Overland transportation between the communities of the North Slope is limited because there are no year-round road connections. In the winter of 2017/2018, the NSB established a CWAT project to allow seasonal transport of highway vehicles from the Dalton Highway to Utqiaġvik and Atqasuk. In the winter of 2018/2019, the CWAT system was extended to Wainwright. In winter 2019/2020, the CWAT system was again constructed to connect all three communities; however, CWAT is reliant upon available annual revenue, so construction each winter is not guaranteed. For the purpose of this study, the proposed all season road is envisioned as a two-lane gravel road from CPAI's Willow Development to Atqasuk.

The proposed 2-lane road is expected to be roughly 24.5 feet wide with 2 horizontal to 1 vertical (2H:1V) side slopes and an assumed embankment thickness of 5 feet to protect the underlying permafrost from thermal degradation. The proposed road would cross numerous significant streams and rivers (e.g. Judy Creek, Fish Creek, Kalikpik Creek, Kealok Creek, Ikpikpuk River, Oumalik River, Topagoruk River, Okpiksak River, Usuktuk River, Pikroka Creek, and the Meade River), depending on the route selected. These larger crossings will require bridges, and culvert batteries will be needed for minor drainages along the route. The Ikpikpuk River is the largest of these crossings, with active channels and floodplains comparable to that of the Colville River. Additional culverts will be required in low-lying areas to facilitate cross drainage during runoff events.

2.4 Benefits of the Willow Development to Atqasuk Road

Table 2.4-1 identifies specific benefits the proposed road provides for residents of Nuiqsut, Atqasuk, and potentially Utqiaġvik and Wainwright if other the routes discussed above are constructed. The list of benefits provides representative examples to highlight key benefits of an all-season road connection between all the communities. All the communities benefit from the road; however, because Utqiaġvik is larger and already has a wider array of existing services and opportunities, a larger proportion of the benefits are derived by residents of Nuiqsut and Atqasuk.

Table 2.4-1. Benefits of the Willow to Atqasuk Road

Benefit Category	Representative Examples of Specific Benefits of an All-Season Road
Supports cultural connectivity	Allows more frequent travel between the communities, enabling additional cross-community connections, increasing the quality of links or bonds among community members, and creating or enhancing the capability to join together in various cultural activities, events, and celebrations. Examples include Inupiaq language workshops, whaling seasons, Kivgiq Festival, Nalukataq, and art workshops (dance, music, and art). Provides NUI residents road access to the NSB. Currently NUI residents must fly to UTQ.
Lowers costs of goods and services	• Allows residents to receive bulk shipments and mail year-round via overland transport • Facilitates trucking of gravel to Atqasuk (where gravel is scarce) for expansion or improvements to the airport and community roads • Opens a transportation corridor that could support installation and maintenance of fiber optic telecommunications lines • Lowers the capital cost of infrastructure development like construction of homes, schools, public buildings, commercial buildings, utilities, etc. • Provides Nuiqsut residents access to NSB government offices • May lower cost of supply for oil and gas companies that may be contemplating acquiring leases in NPR-A
Preserves or enhances subsistence traditions	• Allows access to a wider range of subsistence areas for fishing, hunting, and gathering • Allows more access and options for small engine repair, boat repair, snowmachine sales and service, gunsmithing, etc. • Allows more access and options to enhance subsistence economy (e.g. bartering)
Improves health and safety conditions	• Provides an evacuation route from each community in case of natural disaster or emergency • Allows Nuiqsut residents to access Samuel Simmonds Memorial Hospital, other healthcare and social service providers • Provides access to other airports for air ambulance medevac when inclement weather closes one airport • Allows consolidation of waste streams for recycling or disposal • Helps facilitate cleanup of NPR-A legacy wells and other contaminated sites
Improves access to education opportunities	• Allows residents of each community to attend educational events or presentations in the other connected communities • Improves simpler access to participate in or attend competitive sporting events between high schools and middle schools • Allows Nuiqsut/Wainwright/Atqasuk residents access to Ilisaġvik College • Allows greater access to cultural centers/activities, Simon Paneak Museum, the Iñupiat Heritage Learning Center, and the Residential Learning Center • Allows residents of all communities to exchange indigenous knowledge (elders/youth; subsistence areas)
Enhances workforce development	• Improves access to more job opportunities for all communities • Improves access to more skills training and apprenticeship opportunities for all communities • Provides direct jobs for road construction and maintenance • Could provide the catalyst for new business opportunities • Allows opportunities for workers to fill needed local service gaps for auto repair, plumbing, electrical, child care, construction, and many other services

3.0 Data Analysis and Corridor Identification

There are numerous criteria and constraints that affect routing of proposed roads. The preferred routes are often based on a balance of cost, engineering, environmental, and sociocultural factors. In order to assess the most advantageous route alignments, the first step typically involves analysis of available data to recognize and describe key issues, inform stakeholders, and identify data gaps. The following sections outline the methodology used to identify and characterize the key issues for the proposed road, develop route alternatives, and analyze those alternatives.

3.1 Methodology

To assist in identifying feasible routes for an all-season road, a group of SMEs was convened to research, gather, and analyze available information characterizing the project area and describing features and benefits of the project. Both spatial and non-spatial data and background information were gathered. Spatial data to help visualize and quantify spatial components were captured in a GIS and made available to SMEs to inform their guidance of the GIS Analyst in ascertaining initial inputs for preliminary route development, as well as in the evaluation and refinement of raster analysis-derived route alignments.

Spatial data derived from the three previous route studies were incorporated into a GIS cost-weighted raster dataset prepared for the entire ASTAR program area by Resource Data, Inc. A portion of this raster was clipped to the study area and provided to AES Alaska for use in route development using geoprocessing tools available in ESRI's ArcGIS desktop software package. Cost-weighted raster analysis was used to generate potential route alternatives that align with likely river crossings and to account for features and constraints as identified in previous studies. The resulting routes were then modified as necessary using heads-up digitizing to better align to crossings and to further ensure avoidance of sensitive features (e.g., geohazards, cultural sites, and lake shorelines).

3.2 Corridor Alternatives

Specific alignments were developed and 2,000-foot wide corridors established with the alignment as the center line. The following corridors are identified as preliminary route alternatives for the road and are shown in detail on Figures 3.2-1 through 3.2-3.

- Corridor G – Northern Route
- Corridor H – Middle Route
- Corridor I – Southern Route

Each of these routes ultimately connect to Route A – Coastal Route; identified in the 2019 *Atqasuk to Utqiaġvik All Season Access Road, Arctic Strategic Transportation and Resources Project, North Slope, Alaska* (AES Alaska 2019b).

Figure 3.2-1. Route Corridors - East

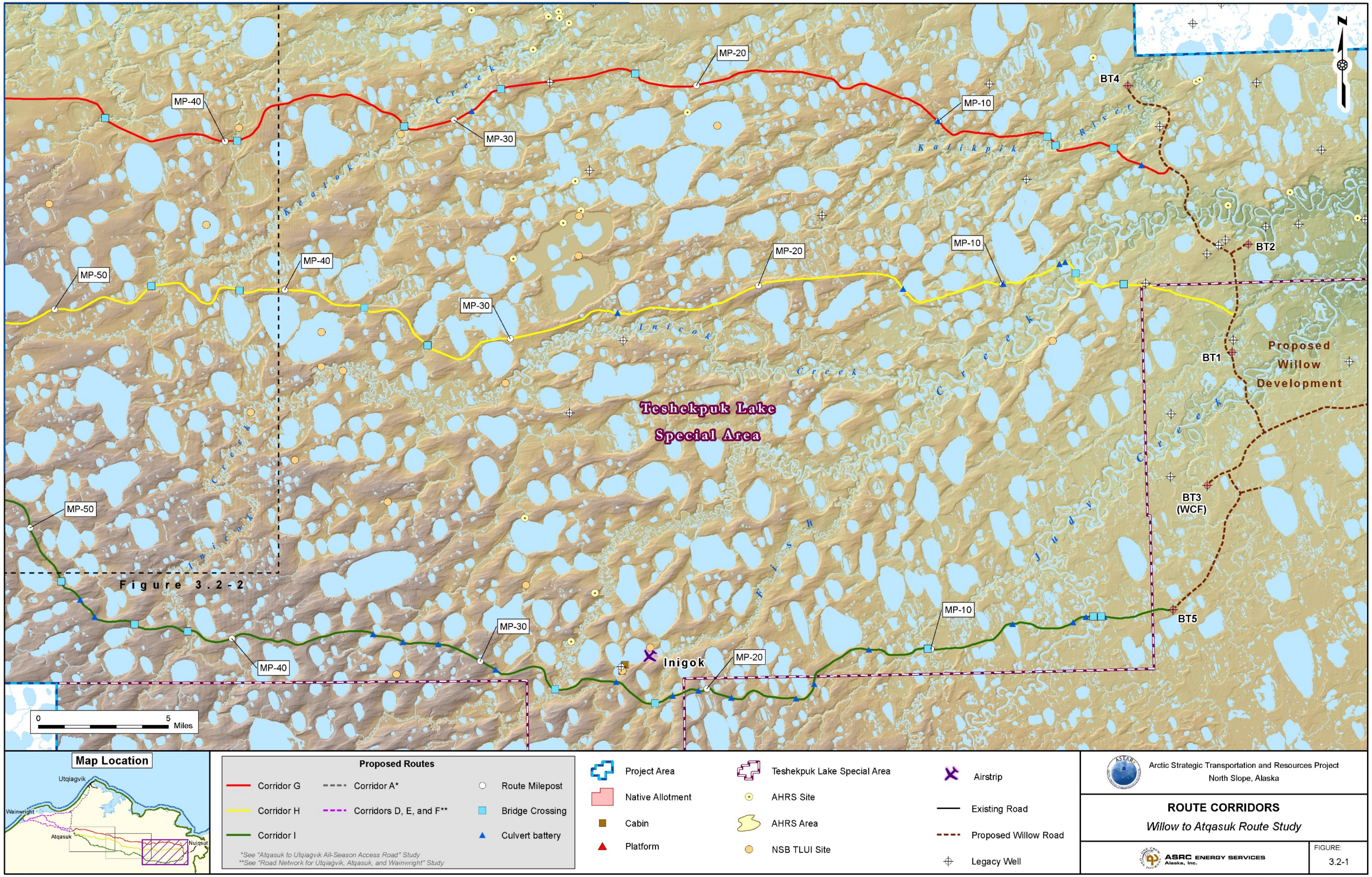

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Figure 3.2-2. Route Corridors – Central

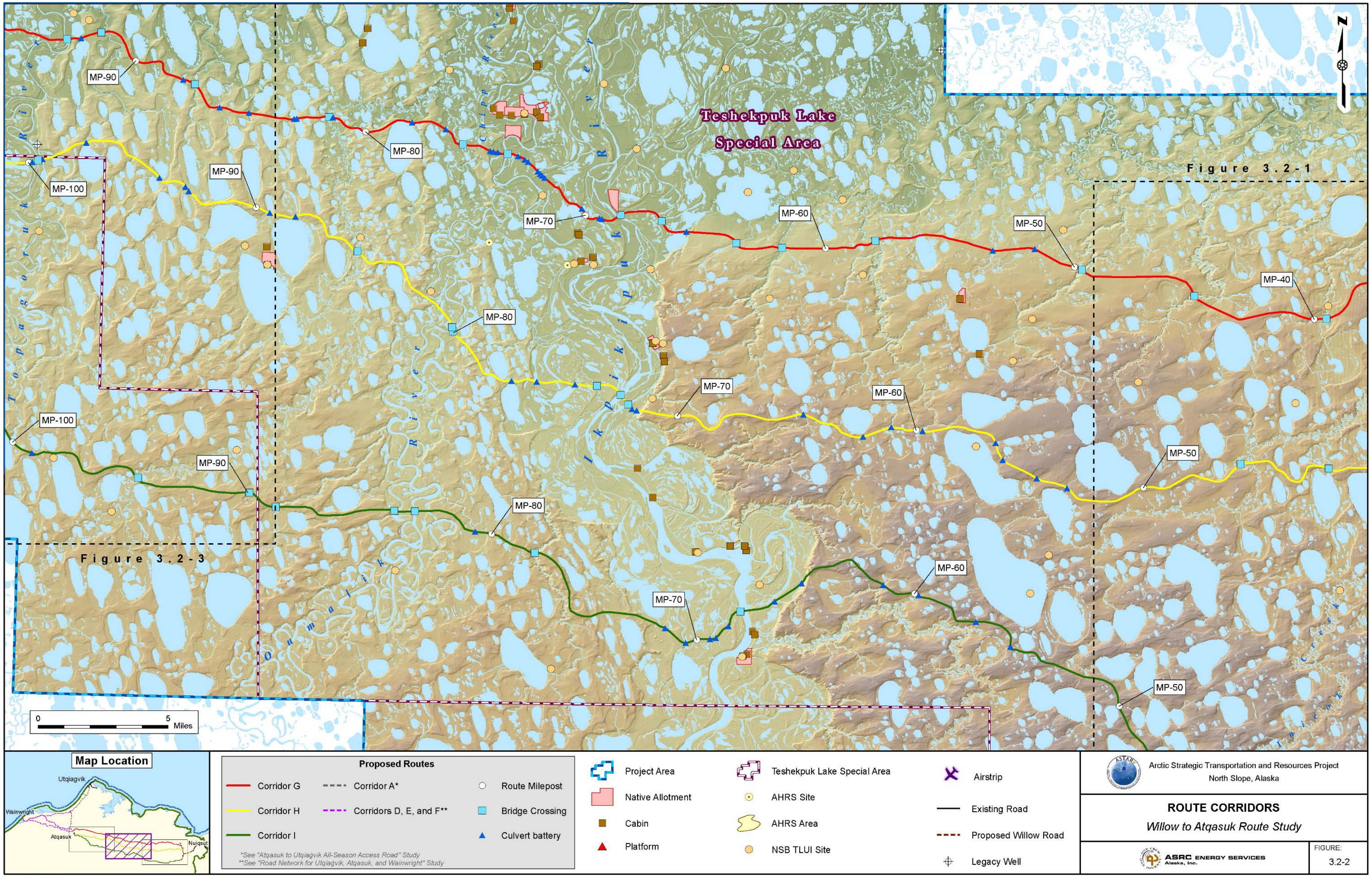

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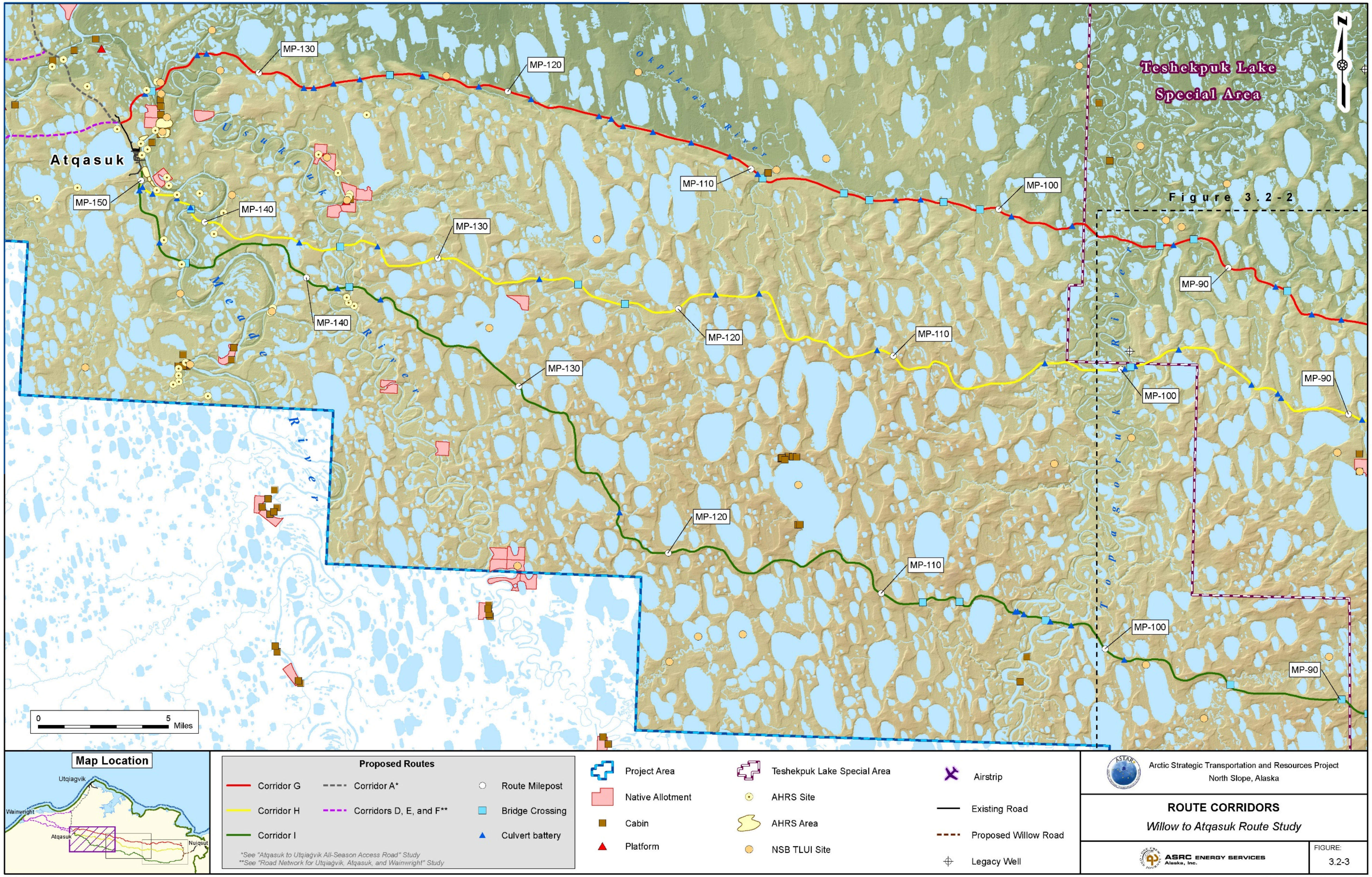
Figure 3.2-3. Route Corridors – West



