Conceptual Engineering / Socioeconomic Impact Study - Alaska Spur Pipeline

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NOTE:

All maps and figures contained within the body of the report are best viewed electronically. If printed, the report body should be printed in color on 8.5-inch by 11-inch standard paper. The appendices contain figures, matrices, and maps that are best viewed electronically. If printed, the appendices which contain figures, matrices, and maps should be printed in color on 11-inch x 17-inch paper.

ACKNOWLEDGEMENT

An Advisory Committee was used within the performance of this study to provide guidance and monitoring of progress and to help assure completeness and relevance of the work performed. DOE would like to acknowledge the significant value of the contributions made by the committee in the process of completing this effort. Participating committee members are listed below.

- Alaska Industrial Development and Export Authority: Ron Miller, Executive Director
- Alaska Governors Office: Michael Menge, Energy Advisor, Office of the Governor
- Alaska Natural Gas Development Authority: Harold Heinze, CEO
- Anchorage ML&P: James Posey, General Manager
- Chugach Electric Association: Lee Thibert, General Manager - Distribution Division Bradley Evans, General Manager – Generation and Transmission Division
- ENSTAR Natural Gas: Tony Izzo, President
- Fairbanks Natural Gas, LLC: Dan Britton, President
- Kenai Peninsula Borough: Bill Popp, Oil, Gas and Mining Liaison

Executive Summary

Study Objectives

The objective of the Conceptual Engineering/Socioeconomic Impact Study – Alaska Spur Pipeline (spur pipeline) commissioned by the U.S. Department of Energy-National Energy Technology Laboratory (DOE-NETL) is to provide current information pertaining to the potential construction of a buried spur pipeline that would bring gas from the proposed Alaska North Slope (ANS) gas line to Interior and Southcentral Alaska. The study is intended to provide comparative information for each of two currently proposed spur line routings. The study presents findings, conclusions, and vital information considered, but does not include recommendations for construction of any particular pipeline configuration along any route.

Two spur pipeline route corridors were evaluated: Fairbanks Spur and Delta Junction Spur (Figure ES.1) The Fairbanks Spur corridor generally follows the Parks Highway through the Alaska Range and terminates at an existing ENSTAR gas transmission pipeline near Wasilla. The Delta Junction Spur corridor generally follows the Richardson Highway through the Alaska Range to the Glennallen area, then follows the Glenn Highway through the Matanuska Valley and terminates at the same ENSTAR transmission pipeline approximately 30 miles further to the east near Palmer. Figure ES.1 shows alignment options evaluated within the two corridors. It should be noted that the pipeline is assumed to be buried for the majority of each alignment and does not have above ground sections, due in part to ambient gas temperatures.

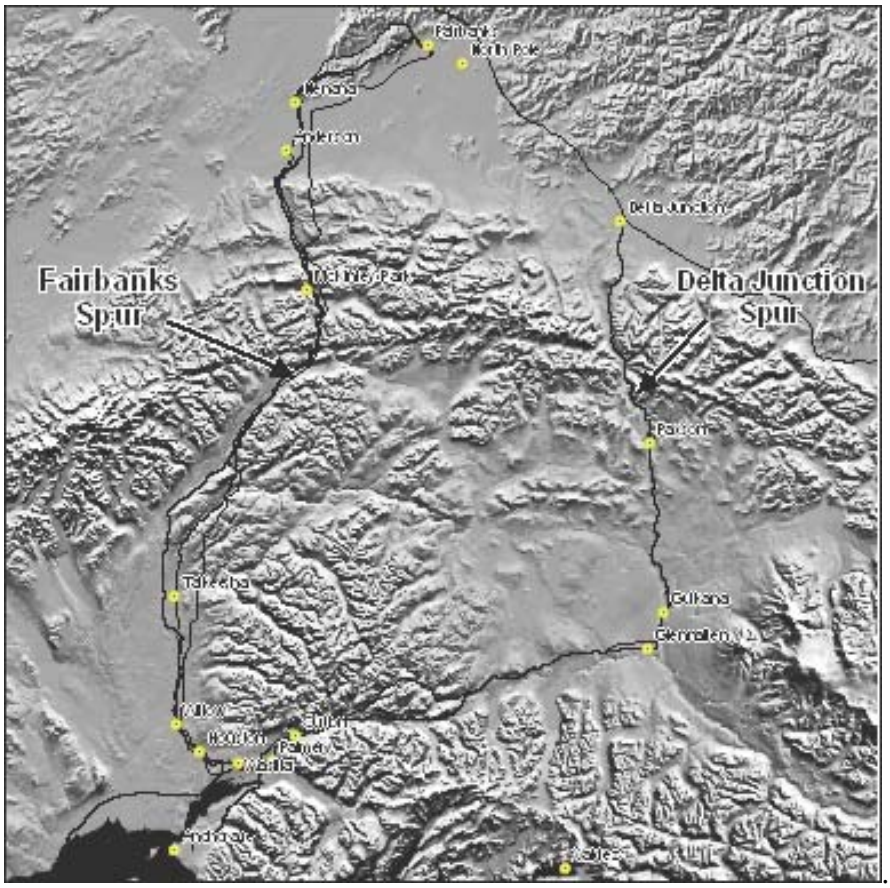


Figure ES.1: Fairbanks and Delta Junction Spur Route Corridors

Work Approach

The study team was comprised of subject experts from Arctic Slope Regional Corporation Constructors, Inc. (ACI); NORSTAR Pipeline Company (NORSTAR) (an affiliate of ENSTAR Natural Gas Company [ENSTAR], which is a division of SEMCO Energy Inc.); and the engineering firm Michael Baker Jr., Inc. (Michael Baker). ACI managed the overall study and addressed permitting, socioeconomic impact and public outreach planning. NORSTAR addressed right-of-way (ROW) considerations, availability of gas for local distribution along the two routes and methods to meet Cook Inlet peak winter gas demand. Michael Baker addressed pipeline sizing and compression; conceptual pipeline design and engineering; estimation of pipeline tariffs including capital cost estimates and economic analysis; and prepared an engineering primer regarding natural gas and cold region pipeline design.

