

June 5, 2017

## WHY ALASKA'S NATURAL GAS PIPELINE SHOULD BE BURIED

### SUMMARY

The Alaska Gasline Development Corporation (AGDC) has proposed to develop a buried natural gas pipeline that will span approximately 800-miles from Prudhoe Bay to Southcentral Alaska. The priority Alaska LNG project mainline is a 42-inch diameter controlled temperature pipeline that will deliver liquefied natural gas (LNG) to foreign markets and meet in-state gas needs. The smaller option for the transport of in-state gas is the 36-inch diameter Alaska Stand Alone Pipeline (ASAP) project. Both projects are involved in separate National Environmental Policy Act (NEPA) processes. The Federal Energy Regulatory Commission (FERC) is the lead agency for the Alaska LNG Environmental Impact Statement (EIS). The U.S. Army Corps of Engineers (USACE) completed a final EIS in 2012 for the ASAP project and is now leading a supplemental EIS effort. AGDC has proposed both projects as having buried pipelines.

The ASAP final EIS characterized the pipeline as almost entirely belowground (BG) and did not consider an aboveground (AG) option as an alternative, with no objections by the lead or cooperating agencies at that time. Years later, after additional engineering, planning, and expense on behalf of AGDC, two cooperating agencies demanded the USACE consider an AG alternative. AGDC provided a cost analysis demonstrating the AG mode would be much more expensive and not practicable. AGDC also provided a technical and environmental analysis showing the BG alternative would be preferred for all areas, including the North Slope, for engineering reasons (constructability, reliability), safety reasons (protection, cover, security), and environmental reasons (fewer impacts to caribou; wetlands impacts could be mitigated). AGDC has demonstrated that through comprehensive monitoring, maintenance, and mitigation programs, the environmental impacts of the BG mainline will be less than or equal to those of an AG pipe. AGDC is concerned the cooperating agencies involved with the ASAP project, may not be considering the full range of reasons AGDC proposed to bury the pipeline and, instead, have focused on a single issue for selection of the project alternative on the North Slope. AGDC's full evaluation of the engineering, safety and security, cost, and all environmental information will support a decision to permit a buried pipeline on the North Slope and the remainder of the pipeline. The concerns discussed for the ASAP project are also relevant for the FERC led Alaska LNG project.

### ACTION REQUESTED

The USACE and FERC should consider the full range of reasons AGDC proposed to bury the pipeline instead of focusing on a single issue for selection of the project mode on the North Slope. Full evaluation of the engineering, safety and security, cost, and all environmental information will support a decision to permit a buried pipeline on the North Slope.

# 1. BACKGROUND

The Alaska Gasline Development Corporation (AGDC) is an independent public corporation owned by the State of Alaska. AGDC has proposed two options for development of a natural gas pipeline that will help to commercialize Alaska’s vast North Slope natural gas resources – a priority project that provides options for transporting gas to foreign markets, but also allows for in-state use (the Alaska LNG project), and a backup project that provides gas only to in-state markets (the Alaska Stand Alone Pipeline (ASAP) project).

The Alaska LNG project and the ASAP project face challenges in terms of construction cost and schedule. For both the \$40 billion priority project (Alaska LNG) and the \$10 billion backup project (ASAP), AGDC has proposed a buried natural gas pipeline from Prudhoe Bay to Southcentral Alaska that would span approximately 800-miles and take approximately three years to construct. In the case of Alaska LNG, the mainline is a 42-inch diameter temperature-controlled natural gas pipeline. The mainline from Prudhoe Bay to Southcentral Alaska is proposed as buried at a depth of at least 30 inches below the surface for the entire length of each project, except at major fault crossings, select bridge crossings, or block valves. For ASAP, it is a 36-inch diameter pipeline. Both gas pipeline options are cold temperature pipelines, unlike the Trans-Alaska Pipeline System (TAPS). TAPS is buried for many miles, including on the North Slope, and is a hot oil pipeline.

## 1.1 THE NATIONAL ENVIRONMENTAL POLICY ACT PROCESS

Both the Alaska LNG project and the ASAP project are engaged in separate National Environmental Policy Act (NEPA) processes. The NEPA process is overseen by a lead federal agency and several cooperating agencies to develop a document that characterizes environmental resources and evaluates environmental impacts of a project.

The Federal Energy Regulatory Commission (FERC) leads the Environmental Impact Statement (EIS) for the Alaska LNG project. The USACE Alaska District leads the EIS and supplemental EIS for the ASAP project. Noteworthy is the ASAP Final EIS, published in 2012, did not consider an AG mode as an alternative, and there were no objections from the lead or cooperating agencies to a BG pipeline at that time. This was followed by additional years of costly design and planning for a BG pipeline.

USACE published a full EIS without any mention of the need to elevate the pipeline above grade. During the supplemental EIS process (2014-2017), however, cooperating agency staff from the U.S. Fish and Wildlife Service (USFWS) Fairbanks field office and Environmental Protection Agency (EPA) Anchorage office, demanded an alternative analysis of an AG pipe, even though this was not the reason for the supplemental EIS. The reasons for the development of a supplemental EIS were a new conceptual design around barging in large modules to a port at Prudhoe Bay and making gas more available in-state through the transportation of lean natural gas. There were potential marine impacts at the northern port and socioeconomics impacts along the route, but USFWS and EPA took this as opportunity to delay the NEPA process by requesting the lead agency (USACE) provide a full analysis of an AG pipeline alternative. The cooperating agencies demanded an environmental impacts comparison of AG versus BG pipelines for the North Slope region, for the continuous/discontinuous permafrost region, and for the entire pipeline route. The two

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cooperating agencies have stated that burying the pipeline on the North Slope of Alaska (the first 60 miles) and potentially other areas to the south would have detrimental impacts to wetlands and arctic/subarctic habitat that would be difficult to recover. The USACE, as the lead federal agency, capitulated to the demands of the cooperating agencies and required AGDC to carry out a full analysis of the AG mode for a forthcoming draft supplemental EIS, resulting in lost time and resources. To have this occur in the supplemental EIS process without cause (i.e., negligible change to pipeline design for the supplemental EIS) is inconsistent with what was acceptable in the EIS for pipeline design. Although the USACE did not issue a Record of Decision (ROD) after the final EIS, AGDC acted upon the potential options put forward in the final EIS, continued with additional years of planning, and design for the BG mode leading up to the supplemental EIS.

At the request of the USACE, AGDC provided a cost analysis of the AG mode, demonstrating it would be much more expensive and not practicable. AGDC also provided a technical and environmental analysis showing the BG mode would be preferred for all areas, including the North Slope, for engineering reasons (constructability, reliability), safety reasons (protection, cover, security), and environmental reasons (fewer impacts to caribou; wetlands impacts could be mitigated). AGDC then provided additional technical reports related to the potential for slumping, permafrost degradation, wetlands impacts, and the influence of climate change.

AGDC is concerned the agencies preparing to issue a draft supplemental EIS may not be considering the full range of reasons AGDC proposed to bury the pipeline and, instead, have focused on a single issue for selection of the project alternative on the North Slope (see section 1.2). AGDC feels full evaluation of the engineering, safety, security, cost, and all environmental information will support a decision to permit a buried pipeline on the North Slope and the remainder of the pipeline.

The concerns discussed for the ASAP project are also relevant for the FERC lead EIS for the Alaska LNG project, as cooperating agencies for that project are likely to also request advancement of an AG mainline alternative for full analysis.<sup>1</sup> AGDC's analyses are thorough, and when considered in their entirety rather than focusing on a single issue, are sufficient for screening-level decision making to evaluate the pipeline alternative.