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3.2.1 Corridor G – Northern Route

The corridor begins near CPAI proposed Willow Development road and Bear Tooth (BT) drill pad 4 and heads westerly approximately 137 miles where it meets Corridor A from the Utqiagvik to Atqasuk route study, just north of Atqasuk. Corridor G is primarily routed through eolian sand deposits which have limited material source potential. This route also crosses over 10 miles of ancient beach and sand deposits which may prove to provide suitable material for road construction. This beach deposit exists along a scarp from around MP-110 to MP-120, and if suitable materials are found there, it could set this route apart from the other two. This corridor has the smallest area of permanently inundated wetlands, which also results in avoiding potential habitats for loons and eiders. However, the corridor crosses 23,401 acres of special area associated with Teshekpuk Lake; this accounts for 96.5 miles of the route intersecting the Teshekpuk Lake Special Area. Corridor G ends just north of Atqasuk. Therefore, vehicle traffic to Atqasuk would be reduced over the other two routes because travelers intending to get to Utqiaġvik do not pass directly through the village.

Corridor G is 7 miles shorter than Corridor H and 13 miles shorter than Corridor I and F but has 77 water crossings. The water crossings include 4 major rivers and a total of 28 bridges that total approximately 5,452 feet. These major river crossings include the: Ikpikipuk River, Oumalik River, Topagoruk River, and Meade River. Corridor G crosses several K-1 river setbacks and K-2 deep-water lake setbacks as described in BLM's Record of Decision (ROD) for NPR-A.

Rough order of magnitude construction costs were estimated using $4.8 million per road mile and $15,000 per bridge foot. Using this methodology, the total cost estimate for Corridor G is lowest due to total road length. However, Corridor G has the second highest bridge construction cost, slightly less than that of Corridor I.

3.2.2 Corridor H – Middle Route

Corridor H begins at the CPAI Willow Development Road between BT1 and BT2 and Fish and Judy Creek. Corridor H extends 144 miles west to gravel road infrastructure near the Atqasuk Airport. Corridor H has a total of 55 water crossing that include 17 bridges. The total bridge length is estimated at approximately 4,594 feet. Corridor H crosses five major rivers including: Fish Creek, Ikpikipuk River, Oumalik River, Topagoruk River, and the Meade River. This corridor runs near the Atqasuk runway and would connect to Corridor A via Village of Atqasuk surface roads to a point along the Landfill Access Road.

Corridor H is 7 miles longer than Corridor G and 7 miles shorter than Corridor I. Corridor H includes a total of 2,828 acres of permanently inundated wetlands, which is the most of any corridor analyzed. Corridor H also contains 23,176 acres of special habitat area associated with Teshekpuk Lake, accounting for 95.3 miles of the route that intersects the Teshekpuk Lake Special Area. Corridor H is routed primarily through eolian sands with no known material sources in close proximity. Any material sources along this route are anticipated to be of poor quality, and include mainly aggregate in the form of sand. Corridor H crosses several K-1 river setbacks and K-2 deep-water lake setbacks as described in BLM's ROD for NPR-A. Corridor H has roughly two times the number of existing BLM oil and gas lease blocks (22) than the other two alternatives.

Rough order of magnitude construction costs were estimated using $4.8 million per road mile and $15,000 per bridge foot. Using this methodology, the estimated construction cost for Corridor H is slightly higher than Corridor G due to its longer total length. However, Corridor H has the lowest total bridge construction costs among the three alternatives.

3.2.3 Corridor I – Southern Route

Corridor I begins at the road terminus of the CPAI Willow Development proposed BT5 and extends 150 miles west to the Atqasuk Airport road. Corridor I would have a total of 60 water crossings that include 20 bridges. The total bridge length is estimated at approximately 4,999 feet. Corridor I crosses five major rivers including: Judy Creek, Ikpikipuk River, Oumalik River, Topagoruk River, and the Meade River. This corridor runs very near the Inigok Airstrip and CPAI's Harpoon prospect. It also runs near the Atqasuk runway, coincident with Corridor H, along its final 500 feet. It would likewise connect to Corridor A via Village of Atqasuk surface roads to a point along the Landfill Access Road.

Corridor I is 13 miles longer than Corridor G and 7 miles longer than Corridor H. Corridor I includes a total of 2,794 acres of permanently inundated wetlands. Corridor H also contains 20,018 acres of special habitat area associated with Teshekpuk Lake, which is the least of any of the corridors. This accounts for 82.6 miles of the route that intersects the Teshekpuk Lake Special Area. As with Corridor H, Corridor I is primarily routed through eolian sands, which may have limited material source potential. Corridor I passes through Inigok, where a historic material source was located to provide construction materials. However, this material source was very sandy and is likely depleted. Corridor I crosses several K-1 river setbacks and K-2 deep-water lake setbacks as described in BLM's ROD for NPR-A. Corridor I crosses roughly less than two times the number of existing BLM lease blocks (14) than Corridor H; however the total lease acreage in Corridor I is 16,947 acres as compared to 12,176 acres in Corridor H. This, along with proximity to existing infrastructure at Inigok and proposed infrastructure at Harpoon, could be a positive attribute when considering proximity to future oil and gas operations and employment opportunities.

Rough order of magnitude construction costs were estimated using $4.8 million per road mile and $15,000 per bridge foot. Using this methodology, Corridor I is the most costly alternative due to bearing the greatest length and highest total bridge construction costs. Proximity to Inigok could help reduce costs due to improved logistics and access to laydown areas.

3.3 Geographic Information System Cost-Weighted Raster Analysis

Alignment of all three corridors were informed by the results of the GIS cost-weighted analysis, as well as SME consultation, aerial imagery, and other GIS datasets, such as the National Hydrography Dataset for crossing locations and alignment. The process used to generate the three initial GIS cost-weighted routes is the same as used in the previous route studies discussed in Section 2.2.

All three cost-weighted routes required detailed post-process realignment to develop corridors satisfying the evaluation and scrutiny of SMEs. Paramount in this process was the evaluation of routes and adjustments required to:

- limit the number and size of river and stream crossings;
- place those crossings at reasonable locations;
- provide better clearance of geohazards;
- locate alignments on better-drained higher ground when possible; and
- provide alignments that allow for reasonable travel speeds (i.e. smoothing road curves and improving approaches to bridge crossings).

The high density of waterbodies within the study area also required close scrutiny of generated routes. Modifications based in these aquatic features resulted in unavoidable sinuosity of many stretches of the corridors.

3.4 Summary of Corridor Features and Benefits

Table 3.4-1 presents a summary of features and benefits unique to each of the corridors for comparison and contrast.

Table 3.4-1. Summary of Features and Benefits of Each Corridor

Criteria	Corridor G Northern Route	Corridor H Middle Route	Corridor I Southern Route
Benefits Overview	In addition to the overall benefits of a road listed in Section 2.4, Corridor G • In comparison to the other route alternatives, Corridor G is the most advantageous route for preserving high-value wetlands; potential eider nesting habitat and yellow-billed loon habitat; and for complying with BLM NPR-A Best Management Practices for lake and river setbacks. • Corridor G provides the greatest potential for a bypass route to Utqiaġvik if preferred by the communities. • Corridor G is the shortest of the three alternatives, so gravel costs and gravel requirements may be less than the other options. This corridor does have the most bridges, the second most total bridge length, the longest single bridge, and the most culvert batteries of the three alternatives but, cumulatively, presents the lowest construction cost. The lack of available gravel in any of the corridors could become crucial in the decision making process and rendering Corridor G the preferred alternative. • Corridor G would connect to Corridor A, just north of Atqasuk. This could result in less traffic and disturbance to the village over the other two options that would require running through the village to access routes leading to Utqiagvik and elsewhere.	In addition to the overall benefits of a road listed in Section 2.4, Corridor H provides the following specific benefits: • Corridor H contains the most BLM leases that could spur development. • Corridor H has the least number of total water crossings which could be a benefit to permitting and wetlands mitigation. • Corridor H potentially has the lowest bridge construction costs. • Corridor H, along with Corridor I, has the least number of geologic hazards associated with pingos.	In addition to the overall benefits of a road listed in Section 2.4, Corridor I provides the following specific benefits: • Corridor I routes very near Inigok Airstrip. Access to material sources associated with Inigok could be a benefit, although the material source used for the construction was sandy and has likely been expended. • Corridor I is the longest route in miles but has the second fewest total water crossings of the three alternatives. • Corridor I appears to present the least impact on cultural and subsistence resources. • Corridor I appears to present the least impact on threatened and endangered species as well as terrestrial mammals. • Corridor I has the least amount of Teshekpuk Special area areas in the corridor which could drive down wetland mitigation requirements and reduce impacts to caribou and waterfowl.
Land Status	Route traverses through surface lands owned by the U.S. government (NPR-A), but has the least number of designated federal lease blocks and lease block acres. Corridor G has the least river setback and deep water lake setbacks restrictions (reference 2013 BLM ROD, K-1 Best Management Practice), but the most acres of Special Habitat area that could be considered an Aquatic Resource of National Importance and result in increased regulatory scrutiny. Corridor G intersects a small corner of one Native allotment at its crossing of the Ikpikpuk River.	Route traverses through surface lands owned by the U.S. government (NPR-A) and has the most designated federal lease blocks. Corridor H traverses the most deep water lake setback areas (reference 2013 BLM ROD, K-1 and K-2 Best Management Practice).and is very similar in Teshekpuk Lake Special Area acreage as Corridor G.	Route traverses through surface lands owned the U.S. government (NPR-A) and has the most designated federal lease acreage. Corridor I traverses the most river setback areas (reference 2013 BLM ROD, K-1 and K-2 Best Management Practice).and has the lowest acreage within the Teshekpuk, Lake Special Area.
Hydrology	Corridor G has approximately 77 river and stream crossings, the most bridges (28), the greatest total bridge length, the longest single bridge, and the most culvert batteries (49) of the three options. As described above, the corridor traverses the least amount of K-1 river setback area.	Corridor H has approximately 55 river and stream crossings, with similar number of bridges (17) and culvert batteries (38) and single bridge length (1,540 feet) to Corridor I. It has the smallest total bridge length of the three options. As described above, the route traverses three K-1 river setback areas, and the greatest acreage of K-2 deep-water lake setbacks.	Corridor I has approximately 60 river and stream crossings, with similar number of bridges (20) and culvert batteries (40) and single bridge length (1,500 feet) to Corridor H. It has the second most total bridge length of the three options. As described above, the route traverses the most K-1 river setback areas, and the least acreage of Teshekpuk Special Area.
Geology / Geotechnical	The majority of all three corridors traverse eolian sands. Corridor G traverses nearly 4 miles of ancient beach deposits and over 13 miles of marine sands overlain by ancient beach deposits. It is likely these deposits are more favorable than eolian sands, although this remains to be field tested. Geologically, it is likely Corridor G is the favorable route.	The majority of Corridor H (75%) traverses eolian sands, but does not appear to have any particular geologic advantage over the other two corridors.	The majority Corridor I (75%) traverses predominantly eolian sands, the only slight advantage this route may have over Corridor H is being close to an older materials site near Inigok. This material site is likely expended, but there may be similar sources nearby. However, this source was predominantly sand.
Existing and Proposed Infrastructure	Corridor G would connect to existing infrastructure at Willow, but would require additional infrastructure near Atqasuk (Corridor A) to complete a connection to Atqasuk. Corridor G crosses the least number of federal lease blocks, but not a significant difference from Corridor I and slightly less than half of Corridor H.	Corridor H would connect to existing infrastructure at Willow, and near Atqasuk airport to complete a connection to Atqasuk. Corridor H crosses the greatest number of federal lease blocks.	Corridor I would connect to existing infrastructure at Willow, and near Atqasuk airport to complete a connection to the Village. Corridor I crosses the similar number of federal lease blocks. as Corridor G. Corridor I connects to the Inigok Airstrip and is in close proximity to CPAI's Harpoon prospect.
Roadway Engineering Considerations	Starting Point: Intersection with proposed Willow Road between BT2 and BT4 Ending Point: Atqasuk Landfill Access Road approximately ¼ mile south of the landfill Route Length: 137.0 miles Min/Max Elevation: 21 feet / 170 feet	Starting Point: Intersection with proposed Willow Road between BT1 and BT2 Ending Point: Puayuuraq Street north or airport Route Length: 143.6 miles Min/Max Elevation: 26 feet / 208 feet	Starting Point: Endpoint of proposed Willow Road at BT5 Ending Point: Puayuuraq Street north or airport Route Length: 150.3 miles Min/Max Elevation: 30 feet / 233 feet