Information in the Conceptual Engineering/Socioeconomic Impact Study was developed based on accepted industry practices, codes and standards; experience and judgment of the study team; and select information from previous studies completed for an Alaskan spur pipeline. Previous studies include:

- SAIC 2005. *Alaska Natural Gas Needs and Market Assessment*. Prepared for the National Energy Technology Laboratory.
- Denali Pipeline Company 1993. *The Denali Pipeline Project (1993)*.
- Alaska Natural Gas Development Authority (ANGDA) 2005. *Permitting Comparison of Parks Highway and Glenn Highway Natural Gas Pipeline Rights-of-Way*. Prepared by Bristol Environmental Services for ANGDA.
- Michael Baker 2005a. *Transport of North Slope Gas to Tidewater*. Prepared by Michael Baker for ANGDA.
- Shaw-Stone & Webster 2006. *Spurline Terminal Conceptual Design*. Prepared by Shaw-Stone & Webster Management Consultants for ANGDA.
- Harding Lawson 1988. *Trans-Alaska Gas System, Final Environmental Impact Statement*. U. S. Department of the Interior, Bureau of Land Management (BLM). Prepared by Harding Lawson Associates for the BLM.
- Alaska Department of Natural Resources (ADNR) 2006. *Alaska/Alberta Working Group, Alaska Natural Gas Pipeline, Natural Gas Composition*.
- Michael Baker 2005b. *Glennallen to Palmer Spur Pipeline – Engineering Report*. Prepared by Michael Baker for ANGDA.

The study team used two specific gas demand scenarios as described in the *Alaska Natural Gas Needs and Market Assessment* (Gas Market Assessment) in the completion of this effort, the study team discussed options for the spur pipeline diameter based on projected demand per the Gas Market Assessment and a determination of whether removal of gas from in-ground storage to meet peak seasonal demand is economically feasible.

Pipeline sizing and compression was addressed by estimating cost of service (COS) for a wide range of pipeline diameter and compression configurations subject to gas flow rates equal to and larger than those described in the Gas Market Assessment. Hundreds of hydraulic simulations and subsequent economic analyses were completed to generate the COS values that were plotted as a function of gas flow to concisely present the vast amount of economic data generated. This COS information could be used by potential future spur pipeline sponsors to evaluate gas demand scenarios that include, but are not limited

to, those presented in the Gas Market Assessment. A discussion of pipeline sizing and compression options for the two gas flow scenarios from the Gas Market Assessment were prepared based on the graphical information in the COS plots.

Specification of compression for a given pipeline was determined via hydraulic simulation. Hydraulic simulation addresses the impacts of pipeline length, alignment elevation changes, internal pipe diameter, pipe wall thickness, operating pressure and design codes. Detailed thermal-hydraulic analysis required to accurately determine pipeline operating temperatures was outside the scope of this study.

In order to meet the study schedule, pipeline sizing and compression were completed concurrent with ROW characterization and selection of pipeline alignments within the two spur pipeline corridors. COS calculations were based on a preliminary alignment along the Fairbanks Spur route. This COS information is applicable to both the final selected Fairbanks and Delta Junction Spur pipeline alignments.

Conceptual pipeline engineering and design consisted of evaluating pipeline alignment options on a segment-by-segment basis within each of the Fairbanks and Delta Junction Spur corridors based on ROW considerations, geological, hydrological, and geotechnical obstacles, and an assessment of pipeline constructability. A total of 63 potential alignment options within the two corridors were evaluated. A matrix of alignment issues was prepared for each route corridor and used to select the final alignments.

The last engineering-related task of the Conceptual Engineering Study was to estimate a tariff rate for transportation of gas through the spur pipeline. The team was directed to calculate delivered price as the sum of the spur pipeline tariff and the expected price of North Slope gas including an estimate of the transportation cost from the North Slope to the spur pipeline. Spur pipeline tariffs were calculated for both the Fairbanks and Delta Junction Spur routes based on the two prescribed demand scenarios from the Gas Market Assessment.

During a mid-project review meeting, NETL representatives, the Advisory Committee and the study team agreed that spur pipeline tariffs would be based on installation of a 20 inch diameter pipeline with an operating pressure of 2,500 pounds per square inch gage (psig). This representative pipeline configuration was selected in order to provide flexibility for future flow capacity expansion via addition of compressor stations and the option to transport large quantities of non-methane hydrocarbons in the dense phase (Section 2). Pipeline capital cost estimates were developed for the Fairbanks and Delta Junction Spur routes based on the alignments selected during the engineering design.

A natural gas processing plant would be required at the spur pipeline inlet to adjust the gas composition prior to entering the spur pipeline. One of the two gas demand scenarios would require a natural gas plant at the spur pipeline terminus in Cook Inlet to separate utility gas from hydrocarbon liquids. Capital and operating costs for the gas plants were included in the overall spur pipeline tariff. Information extracted from the Gas Market Assessment was used to determine both the expected price of North Slope gas and the cost to transport the gas from the North Slope to the inlet of the spur pipeline.

Title investigation and analysis were conducted to support future ROW and permitting objectives along either major route. Information gathered for this analysis was integrated into a computerized land data base. The information was used to identify land ownerships which could affect the complexity of easement acquisition or permitting challenges. Additionally, existing ROW were identified which are available to be utilized for a pipeline project. This analysis does not recommend a particular route.

Existing studies and publications, state and federal regulations, and team knowledge were utilized in analyzing permitting and regulatory issues. The permit matrix was developed in order to provide an organized means of presenting a list of potentially required permits. Previous socioeconomic investigations of the potentially affected areas, State of Alaska records, and existing pipeline studies were used in evaluating the potential socioeconomic impacts of a spur pipeline.