## **1.2 A BELOWGROUND PIPELINE WILL NOT BE MORE ENVIRONMENTALLY HARMFUL THAN AN ABOVEGROUND PIPELINE**

The USFWS and the EPA have raised concerns over buried pipelines, especially on the North Slope, claiming the construction of a buried pipeline would create large channels of open water over the pipeline and an eroded or unstable area that would likely never recover and would revegetate

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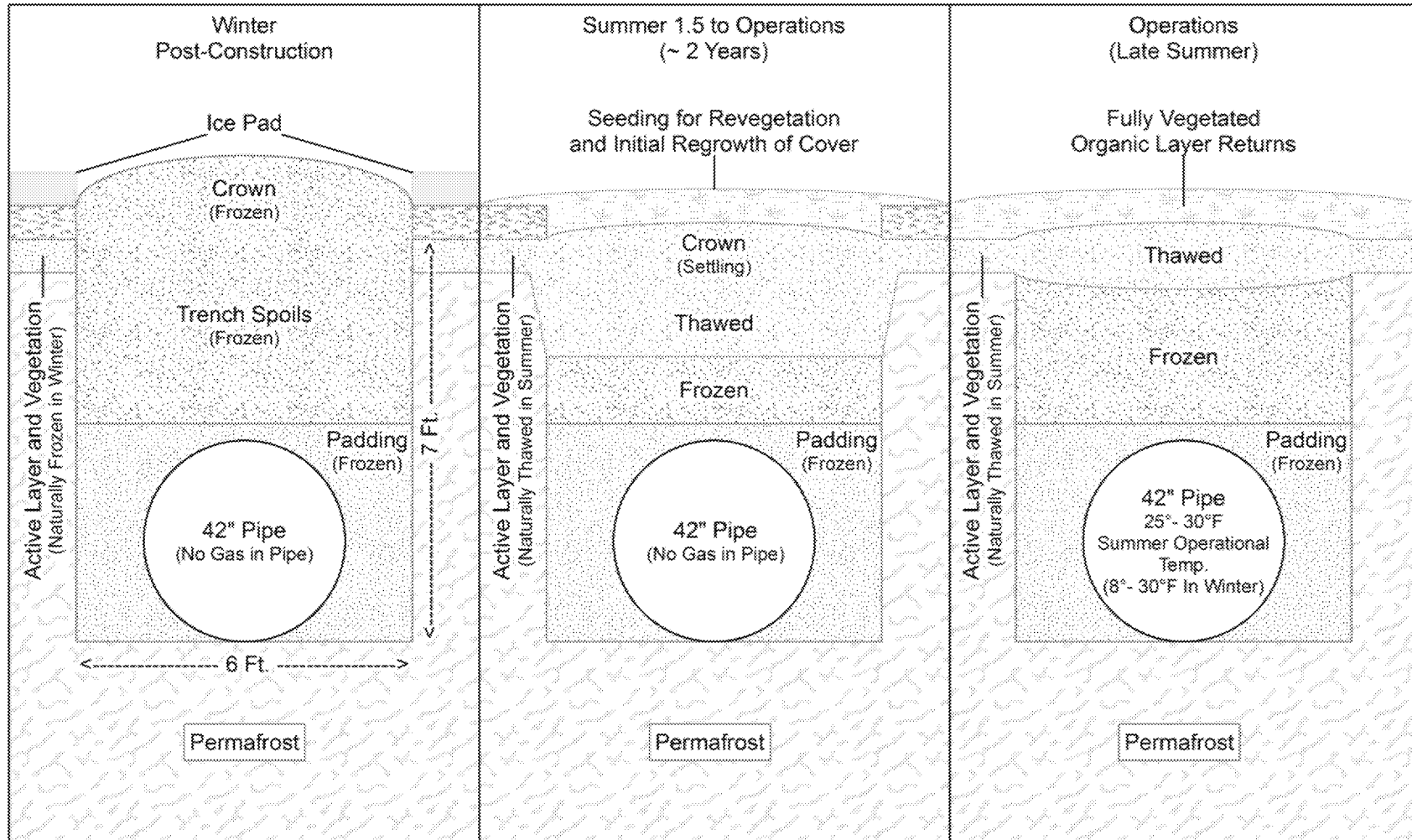
<sup>1</sup> For the Alaska LNG Project, the associated Point Thomson Transmission Line (PTTL) and Prudhoe Bay Transmission Line (PBTL) are designed as AG lines. The Point Thomson line runs east-to-west across the North Slope and is perpendicular to sheet water flow, which runs north-to-south in the same direction of the mainline, which is buried. The PTTL and PBTL are approximately 1-mile long pipelines and are fully contained within the Prudhoe Bay Unit. For these reasons, these supporting lines are proposed as aboveground, while the approximately 800-mile mainline is proposed as buried.

poorly. Comments from USFWS and EPA errantly suggest a BG pipeline might lead to long-term, non-correctable, and non-mitigatable impacts to the terrain.

AGDC has analyzed wetlands impacts, and has also modeled terrain units to evaluate the potential for slumping and drainage in discontinuous permafrost. AGDC proposes to mitigate any potential slumping in thaw-sensitive areas through use of strain based design. AGDC's analyses also take into account and model thermal degradation associated with ground disturbance and also models potential impacts of climate change. AGDC's Revegetation Plan (ASAP) and Restoration Plan (Alaska LNG) describe how impacted terrain will be stabilized and revegetated to the satisfaction of the landowner. AGDC has also explained how the corporation intends to implement a maintenance cycle standard to monitor, detect, and correct any potential issues related to water or erosion. AGDC has requested the agencies look not only to its own analyses, but also to the example of the buried sections of the Trans-Alaska Pipeline System (TAPS) as a stable example of a pipeline representing a more than worst-case scenario (hot oil vs. cold gas).

Some results from AGDC's technical reports are summarized in Attachment 1, while other additional reports have been submitted to the USACE. Through these technical reports, AGDC has demonstrated that the BG mode (Figure 1) is the preferred design for reasons related to engineering constructability, operational reliability, and to health, safety, security and the environment (HSSE). AGDC has proposed numerous measures to avoid, minimize and mitigate environmental impacts associated with the project, and use of a buried pipeline is critical to reducing overall environmental impacts, as demonstrated in Figure 1.

Figure 1. Construction, Operation, and Maintenance of the Buried Alaska LNG Pipeline in North Slope Permafrost (MP0 – MP60)



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## 2. DESIGN FACTOR EVALUATIONS FOR THE NORTH SLOPE – WHY THE BELOWGROUND MODE WAS SELECTED

Several factors were considered in the analysis and selection of the pipeline mode, including: safety and security, operational reliability, available line pipe technology, logistics and schedule, engineering design and constructability, environmental impacts, and cost. Following a review of both design modes, AGDC selected the BG mode as the preferred option for the North Slope. The Design Factor Evaluation is summarized in Table 1.

Table 1. Aboveground & Belowground Design Factor Evaluation Summary - North Slope

FACTOR	ABOVEGROUND (AG) MODE	BELOWGROUND (BG) MODE
<b>Pipeline Safety &amp; Security</b>	<ul style="list-style-type: none"> <li>• Would result in a higher likelihood of staff safety incidents; greater exposure from more complex logistics, longer to construct.</li> <li>• More susceptible to accidental damage (e.g., accidental bullet strike) and rupture.</li> <li>• More susceptible to terrorism or sabotage.</li> <li>• VSMs and snow accumulation may cause increased risk or hindrance to cross-country winter travelers.</li> </ul>	<ul style="list-style-type: none"> <li>• Would result in a lower likelihood of staff safety incidents.</li> <li>• Reduced probability to rupture due to accidental damage from external impact.</li> <li>• Less likely to be struck or sabotaged due to buried mode.</li> <li>• No risk to winter travelers.</li> </ul>
<b>Operational Reliability</b>	<ul style="list-style-type: none"> <li>• Potential for significant hydrocarbon liquid dropout during winter shutdown; slugging issue and longer restart time impacts gas delivery.</li> <li>• The pipe supports are designed to generally minimize thaw settlement or frost heave. Large settlements, should they occur, can be detected visually.</li> <li>• Maintenance work requires only access to pipeline (no digging).</li> <li>• Pipe may be more susceptible to corrosion due to the need for insulated jacketing, which can trap water.</li> <li>• May attract lightning once the pipe moves upward in elevation towards Atigun.</li> </ul>	<ul style="list-style-type: none"> <li>• No liquid dropout potential because gas remains at BG soil temperature and never reaches the critical temperature at which heavier hydrocarbons in the gaseous phase convert to liquid.</li> <li>• Potential for settlement and frost heave remediation during operations.</li> <li>• The position of buried piping would be monitored using in-line inspection tools containing an inertial measurement unit. The position data from each tool run can be compared to previous passes to determine whether excessive displacement has occurred.</li> <li>• Maintenance work could require construction of access roads, maintenance area workpads and excavation of the pipe.</li> <li>• Buried pipe will not attract lightning.</li> </ul>
<b>Line Pipe Technology</b>	<ul style="list-style-type: none"> <li>• Requires step-out technology for high pressure and toughness.</li> <li>• -50°F + environment, increases schedule risk (limited procurement options globally) and pipeline integrity risk (TAPS used 3 mainline pipe suppliers).</li> </ul>	<ul style="list-style-type: none"> <li>• BG line pipe is proven technology, and does not require low temperature steel requirements.</li> </ul>