Criteria	Corridor G Northern Route	Corridor H Middle Route	Corridor I Southern Route
Vehicle Bridges	Total River and Stream Crossings: 77 Total Bridges: 28 Aggregate Bridge Length: 5,452 feet Culvert Batteries: 49	Total River and Stream Crossings: 55 Total Bridges: 17 Aggregate Bridge Length: 4,594 feet Culvert Batteries: 38	Total River and Stream Crossings: 60 Total Bridges: 20 Aggregate Bridge Length: 4,999 feet Culvert Batteries: 40
Cultural Resources	Corridor G encounters three known cultural resource sites. Future route adjustments or other mitigation measures can be implemented to preserve cultural resources that are currently known or are identified during later project stages. Corridor G intersects a small corner of one Native allotment at its crossing of the Ikpikpuk River.	Corridor H encounters three known cultural resource sites. Future route adjustments or other mitigation measures can be implemented to preserve cultural resources that are currently known or are identified during later project stages.	Corridor I encounters four known cultural resource sites. Future route adjustments or other mitigation measures can be implemented to preserve cultural resources that are currently known or are identified during later project stages.
Paleontological Resources	Corridor G does not intersect any known paleontological sites	Corridor H does not intersect any known paleontological sites	Corridor I does not intersect any known paleontological sites
Subsistence Patterns	All routes pass through potential subsistence use areas. Corridor G has one known Native allotment, no camps or cabins within the alignment, nor does it traverse within 1 mile of any.	All routes pass through potential subsistence use areas. Corridor H has no known Native allotments, no camps or cabins within the alignment, nor does it traverse within 1 mile of any.	All routes pass through potential subsistence use areas. Corridor I has no known Native allotments, no camps or cabins within the alignment, nor does it traverse within 1 mile of any. Corridor I could provide increased access to rivers due to its upstream location
Wetlands	In comparison to the other route alternatives, Corridor G is the most advantageous route for preserving high-value wetlands; potential eider nesting habitat and yellow-billed loon habitat; and for complying with BLM NPR-A Best Management Practices for lake and river setbacks. Corridor G does have the most acres of Teshekpuk Special Area that could result in increased compensatory mitigation potential; however, none of the differences are expected to pose a significant advantage in route selection.	Corridors H is less favorable than Corridor G and I for avoiding wetlands that may require compensatory mitigation. However, none of the differences are expected to pose a significant advantage in route selection.	Corridor I has no significant advantage over Corridor G and only slight advantage over Corridor H in regards to wetlands impacts.
Threatened and Endangered Species	None of the corridors has a significant difference in Threatened and Endangered Species or their habitat that would result in an advantage during route section.	None of the corridors has a significant difference in Threatened and Endangered Species or their habitat that would result in an advantage during route section.	None of the corridors has a significant difference in Threatened and Endangered Species or their habitat that would result in an advantage during route section.
Terrestrial Mammals	All route alternatives intersect terrestrial mammal habitat. Both the Western Arctic Herd and the Teshekpuk Herd migrate through the project area, and land managers are sensitive to potential disruptions of caribou movements. Corridor G traverses the greatest length through Teshekpuk Lake Special Area when compared to the other alternatives.	All route alternatives intersect terrestrial mammal habitat. Both the Western Arctic Herd and the Teshekpuk Herd migrate through the project area, and land managers are sensitive to potential disruptions of caribou movements. Corridor H traverses slightly fewer miles through Teshekpuk Lake Special Area than Corridor G.	All route alternatives intersect terrestrial mammal habitat. Both the Western Arctic Herd and the Teshekpuk Herd migrate through the project area, and land managers are sensitive to potential disruptions of caribou movements. Corridor I traverses the fewest miles through Teshekpuk Lake Special Area.
Fish & Fish Habitat	Corridor G crosses 8 designated anadromous streams and no designated anadromous lakes. However, fish surveys will be required at other streams to assess the presence or absence of anadromous fish.	Corridor H crosses 9 designated anadromous streams and two designated anadromous lakes. However, fish surveys will be required at other streams to assess the presence or absence of anadromous fish.	Corridor I crosses 11 designated anadromous streams and seven designated anadromous lakes. However, fish surveys will be required at other streams to assess the presence or absence of anadromous fish.
Avian Resources and Habitat	All corridors possess a low concentration of spectacled and Steller's eider habitat. All corridors are likely to encounter nesting habitat. Nesting surveys and potential route adjustments will be required in later stages of the project.	All corridors possess a low concentration of spectacled and Steller's eider habitat. All corridors are likely to encounter nesting habitat. Nesting surveys and potential route adjustments will be required in later stages of the project.	All corridors possess a low concentration of spectacled and Steller's eider habitat. All corridors are likely to encounter nesting habitat. Nesting surveys and potential route adjustments will be required in later stages of the project.
Environmental Compliance and Permitting	Compared with the other alternatives, Corridor G encounters the least number of river setbacks, is the shortest, and will require the least permitting effort for wetlands, provided impacts to the Teshekpuk Special Area can be effectively mitigated.	When compared with Corridor G, Corridor H intersects a greater number of K-1 river setbacks and K-2 deep-water lake setbacks. In addition, Corridor H will require greater permitting effort for wetlands impacts.	When compared with Corridor G and H, Corridor I intersect a greater number of K-1 river setbacks and less K-2 deep-water lake setbacks. In addition, Corridor I would be the second most difficult route to permit for wetlands impacts, behind Corridor G, but the difference should not be significant.
Construction Cost	Overall construction cost for Corridor G is expected to be the lowest of the three alternatives. The total ROM cost estimate for Corridor G is lowest due to shorter total road length. However, bridge construction cost for Corridor G is second highest, slightly less than Corridor I	Overall construction cost for Corridor H is expected to be the second most of the three alternatives. The estimated ROM construction cost for Corridor H is slightly higher than Corridor G due to its greater total length. However, Corridor H has the lowest total bridge construction cost among the three alternatives.	Overall construction cost for Corridor H is expected to be the highest of the three alternatives. Corridor I is the most costly alternative due to its greater length and total bridge construction costs. Proximity to Inigok could help reduce costs due to access to supplies and laydown areas.

Notes:

BLM = United States Bureau of Land Management
NPR-A = National Petroleum Reserve – Alaska
ROM = Rough Order of Magnitude
MP = milepost
ROD = Record of Decision
USACE = United States Army Corps of Engineers

4.0 Corridor Evaluation

Using the available information, each corridor alternative has been analyzed and ranked in a decision matrix as described in the following sections. The decision matrix is based on the constraints listed in Section 1.2, benefits-related criteria identified in Section 2.4, and supported by SME analysis.

4.1 Corridor Evaluation Criteria

Table 4.1-1 lists each of the decision matrix criteria along with a brief description of the associated factors and constraints to be considered for evaluation.

Table 4.1-1. Decision Matrix Evaluation Criteria for Road Network

Primary Criterion	Factors and Constraints
Benefits-Related Criteria	**To What Degree Does the Route...**
Supports Cultural Connectivity	Improve physical access between the communities. Create or enhance the capability to join together in various activities
Lowers Costs of Goods and Services	Lower the cost of energy, basic goods, utilities, and other services
Preserves or Enhances Subsistence Traditions	Improve local community access to subsistence resources while protecting those resources from outside pressure
Improves Health and Safety Conditions	Provide direct access to medical facilities and services, search and rescue personnel and law enforcement. Increase sustainability of necessary utilities.
Improves Access to Education Opportunities	Create physical access to education facilities, or facilitate attendance at schools, training centers, campuses, and cultural centers/activities
Enhances Workforce Development	Provide temporary and long-term jobs, identify and fill much-needed local service gaps, provide access to skills training or workplace experience, etc.
Constraints-Related Criteria	**To What Degree Does the Route...**
Land Status	Consider land ownership, leases, rights-of-way, Special Areas, etc.
Hydrology	Minimize river and stream crossings, locate crossings with stable bank conditions, consider BLM Best Management Practices setbacks
Geology/ Geotechnical	Consider granular material sources, avoid geohazards, where possible route over favorable (less icy) in situ soils
Existing and Proposed Infrastructure	Take advantage of existing infrastructure where possible, consider synergies between proposed road and other existing or proposed infrastructure
Roadway Engineering Considerations	Consider topography, bridges, culverts, design criteria, material needs and haul distances
Vehicle Bridges	Minimize the number and length of bridges and culverts
Cultural and Paleontological Resources	Avoid impacts to cultural or paleontological resources
Subsistence Patterns	Consider subsistence patterns and avoid or minimize encroachment on Native allotments, camps, or cabins
Wetlands	Avoid or minimize impacts to wetlands that would require compensatory mitigation
Threatened & Endangered Species	Consider regulatory constraints and Best Management Practices for eiders, polar bears, and yellow-billed loons
Terrestrial Mammals	Avoid or minimize disturbance to terrestrial mammals and habitat
Fish and Fish Habitat	Consider anadromous streams and crossing modes
Avian Resources and Habitat	Avoid eider and yellow-billed loon nesting locations and waterfowl nesting concentration areas
Environmental Compliance and Permitting	Minimize environmental and compliance permitting challenges
Construction Cost Estimate	Minimize overall construction cost to the extent practicable

4.2 Matrix Scoring

Table 4.2-1 presents a summary of the criteria scoring for each corridor. Based on the information from SME consultation and on the information presented in Table 4.1-1, each route alternative has been subjectively rated with regard to each criterion. Each route has been assigned a score from 1 to 5 for each criterion using the Likert scale below.

Degree of Favorability
1 – Not at all favorable
2 – Low favorability
3 – Moderately favorable
4 – Very favorable
5 – Extremely favorable

Table 4.2-1. Scoring for Each Corridor Based on Criteria

Criteria	Corridor G	Corridor H	Corridor I	Notes
Supports Cultural Connectivity	5	5	5	All three routes support cultural connectivity.
Lowers Costs of Goods and Services	5	5	5	All routes lower the costs of goods and services.
Preserves or Enhances Subsistence Traditions	4	4	4	All routes enhance access to potential subsistence resources while protecting those resources from outside pressure.
Improves Health and Safety Conditions	5	5	5	All routes equally improve health and safety conditions.
Improves Access to Education Opportunities	4	4	4	All routes equally improve access to education opportunities.
Enhances Workforce Development	4	4	4	All routes support workforce development.
Land Status	4	3	4	All routes cross federal and village corporation lands. Corridor G intersects a small corner of one Native allotment. Corridor H has twice as many federal lease holdings as the other corridors.
Hydrology	2	4	3	The number of crossings for Corridors G, H, and I are 77, 55, and 56, respectively. When compared with Corridor G and I, Corridor H cross a greater number of K-1 river setbacks and K-2 deep-water lake setbacks.
Geology/ Geotechnical	5	4	4	Corridor G traverses the more favorable ancient beach deposits, which will likely provide better material sources and a more stable foundation for road construction.
Existing and Proposed Infrastructure	2	3	4	All corridors provide access to infrastructure. Corridor I has greater access to existing infrastructure due to proximity to Inigok.
Roadway Engineering	2	4	3	From an engineering perspective, the routes are similar with regard to roadway engineering, design criteria, and topography. Corridor G requires the least gravel, followed by Corridor H, then I.
Vehicle Bridges	2	4	3	Corridor G requires 28 bridges (Sum of total bridge length is 5452 feet) Corridor H requires 17 bridges (Sum of total bridge length is 4654 feet) Corridor I requires 19 bridges. Sum of total bridge length is 5645 feet)
Cultural and Paleontological Resources	4	4	5	Based on available information, Corridors G and H similarly encounter higher numbers of cultural sites in their proximity than Corridor I. All three corridors are in proximity to

Criteria	Corridor G	Corridor H	Corridor I	Notes
				numerous sites on their approaches to Atqasuk. Corridor G intersects a small corner of one Native allotment at its crossing of the Ikpikpuk River.
Subsistence Patterns	4	5	5	None of the routes encroach on subsistence camps or cabins. However, Corridor G intersects a small corner of one Native allotment at its crossing of the Ikpikpuk River.
Wetlands	4	2	3	Corridor G is the most favorable route for avoiding wetlands that will require compensatory mitigation, followed by Corridors I and H.
Threatened and Endangered Species	3	4	5	Based on available data, there appear to be limited impacts on threatened and endangered species habitat. However, Corridors G and H encounter more potential habitat near Teshekpuk Lake.
Terrestrial Mammals	3	4	5	All three routes pass through caribou range, however, the alignment of Corridor I lends itself to fewer caribou crossings, and is further removed from Teshekpuk Lake.
Fisheries and Fish Habitat	4	3	2	Each route contain similar amounts of designated Anadromous Fish habitat, but Corridor I contains the most, followed by H and G.
Avian Resources and Habitat	4	3	3	Corridor H and I encounters the most nesting habitat, followed by Corridor G. Nesting surveys and potential route adjustments will be required in later stages of the project.
Environmental Compliance and Permitting	3	3	3	Permitting and compliance will be similar for any of the alternatives. All alternatives will require an Environmental Impact Statement.
Construction Cost Estimate	5	4	3	Total construction costs of the three alternatives are similar, with a difference of approximately 8% between the highest and lowest estimates. The cost estimate for Corridor G is lowest, followed by Corridor H then I. Corridor G and I have similar costs for bridges but Corridor G will incur lower roadway construction costs due to its shorter length. Corridor H has the lowest cost for bridges.
TOTAL	**78**	**81**	**82**	

4.3 Criteria Weighting

Each criterion was analyzed from eight societal and landowner viewpoints: Federal Government, State Government, Local Government (NSB), community residents, village corporations (Ukpeaġvik Iñupiat Corporation [UIC], Kuukpik, and Atqasuk Corporation), regional corporation (Arctic Slope Regional Corporation [ASRC]), environmental non-governmental organizations (NGOs), and pro-development NGOs. A description of each viewpoint is described below.

Federal Interest: This viewpoint considers which criteria are most and least important for the Federal government, specifically BLM, the primary land manager and lessor within the NPR-A.

State Interest: This viewpoint considers which criteria are the most and least important for the State of Alaska in terms of supporting the people and finances of the State. The State of Alaska is not a landowner within the project area, but does have management authority over some resources (e.g. surface waters, wildlife). In addition, the State is the entity sponsoring the ASTAR project.

NSB Interest: This viewpoint considers which criteria are most and least important for the NSB. The NSB would potentially be responsible for construction and maintenance of the road.

Community Interest: This viewpoint considers local issues and needs when considering what criteria are most and least important to the communities and Native landowners in the project vicinity.

Village Corporation Interest: This viewpoint considers which criteria are most and least important to Kuukpik, Atqasuk Corporation, Olgoonik Corporation, and UIC. These corporations are landowners affected by the potential road.

ASRC Interest: This viewpoint considers which criteria are most and least important to ASRC, a landowner within the region.

Environmental NGO Interest: This viewpoint considers issues important to environmental advocates and what criteria have the most and least effect on the environment.

Pro-Development NGO Interest: This viewpoint considers which criteria are the most and least important from development advocates.

This weighting method is based on a similar multi-disciplinary approach by Atkinson et al. (2005) that is intended to reduce bias in the decision-making process for infrastructure projects of this magnitude. This method was recently used by the Alaska Department of Transportation and Public Facilities (ADOT&PF) in the Foothills West Transportation Access Project to rank corridor alternatives for a proposed road to Umiat (ADOT&PF 2009).

Similar to a public input process, this process involves consideration of different societal viewpoints to evaluate the criteria for each corridor. Since this ranking is subjective, additional effort should be placed into developing "real world" viewpoints through future meetings with local community members, agency personnel, local and state government representatives, and other key stakeholders. As the project advances, these stakeholders should review project criteria and help verify the weightings based on their importance and applicability. The weighting should then be adjusted to reflect the views of the actual project stakeholders.

The objective is to subjectively rate each criterion and assign a score from 1 to 5 for each viewpoint, using the Likert scale below.

Level of Importance
1 – Not at all important
2 – Low importance
3 – Moderately important
4 – Very important
5 – Extremely important

Table 4.3-1 identifies the viewpoints, criteria, and the assigned weights for each criterion. Average weight for each criterion represents averaged importance across all viewpoints (right-most column). Preliminary weightings for each viewpoint were generated in a manner as objective as possible by a multidisciplinary group of SMEs. These weightings may change as public input is gathered for the project.