This report is organized as follows:

Section 1 - Introduction and Project Description;

Section 2 - Engineering Design Concepts;

Section 3 - Pipeline Sizing and Compression;

Section 4 - Pipeline Routing and Alignment;

Section 5 - Right-of-Way Considerations;

Section 6 - Permitting and Regulatory Issues;

Section 7 - Socioeconomic Considerations;

Section 8 - Delivered Cost of North Slope Gas to Southcentral Alaska;

Section 9 - Considerations for Future Work

Section 10 - References and Resources; and

Appendices.

A brief description of each section of the study follows.

Section 2: Engineering Design Concepts

A section explaining engineering design concepts was included to provide persons not experienced in natural gas or the design of pipelines that traverse permafrost with basic information and concepts necessary to understand study results. The section contains hypothetical examples and discussions that explain underlying trends that influence spur pipeline design. The section contains a discussion of geotechnical considerations that would impact pipeline design including frost heave and thaw settlement.

Collectively, information in the section supports the following conclusions regarding design trends for a spur pipeline:

- A natural gas highly enriched in non-methane hydrocarbons can be transported in the dense phase via a high pressure pipeline without liquid condensation and formation of slug flow.
- Pipelines traversing discontinuous and sporadic permafrost must be designed with consideration of long-term formation of frost heave and/or thaw settlement and resultant differential movement of the soil.
- Joule-Thompson (J-T) coefficient (temperature drop per unit of pressure drop) depends on the methane content of the gas. A natural gas enriched in non-methane hydrocarbons will experience less J-T cooling than a pipeline transporting utility gas.
- For the same gas flow and composition
    - pressure gradient (pressure drop per unit length of pipe) will be less for a higher pressure than a lower pressure pipeline;
    - J-T coefficient of a methane rich natural gas will be less for a higher pressure pipeline than a lower pressure pipeline; and
    - J-T cooling (temperature drop per unit length of pipe) of a methane rich natural gas will be less for a higher pressure pipeline than a lower pressure pipeline, thereby tending to flatten the pipeline operating temperature profile.

- Weight of a highly enriched natural gas will cause pipeline gas to expand or compress with elevation change thereby influencing local operating pressure and temperature of the pipeline.
- Excluding consideration of frost heave and thaw settlement, capital costs of a pipeline and compression system can be minimized by installing the least number of compressor stations with large sized equipment installed at each station.
- Configuring the pipeline and compressor stations to restrict the range of allowable pipeline operating temperatures, thereby mitigating potential development of adverse frost heave and thaw settlement will add cost to the overall system.

Section 3: Pipeline Sizing and Compression

Pipeline gas flow capacity depends on the pipeline diameter, operating pressure and number of compressor stations installed periodically along the route. Pipeline sizing and compression analyses consisted of generating plots of lifetime COS values at various gas flow rates for a wide range of pipeline and compression configurations. The plots of COS as a function of flow rate can be used to quickly assess the relative economics of a number of pipeline and station configurations.

A gas hydraulic simulation was completed to determine the compression required to achieve a particular flow rate through a given pipeline. Capital costs for the pipeline and gas compression were estimated based on simulation output. An economic analysis was then completed to determine the difference between the gas sale and purchase price required to obtain a 10 percent return on the capital invested. COS was determined as the difference between the gas sale and purchase prices.

Return-on-investment (ROI) was used because it is a relatively simple analytical approach that is independent of financing assumptions. For pipelines, a 10 percent ROI is usually equivalent to a utility type return-on-investment in the range of 12 percent to 13 percent.

A plot of pipeline COS as a function of increasing flow rate is referred to as a “J-curve” because the shape of the curve resembles a backwards “J”. Each data point on a J-curve is generated by completing a pipeline hydraulic simulation at the given flow rate followed by capital cost estimation and economic analysis to determine the corresponding COS.

All points on a J-curve reflect scenarios in which gas flow starts at the given rate and remains the same over the life of the project. J-curves are very useful for general comparison of pipeline options, but do not address the impact of flow ramp-up on project economics. Economic impact attributed to flow ramp-up is addressed in the tariff calculations in Section 8.

J-curve plots were constructed to allow general comparison of a wide range of pipeline configurations subject to a wide range of gas flow rates, and to screen candidate configurations for selection as the basis for estimation of delivered gas price to Cook Inlet as described in Section 8. J-curve analyses were based on a preliminary, but representative, route from Fairbanks to Cook Inlet in order to meet the project schedule. J-curve results are applicable to the final alignments selected for both the Fairbanks and Delta Junction Spur pipeline routes.

The study team was directed to specifically address pipeline sizing and compression for Gas Scenarios 1 and 2 as described in the Gas Market Assessment.

Gas Scenario 1

Gas Scenario 1 (Figure ES.2) as described in the Gas Market Assessment is based on delivery of utility grade natural gas to Cook Inlet beginning at an average annual rate of 110 million standard cubic feet per day (MMscfd) progressively increasing to approximately 300 MMscfd over a 20-year period. It was recommended in the Gas Market assessment that the spur pipeline be sized for 300 MMscfd plus 50

MMscfd of additional flow coupled with 80 MMscfd of gas removed from storage to meet a winter seasonal demand of approximately 435 MMscfd.

Estimates of the delivered price of gas to Cook Inlet were based on Gas Scenario 1 after modification to accommodate a 33 year project life and means of meeting seasonal winter demand specified by the study team. The annual increase in flow for the last few years of the 20 year schedule presented in the Gas Market Assessment was used to extend the demand curve for an additional 13 years. The gas flow rate projected for year 33 is approximately 350 MMscfd. It is the opinion of the study team that peak seasonal winter demand could be met by a combination of removal of gas from in-ground storage and LNG imported to Cook Inlet without necessarily needing to increase pipeline capacity over the average annual rate. Delivered gas price to Cook Inlet was based on a pipeline configured to deliver a minimum of 350 MMscfd in the 33rd year of the project.