FACTOR	ABOVEGROUND (AG) MODE	BELOWGROUND (BG) MODE
<b>Logistics and Schedule</b>	<ul style="list-style-type: none"> <li>• More complex logistics due to higher pipe tolerance and a more exacting installation process; installation of VSMs is time consuming.</li> <li>• Increased logistical challenges related to transport and storage of materials.</li> <li>• Increased logistical challenges related to training or scheduling of experienced welders to install pipe at 7ft, as required by North Slope ordinance.</li> <li>• Possibly two construction seasons (1 for VSMs, one for pipeline).</li> </ul>	<ul style="list-style-type: none"> <li>• Easier logistics of installation – chain trencher over ice pad; rigid side walls, easy welding / balancing; use of padding.</li> <li>• Fewer materials to ship.</li> <li>• One construction season.</li> </ul>
<b>Engineering Design and Constructability</b>	<ul style="list-style-type: none"> <li>• Challenging line pipe weld qualification program.</li> <li>• Induction bends may be needed at expansion loops, road crossings, and pipe rack crossings.</li> <li>• Insulation and jacketing needed to reduce the effects of heat transfer; these jackets can trap water and may make the pipe more susceptible to corrosion.</li> <li>• Pipe rack jumpers are needed to cross existing pipelines, primarily in the northernmost portion of the pipeline; can be complicated.</li> <li>• No cathodic protection required.</li> <li>• All AG pipelines must be modeled for susceptibility to WIV; can be mitigated through with balancing with weights/tuning mechanisms.</li> <li>• Susceptible to VSM movement from heaving and pinpoint pipe stress; cut and replaced VSMs that have heaved require continued monitoring and maintenance; can be mitigated somewhat with longer VSMs.</li> </ul>	<ul style="list-style-type: none"> <li>• Requires implementation of procedures required for impact avoidance and stabilization in permafrost areas.</li> <li>• Potential need for import of thaw stable backfill materials, ditch plugs, and other mitigation methods to ensure trench stabilization.</li> <li>• Increased reclamation efforts during operations.</li> <li>• BG construction can be completed sooner than the AG. Maintaining snow-free trench with multiple crews between trench and backfill will be challenging.</li> <li>• Potentially no need for induction bends except at gas treatment facility tie-in.</li> <li>• No need for insulation, as the gas will be operated below freezing to avoid thawing permafrost and ambient soil temperatures remain above the critical temperature year round.</li> <li>• No need for jumpers, as the pipeline will be buried under the existing pipelines and will cross them near mid-span between supports, where feasible.</li> <li>• Cathodic protection required for BG pipelines.</li> <li>• WIV is not a consideration for BG pipelines.</li> </ul>
<b>Environmental Impacts</b>	<ul style="list-style-type: none"> <li>• VSMs reduce pipeline impact to wetlands.</li> <li>• Increased direct/indirect impacts to subsistence activities and users.</li> <li>• Communities and non-government organizations express concern over impacts to subsistence activities and pipe in viewshed.</li> <li>• Low susceptibility to erosion; low to moderate level of stabilization effort required.</li> <li>• Major permanent visual resource impacts from ground and air – the AG pipeline will impact viewshed at ground observer height of 7–12 ft.</li> </ul>	<ul style="list-style-type: none"> <li>• Pipeline impacts to the organic layer minimized to 5-6 ft. wide; Mitigatable impacts to waters and wetlands</li> <li>• Minimal direct/indirect impacts to subsistence activities or users.</li> <li>• No pipe in the viewshed.</li> <li>• Erosion concerns mitigated with proper design, geotechnical information and water management/revegetation plans.</li> <li>• Increased stabilization efforts expected in first 5 years.</li> <li>• Minor long-term visual resource impacts – surface disturbance initially; revegetation.</li> </ul>
<b>Cost</b>	<ul style="list-style-type: none"> <li>• Higher capital expenditure (CAPEX) – significant cost upfront</li> <li>• Higher permanent materials cost; driven mostly by mainline pipe and vertical support system.</li> <li>• Transportation cost of materials will be substantial.</li> <li>• Higher staffing cost due to greater installation time will be substantial.</li> </ul>	<ul style="list-style-type: none"> <li>• Lower CAPEX – fewer materials and ease of installation.</li> <li>• Some added cost and logistics for select bedding/padding material.</li> </ul>

## 2.1 PIPELINE SAFETY AND SECURITY

### 2.1.1 CONSTRUCTION PHASE SAFETY AND SECURITY

Construction and personnel safety risk increases with an AG mode. This is a direct correlation with the increase in vehicle and equipment traffic and usage required to haul and install at least 5,000 vertical support members (VSMs) and horizontal support members (HSMs) prior to installation of the AG pipeline. The AG pipe must be hoisted, balanced, and secured at a height of at least seven feet to allow for wildlife passage, as required by North Slope Borough ordinance. The increased traffic and handling and extended construction season associated with AG construction would result in an increased probability for staff safety incidents.

### 2.1.2 OPERATIONAL PHASE SAFETY AND SECURITY

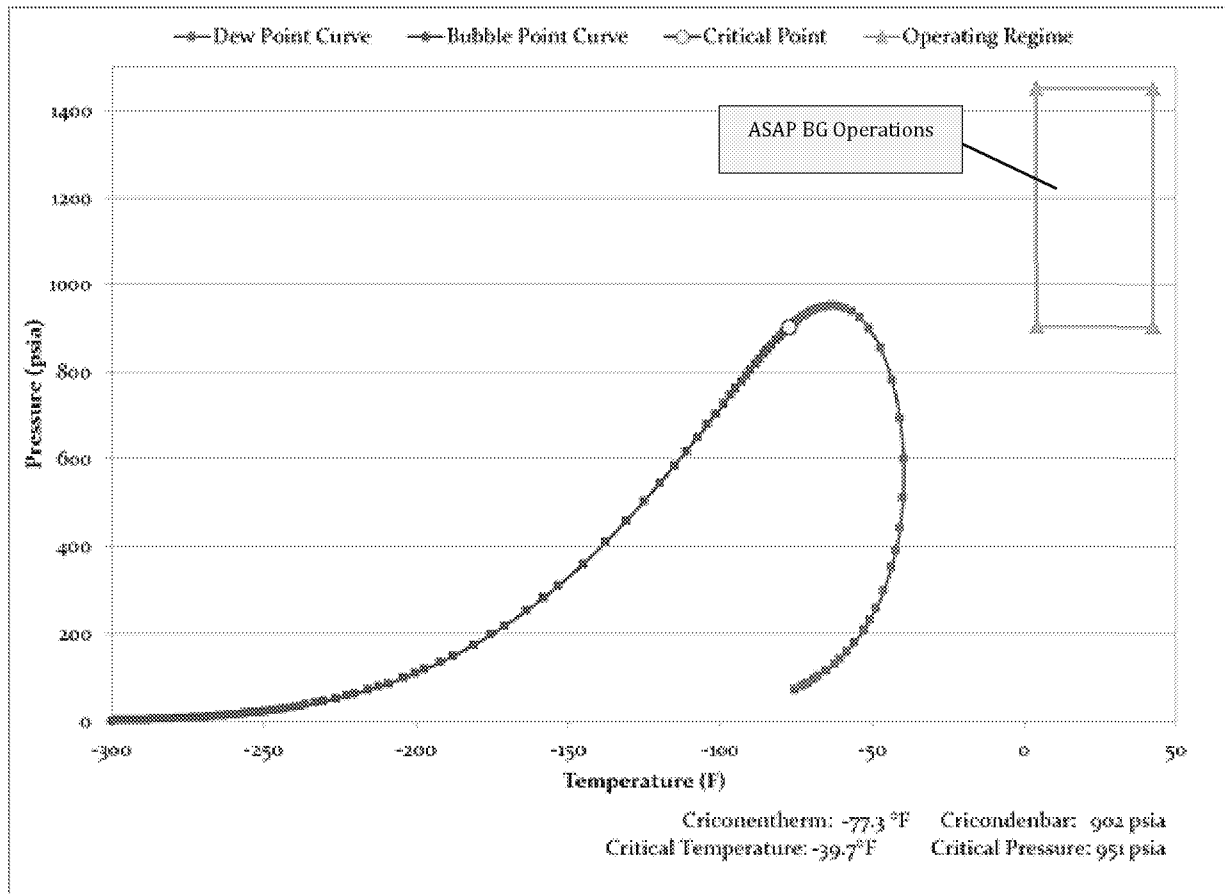
BG pipeline design and operations for natural gas transmission have proven reliability as it pertains to pipeline integrity and security. In the unlikely event of a BG pipeline failure, the intact sections adjacent to ruptures are restrained and in the event of ignition, protected from the effects of thermal radiation by the surrounding soil beyond the ends of the rupture. A near-vertical flame is typical of a relatively short BG pipeline failure.