Table 4.3-1. Interim Criteria Weighting by Viewpoint

Federal	State	NSB	Community	Village Corp.	ASRC	Environ-mental NGO	Pro-Development NGO	Average Weight
Cultural Connectivity 2	Cultural Connectivity 4	Cultural Connectivity 5	Cultural Connectivity 5	Cultural Connectivity 5	Cultural Connectivity 5	Cultural Connectivity 2	Cultural Connectivity 4	Cultural Connectivity 4.00
Lower Costs 1	Lower Costs 3	Lower Costs 5	Lower Costs 5	Lower Costs 5	Lower Costs 5	Lower Costs 1	Lower Costs 5	Lower Costs 3.75
Preserve or Enhance Subsistence 3	Preserve or Enhance Subsistence 4	Preserve or Enhance Subsistence 5	Preserve or Enhance Subsistence 5	Preserve or Enhance Subsistence 5	Preserve or Enhance Subsistence 5	Preserve or Enhance Subsistence 3	Preserve or Enhance Subsistence 3	Preserve or Enhance Subsistence 4.13
Improve H&S Conditions 1	Improve H&S Conditions 4	Improve H&S Conditions 5	Improve H&S Conditions 5	Improve H&S Conditions 5	Improve H&S Conditions 5	Improve H&S Conditions 1	Improve H&S Conditions 4	Improve H&S Conditions 3.75
Improve Education Access Opportunities 1	Improve Education Access Opportunities 4	Improve Education Access Opportunities 5	Improve Education Access Opportunities 5	Improve Education Access Opportunities 5	Improve Education Access Opportunities 5	Improve Education Access Opportunities 1	Improve Education Access Opportunities 4	Improve Education Access Opportunities 3.75
Enhance Workforce Development 1	Enhance Workforce Development 5	Enhance Workforce Development 5	Enhance Workforce Development 5	Enhance Workforce Development 5	Enhance Workforce Development 5	Enhance Workforce Development 1	Enhance Workforce Development 5	Enhance Workforce Development 4.00
Land Status 5	Land Status 2	Land Status 5	Land Status 4	Land Status 5	Land Status 5	Land Status 1	Land Status 3	Land Status 3.75
Hydrology 4	Hydrology 4	Hydrology 3	Hydrology 3	Hydrology 3	Hydrology 3	Hydrology 5	Hydrology 3	Hydrology 3.50
Geology/ Geotech 3	Geology/ Geotech 4	Geology/ Geotech 4	Geology/ Geotech 3	Geology/ Geotech 3	Geology/ Geotech 3	Geology/ Geotech 4	Geology/ Geotech 3	Geology/ Geotech 3.38
Infrastructure 4	Infrastructure 2	Infrastructure 4	Infrastructure 4	Infrastructure 3	Infrastructure 3	Infrastructure 1	Infrastructure 3	Infrastructure 3.00
Roadway Engineering 2	Roadway Engineering 3	Roadway Engineering 5	Roadway Engineering 3	Roadway Engineering 3	Roadway Engineering 3	Roadway Engineering 1	Roadway Engineering 4	Roadway Engineering 3.00
Vehicle Bridges 4	Vehicle Bridges 5	Vehicle Bridges 3	Vehicle Bridges 3	Vehicle Bridges 3	Vehicle Bridges 3	Vehicle Bridges 2	Vehicle Bridges 5	Vehicle Bridges 3.50
Cultural & Paleo Resources 4	Cultural & Paleo Resources 4	Cultural & Paleo Resources 5	Cultural & Paleo Resources 5	Cultural & Paleo Resources 5	Cultural & Paleo Resources 5	Cultural & Paleo Resources 3	Cultural & Paleo Resources 3	Cultural & Paleo Resources 4.25
Subsistence Patterns 3	Subsistence Patterns 4	Subsistence Patterns 5	Subsistence Patterns 5	Subsistence Patterns 5	Subsistence Patterns 5	Subsistence Patterns 2	Subsistence Patterns 3	Subsistence Patterns 4.00

Federal	State	NSB	Community	Village Corp.	ASRC	Environ-mental NGO	Pro-Development NGO	Average Weight
Wetlands 3	Wetlands 4	Wetlands 3	Wetlands 3	Wetlands 3	Wetlands 3	Wetlands 5	Wetlands 3	Wetlands 3.38
T&E Species 5	T&E Species 4	T&E Species 4	T&E Species 4	T&E Species 4	T&E Species 4	T&E Species 5	T&E Species 3	T&E Species 4.13
Terrestrial Mammals 4	Terrestrial Mammals 4	Terrestrial Mammals 4	Terrestrial Mammals 5	Terrestrial Mammals 5	Terrestrial Mammals 4	Terrestrial Mammals 5	Terrestrial Mammals 4	Terrestrial Mammals 4.38
Fish & Fish Habitat 4	Fish & Fish Habitat 5	Fish & Fish Habitat 5	Fish & Fish Habitat 5	Fish & Fish Habitat 5	Fish & Fish Habitat 5	Fish & Fish Habitat 5	Fish & Fish Habitat 3	Fish & Fish Habitat 4.63
Avian Resources and Habitat 4	Avian Resources and Habitat 4	Avian Resources and Habitat 5	Avian Resources and Habitat 5	Avian Resources and Habitat 5	Avian Resources and Habitat 5	Avian Resources and Habitat 5	Avian Resources and Habitat s 3	Avian Resources and Habitat 4.50
Compliance & Permitting 5	Compliance & Permitting 5	Compliance & Permitting 4	Compliance & Permitting 4	Compliance & Permitting 4	Compliance & Permitting 4	Compliance & Permitting 5	Compliance & Permitting 4	Compliance & Permitting 4.38
Construction Cost 1	Construction Cost 3	Construction Cost 5	Construction Cost 2	Construction Cost 2	Construction Cost 2	Construction Cost 1	Construction Cost 4	Construction Cost 2.50

4.4 Weighted Decision Matrix Evaluation

Criteria for each corridor were ranked using the scoring presented in Section 4.2, and by applying the weighting factors developed in Section 4.3. The resulting Weighted Decision Matrix is shown in Table 4.4-1. As shown in the table, the matrix ranks Corridor I (Southern Route) as the most advantageous option, followed by Corridor H (Middle Route), and then Corridor G (Northern Route) in descending order.

Table 4.4-1. Interim Corridor Decision Matrix

Criterion	Weight	Scores for Corridors					
		Corridor G		Corridor H		Corridor I	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Supports Cultural Connectivity	4.00	5	20.0	5	20.0	5	20.0
Lowers Costs of Goods and Services	3.75	5	18.8	5	18.8	5	18.8
Preserves or Enhances Subsistence Traditions	4.13	4	16.5	4	16.5	4	16.5
Improves Health and Safety Conditions	3.75	5	18.8	5	18.8	5	18.8
Improves Access to Education Opportunities	3.75	4	15.0	4	15.0	4	15.0
Enhances Workforce Development	4.00	4	16.0	4	16.0	4	16.0
Land Status	3.75	4	15.0	3	11.3	4	15.0
Hydrology	3.50	2	7.0	4	14.0	3	10.5
Geology/ Geotechnical	3.38	5	16.9	4	13.5	4	13.5
Existing Infrastructure	3.00	2	6.0	3	9.0	4	12.0
Roadway Engineering	3.00	2	6.0	4	12.0	3	9.0
Vehicle Bridges	3.50	2	7.0	4	14.0	3	10.5
Cultural and Paleontological Resources	4.25	4	17.0	4	17.0	5	21.3
Subsistence Patterns	4.00	4	16.0	5	20.0	5	20.0
Wetlands	3.38	4	13.5	2	6.8	3	10.1
Threatened & Endangered Species	4.13	3	12.4	4	16.5	5	20.6
Terrestrial Mammals	4.38	3	13.1	4	17.5	5	21.9
Fish & Fish Habitat	4.63	4	18.5	3	13.9	2	9.3
Avian Resources and Habitat	4.50	4	18.0	3	13.5	3	13.5
Regulatory & Permitting	4.38	3	13.1	3	13.1	3	13.1
Construction Cost Estimate	2.50	5	12.5	4	10.0	3	7.5
TOTALS			**297.1**		**307.2**		**312.9**

5.0 Summary and Data Gaps

This desktop analysis provides ASTAR stakeholders with a better understanding of potential benefits that could result from development of a road network linking the proposed CPAI Willow Development roads to the community of Atqasuk, as well as important engineering, environmental, regulatory, and stakeholder inputs that affect routing. These corridors, along with the road corridors developed for the studies discussed in Section 2.2, would provide a road network connecting the North Slope communities of Atqasuk, Nuiqsut, Utqiaġvik, and Wainwright. Such a network enhances all of the benefits-related features of a road project identified in Section 2.4. In addition, connecting the four communities opens potential opportunities for development of a regional port for freight and fuel deliveries.

The road corridors presented in this report were developed without the benefit of stakeholder engagement. Before advancing the project further, a stakeholder engagement plan should be developed and implemented to solicit input specific to the project, and use the input to refine the project description and analysis. Stakeholder involvement is one of the most critical components of project analysis, and despite the preliminary information presented in this desktop study, the stakeholder’s preferences could significantly alter the outcome of this study and the preferred routing. Nevertheless, based on the outcome of our preliminary analysis and comparison, it appears that Corridor I (Southern Route) is the most favorable route for extending the road network to Atqasuk, followed by Corridors H (Middle Route) and G (Northern Route) in descending order. Compared to the other alternatives, Corridor I offers somewhat greater benefits and fewer environmental constraints.

The BLM is currently in the process of revising the Integrated Activity Plan (IAP) for the NPR-A. When the revision is completed, the IAP should be reviewed to assess whether any changes to stipulations or Best Management Practices (BMPs) affect the proposed Willow Development roads to Atqasuk route corridors. While the BLM IAP offers guidance for projects in the NPR-A, this road network is a community infrastructure project and, pending revision to the IAP ROD, may be exempt from some of the stipulations and BMPs.

Recommended follow-on studies and activities are listed in Table 5.0-1. The list is not comprehensive but provides guidance for initial steps necessary to fill data gaps and advance the project. In order to establish priorities, the lead-time, duration, and inter-relationship of these activities should to be established in a detailed project execution plan.

Table 5.0-1. Recommended Follow-On Studies and Activities for Atqasuk to Utqiaġvik Road

Item	Objective	Purpose
Corridor Routing		
LIDAR	Obtain LIDAR survey of road corridor(s)	Support preliminary engineering, wetlands pre-mapping, etc.
Route Reconnaissance	Conduct visual reconnaissance overflight of road corridor(s) with subject matter experts.	Validate and refine route(s) selected during desktop analysis. First-hand observations of terrain features, river crossings, etc.
Engineering		
Geotechnical Reconnaissance	Conduct reconnaissance to assess geotechnical and geological conditions.	Support planning for field studies, identify target areas for geotechnical exploration (potential borrow sources, river crossings, etc.).
Geotechnical Exploration	Geotechnical drilling program to characterize soil and permafrost conditions	Support engineering analyses for routing, river crossings, and material site development. Validate terrain unit mapping.
Hydrology Studies	Obtain hydrologic data for river and stream crossings.	Support engineering design and construction planning for bridges and culverts. Support ADF&G requirements for permits to work in waterbodies.
Conceptual Engineering	Perform conceptual-level engineering.	Support initial cost estimates, environmental documentation and financial planning.
Estimate Water Needs	Estimate construction and operational water needs.	Estimate construction water needs for construction-phase ice roads, and operational phase dust control. Support compliance with ADF&G requirements for water withdrawal and ADNR Permits for Temporary Water Use.
Preliminary Construction Execution Plan	Define construction approach and timeline.	Validate and refine cost estimate and schedule with regard to task sequencing, seasonality, logistics, and construction camps.
Cultural		
Cultural Resource Windshield Survey	Conduct visual reconnaissance overflight of road corridor(s) with archaeologists.	Support analyses for routing.
Cultural Resource Surveys	Complete field surveys of high-potential areas.	Support permitting and design of mitigation measures. Support preparation of Alaska Cultural Resource Permit (field studies investigation) and Section 106 Consultation per 36 CFR 800.
Environmental		
Wetlands	Conduct pre-mapping and field delineation of wetlands.	Support USACE Section 404/Section 401 permitting and design of mitigation measures.
Lake Studies	Identify and survey potential water sources.	Identify water sources for construction ice roads and dust control. Support construction cost estimates. Support permitting for temporary water use. Support preparation of permits for water withdrawal, temporary water use, water rights.
Fish Habitat	See Hydrology Studies. Obtain fisheries data and habitat information for stream-crossing method evaluation.	Support stream crossing method selection. Required by Title 16 of the Alaska Statutes. Both resident and anadromous fisheries evaluated. State has responsibilities related to protecting fisheries – rivers, lakes, and streams.
Bird Surveys	Identify nest locations for Threatened and Endangered eiders, and possibly loons.	Support permitting and compliance with Migratory Bird Treaty Act and Endangered Species Act Section 7. Support consultation requirements.

Item	Objective	Purpose
Environmental Evaluation Document	Conduct preliminary environmental evaluation and impacts analysis.	Prepare baseline information that can be used by federal agency. NEPA analysis and preparation of NEPA document (EA, EIS). Major federal permits will trigger NEPA.
Regulatory		
Stakeholder Strategy	Develop stakeholder strategy for engagement.	Support agency requirements for consultation (USFWS, BLM) as well as federal requirements for Environmental Justice (EO 12898, EO 13175)
Agency Coordination	Engage with local, state, and federal agencies.	Solicit agency input. Track development of BLM IAP/EIS for NPR-A. Consult with NSB.
Regulatory Strategy	Develop regulatory strategy for permitting.	Support timely permitting and early identification of potential permit stipulations.
Finance		
Finance	Identify potential funding sources for follow-on studies, engineering, and construction.	Support community desire for all-season road.
Lands		
Land Services	Develop detailed land ownership and boundary information along route(s).	Support right-of-entry permissions for field studies, ROW acquisition, etc.
Right of Way	Identify proposed route, and develop detailed project description.	Support preparation of ROW lease/grant agreements and land use permits.
Access Approvals	Fieldwork access approvals needed across NSB, Native, and federal lands.	NSB, BLM, Atqasuk Corporation, Kuukpik Corporation and other landowners require prior authorizations for conducting fieldwork on their lands.

Notes:

ADF&G = Alaska Department of Fish and Game
ADNR = Alaska Department of Natural Resources
BLM = United States Bureau of Land Management
CFR = Code of Federal Regulations
EA = Environmental Assessment
EIS = Environmental Impact Statement
EO = Executive Order
IAP = Integrated Activity Plan
LIDAR = Light Detecting and Ranging
NEPA = National Environmental Policy Act
NPR-A = National Petroleum Reserve - Alaska
NSB = North Slope Borough
ROW = right-of-way
Section 106 = Section 106 of the National Historic Preservation Act
Section 401/404 = Sections 401 and 404 of the Clean Water Act
USACE = United States Army Corps of Engineers
USFWS = United States Fish and Wildlife Service

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APPENDIX A
Subject Matter Expert Analysis

- Technical Memorandum 1 – GIS Raster Analysis*
- Technical Memorandum 2 – Land Status*
- Technical Memorandum 3 – River Hydrology
- Technical Memorandum 4 – Geology / Geotechnical*
- Technical Memorandum 5 – Existing and Proposed Infrastructure*
- Technical Memorandum 6 – Roadway Engineering*
- Technical Memorandum 7 – Vehicle Bridges*
- Technical Memorandum 8 – Cultural Resources*
- Technical Memorandum 9 – Paleontological Resources*
- Technical Memorandum 10 – Subsistence Patterns*
- Technical Memorandum 11 – Wetlands*
- Technical Memorandum 12 – Threatened and Endangered Species*
- Technical Memorandum 13 – Terrestrial Mammals*
- Technical Memorandum 14 – Fish and Fish Habitat*
- Technical Memorandum 15 – Avian Resources and Habitat*
- Technical Memorandum 16 – Environmental Compliance and Permitting*
- Technical Memorandum 17 – Construction Cost*

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Technical Memorandum 1 – GIS Raster Analysis

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Technical Memorandum 2 – Land Status

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Technical Memorandum 3 – River Hydrology

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Technical Memorandum 3 – River Hydrology

Prepared by: Claire Ellis, EIT

Reviewed by: Alexandra Jefferies, PE (PND Engineers, Inc.)