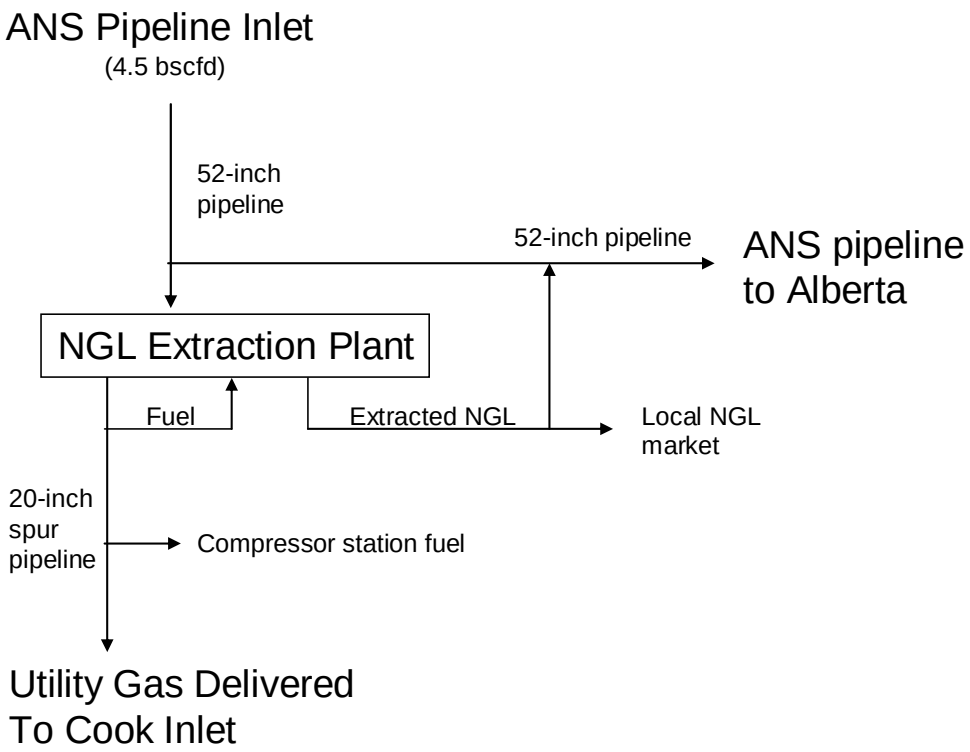


Figure ES.2: Gas Scenario 1 - Project Configuration

Gas Scenario 2

Gas Scenario 2 (Figure ES.3) as described in the Gas Market Assessment is the same as Gas Scenario 1 with the addition of 75,000 barrels per day (bpd) of ethane for feed to a petrochemical plant in Cook Inlet, 63,000 bpd of propane and butane mix for sale as liquefied petroleum gas (LPG), and 15,000 bpd of pentane and heavier components sold for gasoline blending. It was recommended in the Gas Market Assessment that the spur pipeline be designed for 590 MMscfd of gas flow.

Estimates for the delivered price of gas to Cook Inlet per Gas Scenario 2 were based on the 33-year utility demand schedule described above plus addition of sufficient ethane and heavier components to deliver 75,000 bpd of ethane to Cook Inlet. The composition of the ANS pipeline gas as described on the Alaska Governor's website regarding state negotiations with the North Slope gas producers was used for the calculations of delivered gas price instead of the ANS pipeline gas composition contained in the Gas

Market Assessment. The information on the Governor's website was posted after issue of the Gas Market Assessment and was considered to be more timely and representative of probable conditions than the gas compositional information in the Gas Market Assessment.

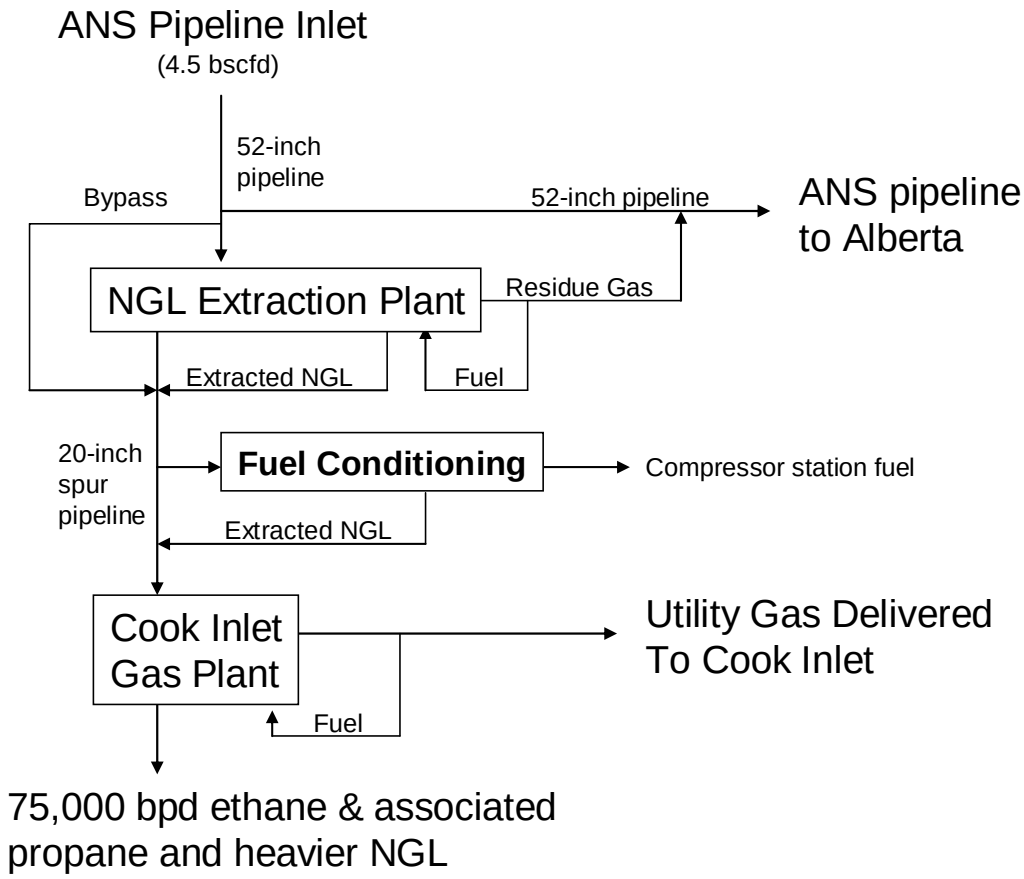


Figure ES.3: Gas Scenario 2 – Project Configuration

J-curve Results - General

J-curves were prepared for a range of pipeline diameters and operating pressures to accommodate the largest flow rate identified in any of the scenarios identified in the Gas Market Assessment. J-curve plots are contained in Appendix 3-7 and address transport of utility gas during the summer subject to all possible combinations of the following:

- Outside pipeline diameters of 18, 20, 24 and 28 inches
- Operating pressures of 1,480 and 2,500 psig
- Gas compressor sets of 7,700; 10,000; 13,000 and 20,000 horsepower (hp).

J-curves allow concise presentation of a large amount of economic data generated via a huge amount of supporting work. Information presented in the J-curves contained in Appendix 3-7 support the following conclusions:

- COS for a given pipeline will decline with flow as compression is added to a point at which COS values will rise because costs to add large amounts of incremental compression do not justify the incremental increase in flow;

- Smaller diameter pipelines have a lower COS and are more economical at lower flow rates;
- At higher flow rates there may be multiple diameter and compression combinations that are economically equivalent and the option may exist to install a smaller diameter pipeline with more stations or a larger diameter pipeline with fewer stations;
- High-pressure pipelines are less economic than low-pressure pipelines for transport of utility gas at relatively low flow rates; the economics of high and low pressure pipelines approach one another as flow rate increases and high-pressure pipelines may be more economical at high flow rates;
- Size of the turbine compressor set at the stations has little influence on the pipeline COS, but does impact the maximum flow capacity of a given pipeline and station system.

J-curve Results – Gas Scenario 1

J-curves for the flow ranges per Gas Scenario 1 are shown in (Figure ES.4). Compression at the maximum volume of each curve is provided in the figure legend.

Utility grade gas per Gas Scenario 1 can be transported via a low-pressure (1,480 psig) pipeline. Selection of a low-pressure pipeline would forever preclude transport of large amounts of non-methane hydrocarbons in the dense phase. J-curves for high pressure (2,500 psig) pipelines are included to show relative costs to provide for potential future transport of an enriched natural gas.

Individual J-curve data points are based on a constant pipeline flow rate over the life of the project. Annual average flow through the pipeline will ramp-up slowly from approximately 110 MMscfd at start-up to approximately 350 MMscfd by the end the assumed 33 year project life. Spur pipeline project economics will be greatly influenced by time value of money and the protracted ramp-up schedule. Detailed economic analyses based on flow ramp-up are required to definitively determine the relative economics of configurations where J-curves cross within the flow ramp-up range.

A pipeline and station configuration that exhibits greater COS values than an alternative configuration at all flow rates under consideration for Gas Scenario 1 can be deemed as being less economic. When J-curves cross, the configuration with the higher COS values at lower flows that occur earlier in the project life should be less economically favorable due to discounting for time value of money.

The following can be inferred based on the information from Gas Scenario 1:

- A 24 inch diameter high pressure pipeline can be excluded from consideration since the COS values are greater than those of all other options at all flow rates except the highest rates that would not occur until late project life;
- A 20 inch diameter high-pressure pipeline should be less economic than an 18 inch diameter high pressure pipeline since the COS values for a 20 inch pipeline are greater than those of the 18 inch diameter pipeline at all flow rates except the highest rates that would not occur until late project life;
- Economics for 18 inch and 20 inch diameter low pressure pipelines over the life of the project may be roughly equivalent since the respective J-curves cross within the range of flow ramp-up;
- A 24 inch diameter low pressure pipeline should be less economic than an 18 inch diameter high pressure pipeline since the COS values for a 24 inch low-pressure pipeline are greater at all flow rates except the highest rates that would not occur until late project life; selection of

an 18 inch high pressure pipeline would provide for transport of a natural gas enriched in non-methane hydrocarbons.