The AG pipe is less secure than the BG mode, and it is more vulnerable to accidental and intentional damage (i.e., sabotage). An AG line could explode or leak if it is hit by accidental or intentional bullet strikes (a concern that arose in public meetings over the development of the Point Thomson Project). The pipe and VSMs are vulnerable to strikes from aircraft and ground-based vehicles. The AG pipe is also more vulnerable to terrorism attacks. Rupture of the AG gas transmission pipeline could cause significant damage to the support structures, along with consequent service disruption, potentially requiring mobilization of a significant reconstruction effort.

## 2.2 OPERATIONAL RELIABILITY

The phase envelope is a significant consideration in natural gas pipeline mode evaluation on the North Slope because of the potential for the transported gas to transition from a single-phase (gas) to two phases (gas-liquid). There is no chance of two-phase flow as long as the pressure and temperature conditions within the pipeline remain outside of the gas phase envelope in all instances (e.g., the BG scenario, as BG temperatures will never get cold enough). However, in the event of a prolonged shutdown during winter that resulted in a pressure drop, the AG mode would subject the pipeline to hydrocarbon liquid dropout at cold ambient temperatures (Figure 2). This would subsequently lead to substantial pooling of liquids at low elevations or at low spots and bends in the pipe.

Figure 2. Phase Envelope Diagram (ASAP Example)



BG temperatures will never be low enough to put the pipeline at risk of hydrocarbon liquid dropout and severe mechanical disruption (e.g., it can never move completely from the green box, representing operational pressure/temperature, to inside the red/blue phase envelope, during which liquid dropout occurs). Reduced pressure during prolonged shut down during a cold winter in the aboveground (AG) mode would put the pipeline at risk of moving inside the phase envelope, causing extensive pooling of liquids and severe mechanical disruption.

Should this scenario occur for the AG design, condensate formation inside the GCF and the pipeline will occur. The volume of condensate yielded can be predicted by analyzing the gas phase compositions upstream and downstream of a potential condensation location and determining the gallons of liquids per thousand standard cubic feet of gas for the liquefiable components in each stream.

The pipeline facilities (gas treatment/compressor stations) and pipeline are not designed to manage a liquid volume load from the mainline. Hydrocarbon liquid dropout in the AG pipeline could result in an extended shutdown due to the difficulty in cleaning, drying, and restarting a blocked pipeline. In contrast, a winter shutdown of the BG pipeline would never result in hydrate formation since the winter ground temperature is warmer than the temperature at which single-phase gas can become a two-phase gas-liquid combination.

### 2.3 LINE PIPE TECHNOLOGY

The BG case design temperature is colder than the winter soil temperature at the depth of the buried pipe. The AG case design temperature of -50°F is due to the winter air ambient temperature. At this temperature or below, special operational measures, such as lowering pipeline pressure, may be required. Pipe sources may be limited to large Longitudinal Submerged Arc Welded (LSAW) pipe manufacturers due to the large diameter, wall thickness, grade strength and low temperature design requirements of the pipe. For AG pipe, the number of potential manufacturers will be even more limited due to pipe specifications requiring increased wall thickness, and lower temperature design capabilities.

### 2.4 ENGINEERING DESIGN AND CONSTRUCTABILITY

For the AG mode, the VSM installation process is extremely costly, time consuming, and would require increased logistical efforts, material handling challenges, and additional schedule risk. When compared with the BG case, the AG case would require a substantial increase in barge shipping and domestic highway truck traffic for hauling additional materials, such as VSMs, HSMs, slides, guides, and anchors. AG installation is also likely to result in greater personnel and scheduling challenges, including the need for more out-of-state labor or more in-state labor training. The AG mode would require a separate weld qualification program, in addition to that for the mainline for workers and installation of VSMs structures noted above.

The BG case would require the use of an ice pad for transport of the pipe on heavy equipment, including a chain trencher, sidebooms, and trucks (see Figure A1-1 in Attachment 1). A trencher running over an ice pad would cut a 5 to 6 foot wide trench through the soil to minimize impacts of construction. Bedding and padding would be installed against vertical sidewalls. Soils would be scraped back into the trench and crowned with additional spoil. Winter construction would result in a lower probability of staff safety incidents. Attachment 1 provides the details of Planning, Construction, Operation, and Maintenance Procedures.

Former Alyeska Pipeline Service Company staff recommend crowning the surface of the filled trench with soil in winter to an elevation slightly above the surface of the tundra. The goal is to have an even-lying surface at the impacted area over the pipe in summer, once processes of thawing, natural gravity compaction, and some drainage have occurred so that stabilization through revegetation and maintenance can proceed. After installation, the pipe would be monitored as part of the field surveillance program to address slumping, heaving, or ponding issues, employing the maintenance cycle standard of “Monitor, Detect, Correct” to ensure that these conditions are addressed in a timely manner.

The AG mode would require installation of the pipe on more than 5,000 VSMs, similar to what TAPS uses in its aboveground sections, to support the large diameter pipeline above the tundra. This assumes a single VSM structure. If a dual VSM structure is required (two vertical support members at every location) this number could increase to over 10,000 VSMs. If an AG mode was required for more than just the North Slope (first 60 miles), the need for VSMs would be much greater.

The VSM installation process required for an AG mode is more costly, more time consuming, and more complex than the BG mode. Increased and more complicated logistical efforts include additional material handling challenges, more barge, rail, and highway truck traffic, additional schedule and safety risk, more challenging welding and balancing procedures, and increased structural challenges and risks related to wind or frost heaving, leading to VSM movement.

Complex welding and balancing procedures are required for the AG mode because pipe tolerances are much more exacting. AG installation would be more complicated, would take longer, and would potentially result in personnel and scheduling challenges to ensure additional experience was applied to the pipeline installation process. For these reasons, it is possible that the AG mode could add an additional year to pipe installation and disrupt the project-wide construction schedule.

#### 2.4.1 WIND INDUCED VIBRATION

The AG mode would be required to address Wind Induced Vibration (WIV), a phenomena in which wind damages a linear structure by forcing it to vibrate at its natural frequency. WIV famously lead to the destruction of the Tacoma Narrows Bridge in 1940, and there have been some instances of pipelines impacted by WIV failures on the North Slope. AG pipelines must be modeled for their susceptibility to WIV. The effects of WIV are mitigated by placing appropriate weights and tuning structures on or near the center of the span between the VSMs. AG pipelines on the North Slope that possess a north-south alignment are typically more susceptible to WIV than pipelines with an east-west alignment, because the prevailing winds blow in an east-west direction in the Kuparuk and Alpine areas. BG pipelines are not susceptible to WIV, and do not require weight or tuning structure setting, monitoring, or maintenance.

#### 2.4.2 FROST HEAVING AND THAW SETTLEMENT

The AG pipeline would be susceptible to uplift bending if the VSM support structure moved due to frost heave. VSM holes can extend from the surface down to a 15-20ft depth and can collect water when open or while they are settling. VSMs also conduct heat between the air and the ground. In certain conditions these processes can exacerbate frost heaving and lead to VSM upheaval. VSM upheaval is usually mitigated during the design phase of the project by utilizing geotechnical information and predicting how much VSM embedment is required to reduce movement. Engineers typically add additional VSM length below grade to mitigate against vertical movement.

When a VSM moves upward after pipeline installation, the conventional maintenance solution is to drill and set two more VSMs on either side of the heaving VSMs (this requires ice road access on both sides of the pipe) and then provide support at grade while the pipe is lowered onto the HSM. Additional maintenance will still be required for the heaving VSM, as it will probably continue to heave and will need to be cut to keep from impacting the pipeline. VSMs in wet areas also have a tendency to settle and drop in elevation. In an AG scenario, thaw settlement that causes a VSM to drop in elevation could place stress on the pipe and the adjacent VSMs.

BG pipelines are susceptible to frost heaving and settlement, but because VSMs are not used in the BG mode, there are no issues related to open holes collecting water or having long, metal posts conduct heat between the ground and the air. Based on geotechnical data, AGDC engineers and contractors believe the risk of BG pipe heaving is very low for the first 60 miles. For the BG mode, long, continuous segments of pipe surface area are supported by the ground. This allows the BG pipe to tolerate moderate heaving and exhibit flexibility better than an AG pipe, which is supported by pipe shoes, which are relatively short when compared to the length of the pipe span. The BG pipe is bedded with thaw-stable, non-frost susceptible materials and will operate at below-freezing temperatures of approximately 8-30°F in winter and 25-30°F in summer (Figure 1). This helps to mitigate against permafrost degradation, pipe thaw settlement, and surface slumping. Pipeline integrity will be monitored regularly through the use of inline inspection devices (smart pigs).