Date: June 2020

Overview

The purpose of this memorandum is to provide a high-level review of the hydrological features within the project area of a proposed all-season gravel road that would provide a connection between Nuiqsut and Utqiaġvik by linking the proposed ConocoPhillips Alaska, Inc (CPAI) Willow road network to the village of Atqasuk, linking from Atqasuk to Utqiaġvik via proposed alignments that were investigated under a separate study. This project will expand the region's transportation network, providing economic opportunities and improved services for North Slope Borough (NSB) communities. PND Engineers, Inc. conducted this hydrologic investigation for ASRC Energy Services Alaska and the Arctic Strategic Transportation and Resources project team in order to assess crossing locations at all pertinent waterways within the project area. Preliminary assessment of river crossings was a key factor in informing the presented alternatives. Figure TM3-1 displays the project corridors.

The project is located in the Arctic Coastal Plain, which is underlain by continuous permafrost about 820 to 990 feet thick. The presence of permafrost is the cause of surficial features such as thaw lakes, drained lakes, high- and low-centered polygons, strangmoor ridges, and reticulate-patterned ground which covers the area (Kane et al. 2012). A few small streams in the project area such as Fish Creek and Kealok Creek originate in the Arctic Coastal Plain, while larger streams such as the Ikpikpuk, Topagoruk, and Meade rivers originate in the foothills of the Brooks Range, and all ultimately outlet to the Arctic Ocean. Permafrost in the area creates an impermeable layer, making the drainages hydraulically tight; however, taliks (or perennial unfrozen sections of ground) create pathways for groundwater seepage to the surface, which can lead to icing and the presence of aufeis.

The project area has a low hydraulic gradient and relatively little precipitation in comparison to the gradient and annual precipitation in the foothills and Brooks Range mountains to the south. These areas to the south account for a significant portion of spring flows in the major river systems. The coastal plain receives approximately 4.0 inches of annual precipitation, whereas the Brooks Range receives approximately 13.4 inches, according to the National Oceanic and Atmospheric Administration (NOAA 2019).

This report summarizes details of stream crossings along each route and discusses the practical feasibility of construction of each of the three alternative corridors.

Drainage Basins

The open-water hydrologic cycle in the project area within the Arctic Coastal Plain is characterized by a short, intense breakup event followed by quickly receding flood levels and a prolonged period of low flows, with small occasional rain-induced flow events. In winter months, little to no flow occurs in many of the smaller streams and tributaries, while larger streams may maintain some flow year-round.

The spring breakup flood generally occurs between mid-May and mid-June. The flood peak magnitude and total volume depends on several factors: accumulation of snowfall, additional rainfall during breakup, ambient temperature, intensity of sunlight radiation, and ice and snow jamming effects. Ice breakup can be either thermal or mechanical, with mechanical breakups and increased likelihood of ice jams occurring more often in years with rapidly warming temperatures and significant direct sunshine.

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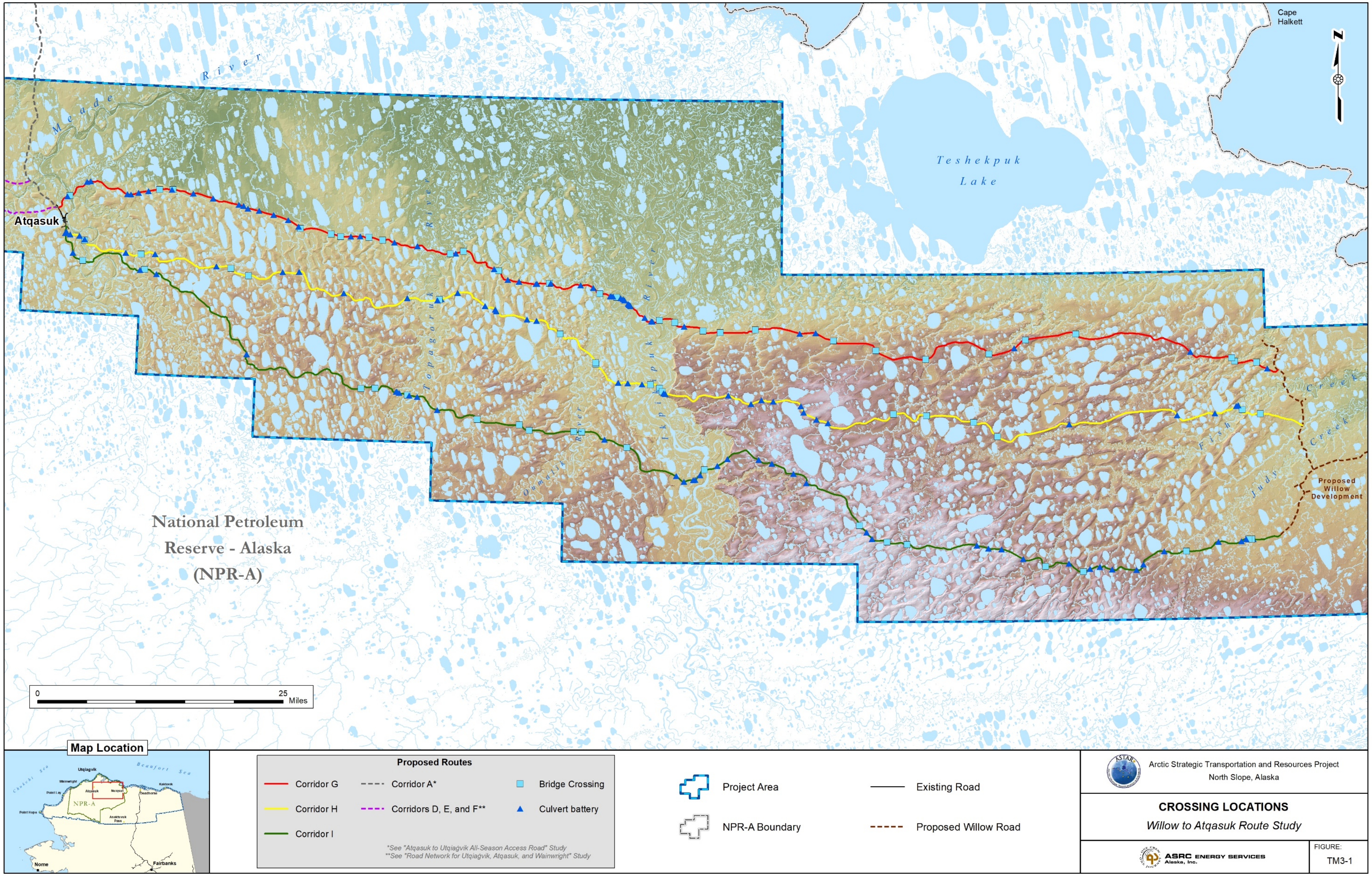
Figure TM3-1. Crossing Locations



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The hydrologic unit codes (HUC) identifying the geographic region, subregion, accounting unit, and cataloging unit for each drainage in the project area are given in Table TM3-1, along with the area of each watershed. The majority of the HUCs, presented below, are 10-unit (HUC10s), with the medium streams containing one or more HUCs. The larger rivers in the project area, the Ikpikpuk River and Meade River, encompass an 8-unit HUC (HUC 8), which is presented below.

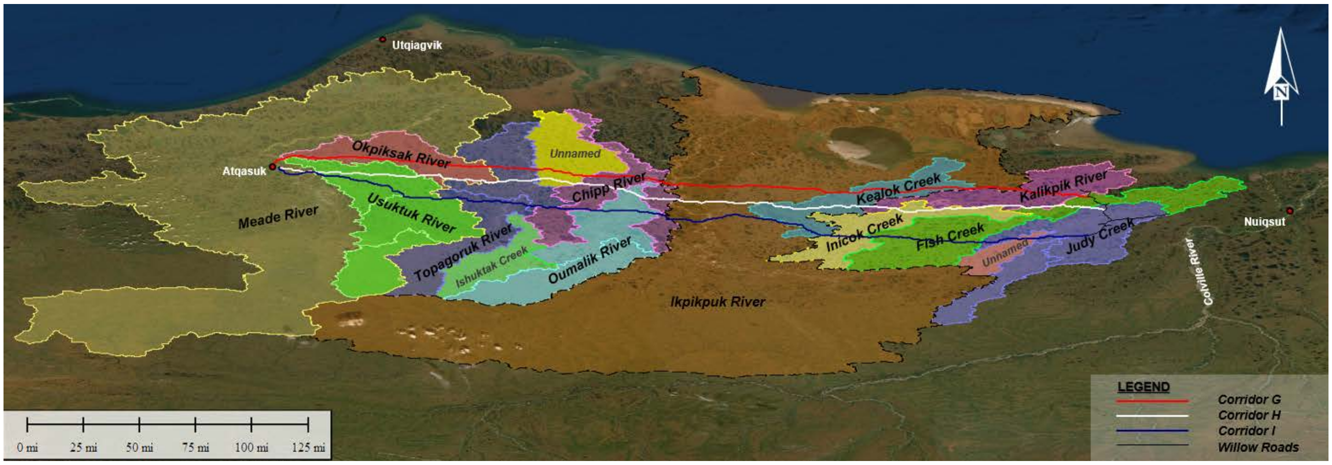
Table TM3-1. Project Area Drainage Basins

Associated Area	HUC(s)	Watershed Area (mi^2)
Fish Creek	1906020507, 1906020501	915
Judy Creek	1906020505, 1906020503	568[1]
Unnamed Tributary to Judy Creek	1906020504	108
Kalikpik River	1906020508	360
Inicok Creek	1906020502	320[2]
Kealok Creek	1906020417	332[3]
Ikpikpuk River	19060204	6,779
Chipp River	1906020603	1,025[4]
Oumalik River	1906020602, 1906020601	617
Unnamed Stream	1906020607	293
Topagoruk River	1906020606, 1906020605, 1906020604	941
Okpiksak River	1906020313	320
Usuktuk River	1906020309, 1906020308, 1906020307	773
Meade River	19060203	5,035[5]

1. The Judy Creek drainage is not included in the Fish Creek area as the confluence is downstream of the crossing location.
2. The Inicok Creek drainage area is included in the Fish Creek drainage area.
3. The Kealok Creek drainage area is included in the Ikpikpuk River drainage area.
4. The Chipp River drainage area includes the Oumalik River drainage area.
5. The Meade River drainage area includes the Usuktuk River drainage area.

The combined drainage areas of all crossed streams is approximately 16,664 mi^2. In order to simplify the analysis of these drainage basins, the HUCs are provided for drainages of major crossings. The delineated drainage basins for the project area are displayed in Figure TM3-2.

Figure TM3-1. Project Area with Drainage Basins



Streams, as defined geographically by their HUCs in Table TM3-1 and shown in Figure TM3-2, are further described below. Such streams were generally selected to be discussed in this memo as they are either a significant river adjacent to an endpoint community and/or a route alternative, or are a named stream basin crossed by one or more of the alternative alignments.

Fish Creek

Fish Creek flows eastward from its headwaters in the Arctic Coastal Plain to outlet into the Beaufort Sea, forming a delta at the southern edge of Harrison Bay. The stream substrate consists primarily of saturated sands and is susceptible to scour. High cut banks, prone to sloughing, appear on outside meander bends, and gently sloping sand banks occur on inside meander bends (Morris 2003). A stream gage site established by the Bureau of Land Management (BLM) and U.S. Geological Survey (USGS) is located on Fish Creek approximately 4 miles upstream of the mouth of Judy Creek and is currently being operated by the University of Alaska, Fairbanks (UAF), with publicly available streamflow records dating back to 2005. Several species of anadromous fish have been catalogued in this stream, including broad whitefish, humpback whitefish, undifferentiated whitefish, chum salmon, king salmon, pink salmon, and Dolly Varden (Johnson and Blossom 2019).

Fish Creek is crossed by Corridor H at a location on the stream prior to its confluence with Judy Creek, as well as Corridor I closer to its headwaters.

Judy Creek

Judy Creek begins in the foothills of the Brooks Range and flows northwards through the Arctic Coastal Plain to its confluence with Fish Creek just south of Harrison Bay on the Beaufort Sea. Numerous tundra streams and lake complexes contribute to Judy Creek as it progresses towards Fish Creek. The stream features a wide floodplain along its length. Lower Judy Creek is similar to lower Fish Creek with high cut banks and gentle slopes on inner bends. Publicly available streamflow records are available from a gage station operated by USGS between 2005 and 2009, located roughly 6 miles upstream of the mouth of Judy Creek. Several species of anadromous fish have been catalogued in this stream, including chum salmon, pink salmon, broad whitefish, humpback whitefish, undifferentiated whitefish, and Dolly Varden (Johnson and Blossom, 2019).

Judy Creek and a small unnamed tributary to Judy Creek are crossed by Corridor I.

Kalikpik River

The Kalikpik River's headwaters are in the Arctic Coastal Plain and its outlet is at a delta on the west side of Harrison Bay on the Beaufort Sea. The stream begins south of Teshekpuk Lake and flows eastward, being fed by numerous small and large thermokarst lakes and drainages as it routes towards the coast. No publicly available streamflow or breakup data is available for the Kalikpik River. Broad whitefish, undifferentiated whitefish, and least cisco are documented as present in the river.

The Kalikpik River is crossed by Corridor G, as well as Corridor H near the stream's headwaters.

Inigok Creek

Inigok Creek, identified as Inicok Creek on maps and the HUC, begins in the Arctic Coastal Plain and flows eastward to its confluence with Fish Creek. Numerous thermokarst lakes and tundra streams contribute to Inigok Creek's drainage. The stream is tightly meandering with a multitude of oxbow lakes. No publicly available streamflow or breakup data is available for Inigok Creek. Chum salmon, pink salmon, broad whitefish, and undifferentiated whitefish have been documented as present in this stream.

Inigok Creek is crossed by Corridor I and is paralleled by Corridor H for nearly 30 miles.

Kealok Creek

Kealok Creek begins in the Arctic Coastal Plain and flows in a northeasterly direction to its outlet at the southeastern shore of Teshekpuk Lake. The stream is primarily meandering, with some straightening and braiding occurring in the lower reaches as it approaches Teshekpuk Lake. Oxbow lakes occur along the upper portion of the stream. No publicly available streamflow or breakup data is available for Kealok Creek. Presence of fish in Kealok Creek is unknown; however, Teshekpuk Lake is documented to contain least cisco, broad whitefish, arctic grayling, ninespine stickleback, burbot, arctic char, northern pike, and humpback whitefish (MJM 2007).

Kealok Creek is crossed by both corridors G and H. Corridor I crosses the upstream tributaries of Kealok Creek near to its headwaters.

Ikpikpuk River

The Ikpikpuk River has a contributing drainage basin area of approximately square 6,779 miles. Its headwaters are located in the foothills of the Brooks Range and it outlets into a large delta on the southern edge of Smith Bay on the Beaufort Sea. The upper reaches of the Ikpikpuk River are tightly meandering with numerous oxbow lakes and meander scars present, before it gradually loosens out into larger meanders with less frequently occurring lakes and scarring as it continues through the Arctic Coastal Plain and approaches Smith Bay. Publicly available streamflow records are available from a historic USGS gage station located on the Ikpikpuk approximately 12 miles upstream of the mouth of the Price River. Several species of anadromous fish have been catalogued in this stream, including chum salmon, arctic cisco, broad whitefish, humpback whitefish, and least cisco, in addition to spawning and rearing undifferentiated whitefish and pink salmon.

The Ikpikpuk River is crossed by all three corridor alternatives, roughly midway between Willow and Atqasuk.