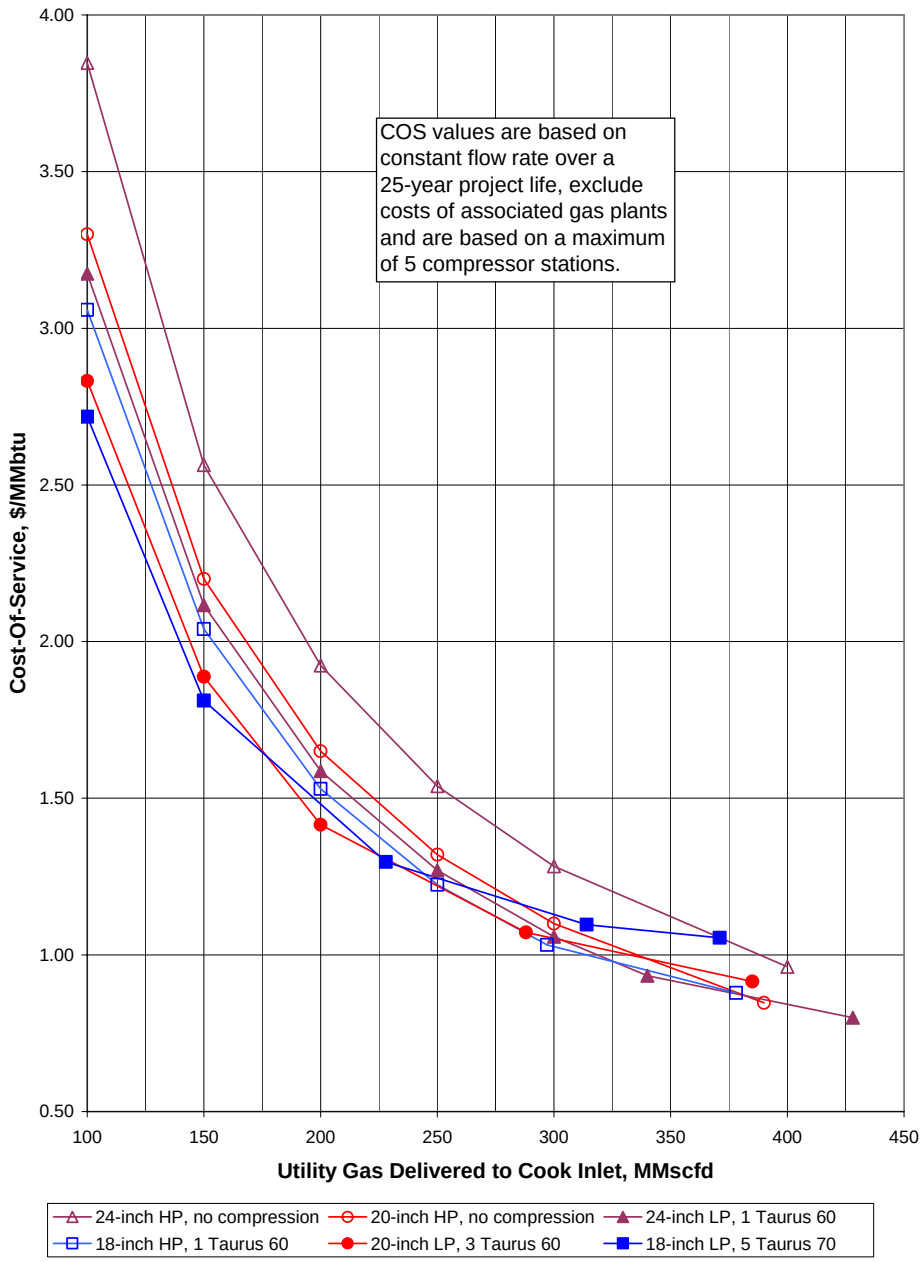


Figure ES.4: J-curves for Gas Scenario 1

J-curve Results – Gas Scenario 2

Procedures used to prepare J-curves for Gas Scenario 2 are identical to those of Gas Scenario 1 except that only high pressure pipelines were considered since Gas Scenario 2 involves transport of an enriched natural gas. J-curves for Gas Scenario 2 are shown in Figure ES.5.

Gas Scenario 2 is the same as Gas Scenario 1 except that approximately 215 MMscfd of non-methane hydrocarbons would be blended with the utility gas. Flow rate along the x-axis of Figure ES.5 refers to

the rate of utility gas delivered to Cook Inlet and excludes NGL hydrocarbons extracted in Cook Inlet. Relatively flat or upward sloping portions of the curves reflect the impact of incremental capital costs for addition of compression.

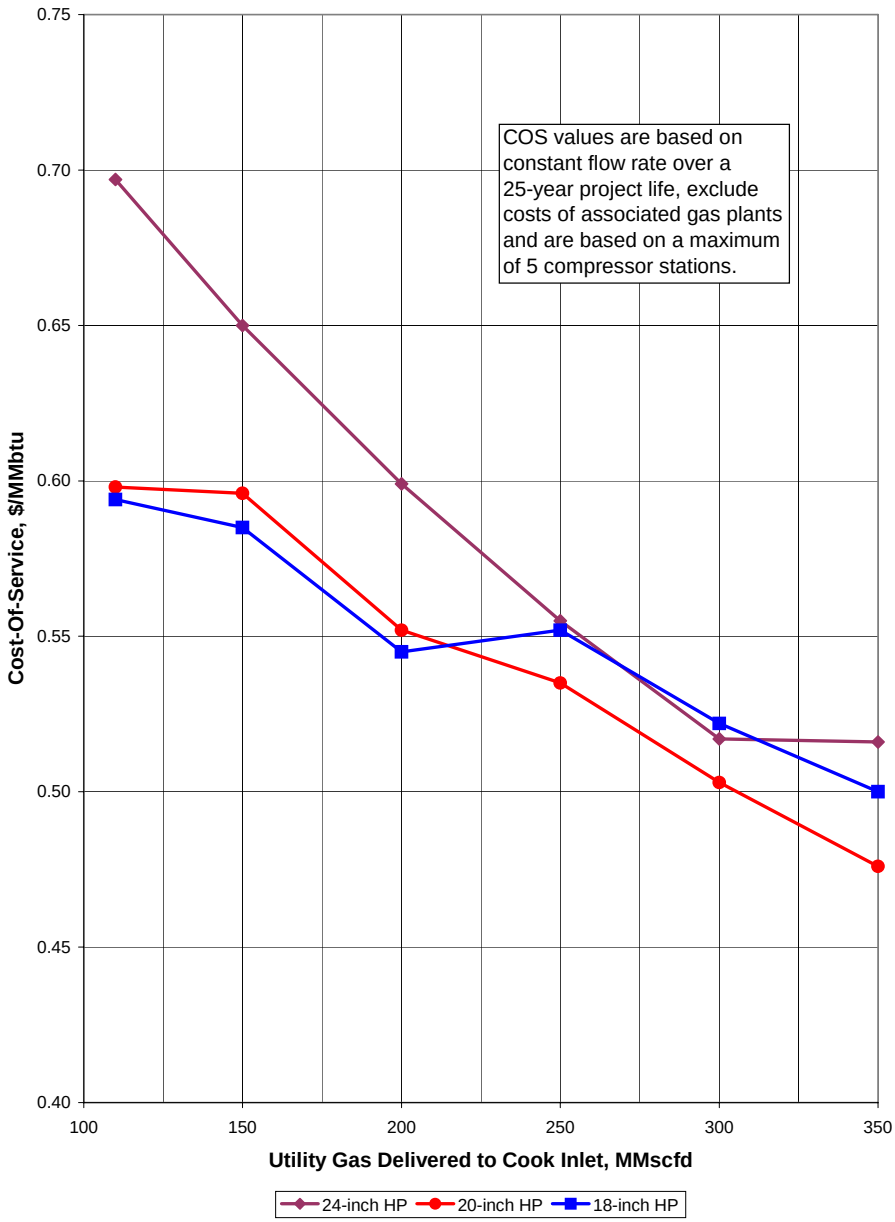


Figure ES.5: J-curves for Gas Scenario 2

Similar to the logic described for evaluation the J-curves for Gas Scenario 1, the following can be inferred for Gas Scenario 2 based on the information shown in Figure ES.5.