## 2.5 LOGISTICS AND SCHEDULE

North of the Brooks Range, the end of the winter season is late April or early May. This yields a duration from early January to late April for pipeline construction of up to 120 days. An AG design would require installation of VSMs at approximately 5,000 locations. It is possible an AG design could require two winter seasons: the first for installation of VSMs and the second for the installation of the pipe. This would impact cost, schedule, and simultaneous operations with other mainline spreads, camp space, and logistics.

For BG design only one winter season would be required. The winter section lengths were planned to allow as much time as possible between the completion of the pipe laying and the end of season dates, allowing adequate time to complete coating, cathodic protection, lowering-in, bedding, padding, backfill, tie-ins, and cleanup.

The civil contractor will construct an ice work pad on the Right of Way (ROW) prior to pipe stringing. Frost packing of the ROW with tundra-legal equipment could begin in November, but on tundra ice pad construction is assumed to start in early or mid-December. The ice pad crew will ensure that enough ROW is prepared ahead of the pipe lay crew. The entire section is flat terrain and will be constructed during the winter pipe lay season.

## 2.6 ENVIRONMENTAL IMPACT

### 2.6.1 SOILS AND HYDROLOGY

The BG mode requires specific procedures for adequately controlling soil erosion along the constructed pipeline. AGDC is working with the Alaska Department of Natural Resources (ADNR) Plant Materials Center to develop specific revegetation procedures in a Revegetation and Erosion Stabilization Plan for the Project. Implementation of these specific procedures will help to reduce soil erosion and improve stability through revegetation and other means.

The BG mode also requires specific procedures for adequately managing water along the constructed pipeline, including surface water and subsurface hydrologic flow. ASAP has retained the services of individuals with over 30 years of experience stabilizing and maintaining TAPS on

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the North Slope to assist in the development of these procedures. Based on the recommendations of these individuals, AGDC's goal is to maintain natural surface water flow patterns with as little change as possible.

AGDC's goal will be to maintain a stable surface and to manage water and drainage within the ROW during operations and maintenance. AGDC will apply a programmatic maintenance cycle standard of 'Monitor, Detect, Correct' to its soil stabilization and water management efforts during the operations and maintenance phase of the project so any potential issues related to erosion, slumping, ponding, or inadequate drainage can be addressed in a timely manner.

## 2.6.2 PERMAFROST

Impacts to North Slope permafrost will be minimized by:

- Constructing in winter and restricting impacts to the organic layer to a very small footprint (a 5 to 6 ft. wide trench will be dug and filled with thaw stable bedding and padding, the pipe, and trench spoils in winter).
- Use of ice pads, frost packing, and ice roads during winter construction to avoid unneeded disturbance to the organic layer.
- Reducing the pipe dormancy period to only two years and maintaining a year-round operational temperature of the pipe that is below freezing for the first 60 miles (see Figure 1).
- Maintaining existing surface water channels in their natural flow path to avoid water seepage into the area of the filled trench.
- Seeding the first summer after construction with a mixture of annuals and native seeds to regrow the organic layer and replace a vegetative covering as soon as possible.
- Instituting a programmatic maintenance cycle standard of 'Monitor, Detect, Correct' for hydrology.

## 2.6.3 WETLANDS, VEGETATION, AND LAND

The overall acreage impact to wetlands and vegetation on the North Slope due to the pipeline would be greater for the BG design than the AG design because of trenching, in comparison with the "posthole footprint" that would result from VSM installation under the AG option. However, in the BG mode, a route was selected to avoid wetlands of higher functional values whenever possible. Upland areas were targeted, and open water areas were avoided where possible.

Seeding and revegetation for the BG mode will be done with approved seed mixes that include native species and other annuals. As noted above, AGDC will work with the ADNRC Plant Materials Center to develop a specific plan for revegetation and stabilization that will provide specific information on seed mixes, mulches, hydro seed applications, clearing, maintenance, and

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monitoring. Upon completion of use of the ROW, AGDC will be required by lease stipulation to restore the land to the satisfaction of ADNDR.

#### 2.6.4 ENDANGERED SPECIES AND OTHER FAUNA

Habitat for eiders and other waterfowl is potentially impacted by the AG and the BG design. The BG design would have more impacts to wetlands, but the difference in how waterfowl would use the area over or under the pipe is unknown and may be negligible. The BG alignment was specifically selected to minimize impacts to existing ponds and other higher value wetlands. It is not known if the visual perception of an AG pipeline or disturbance from a BG pipeline could deter birds or fragment habitat, or even be used as a means of navigation from the air. The AG pipeline would be expected to result in some minimal nighttime bird strikes resulting in mortality or injury.

While habitat is often only discussed or mapped 2-dimensionally, the reality is habitat is the 3-dimensional space that fauna occupy or use. Behavior and habitat use by waterfowl and other fauna could conceivably be even more impacted by an AG pipe and VSMs (visual disturbance, strikes, shading and plant growth, snow accumulation or blockage, and long-wave radiation impacts on snow); whereas the BG design would be a revegetated corridor maintained for operation.

Wildlife migration and subsistence users would not be impacted substantially by the BG mode, but the AG mode could potentially impact wildlife migration and subsistence activities. Subsistence users have previously commented on the impacts of proposed AG features on the North Slope. Transcripts from the TAPS renewal Draft EIS Public Hearing in Barrow, Alaska recorded North Slope Borough (NSB) Mayor George Ahmaogak’s public testimony, as he spoke on behalf of the NSB in regard to his concern about additional AG features that could impact wildlife on the North Slope. Mayor Ahmaogak commented that:

“Caribou migration patterns were altered, changed by construction of the Trans-Alaska Pipeline system and the associated Dalton Highway. Studies, scientific studies utilizing radio collars on caribou indicated that to a great extent, these obstacles continue to impede the free movement of the affected North Slope herds... Subsistence users in our communities of Nuiqsut and Anaktuvuk Pass have long noted these changes and they have to cope with the absence of game in traditional harvest areas.” (BLM TAPS renewal hearing)

An additional AG feature on the North Slope in the same vicinity of TAPS and the Dalton Highway could potentially impact caribou behavior and movement. Burying the pipeline on the North Slope is likely to reduce impacts to wildlife migration and movement, particularly caribou. Surprisingly, the Center for Biological Diversity expressed concerns over the AG design impacting caribou over the first 6 miles of the route during the DEIS, citing “adverse impacts” to large migratory mammals. Their comments also mentioned that the AG portion of the pipeline on the North Slope could “delay caribou movements” and that it might disturb herds or individuals. They also stated:

“The Bureau of Land Management has identified numerous potential adverse effects of less extensive pipelines and also indicates that onshore gas activities, especially roads, can displace

caribou and reduce caribou densities for miles. Snow drifts under a pipeline can block or interrupt caribou movements.” (Center for Biological Diversity comment on ASAP DEIS)

Furthermore, the USFWS reviewed the ASAP Project during the EIS review period and published the results of its evaluation in a formal legal document, termed a Biological Opinion (BiOp), dated July 10, 2012. In its BiOp, the USFWS specifically identified and described the AG and the BG mode on the North Slope, including geographic and design features of each. The BiOp expressed no concern over impacts associated with use of the BG mode through permafrost areas, nor did it reference any expected impacts to water, soils, or endangered species habitat. To the contrary, the USFWS stated that the proposed design is, “not likely to adversely affect Steller’s eiders” and is, “not likely to jeopardize the continued existence of spectacled eiders or polar bears, and is not likely to destroy or adversely modify polar bear critical habitat” (USACE FEIS). However, during the ASAP Supplemental EIS process years later (2014-2017), the USFWS has made many comments requesting an AG pipe, contributing to significant delay in completing the NEPA process and resulting in the USACE carrying forward several AG alternatives in the Draft Supplemental EIS. Similar comments have been made by USFWS and EPA staff to FERC for the Alaska LNG Project, and AGDC expects that these cooperating agencies will attempt to persuade FERC to carry forward AG alternatives.

#### 2.6.5 OTHER ENVIRONMENTAL IMPACTS

A BG pipe mode would also reduce viewshed impacts to human residents. An AG pipeline for 60 miles is a substantial 30+ year permanent viewshed impact compared with a BG trench that will be stabilized, in part, through revegetation. Snowdrifts caused by the AG mode and VSMs also can present an impediment and a safety hazard to hunters or other travelers traversing the tundra by snowmachine.

#### 2.7 COST

The AG mode will have a higher installation cost than the BG mode and will substantially increase the Project’s capital expenditures (CAPEX) (Table 1). The higher costs associated with the AG mode are associated with increased amounts of materials, material transportation and handling, and more staffing time due to a longer installation process. These higher costs associated with the AG pipe would be passed on to consumers (residents, businesses, government entities, and projects) through higher tariffs and burner tip rates, whereas the BG gas would provide cheaper gas for Alaskans.