Chipp River

The Chipp River results as a bifurcation of the Ikpikpuk River and the continuation of the Oumalik River, occurring roughly midway between the foothills of the Brooks Range and the Beaufort Sea. Only a few miles downstream from the mouth of the Ikpikpuk River, the Chipp is joined by the Oumalik River, and continues southward to its outlet at Admiralty Bay. No publicly available streamflow or breakup data was found for the Chipp River. Several species of anadromous fish have been catalogued on this stream, including broad whitefish, humpback whitefish, least cisco, chum salmon, spawning pink salmon, and spawning and rearing undifferentiated whitefish. Longnose sucker, slimy sculpin, northern pike, burbot, and ninespine stickleback have also been documented in the stream (Bradley et al. 2016).

The Chipp River is crossed by Corridor G just downstream from its confluence with the Oumalik River.

Oumalik River

The Oumalik River flows from its headwaters in the foothills of the Brooks Range northward to parallel the Ikpikpuk River and join with the Chipp River. The stream follows a highly sinuous path along the entirety of its length and features wide flood channels along its bends. No publicly available streamflow or breakup data was found for the Oumalik River. Broad, humpback, and undifferentiated whitefish have been documented in this stream.

The Oumalik River is crossed by corridors H and I.

Topagoruk River

The Topagoruk River flows northward approximately 160 miles from its headwaters, in the foothills of the Brooks Range, to where it outlets into the south end of Admiralty Bay. The Topagoruk has a drainage basin of approximately 941 square miles. From its headwaters, the river follows a meandering and sinuous path with numerous oxbow lakes and meander scars occurring along its length, straightening and branching as it reaches a delta at Admiralty Bay. No publicly available streamflow or breakup data was found for the Topagoruk River. Spawning and rearing broad whitefish, humpback whitefish and undifferentiated whitefish are documented in the Topagoruk. Additionally, least cisco, arctic grayling, slimy sculpin, and ninespine stickleback are also known to occur in the stream (Bradley et al. 2016).

The Topagoruk River is crossed by corridors G, H, and I.

Okpiksak River

The Okpiksak River begins in the Arctic Coastal Plain and flows northward, joining the Meade River midway between the village of Atqasuk and Admiralty Bay. The Okpiksak begins as a beaded stream then transitions to meandering as it progresses northward. No publicly available streamflow or breakup data was found for the Okpiksak River. Broad whitefish have been cataloged in this stream to approximately 9 river miles downstream of the Corridor G crossing.

The Okpiksak River is crossed by Corridor G, and multiple smaller tributaries closer to the stream's headwaters are crossed by Corridor H.

Usuktuk River

The Usuktuk River begins in the foothills of the Brooks Range and flows northward, roughly paralleling the Meade River for much of its length, before joining the Meade River a few miles downstream of the village of Atqasuk. The stream is tightly meandering, with numerous oxbow lakes and meander scars. No publicly available streamflow or breakup data was found for the Usuktuk River. Broad whitefish are documented as present in the stream.

The Usuktuk River is crossed by corridors H and I. Corridor G crosses the Meade River right at the confluence of the Meade and Usuktuk River.

Meade River

The Meade River has a contributing drainage basin area of approximately square 5,035 miles, and at Atqusuk, where the drainage basin is 1,790 square miles, the peak streamflow recorded (in over 14 years of measurements) was 55,900 cubic feet per second in 2015 (USGS 2020). It has headwaters along Kulugra Ridge within the foothills of the Brooks Range, and drains into Admiralty Bay in the Beaufort Sea. Publicly available streamflow records are available from a USGS stream gage located near Atqasuk. The gage station is currently operated, and available streamflow data dates back to 1977. The Meade River has been documented as having spawning chum salmon as well as broad, humpback, and undifferentiated whitefishes present.

The Meade River is crossed by corridors G, H, and I as the routes approach their termination at the village of Atqasuk. Corridors H and I cross the Meade River upstream of Atqasuk, while Corridor G crosses the Meade River downstream of the village at the confluence with the Usuktuk River.

Stream and River Crossings

Hydrologic conditions along the three proposed corridors were reviewed and analyzed using Global Mapper, a geographic information system (GIS)-based program. This analysis consisted of a desktop-only study incorporating GIS data, aerial imagery, and precipitation and stream gage data where available. Analysis of major stream crossings within the project area are discussed below.

Careful consideration of major crossing locations and orientation was taken into consideration during development of the three routes. Where feasible, the crossing location was selected to allow for the shortest span within the reach and along a straight, stable section of the stream.

Alternatives Comparison

Crossings were organized by channel size and designated as major crossings, intermediate crossings, minor crossings, and culvert batteries, as presented in Table TM3-2 to allow for alternative comparison. Major crossings are seen as multi-span bridges greater than 100 feet in total length. Intermediate crossings are anticipated to consist of bridges that would span between 50 and 100 feet. Minor crossings would be single-span bridges over smaller streams, with spans less than 50 feet. In addition to bridge crossings, smaller streams were identified along the alternatives that would likely be crossed with large culverts (i.e., culvert batteries).

The typical need for cross drainage culverts on the Arctic Coastal Plain averages out to approximately one per 500 feet of road length. These culverts are intended to facilitate flow through a road corridor during spring breakup, minimizing ponding and disruption of natural drainage patterns. The initial cross-drainage culvert quantity estimate, based on this average, is provided in the last column of Table TM3-2. Depending on the microtopography along the route and the orientation of the road relative to the local terrain, additional (or fewer) culverts may be required. Refinement of cross-drainage culvert quantities can be completed based on route walks and topographic survey or Light Detection and Ranging (LIDAR) review.

Table TM3-2. Crossing Summary by Alternative

Route	Culvert Batteries	Minor Crossings (<50 feet)	Intermediate Crossings (50 to 100 feet)	Major Crossings (>100 feet)	Cross-Drainage Culverts
Corridor G	49	12	5	11	1450
Corridor H	38	8	1	8	1520
Corridor I	40	6	3	11	1590

A general discussion of each of corridor route is included below. This includes discussion of the general route as it affects drainage, as well as a general discussion of the stream crossings that are likely to require bridges.

Corridor G

Corridor G links from the north end of the proposed CPAI Willow development road system, west of Nuiqsut, directly to the village of Atqasuk. This is the northernmost route assessed in this study, and generally follows high ground.

Corridor G departs the proposed Willow road system and crosses a large tributary to the Kalikpik River after approximately 2.5 miles, and the main channel of the Kalikpik River another 2.5 miles further west. The tributary is a small meandering stream with a crossing location at a relatively straight and narrow reach. Likewise, the main channel is meandering, with a proposed crossing at a straighter reach of the stream, avoiding meander scars and an oxbow lake. The channel is wide at this location, but the perpendicular crossing at a straight reach is preferable to alternative locations.

The route continues westward, roughly paralleling the Kalikpik River and crossing several small tributary and thermokarst drainage streams along its path. The corridor primarily maintains high ground through this area, avoiding frequent lakes with small jogs, and requiring only a few culvert batteries for small stream crossings.

About a quarter way through the alignment, from the east, the route encounters Kealok Creek, a meandering braided channel, at a location between bends in the river where the stream is fairly straight. Oxbow lakes and meander scars are frequent along the channel, but the proposed crossing location lies in a narrow, more-confined floodplain than found in most areas within this reach.

The route then enters an area with more sparsely distributed lakes and several streams. The first crossing after Kealok Creek is over a large tributary to Kealok Creek (G8) draining from a thermokarst lake. To the west of this crossing, four additional significant streams are encountered, likely to require intermediate structures (G9, G10, G13, and G14), as well as several culvert batteries before the corridor reaches the Ikpikpuk River. Each of the four significant streams are meandering channels with fairly defined banks, and are crossed along straight sections of channel at a perpendicular angle, reducing erosion and scour potential at bridge sites.

The corridor continues on generally high, dry ground before dropping into the Ikpikpuk River floodplain. As the route approaches the main river crossing, it crosses multiple paleochannels, one of which appears to have the capacity to convey larger flows during flood events and will require a major bridge crossing. The corridor runs for almost 3 miles within the floodplain before crossing the main channel. The corridor continues to cross the main channel of the Ikpikpuk at a straight reach that appears to be a consistently confined single channel; whereas upstream and downstream there are braids and side channels across the width. The route continues westward for approximately 5 miles through the Ikpikpuk River and Chipp River shared floodplain before crossing the Chipp River.

The Chipp River follows a very sinuous path, and the corridor crosses it at a slight skew through the floodplain where numerous paleochannels exist. The bankfull width at this location is approximately 350 feet, but the unvegetated potentially active floodplain width expected to be spanned is approximately 1,200 feet.

As the corridor continues westward, it follows a winding path between densely distributed lakes before approaching the Topagoruk River. Three minor crossing structures over small unnamed beaded streams (G31, G40 and G42) and one intermediate bridge over an unnamed meandering stream (G35) are expected within the stretch of the corridor between the Chipp River and the Topagoruk.

The Topagoruk River is loosely meandering, and the crossing location occurs at a relatively straight stretch between bends where the route can cross while avoiding meander scars and paleochannels. As the corridor continues westward it crosses numerous unnamed tundra streams before reaching the Okpiksak River. One of these crossed tundra streams (identified as crossing G46) is a smaller lake drainage tributary to the Topagoruk River. The bankfull width at this location is approximately 170 feet, which would require a major crossing structure to span. However, this stream does not appear to convey large flows, so with additional site data (such as survey), this crossing location could potentially be optimized to reduce the structure size. The other unnamed streams occurring between the Topagoruk and Okpiksak rivers that are expected to require bridge crossings are beaded, with what appear to be confined channels and stable banks. The corridor approaches and departs the Okpiksak River crossing on relatively high ground, and a major bridge would appear to adequately span this braided stream.

Corridor G continues west for nearly 25 miles following a relatively straight path through moderately spaced thermokarst lakes before encountering the Meade River just north of the village of Atqasuk. Numerous small streams flow through this area, consisting of beaded channels and polygonal drainages, with only two likely to require minor bridges and the remainder anticipated to be crossed by culvert batteries. The corridor crosses the Meade River at the confluence with the Usuktuk River, with the route oriented to avoid a large paleochannel to the north. The channel is wide at this location, and being at the confluence, significant erosion control may be required at the east abutment to protect it from Usuktuk River incoming flows.

Table TM3-3. Corridor G Route Bridge and Culvert Battery Summary

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
G1	70° 16' 53.2402" N	152° 15' 10.9503" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G2	70° 17' 29.3034" N	152° 17' 50.9049" W	27.0	Minor	Single	12	BCp, Wp
Kalikpik River	70° 17' 37.7808" N	152° 23' 27.2728" W	163.0	Major	Single	230	BCp, Wp
G3	70° 17' 55.5648" N	152° 24' 13.6162" W	1.0	Minor	Beaded	14	Unknown
G4	70° 18' 33.1865" N	152° 34' 46.9865" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G5	70° 20' 19.8126" N	153° 04' 03.3350" W	15	Minor	Beaded	7	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
G6	70° 19' 51.9726" N	153° 17' 03.8421" W	<0.5	Major	Single	60	Unknown
G7	70° 19' 07.5986" N	153° 19' 56.3464" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
Kealok Creek	70° 18' 37.7660" N	153° 26' 27.4135" W	210	Major	Single	325	Unknown
G8	70° 18' 11.0355" N	153° 42' 39.5860" W	12	Major	Single	122	Unknown
G9	70° 18' 57.8590" N	153° 55' 26.0776" W	18	Intermediate	Single	30	Unknown
G10	70° 19' 51.3503" N	154° 06' 18.4572" W	27	Intermediate	Single	35	Unknown
G11	70° 20' 33.3105" N	154° 10' 54.8964" W	2	Culvert battery	Polygon	Too small to determine	Unknown
G12	70° 20' 29.8948" N	154° 14' 58.2196" W	2	Culvert battery	Polygon	Too small to determine	Unknown
G13	70° 20' 48.6119" N	154° 26' 21.6662" W	47	Intermediate	Single	50	Unknown
G14	70° 20' 32.3363" N	154° 35' 25.2480" W	29	Minor	Single	16	Unknown
G15	70° 20' 40.8600" N	154° 39' 50.8925" W	5	Minor	Beaded	10	Unknown
G16	70° 21' 03.4435" N	154° 44' 42.1952" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G17	70° 21' 24.6493" N	154° 47' 06.2486" W	<0.5	Major	Paleochannel	155	Unknown
Ikpikpuk River	70° 21' 35.6312" N	154° 51' 04.6996" W	4,228	Major	Single	1800	CHp, Psr, BCp, HWp, LCp, Wsr, Pp
G18	70° 21' 26.8623" N	154° 52' 54.4658" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G19	70° 21' 28.4820" N	154° 53' 09.1854" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G20	70° 21' 47.2589" N	154° 54' 52.6912" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G21	70° 22' 49.6035" N	154° 58' 31.8035" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G22	70° 22' 53.8743" N	154° 58' 46.1471" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G23	70° 22' 57.2206" N	154° 58' 57.4633" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G24	70° 22' 59.1306" N	154° 59' 34.2163" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
G25	70° 23' 20.9769" N	155° 00' 09.2457" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G26	70° 23' 25.7571" N	155° 00' 28.8690" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G27	70° 23' 32.5505" N	155° 01' 08.0066" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
Chipp River	70° 23' 36.8774" N	155° 02' 08.5163" W	730	Major	Single	350	BCp, HWsp, Wsr, BCsr,
G28	70° 23' 39.6777" N	155° 03' 07.2229" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G29	70° 23' 40.7227" N	155° 03' 31.6104" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G30	70° 23' 42.1267" N	155° 03' 50.6477" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
G31	70° 23' 54.5135" N	155° 06' 30.3560" W	14	Minor	Beaded	15	Unknown
G32	70° 24' 24.5573" N	155° 08' 12.8819" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G33	70° 24' 37.2963" N	155° 11' 29.8654" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G34	70 24' 44.7678" N	155 19' 11.475"	<0.5	Culvert battery	Paleochannel	25	Unknown
G35	70° 24' 45.4996" N	155° 19' 33.8765" W	201	Intermediate	Single	57	BCp
G36	70° 24' 40.9029" N	155° 22' 43.3450" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
G37	70° 24' 39.8123" N	155° 22' 58.0373" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
G38	70° 24' 50.0861" N	155° 27' 21.9120" W	2.5	Culvert battery	Polygon	Too small to determine	Unknown
G39	70° 24' 59.9436" N	155° 30' 14.6688" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G40	70° 25' 46.4174" N	155° 32' 40.5450" W	11	Minor	Beaded	10	Unknown
G41	70° 25' 54.8696" N	155° 33' 50.2915" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G42	70° 27' 27.0572" N	155° 41' 54.9870" W	26	Minor	Beaded	34	Unknown
G43	70° 27' 14.1677" N	155° 43' 52.9727" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
Topagoruk River	70° 27' 11.6211" N	155° 45' 14.6921" W	771	Major	Single	365	BCsr, HWsr, Wsr, BCp

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
G44	70° 27' 47.7047" N	155° 53' 46.9737" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
G45	70° 28' 03.6594" N	155° 59' 44.6442" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G46	70° 28' 15.2891" N	156° 02' 49.5367" W	<0.5	Major	Beaded	170	Unknown
G47	70° 28' 28.2947" N	156° 06' 25.0419" W	20	Minor	Beaded	15	Unknown
G48	70° 28' 31.6672" N	156° 08' 39.6219" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G49	70° 28' 29.1058" N	156° 11' 03.6222" W	2	Culvert battery	Polygon	Too small to determine	Unknown
G50	70° 28' 28.4127" N	156° 13' 37.7464" W	9	Intermediate	Beaded	30	Unknown
G51	70° 28' 39.2377" N	156° 16' 08.5537" W	14	Minor	Beaded	20	Unknown
Okpiksak River	70° 29' 03.8058" N	156° 24' 07.0457" W	34	Major	Braided	100	Unknown
G52	70° 29' 12.8437" N	156° 24' 37.5936" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G53	70° 29' 46.2780" N	156° 27' 24.5814" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G54	70° 30' 11.0898" N	156° 31' 13.9569" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G55	70° 30' 29.9379" N	156° 34' 59.6997" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G56	70° 30' 39.0775" N	156° 37' 56.5187" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
G57	70° 30' 52.9240" N	156° 39' 07.0147" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
G58	70° 30' 57.8285" N	156° 40' 19.9436" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G59	70° 31' 26.6852" N	156° 47' 00.8415" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
G60	70° 31' 47.7097" N	156° 52' 11.4393" W	1.5	Culvert battery	Beaded	10	Unknown
G61	70° 32' 05.2881" N	156° 57' 29.3970" W	8.5	Minor	Beaded	10	Unknown
G62	70° 32' 03.8017" N	156° 57' 43.7729" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G63	70° 32' 02.8019" N	157° 00' 55.9270" W	6	Minor	Beaded	10	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
G64	70° 31' 51.3280" N	157° 03' 50.4734" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G65	70 31' 40.6500" N	157 06' 23.7700" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G66	70° 31' 29.4313" N	157° 08' 18.3118" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G67	70° 31' 28.7820" N	157° 09' 15.5901" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G68	70° 32' 28.4331" N	157° 18' 56.0099" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
G69	70° 32' 24.7522" N	157° 19' 50.0644" W	<0.5	Culvert battery	Polygon	65	Unknown
Meade River	70° 31' 07.0290" N	157° 24' 05.3599" W	2571	Major	Single	1400	BCp, CHs, Wp
G70	70° 31' 01.1496" N	157° 24' 43.1808" W	<0.5	Culvert battery	Paleochannel	600	Unknown

1. Fish presence is based on data from the Anadromous Waters Catalog (ADF&G 2019).
2. CH – chum salmon; P – pink salmon; W – undifferentiated whitefishes, BC – broad whitefish; HW – humpback whitefish; LC – least cisco.
3. p – present; s – spawning; r – rearing.