- A 24 inch diameter pipeline can be excluded from consideration since the COS exceeds that of a 20 inch diameter pipeline at all flow rates;

- Economics for 18 inch and 20 inch diameter high pressure pipelines over the life of the project should be roughly equivalent since the COS values are similar in early life and the J-curves cross within the flow ramp-up range.

Pipeline COS expressed on a thermal basis varies significantly with gas composition and will be lower for a given flow rate if the natural gas is enriched with non-methane hydrocarbons. However, transport of an enriched gas may require installation of large natural gas processing facilities at the spur pipeline starting point to acquire more non-methane hydrocarbons as well as facilities at the pipeline terminus to extract those hydrocarbons and produce a utility (primarily methane) gas. Capital costs for natural gas processing plants and the resultant impact on spur pipeline economics are addressed in the tariff calculations contained in Section 8.

Section 4. Pipeline Routing and Alignment

Alignment Selection Methodology

Pipeline alignments were developed for both the Fairbanks and Delta Junction Spur corridors. Selection of the respective alignments within the two corridors reflects a quantitative and qualitative balance of the following issues and criteria:

- Minimize total length of route;
- Avoid environmentally sensitive areas;
- Minimize the number of stream and river crossings;
- Minimize blocking cross drainage;
- Avoid geohazardous areas;
- Provide for a high degree of pipeline constructability;
- Maximize routing in geotechnical conditions favorable to pipeline operating characteristics;
- Use existing infrastructure to the extent possible and appropriate;
- Locate pipeline to facilitate maintenance and repair work; and
- Minimize costs related to engineering, construction and maintenance.

Alignments within both the Fairbanks and Delta Junction Spur corridors were to be identified without bias or regard to which corridor would ultimately be selected by an eventual spur pipeline sponsor. Conclusions and information presented in this study should not be construed as a recommendation for either route option.

Each corridor was divided into logical segments with multiple alignment options. Candidate alignments included ROW for highway, electrical power transmission lines, the Alaska Railroad, abandoned roads and pipeline projects that have been proposed, but not built.

Alignment options within a segment were compared based on four categories: engineering obstacles and opportunities; permitting; socioeconomic impacts; and ROW issues. A relative ranking was assigned to each alignment option on a category-by-category basis. Relative rankings addressed physiographic, meteorological, hydrological (including wetlands), biological (fish and wildlife), and human resources characteristics.

Categories within a given segment were weighted by importance. The final rankings of alignment options within a segment were the product of the category relative ranking multiplied by the weighting factor for each category. Rankings were input into a matrix of alignment characteristics that includes geotechnical, environmental, permitting, construction, land ownership and other issues that influence route alignment selection (Appendix 4-2). Portions of the matrices are presented in Tables 4.3 through 4.15 of the study. Comparisons between the selected alignments for the two routes do not constitute recommendation of a preferred route.

Several site visits were conducted for areas deemed costly or difficult to traverse based on "desk top" evaluation of available information. Information gathered during the site visits was used determine the degree of difficulty and likely construction productivity rates for input into the pipeline capital cost estimates.

Alignment Sheets

Alignment sheets were generated for the respective alignments selected within the Fairbanks and Delta Junction Spur routes. Elevation profiles on the alignment sheets were generated by draping the alignments over digital elevation modeling (DEM) data that is publicly available. The alignments sheets contain plan-view detail to provide background images along the alignment that is a combination of aerial photography and satellite imagery, which was patched together where necessary. Land ownership data, compressor station locations, material laydown areas, camp locations, and other pertinent information are provided in the data bands along the top and bottoms of the plan and profile windows. Alignment sheets are provided in Appendix 4-4.

Conclusions

Alignments were identified within both the Fairbanks and Delta Junction Spur corridors which could be constructed. Although both routes contain challenging issues that would need to be addressed in the future, neither route corridor contains an insurmountable problem that would preclude it from consideration for a spur pipeline.

Both corridors have similar physical features. Each contains broad river valleys and is crosscut by the rugged mountainous terrain of the Alaska Range. Both routes traverse areas of permafrost and wetlands. Both corridors support important wildlife and fishery resources. Both corridors cross seismically hazardous areas and active faults. Excluding beginning and end terminuses, neither corridor intersects large population centers, although a few mid-size communities exist in each: Nenana, Healy and Willow in the Fairbanks Spur corridor, and Glennallen in the Delta Junction Spur corridor. A few smaller communities are in both corridors located within and to the south of the Alaska Range. Both spur corridors terminate at logical locations for tie into the same existing ENSTAR utility gas line between Beluga and Anchorage.

Differences between the routes would impact construction and capital costs. At approximately 322 miles, the length of the Fairbanks Spur route is approximately 41 miles longer than the 281-mile Delta Junction Spur route. The Delta Junction Spur route traverses more permafrost and soils prone to frost heave and thaw settlement. All compressors along the Delta Junction Spur route would likely require chilling of the discharge gas before it reenters the pipeline, whereas the last compressor on the Fairbanks Spur route would likely discharge warm gas back into the pipeline. Overall, the terrain along the Delta Junction Spur route is more rugged because it traverses a second mountainous area along the Matanuska Valley. Construction costs on a per foot basis would be higher for the Delta Junction Spur route because of rugged terrain. The maximum elevations of the Fairbanks and Delta Junction alignments are approximately 2,400 and 3,600 feet above mean sea level, respectively.