### 3. WHY THE ABOVEGROUND PIPELINE MODE WAS NOT SELECTED

The AG pipe option was not selected for the first 60 miles of the pipeline on the North Slope. The engineering reasons for not selecting this option lie in challenges to constructability, increased operational risk, more complex logistics, and higher project costs. Other considerations are the security of the AG line, impacts to visual resources, public comments on impacts to subsistence species, such as caribou, environmental impacts to aquatic habitat, and impacts to non-aquatic wildlife during both construction and operations.

The AG procedure requires more equipment, more material, more temporary support infrastructure, and more time to construct than the relatively simpler process of trenching, bedding, padding, and covering with backfill. There is also increased time and effort required for balancing the VSMs and aligning the pipe on the VSMs.

In the AG design that was not selected for the North Slope component of the project, the pipeline is supported at intervals by engineered structures, typically constructed of steel or concrete. The impacts of WIV and frost heaving of VSMs create unique challenges. The vertical separation of the pipe from the subsurface eliminates consideration for geohazards resulting from changes in subsurface support, such as thaw settlement. The support structure is typically a round structural member with embedment designed to resist axial and longitudinal loadings transmitted to the support from the pipeline. The pipe itself, not being constrained by surrounding soil, is thus free to expand and contract in response to such loadings as operational changes in temperature. Consequently, the longitudinal stresses induced in the pipeline are relatively small, provided the supports are spaced appropriately. However, the displacement of the pipe on the supports must be accounted for by installation of expansion loops.

This type of installation is typical on the North Slope of Alaska where hot, buried pipelines could disrupt the permafrost conditions. It was also the solution of choice for TAPS to mitigate the effect of thaw settlement; approximately half of its length is aboveground (greater than 400 miles). Natural gas pipelines, which typically run chilled or near ambient temperature, have less of a technical requirement to avoid burial.

The technical disadvantages to the AG scenario include flow assurance considerations for the natural gas product to ensure there is no liquid dropout that could collect and cause internal corrosion. The pipe material may be subject to low temperatures from the ambient conditions, and may require special fracture control provisions. There are also well-known disadvantages for its use which may be more pronounced for Alaska LNG or ASAP, especially if used along the Dalton Highway Corridor: the configuration is highly visible, must allow for passage beneath the pipe, must allow for lateral variations in the ROW to accommodate expansion loops, and would be subject to additional security concerns.

**4. ATTACHMENT 1. BELOWGROUND PIPELINE PLANNING,  
CONSTRUCTION, MONITORING, AND MAINTENANCE PROCEDURES  
FOR ALASKA'S NORTH SLOPE**

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# 1. PRE-CONSTRUCTION PLANNING

## 1.1 GEOHAZARD AVOIDANCE AND SPECIAL DESIGN AREA ENGINEERING

The pipeline route and design were developed and refined in consideration of extensive hydrologic, geologic, and geotechnical data. AGDC has developed a robust geotechnical program where engineers have acquired a significant body of information that will continually be supplemented up through construction to best inform the engineering design team. This information was utilized in evaluation of the BG and AG modes and the route alignment. As part of this program, engineers have acquired and reviewed:

- Orthorectified aerial photography (approx. 3,733 sq. mi.).
- Digital Elevation Modeling (DEM) derived from LiDAR surveys (approx. 2,079 sq. mi.).
- Terrain unit mapping.
- Borehole soils data (including access to over 10,000 discrete boreholes).
- Permafrost investigations and ground temperature monitoring.
- Geohazard Evaluation and Mitigation Analysis Reports (GEMARs) covering topics such as Hydrotechnics, Soil Geochemistry, Unique Soil Structure, Surface Fault Rupture, Tectonics and Seismicity, Landslides (slope stability), Erosion and Buoyancy, Freezing of Thawed Soils and Thawing of Frozen Soils.
- Assessments of potentially active tectonic faults.
- Trip reports from multiple field reconnaissance investigations or site visits.

These engineering reviews were important for long-term soil stabilization, pipeline integrity, avoiding burial of the pipe in areas sensitive to thaw degradation, and burial of the pipe in areas susceptible to seismic disturbance or major fault movements. Special design areas included fault crossings, water crossings and pinch points (e.g. Atigun Pass, Denali commercial area). AGDC engineers also worked with the Alaska Division of Geological and Geophysical Surveys (DGGS) and supported their efforts to identify and assess of geologic hazards along the pipeline route, although the majority of these potential hazards were south of the Brooks Range.

Conditions have been identified through AGDC's geotechnical program that may cause ditch displacement and subsequent pipe curvature and distress. This requires experience in identification of those surface characteristics that have been shown to contribute to potential route hazards, followed by an extensive subsurface investigation program to identify the remaining hazard, and, finally, analytical design tools to quantify the effect on pipe behavior. As the samples recovered from the boreholes are processed by soil laboratories, the results feed into the projects' respective geospatial information system (GIS) and geotechnical databases, and then are used in the evaluation of route hazards. The process of route threat identification, evaluation, and avoidance is an ongoing process for which many aspects will continue throughout the operational life of the Project.

## 1.2 AVOIDANCE OF HIGH VALUE WETLANDS

While approximately 83 percent of the North Slope is considered wetlands; these wetlands vary in their intrinsic value based on the function they provide in the ecosystem. The current pipeline route used aerial photography and approved wetland field survey methods to delineate wetlands,

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develop an aquatic site assessment to rank functions and values of wetlands, and to route the pipeline around open water and higher value wetlands where possible.

### 1.3 WATERWAYS ANALYSIS

AGDC’s waterways engineers have spent several summers of field work assessing flow and stream bank characteristics of the streams along the pipeline route. The reason for this work is that it will be important for AGDC construction engineers to maintain existing surface water flow following burial of the pipe in winter. AGDC plans to carry out work on the North Slope in winter when water is frozen, and then work in the years following construction to ensure minimal disruption to surface water flow patterns, ensuring that water does not get directed into the trench and instead continues in its naturally flowing direction towards larger waterbodies.

## 2. CONSTRUCTION OF THE BELOWGROUND PIPE

### 2.1 ICE ROADS, ICE PADS, AND FROST PACKING

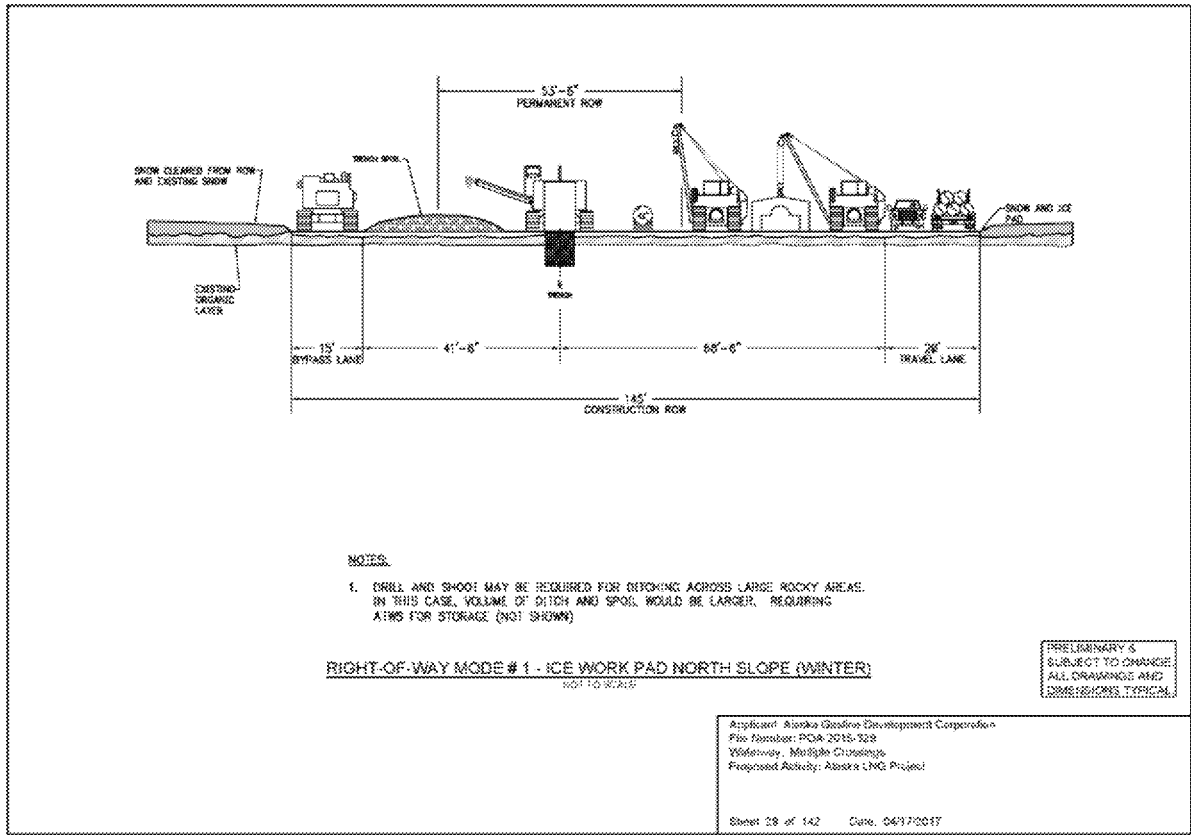
Mitigation measures will be used during pipeline construction on the North Slope to protect high value wetlands and avoid disturbing the organic layer and permafrost. Ice roads and pads will be constructed in order to provide a flat, stable working surface and move heavy equipment along the pipeline route on the North Slope. Frost packing (use of condensed snow as a driving surface) will also be used in some areas, where possible.