Corridor G is the shortest of the three alternatives, generally following higher ground; however, it crosses a greater number of streams than the others, requiring more significant crossing structures (i.e., culvert batteries and bridges). This corridor is estimated to require 49 culvert batteries, 12 minor structure crossings, 5 intermediate structure crossings, and 11 major structure crossings.

Corridor H

Corridor H connects Nuiqsut to Atqasuk via the proposed CPAI Willow development, providing access to the corridors routing from Atqasuk to Utqiagvik as reviewed under a previous study. This is the central route of those assessed in this study.

This route begins from the proposed Willow development, north of Judy Creek. From its start, Corridor H heads westward, avoiding small thermokarst lakes and ponds before reaching an unnamed beaded stream (H1) with high sinuosity, particularly at the proposed crossing location. The alignment approach and crossing will likely need refinement during future design efforts in order to optimize the crossing location.

The next crossing along the route occurs over Fish Creek, where the corridor moves into the floodplain and crosses the stream at a straight reach perpendicular to the flow, avoiding paleochannels to the extent practical. In order to avoid larger lakes, the route must continue winding through the floodplain for a total of approximately 2.5 miles.

Corridor H continues due west, threading between densely distributed thermokarst lakes on high ground and following a roughly parallel course to Inigok Creek for nearly 25 miles before the next bridge crossing, passing only paleochannels and polygon drainages along this path. The next several bridge crossings are minor, crossing smaller meandering unnamed streams. The next named stream crossing is at Kealok Creek, where the route approaches perpendicular to the stream at a straight reach, avoiding upstream and downstream oxbows, and crosses where the channel has fairly defined banks.

As the corridor continues west towards the Ikpikpuk River floodplain, it enters a wet area with numerous small polygonal and beaded tundra streams and lakes. Although a wetter area, the stream channels within this section are smaller and likely to only require culvert batteries to convey their flows.

The Ikpikpuk River is typically meandering with large gravel bars, braids, and paleochannels and an extensive floodplain. The route crosses the Ikpikpuk at a location between bends in the river, where the channel depth and width appear to be normalized. The route passes through the floodplain for a total of over 4.5 miles, crossing multiple paleochannels, smaller side channels, and tributaries within the floodplain.

Just to the west of the Ikpikpuk River crossing, Corridor H crosses the Oumalik River. Like many of the other streams, the Oumalik is meandering with a wide floodplain and a multitude of paleochannels and oxbow lakes. The corridor approaches the stream through a higher area and crosses mostly perpendicular to the main channel, avoiding wider areas of meander scars and oxbows. However, this crossing location occurs on a bend, and the southeast abutment of the crossing structure would lie on a cut bank. Based on aerial imagery investigation, this section of the stream, contains two main channels, with the primary channel having a bankfull width of 455 feet and the secondary channel to the west having a bankfull width of 110 feet. Crossing of the stream at this location would require either a single major bridge to span both channels, or two major bridges spanning each channel separately (as is presented in this memo). After crossing the Oumalik River, the route continues another approximately 1.2 miles through the low-lying area before leaving the Oumalik River floodplain and regaining higher and dryer ground.

Corridor H continues following dry ground for approximately 17 more miles, crossing through densely distributed thermokarst lakes and ponds and over numerous small streams. Only one potential bridge crossing is anticipated prior to the route reaching the Topagoruk River floodplain. The route crosses the Topagoruk River where the channel is well-defined and the apparent active floodplain width is minimized. The crossing occurs at a relatively straight section of the stream on an outer bend with a cut bank on the east side of the crossing.

The corridor maintains its direction for a total of approximately 3.5 miles through the Topagoruk River floodplain before rising up to significantly higher ground. As the route continues westward it jogs north and south as it traverses through some thirty miles of densely populated lakes and associated drainages, and tundra streams.

Corridor H then meets the Usuktuk River at a location lacking significant paleochannels, where the floodplain width is minimized. Although the stream at the crossing location is relatively straight compared to the upstream and downstream reaches of the stream, the channel is set slightly on an outer bend and the west abutment of the crossing structure will be set on a cut bank. The Usuktuk River floodplain is well-defined with the route traversing through almost 1.5 miles from one end to the other. The corridor returns to higher ground for approximately 4.3 miles before dropping into the Meade River floodplain. The route crosses the Meade at a straight reach at the bottom of a U-shaped bend. This section of channel appears to be fairly stable with gradual banks on both sides. The route crosses through approximately 2.2 miles of Meade River floodplain and then terminates to the west, just south of the village of Atqasuk.

The bridge crossings and culvert batteries for this corridor are listed below in Table TM3-4.

Table TM3- 4. Corridor H Route Bridge and Culvert Battery Crossing Summary

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
H1	70° 12' 52.0204" N	152° 17' 12.2657" W	13.0	Minor	Beaded	5	BCp, Wp
Fish Creek	70° 13' 16.5508" N	152° 21' 50.3130" W	727.0	Major	Single	440	CHp, BCp, Pp, Wp, Ps
H2	70° 13' 39.9033" N	152° 22' 47.7870" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
H3	70° 13' 36.5346" N	152° 23' 21.0631" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
H4	70° 12' 58.9561" N	152° 28' 49.5310" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H5	70° 12' 52.8058" N	152° 38' 29.6704" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H6	70° 12' 13.8153" N	153° 06' 03.8998" W	<0.5	Culvert battery	Polygon	Too small to determine	BCp, Wp
H7	70° 11' 12.4606" N	153° 24' 24.4730" W	22.0	Minor	Single	25	Unknown
H8	70° 12' 29.8176" N	153° 30' 27.2994" W	7	Minor	Single	10	Unknown
H9	70° 13' 06.2863" N	153° 42' 29.5908" W	8.5	Minor	Single	15	Unknown
Kealok Creek	70° 13' 15.9460" N	153° 50' 59.2448" W	81.0	Minor	Single	35	Unknown
H10	70° 12' 27.2391" N	154° 07' 43.8464" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H11	70° 12' 46.6674" N	154° 10' 39.4830" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
H12	70° 13' 24.0753" N	154° 13' 56.1483" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
H13	70° 13' 58.3560" N	154° 14' 37.5621" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
H14	70° 14' 22.4782" N	154° 21' 41.5841" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H15	70° 14' 29.5775" N	154° 24' 42.8638" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H16	70° 14' 09.5317" N	154° 27' 25.1435" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
H17	70° 14' 53.9848" N	154° 33' 11.9192" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H18	70 14' 58.7500" N	154 49' 20.1500" W	<0.5	Culvert battery	Paleochannel	10	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi^2)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
H19	70° 15' 02.1179" N	154° 49' 46.0146" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
Ikpikpuk Side Channel	70° 15' 10.9440" N	154° 50' 08.2435" W	<0.5	Major	Braided	330	CHp, Psr, BCp, HWp, LCp, Wsr, Pp
Ikpikpuk River	70° 15' 29.9167" N	154° 50' 51.0829" W	4,200.0	Major	Braided	1540	CHp, Psr, BCp, HWp, LCp, Wsr, Pp
H20	70° 15' 47.7573" N	154° 53' 10.0063" W	75.0	Minor	Single	16	Unknown
H21	70° 15' 49.7777" N	154° 55' 18.0470" W	<0.5	Culvert battery	Paleochannel	80	Unknown
H22	70° 15' 54.1979" N	154° 58' 59.5464" W	4.5	Culvert battery	Beaded	13	Unknown
H23	70° 15' 55.5300" N	155° 01' 26.3209" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
Oumalik River	70° 17' 34.4714" N	155° 07' 09.3630" W	617.0	Major	Single	455	BCsr, HWsr, Wsr
Oumalik River Channel 2	70° 17' 42.1923" N	155° 07' 15.5646" W	617.0	Major	Single	110	BCsr, HWsr, Wsr
H24	70° 17' 46.5096" N	155° 07' 19.0328" W	<0.5	Culvert battery	Paleochannel	153	Unknown
H25	70° 20' 13.7101" N	155° 16' 33.3336" W	142.0	Intermediate	Single	57	BCp
H26	70° 21' 21.4985" N	155° 22' 38.4888" W	<0.5	Culvert battery	Polygon	145	Unknown
H27	70° 21' 27.8342" N	155° 25' 08.6029" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H28	70° 22' 08.5467" N	155° 33' 03.3656" W	<0.5	Culvert battery	Polygon	15	Unknown
H29	70° 22' 17.0911" N	155° 33' 22.4419" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H30	70° 22' 34.2224" N	155° 35' 56.1597" W	<0.5	Culvert battery	Single	Too small to determine	Unknown
H31	70° 23' 41.7131" N	155° 43' 06.2244" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H32	70° 23' 05.8769" N	155° 47' 19.0584" W	<0.5	Culvert battery	Paleochannel	50	Unknown
Topagoruk River	70° 23' 03.3727" N	155° 47' 44.9659" W	722	Major	Single	515.00	HWsr, Wsr, BCsr, BCp

Crossing	Latitude	Longitude	Drainage Area (mi^2)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[1,2,3]
H33	70° 22' 59.8590" N	155° 48' 17.5352" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
H34	70° 23' 06.5095" N	155° 56' 03.8262" W	15.0	Culvert battery	Beaded	11	Unknown
H35	70° 23' 22.3135" N	156° 12' 24.9913" W	2	Culvert battery	Beaded	Too small to determine	Unknown
H36	70° 25' 09.4192" N	156° 24' 04.4698" W	7	Culvert battery	Beaded	Too small to determine	Unknown
H37	70° 25' 04.1466" N	156° 28' 17.8608" W	2	Culvert battery	Beaded	Too small to determine	Unknown
H38	70° 24' 38.0561" N	156° 37' 04.3342" W	58	Minor	Single	24	Unknown
H39	70° 25' 13.8491" N	156° 41' 40.8603" W	16	Minor	Beaded	15	Unknown
H40	70° 25' 21.7747" N	156° 45' 29.3224" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
H41	70° 26' 13.6080" N	157° 01' 22.6249" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
Usuktuk River	70° 26' 09.3066" N	157° 04' 59.1908" W	600	Major	Single	475	BCp
H42	70° 26' 13.5721" N	157° 08' 59.4644" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
Meade River	70° 27' 10.8260" N	157° 19' 41.7036" W	1770	Major	Single	550	CHs, Wp, BCp
H43	70° 27' 14.6900" N	157° 19' 43.9858" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
H44	70° 27' 32.0059" N	157° 21' 06.8600" W	10	Culvert battery	Polygon	Too small to determine	Unknown
H45	70° 27' 37.9942" N	157° 23' 30.4221" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
H46	70° 27' 51.2178" N	157° 24' 32.5185" W	10	Culvert battery	Beaded	Too small to determine	Unknown

1. Fish presence is based on data from the Anadromous Waters Catalog (ADF&G 2019).
2. CH – chum salmon; P – pink salmon; W – undifferentiated whitefishes, BC – broad whitefish; HW – humpback whitefish; LC – least cisco.
3. p – present; s – spawning; r – rearing.

Corridor H generally follows higher ground, resulting in minimal need for cross-drainage/equalizing culverts. This corridor crosses the fewest defined stream channels with the least quantity of culvert batteries, intermediate, and major structures of the three alternatives. This corridor is estimated to require 38 culvert batteries, 8 minor structure crossings, 1 intermediate structure crossing, and 8 major structure crossings.

Corridor I

Corridor I connects Nuiqsut to Utqiagvik by providing a link between the proposed CPAI Willow development and the village of Atqasuk. This alignment is the southernmost route assessed in this study.

The alignment begins at the southern extent of the Willow road system, and runs southward, crossing through an area of relatively sparsely distributed lakes and polygonal ground. The first crossings occur at Judy Creek as the route traverses through approximately 0.75 miles of floodplain. These crossings include two culvert batteries spanning paleochannels and two major bridge structures, with one bridge being over a large paleochannel that appears to have the potential to convey significant flow during flood events. The route then crosses over a large unnamed tributary to Judy Creek (I6), which is a meandering stream with a bankfull width of 155 feet at the crossing location. The corridor is able to wind through oxbow lakes to cross this channel at a fairly straight section, perpendicular to the flow.

Corridor I continues westward through patterned ground, jogging southward to maneuver through a dense cluster of lakes and crossing several small beaded streams with culvert batteries before approaching the main channel of Fish Creek just east of Inigok airstrip. Fish Creek's channel is fairly confined at the Corridor I crossing, with defined and apparent stable banks. Just west of the Inigok airstrip, the route crosses the much larger East Fork Fish Creek channel. The corridor crosses at a slight bend in the channel, avoiding large adjacent oxbows. Based on aerial imagery, the east bank of the crossing appears to have a slight cut bank.

The route continues westward for 15 miles, following a relatively straight path with minor deviations to north and south in order to avoid clusters of thermokarst lakes and tundra drainages, before crossing the higher reaches of Inigok Creek. The stream is channelized, straight, and has well-defined banks at the crossing location.

As the corridor moves beyond Inigok Creek, it begins to redirect northward, skirting along the northern edge of a wet area and a chain of large thermokarst lakes to the north for over 20 miles before reaching the Ikpikpuk River floodplain. This 20-mile stretch generally follows high ground, crossing roughly ten small streams, only two of which are likely to require bridges.

The Ikpikpuk River floodplain is extensive, with the Corridor I route dropping down a large bluff and traversing over 7 miles through lowlands, paleochannels and small floodplain side channels. The main channel crossing occurs at a straight stretch of the river where the active channel width is relatively minimized and confined. Additional conveyance—likely through culvert batteries—will be required throughout the floodplain.

The route continues to the northwest towards the Oumalik River, traversing through wet terrain and crossing several small tundra streams. Two major crossing structures are expected for crossing the Oumalik and a large paleochannel existing on the west side of the main channel. The Oumalik River is braided and the active floodplain appears to be fairly confined; however, the channel's movement within the banks is dynamic, potentially risking erosion at this location. The west side of the floodplain is low ground, with a large relic channel that has the potential to convey large flows during flood events cutting through the floodplain.