### 2.2 TRENCHING AND PIPE INSTALLATION

Heavy equipment working over an ice workpad (trencher, sidebooms, and trucks) will work north-to-south to dig a 5ft-wide trench to the desired depth (generally, 6ft.), casting spoils to the opposite side of the trench. Heavy equipment and trucks will drive on the working side of the trench, which will be protected by an ice pad and result in no impact to wetlands from transportation. A trencher, which is not compatible with large cobble or boulder areas, can be used because of the presence of a uniform deposit of fine-grained soils within trench depth on the ACP. The trencher will drive over an ice pad while digging the trench. Trench spoils will be cast onto the spoils side of the trench (opposite the working side of the trench), onto either ice, frost packing, or snow. Soils will be backfilled into the trench after installation (see below for more detail).

It is unlikely that the entire volume of trench spoils will be able to be immediately removed from the snowpack on the spoils side of the trench. A thin layer of spoils is likely to remain on the spoils side of the trench. Some of this material may be used to repair slumped areas or re-inforce crowns that will be re-seeded and revegetated after spring thaw. Any remaining trench spoil lying on the spoil side of the trench may ultimately be removed in a future winter or may be revegetated. Upon digging the trench, construction teams will assess surficial and subsurface hydrology, as well as the potential for erosion and ponding. Engineers will use this information to inform their decisions for placing ditch plugs or other subsurface hydrology control measures where possible.

Figure A1-1 Pipeline Construction on Alaska’s North Slope



Installation of the buried Alaska LNG pipeline on the North Slope in winter would occur using a 6-ft wide chain trencher operating over an ice pad. The rigidity of the frozen soils and the soil type would allow workers in and out of the ditch without need for expanding the side slopes of the ditch.

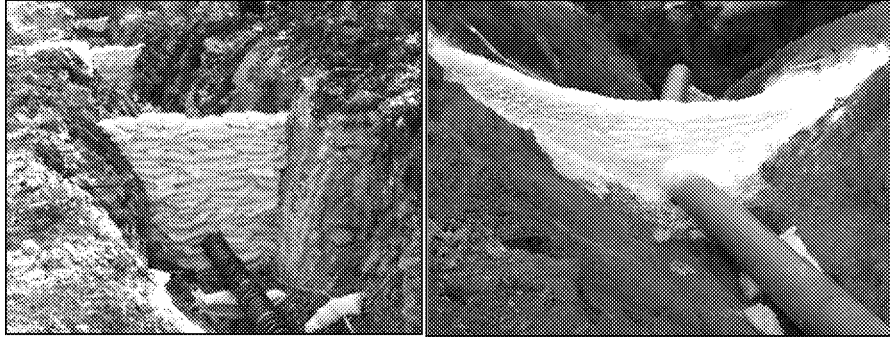
**2.2.1 THAW-STABLE BEDDING AND PADDING MATERIAL**

After trenching is completed, non-native bedding and padding material will be added. This material will be mined to meet project specifications. The bedding material will be thaw-stable in order to provide required structural support to the pipeline and avoid settlement.

**2.2.2 DITCH PLUG INSTALLATION**

Ditch plugs are designed to stop water flow through the trench line and therefore mitigate against undesired waterflow or seepage; they can be made from different types of materials (Figure A1-2). Ditch plugs are typically installed on each side of an excavated water crossing and in other locations along the ROW as required and directed by the owner’s ROW inspector. They are useful in avoiding French drain effects, and can be used to direct and inhibit the flow of water. Experts who formerly worked on TAPS with Alyeska Pipeline Service Company have recommended a higher number of ditch plugs for the gas pipeline than was used on TAPS to help control water and reduce ponding. Ditch plugs will also be used in the trench on either side of stream crossings to ensure water does not penetrate into the ditch.

Figure A1-2. Ditch Plugs Made from Different Types of Material



Examples of different types of ditch plugs used for water management in buried pipeline construction

### 2.2.3 DITCH BACKFILLING

The pipeline will be placed within the trench during the same winter construction season in which it is dug. The pipe will be padded with thaw-stable material, and the remaining portion of the trench will be filled with native trench spoils or other select backfill. Per federal regulation, at least 30 inches of normal soil cover must be used to cover the pipe. During construction, soil will be replaced soon after the pipeline section is laid down to reduce the introduction of snow or rain into the trench. Seeding of the backfilled trench will be monitored after construction to confirm that the reseeded ditch line supports continued long-term plant populations and that fill above the pipe does not erode.

### 2.2.4 CROWNING

The excess trench material will be used in trench crowning (a very slight mounding over the pipe), contouring terrain, and other stabilization and mitigation efforts. Some of the excess spoil material overlaying existing vegetation may be hauled off to disposal sites, or it may be seeded or left in place, depending on Project operational and maintenance needs at that time. The slope of the crown over the trench is critical to stabilizing soils and directing ponding, thereby mitigating some potential impacts related to erosion and drainage. In crowning, the native material that is replaced over the trench is almost near to flat.

Crowning is a procedure that is important for both soil stabilization and water management. It is characterized as a mild mounding of trench spoils above the pipeline trench to an appropriate finish grade that will help to direct moisture away from the top of the pipe and mitigate against slumping. Crowning promotes movement of water along a desired vertical and horizontal gradient. As the ditch soils thaw in spring, the extra weight and height of soil will compact the soil below and bring the surface above the pipeline near to flat.

- Options available to direct flow from the crowned trench line include:
- Installation of wattles (intentional depressions) at an angle and at predetermined spacing along the crowned trench line based on slope angle to direct flow away from the ditch line.
- Installation of flexible piping to carry offsite and upgradient water across the ditch line to vegetated downslope areas.

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- Periodic installation of armored flow breaks in the crowned section to transfer water from one side of the ditch line to the other for storm drainage.
- Use of native fill berms to direct flow away from the crowned ditch at specified intervals based on slope.
- Construction of drainage channels to direct flow from the construction area.
- Installation of permanent culverts in some areas.
- Development of earthen ditch blocks used to retain or direct water.
- Use of gravel or gabion channels or swales.

#### 2.2.5 TERRAIN CONTOURING

Terrain contouring is a procedure that is important for both soil stabilization and water management. It is the use of excess ditch spoils and/or other materials to contour surrounding terrain in an effort to control or reduce erosion through the control of hydrologic movement, as needed to promote preferential surface and subsurface flows. Material sites, camp sites, ice roads and pads, temporary-use areas, and temporary access roads will be re-contoured and restored to an acceptable condition as required by applicable permits. Generally, revegetation of disturbed areas is planned for long-term stabilization.

#### 2.2.6 CLEANUP

Following pipe installation, ditch backfilling, and hydrotesting, crews will perform cleanup, including leveling of the pipeline ROW and shaping of a crown over the pipeline ditch, as required. Crews will dispose of remaining scrap materials, timber, or other debris. Wood debris will be disposed of, and scrap materials and rubbish will be hauled to designated waste accumulation locations, incinerated, hauled to a permitted landfill for disposal, or some combination. Crews will be equipped with dozers, front-end loaders, and dump trucks to facilitate clearing and construction ROW cleanup. Snow pad areas will require a summer cleanup check to verify that construction materials were removed from the construction ROW. Remaining debris will be removed using low-ground-pressure vehicles to minimize disturbance to surface vegetation.

#### 2.2.7 DORMANT PERIOD

The BG pipe and surrounding material (bedding/padding, trench spoils, crown) and permafrost will remain frozen in place up through spring/summer melt (Figure 1). At that time, the crown and back-filled trench spoils will settle over the pipe and the thaw-stable bedding. The surrounding permafrost will melt slightly around the portion of the trench that thaws (Figure 1). The pipe will lay dormant at ambient temperature for approximately two years without any flow of gas while construction and testing of the GCF and pipeline occur and are completed.