To the west of the Oumalik River crossings, the route follows a gently meandering path across patterned ground between closely spaced thermokarst lakes and over several small tundra streams. At a location approximately equidistant between the Oumalik and Topagoruk rivers, the corridor crosses a large tributary to the Oumalik River. This tributary follows a sinuous path and has a well-defined channel. As Corridor I approaches the Topagoruk River floodplain, the ground becomes more patterned, and thermokarst lakes more frequent. Numerous meander scars and oxbow lakes exist on both sides of the Topagoruk River, crossed by the route as it traverses a little over 2 miles through the floodplain. The main channel crossing is proposed at a straight stretch in the river where the channel is relatively well-defined and the active channel width is minimized.

Corridor I continues westward from the Topagoruk River, following higher ground while gradually shifting northward, maneuvering through densely spaced thermokarst lakes and across a few small tundra drainages along the approximately 30-mile length of the corridor between the Topagoruk and the Usuktuk rivers.

The route approaches the Usuktuk River at a fairly straight section of the stream, avoiding adjacent oxbow lakes and crossing where the river's active channel and floodplain widths are minimized. Along this reach, the Usuktuk and Meade rivers run roughly parallel to each other with separate defined floodplains. As the route continues westward from the Usuktuk, it follows the outside curvature of a sharp U-shaped bend in the Meade River in order to gain a straight crossing across its active channel.

Corridor I continues nearly due north after crossing the Meade River and terminates at the southern tip of the existing road system serving the village of Atqasuk.

The bridge crossings and culvert batteries for this corridor are listed below in Table TM3-5.

Table TM3-5. Corridor I Route Bridge and Culvert Battery Summary

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[6,7,8]
I1	70° 01' 37.8297" N	152° 19' 52.5372" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
Judy Creek	70° 01' 38.2543" N	152° 20' 11.1258" W	30.0	Major	Single	250	Unknown
I2	70° 01' 38.5898" N	152° 20' 56.5638" W	<0.5	Major	Paleochannel	255	Unknown
I3	70° 01' 38.4977" N	152° 21' 38.9959" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I4	70° 01' 27.9961" N	152° 22' 52.3170" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I5	70 01' 27.4600" N	152 28' 40.8200"	<0.5	Culvert battery	Polygon	75	Unknown
I6	70° 00' 41.5127" N	152° 36' 49.9468" W	100	Major	Single	155	Unknown
I7	70° 00' 41.4790" N	152° 42' 28.8459" W	9.0	Culvert battery	Beaded	15	Unknown
I8	69° 59' 34.1905" N	152° 47' 46.2439" W	9	Culvert battery	Beaded	10	Unknown
I9	69° 59' 05.1879" N	152° 49' 30.5517" W	9.0	Culvert battery	Beaded	Too small to determine	Unknown
I10	69° 59' 09.1927" N	152° 55' 40.7865" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I11	69° 59' 24.2940" N	152° 58' 48.6942" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[6,7,8]
I12	69° 59' 14.9436" N	153° 01' 17.1237" W	9.0	Culvert battery	Polygon	5	Unknown
Fish Creek	69° 59' 00.3816" N	153° 02' 59.0830" W	37.0	Intermediate	Single	73	Unknown
I13	69°59'44.29"N	153° 6'37.49"W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
East Fork Fish Creek	69° 59' 31.2512" N	153° 12' 31.1290" W	144	Major	Single	100	BCp, Wp,
I14	70° 0'50.47"N	153°21'22.05"W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I15	70° 01' 05.4011" N	153° 23' 37.5696" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I16	70° 01' 10.4310" N	153° 27' 00.7519" W	<0.5	Culvert battery	Polygon	Too small to determine	BCp, Wp
I17	70° 01' 26.8385" N	153° 29' 51.9639" W	<0.5	Culvert battery	Polygon	Too small to determine	BCp, Wp
Inigok Creek	70° 01' 34.6655" N	153° 47' 36.4849" W	124.0	Intermediate	Single	40	BCp, Wp
I18	70° 01' 48.4577" N	153° 52' 40.7323" W	11.0	Minor	Beaded	5	BCp, Wp
I19	70° 02' 03.9132" N	153° 56' 28.5306" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I20	70° 02' 39.0681" N	153° 57' 52.8857" W	2	Culvert battery	Beaded	Too small to determine	Unknown
I21	70° 03' 16.0552" N	153° 59' 40.3330" W	10	Minor	Beaded	15	Unknown
I22	70° 07' 04.4134" N	154° 13' 08.7003" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I23	70° 07' 55.0312" N	154° 16' 27.2688" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I24	70° 08' 48.1411" N	154° 21' 58.9457" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I25	70° 09' 08.4370" N	154° 25' 22.0747" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi^2)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[6,7,8]
I26	70° 09' 11.0937" N	154° 33' 15.5735" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I27	70° 08' 33.7455" N	154° 35' 49.6743" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
Ikpikpuk River	70° 08' 12.9347" N	154° 39' 06.1241" W	4,150.0	Major	Single	1425	CHp, Psr, BCps, HWp, LCp, Wsr, Pp, BCsr, HWsr, LCsr, HWsp
I28	70° 07' 42.6763" N	154° 40' 15.1821" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I29	70° 07' 18.2678" N	154° 41' 26.6329" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I30	70° 07' 15.8844" N	154° 41' 59.1055" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I31	70° 07' 07.8274" N	154° 44' 19.8674" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
I32	70° 07' 37.5145" N	154° 46' 18.7857" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I33	70° 10' 06.7811" N	154° 58' 56.3243" W	55.0	Minor	Single	6	Unknown
I34	70° 10' 47.9763" N	155° 04' 42.3339" W	<0.5	Culvert battery	Beaded	Too small to determine	Unknown
Oumalik River	70° 11' 27.4331" N	155° 10' 32.4745" W	577.0	Major	Single	550	BCsr, HWsr, Wsr
I35	70° 11' 27.4403" N	155° 12' 32.5820" W	<0.5	Major	Paleochannel	390	Unknown
I36	70° 11' 30.6764" N	155° 23' 56.9281" W	2	Minor	Beaded	19	Unknown
I37	70° 11' 58.5842" N	155° 26' 30.9312" W	<0.5	Minor	Polygon	15	Unknown
I38	70° 12' 23.2890" N	155° 37' 17.5452" W	58	Intermediate	Single	40	Unknown
I39	70° 13' 08.2330" N	155° 47' 34.6681" W	3	Culvert battery	Beaded	5	Unknown

Crossing	Latitude	Longitude	Drainage Area (mi²)	Structure Type	Channel Type	Bankfull Width (ft)	Fish Present[6,7,8]
I40	70° 14' 15.4679" N	155° 52' 47.4604" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I41	70°14'21.91"N	155°54'47.85"W	<0.5	Culvert battery	Paleochannel	20	Unknown
Topagoruk River	70° 14' 24.1362" N	155° 55' 16.6585" W	547	Major	Single	450.00	BCsr, HWsr, Wsr, BCp
I42	70° 14' 35.5600" N	155° 57' 24.5358" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I43	70° 14' 40.6422" N	155° 58' 00.3923" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I44	70° 14' 39.7733" N	155° 58' 13.1091" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
I45	70° 14' 56.6302" N	156° 03' 38.9984" W	<0.5	Major	Single	110	Unknown
I46	70° 14' 53.0030" N	156° 07' 11.6498" W	35	Minor	Single	30	BCp
I47	70° 17' 34.2320" N	156° 36' 48.8983" W	<0.5	Culvert battery	Polygon	81	Unknown
I48	70° 24' 25.5026" N	157° 00' 49.7904" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
Usuktuk River	70° 24' 48.4023" N	157° 03' 55.5448" W	605	Major	Single	330	BCp
I49	70° 24' 44.5506" N	157° 05' 03.3024" W	<0.5	Culvert battery	Paleochannel	Too small to determine	Unknown
Meade River	70° 25' 20.9956" N	157° 19' 56.2746" W	1766	Major	Single	741.00	BCp
I50	70° 25' 59.8359" N	157° 22' 35.8489" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown
I51	70° 27' 43.8340" N	157° 24' 49.0775" W	<0.5	Culvert battery	Polygon	Too small to determine	Unknown

6. Fish presence is based on data from the Anadromous Waters Catalog (ADF&G 2019).
7. CH – chum salmon; P – pink salmon; W – undifferentiated whitefishes, BC – broad whitefish; HW – humpback whitefish; LC – least cisco.
8. p – present; s – spawning; r – rearing.

Corridor I is the longest and most southerly route evaluated, providing a path from the Willow road system to the village of Atqasuk. This alternative traverses through much wetter ground than the other two alternatives, but has fewer stream crossings than Corridor G. Corridor I is estimated to require 40 culvert batteries, 6 minor structure crossings, 3 intermediate structure crossings, and 11 major structure crossings.

Available Stream Data

Little hydrologic data is available for the project area. Available data includes historic stream gage records as well as breakup reports and assessments. The available data is primarily for those areas along the east and west extents of the corridors where the project abuts or overlaps existing or proposed development and study areas.

Long-term USGS gage stations, operated by the BLM, exist at locations along Fish Creek, Judy Creek, and the Ikpikpuk River with historic streamflow data available back to 2004. In 2012, UAF began operating these gage stations in support of their National Petroleum Reserve–Alaska Hydrology study. Gaged discharge data on the Meade River dates back to 1977, but peak streamflow data has only been collected at this site since 2006. Information available from these current and historic USGS gage stations include streamflow measurements in addition to some water quality and basic weather records. A summary of active and inactive USGS gages in the project area are provided in Table TM3-6.

Table TM3-6. Available USGS Gage Data in Project Area

Gage No.	Site Name	Latitude	Longitude	Years Active[1]	Peaks Measured
15860000	FISH C NR NUIQSUT AK	70°16’14”N	151°52’09” W	2004-2009	5
15861000	JUDY C NR NUIQSUT AK	70°13’14”N	151°50’05” W	2004-2009	5
15820000	IKPIKPUK R BL FRY C NR ALAKTAK AK	69°46’00.5”N	154°39’40.6” W	2004-2009	5
15803000	MEADE R AT ATQASUK AK	70°29’45”N	157°23’33” W	1977-Current	14

1. Years active indicates those years monitored by USGS. In 2012, UAF began gaging Fish Creek, Judy Creek, and the Ikpikpuk River at these historic gage locations.

Spring breakup monitoring and hydrologic assessment reports for the Fish Creek Drainage Basin are also available. These studies were primarily focused along the eastern portion of the Fish Creek Basin and were conducted for CPAI by Michael Baker Jr., Inc. (Baker 2010, 2014). Each study consisted of between 7 to 18 monitoring stations located throughout the eastern extents of the Fish Creek drainage. Observations and measurements of the streamflow at each station were recorded in order to gain an understanding of the typical breakup behaviors and hydrology of the area. No direct measurements were conducted on Fish Creek or Judy Creek specifically as a part of these studies.

Additional historic records include preliminary 100-year floodplain width estimates for Fish Creek and Judy Creek as developed by the URS Corporation in 2002, in addition to 2001 and 2002 breakup reports on Fish and Judy creeks. These reports include detailed stream descriptions and observations, as well as flow data and stage measurements at multiple locations within the proposed project area that could be used for future design efforts in conjunction with available USGS and UAF data.

Data Gaps

Very little historical data is available for many of the streams within the center portion of the project area. This includes lack of survey data, general research and observations, and streamflow records. Future field efforts should include gathering survey data as well as stage and discharge measurements throughout spring breakup and during summer low-flow conditions.

CPAI-owned data is also likely available around the proposed Willow development, including additional gage data on Fish Creek, Judy Creek, and smaller streams within the project area. Additional available data could include LIDAR, site survey, and lake data.

Alternative corridors should also be inspected on-foot with helicopter support in order to better identify cross-drainage locations and quantities, find improvements to route centerline alignments based on local topography, and to identify any major flaws in the routes or crossing locations due to unforeseen topography or other challenges that would require alignment adjustments. Additional assessment of streambank stability and crossing locations should be conducted, including onsite observation of the crossing locations and potential abutment locations.

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Technical Memorandum 4 – Geology / Geotechnical

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APPENDIX B

Bridge Crossing Summary

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Table TM7-1. Bridge Crossing Summary

Route	Bridge ID	Crossing Name	Est. Bridge Length (ft)	Number of Piers	Ice Breakers
Corridor G	1.01	G2	30	0	No
Corridor G	1.02	Kalikpik River	250	2	No
Corridor G	1.03	G3	20	0	No
Corridor G	1.04	G5	20	0	No
Corridor G	1.05	G6	100	0	No
Corridor G	1.06	Kealok Creek	540	2	Yes
Corridor G	1.07	G8	130	1	No
Corridor G	1.08	G9	75	0	No
Corridor G	1.09	G10	65	0	No
Corridor G	1.10	G13	75	0	No
Corridor G	1.11	G14	20	0	No
Corridor G	1.12	G15	50	0	No
Corridor G	1.13	G17	180	1	No
Corridor G	1.14	Ikpikpuk River	2500	13	Yes
Corridor G	1.15	Chipp River	1200	6	Yes
Corridor G	1.16	G31	30	0	No
Corridor G	1.17	G35	80	0	No
Corridor G	1.18	G40	35	0	No
Corridor G	1.19	G42	50	0	No
Corridor G	1.20	Topagoruk River	420	3	No
Corridor G	1.21	G46	230	2	No
Corridor G	1.22	G47	45	0	No
Corridor G	1.23	G50	55	0	No
Corridor G	1.24	G51	50	0	No
Corridor G	1.25	Okpiksak River	450	4	No
Corridor G	1.26	G61	40	0	No
Corridor G	1.27	G63	40	0	No
Corridor G	1.28	Meade River	1700	9	Yes
Corridor H	2.01	H1	20	0	No
Corridor H	2.02	Fish Creek	750	4	Yes
Corridor H	2.03	H7	30	0	No
Corridor H	2.04	H8	20	0	No
Corridor H	2.05	H9	120	1	No
Corridor H	2.06	Kealok Creek	50	0	No

Route	Bridge ID	Crossing Name	Est. Bridge Length (ft)	Number of Piers	Ice Breakers
Corridor H	2.07	Ikpikpuk Side Channel	600	3	Yes
Corridor H	2.08	Ikpikpuk River	1600	8	Yes
Corridor H	2.09	H20	40	0	No
Corridor H	2.10	Oumalik River	550	3	Yes
Corridor H	2.11	Oumalik River Channel 2	150	1	No
Corridor H	2.12	H25	75	0	No
Corridor H	2.13	Topagoruk River	570	3	Yes
Corridor H	2.14	H38	40	0	No
Corridor H	2.15	H39	40	0	No
Corridor H	2.16	Usuktuk River	520	2	Yes
Corridor H	2.17	Meade River	900	4	Yes
Corridor I	3.01	Judy Creek	300	2	No
Corridor I	3.02	I2	280	2	No
Corridor I	3.03	I6	200	1	No
Corridor I	3.04	Fish Creek	80	0	No
Corridor I	3.05	East Fork Fish Creek	110	0	No
Corridor I	3.06	Inigok Creek	60	0	No
Corridor I	3.07	I18	30	0	No
Corridor I	3.08	I21	50	0	No
Corridor I	3.09	Ikpikpuk River	1500	8	Yes
Corridor I	3.10	I33	25	0	No
Corridor I	3.11	Oumalik River	1400	7	Yes
Corridor I	3.12	I35	400	3	No
Corridor I	3.13	I36	40	0	No
Corridor I	3.14	I37	50	0	No
Corridor I	3.15	I38	75	0	No
Corridor I	3.16	Topagoruk River	650	3	Yes
Corridor I	3.17	I45	120	1	No
Corridor I	3.18	I46	40	0	No
Corridor I	3.19	Usuktuk River	400	3	No
Corridor I	3.20	Meade River	800	4	Yes

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