### 3. POST-CONSTRUCTION MONITORING AND MAINTENANCE

#### 3.1 EXPERIENCED PERSONNEL AND PRECEDENT

AGDC has retained the services of engineers and environmental scientists with 30 years of experience in stabilizing soils and managing hydrologic issues associated with other buried pipelines in Alaska, including some on the North Slope. These experts include Pipeline and Civil Maintenance (P&CM) engineers for Alyeska Pipeline Service Company and other experts who have experience with TAPS, a pipeline that has several belowground sections on the North Slope. These experts have first-hand knowledge and experience implementing successive-year soil stabilization and water management techniques and assessing needs to mitigate against erosion. These individuals have contributed to the development of stabilization measures for the first five years after construction and to the long-term maintenance planning efforts for the gasline.

#### 3.2 TRENCH STABILIZATION

Monitoring and re-stabilization will occur in the years after construction of the pipeline to ensure resulting environmental impacts are minimized and that any unexpected impacts are addressed through additional required action. Stabilization of the backfilled ditch may be a multi-year process in some areas, particularly areas with fine-grained, ice-rich soils. Rehabilitation, especially in ice-rich soils, may require trench maintenance and long-term thermal stabilization activities before the habitat achieves stability.

#### 3.3 EROSION CONTROL

Storm drainage design at the surface above the pipe will help to control flow along the crowned ditch and the project. The crown is not likely to remain more than 1 to 2 years after the annual freeze-thaw cycle because of resulting settlement. Temporary and permanent erosion and sediment control procedures and drainage controls will be designed to work in concert to provide acceptable erosion and sediment control for the project.

Erosion control measures for ditch excavations performed through stream beds and banks will be applied as soon as the backfill is placed into the ditch to complete pipe coverage. Specific materials to use for erosion control of the bed and banks will be determined on a case-by-case basis and identified in the construction plans for each crossing.

The project will develop appropriate methods to respond to local conditions based on existing terrain, geology, hydrology, slope, disturbed area, thermal regime, climate, and other factors in the final design and relevant plans.

#### 3.4 REVEGETATION

Areas that are impacted by construction will be re-seeded with natural vegetation to improve stabilization of soils and minimize erosion around the pipe. AGDC has worked with the ADNR Plant Materials Center to develop a specific Revegetation and Erosion Stabilization Plan.

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Soil stabilization procedures were developed through consultation with former P&CM engineers and scientists with first-hand experience in implementing successive-year soil stabilization techniques and assessing needs to mitigate against erosion for buried Arctic pipelines. Procedures for ensuring soil stabilization include geohazard avoidance and special design area engineering, use of engineered material for bedding and padding, soil replacement and stabilization at installation, crowning, terrain contouring, armoring, revegetation, fertilization, control of non-native plants, and through monitoring and maintenance for several years after construction. Seeding and revegetation would be done with approved seed mixtures of annuals and native species and re-shaping of the ditch spoil after initial thawing would be done to prevent any ponding due to thaw slump.

Spring seeding of the impacted area promotes vegetative growth and the stability of soils to minimize erosion around the pipeline. Seeding of the disturbed corridor will be conducted in consultation with the BLM and State of Alaska and will adhere to the ADNR Plant Materials Center Revegetation Manual for Alaska (Wright, 2009). The methods and procedures outlined in the manual provide specific regional information for revegetation of disturbed areas with native plants to limit the potential for colonization by invasive species. A Non-native Invasive Plant Prevention Plan will also be developed and consulted to limit the potential for colonization by invasive species.

Seed mixes will be developed for different geographic areas and fertilizers applied at an optimum rate per acre. Hand methods, hydroseeding, and aerial seeding will be employed to stabilize surfaces as required and will be identified in more specific planning documents leading up to construction.

AGDC will continue to re-seed and monitor the success of vegetation as necessary while the ROW is being used for maintenance during operations. As required by the ROW lease, upon completion of use, the lands will be restored to the satisfaction of the landowner.

#### 3.4.1 FERTILIZATION

The application of fertilizer will be conducted in consultation with ADNR. Standard practices and planning will be followed so that adequate volume, type, and quality of fertilizer are used where needed. Ground-disturbed areas may be fertilized, if appropriate, as construction progresses. Erosion control measures will be applied on top of the seed and fertilizer application. As project development proceeds, specific uses will be determined. Fertilizers will be used sparingly in areas where invasive plants are known to exist in order to limit their infiltration.

#### 3.4.2 CONTROL OF NON-NATIVE PLANTS

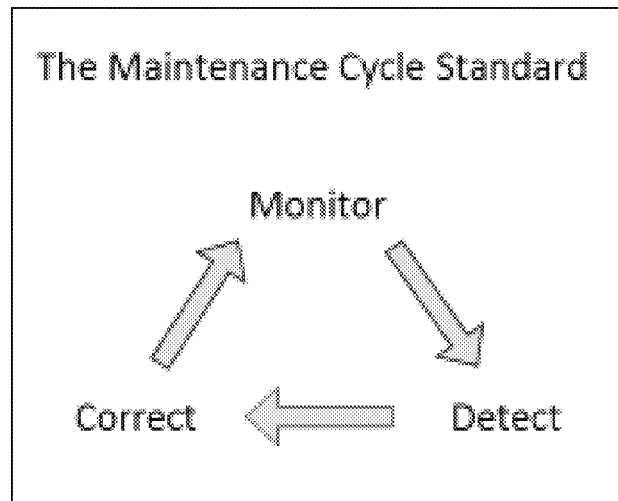
Procedures will be developed in consultation with ADNR to control the introduction and spread of non-native invasive plants during pre-construction, construction, and monitoring phases of the project. Invasive plants can be introduced from the use of airports (particularly at gravel airstrips), material sites, and temporary-use areas, such as Pipe Storage Yards (PSYs) and camps. Control of invasive plants is likely to be a requirement of ROW lease stipulations to restore land to the satisfaction of different land owners.

### 3.4.3 OPERATIONS AND FIELD SURVEILLANCE

When a gasline is fully constructed and when testing and operations begin, the pipeline will transport gas at below-freezing temperatures (8-30°F) on the North Slope (Figure 1). Soils and water will be monitored regularly after installation of the pipe following the programmatic maintenance cycle standard of “Monitor, Detect, Correct” (see Figure A1-3). Where depressions or slumping occurs in spring/summer, additional ditch spoil will be placed to flatten the surface and reduced the amount of standing water. For the first several years after construction soil stabilization efforts will focus strongly on control of erosion through revegetation per the methods above and water management. If, after several years of revegetation efforts, plant cover does not sufficiently return to stabilize soils, ASAP will consider alterations to the methodologies of its revegetation procedures in consultation with ADNR to encourage additional growth.

AGDC will monitor the pipeline in the years after construction to determine where modifications may be needed to ensure proper water management. Crews will document and inspect areas of ponding water over the pipe and recommend site-specific improvements in subterranean infrastructure or water flow to ensure that prolonged ponding is limited or reduced. Additional improvements may be added in certain areas, depending on the level of moisture, drying, and settling that occurs over and around the pipe.

Figure A1-3. Programmatic Maintenance Cycle Standard



It is possible that some ponding could occur along the route in areas directly over the trench intermittently during the first spring after soils thaw, but will then drain as temperatures warm surrounding soils near the surface. The north-to-south configuration of the pipeline means that the direction of sheet water flow will be directed by the downward gravitational gradient of the terrain, moving from higher elevations near the Brooks Range foothills, north to the lower elevations of the coastal areas near the Beaufort Sea. The pipe, running parallel to this flow gradient, will generally not inhibit the slow movement of groundwater along this gradient. The lack of a mound, or high-slope crown, over the trench will keep water from ponding in trenches on either side of the mound.


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The low or nearly-flat, sloped crown will encourage proper drainage, and in some instances, initial ponding directly over the trench in areas where subsidence occurs. Historic knowledge from experts who have worked on TAPS and North Slope buried pipelines believe the initial temporary impacts associated with constructing the pipeline will be manageable with regard to stabilization, especially for a below-freezing temperature pipe. Based on the recommendations of experts in BG pipe erosion control and water management, increased stabilization efforts will be required for the first 5 years following construction.

### REVISION HISTORY

Rev	Date	Issue Reason	Originator	Reviewer / Endorser
0	05-June-2017	Use	901 [Alaska LNG]	
Approver		Frank T. Richards, P.E.		
Approver Signature				
Modification(s) Description		AKLNG-4020-YYY-YPW-DOC-00001		

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