The selected Fairbanks alignment crosses Denali National Park and Preserve and passes through Denali State Park on the existing ROW for the Parks Highway. Acquisition of a ROW permit to cross Denali

National Park and Preserve would need to be completed well in advance of any potential construction along this route. In 2002, Congress passed Public Law 107-223 which authorized the Secretary of the Interior to issue ROW permits for natural gas pipelines within the boundaries of the Great Smoky Mountains National Park. Similar legislation would need to be passed to authorize the Secretary of the Interior to grant a ROW permit for the construction and operation of a natural gas pipeline through or across Denali National Park and Preserve lands.

The Delta Junction Spur route passes along the Delta River, segments of which are designated as wild, scenic or recreational under the authority of the Wild and Scenic Rivers Act (16 USC Chapter 28). Alignment along the Delta River should not pose a permitting issue as long as it remains outside of the area designated as wild and scenic.

Section 5. ROW Considerations

A land title investigation was conducted by NORSTAR for both spur pipeline alignments. Nearly all of the selected alignment land parcels for both the Fairbanks Spur and the Delta Junction Spur are situated within the limits of the existing highway ROW limits, section line easements, and some powerline ROW. However, some limited segments of ROW would need to be acquired for pipeline alignment. Those segments may be needed to ameliorate topographic or constructability issues and access challenges. A temporary ROW width between 60 and 100 ft would provide enough for construction and installation of a pipeline.

Temporary ROW up to 0.5 mile wide may be required. A 0.5 mile wide temporary ROW is thought to affect only governmental lands for purposes of accessibility. After construction, a reduced permanent ROW, sufficiently wide to allow monitoring and maintenance of the pipeline and related pipeline facilities would be required. A typical permanent ROW width for similar pipelines ranges between 20 and 50 ft.

The location of land parcels and the type of land ownership would determine if a ROW exists and is available to be utilized for pipeline alignment and it would also determine what type of ROW would be asserted. ROW determinations and acquisition would be accomplished in two ways. First, lands owned or managed by the various governmental agencies and public land trusts are regulated and managed under specific agency regulations and land disposition policy. The process for acquisition may include easement applications, applications for permits, surveys, mapping, and in some cases, public hearing. The second general method relates to privately owned lands. These include properties within private sector ownership and some quasi-private lands that may be under the control of Alaska Native corporations (e.g., Native allotments and trust lands). ROW acquisition may require fair market value appraisals, legal documentation and monetary compensation. After a pipeline alignment is established, home and business relocation and other issues to be revealed would need a detailed evaluation.

Thousands of land parcels were researched along both the Fairbanks Spur and Delta Junction Spur. Table 5.1 in section 5 summarizes the breakdown of land parcel ownership between routes. Many of the parcels have an existing Public Land Order (PLO) ROW or a Section Line (RS2477) ROW available for project utilization. These ROW would be acquired by permits, etc. as described above. Land parcels owned by federal, state, borough and Alaska Railroad Corporation (ARRC) would have ROW created by the same agency permitting application methods. As a result of existing and permitted ROW, only 25% of the total parcels would require actual ROW purchases.

Approximately 75 percent of the land adjacent to the selected pipeline alignments is publicly owned or designated for highway ROW, parks, forests, or public recreation. Some lands are under the jurisdiction of the military and coordination would be needed to assure that adverse impacts to military operations would be avoided or minimized in such areas.

A description of the various ROW types, their statutorial and regulatory basis and history was developed for this report. Particularly important are the ROW on federal lands within Denali National Park and Preserve, military reserve lands, and lands in Interim Conveyance to Native corporations. For lands in Interim Conveyance, BLM or Bureau of Indian Affairs (BIA) have jurisdiction and, with the consent of the appropriate Native entity, would issue ROW permits and other easement authorizations.

Where the spur alignment passes through municipal or borough lands, ROW would also be subject to the planning, platting, and land use authority of those jurisdictions. These may include the City of Fairbanks, City of Palmer, City of Wasilla, the Matanuska-Susitna Borough, the Denali Borough, and the Fairbanks North Star Borough.

Land ownership information is shown on the alignment maps. Typical land title records frequently change because of sale or agency conveyance actions and some portions of the alignment may need updating in the future. Figures 5.1 through 5.23 graphically portray the land ownership situation on both spur route alignments.

Section 6. Permitting and Regulatory Issues

The permitting process for the spur pipeline project would not be significantly different between the Fairbanks and the Delta Junction Spur routes. Permitting details may vary based on physiographic, hydrological, and land use specifics particular to each route. Development of a comprehensive project description would be vital for creating permit applications to be submitted to local, state and federal agencies.

The timeframe for completion of all studies, conceptual engineering design, and conducting the NEPA process would require a minimum of two years. A minimum of two field study seasons would be necessary for conducting crucial geophysical, wetland and hydrological surveys, seismic hazards assessment, and wildlife and fish surveys.

Key permits for the project include:

- Clean Water Act Section 404 - U.S. Army Corps of Engineers (USACE)
- National Pollutant Discharge Elimination System (NPDES) - U.S. Environmental Protection Agency (EPA)
- Clean Air Act air quality modeling, permitting and monitoring - EPA, ADEC
- State Pipeline ROW –ADNR coordinated by the Joint Pipeline Office (JPO)
- Federal Pipeline ROW – Federal Energy Regulatory Commission (FERC)

The National Environmental Policy Act (NEPA) process would be initiated by the project sponsor's preparation of an Environmental Evaluation Document (EED) to be used by the lead agency (determined at the time a project is sufficiently developed to initiate permit applications) in preparing an Environmental Assessment (EA) the results of which would be either a Finding of No Significant Impact (FONSI) or the requirement to conduct a full Environmental Impact Statement (EIS). Public meetings and workshops with stakeholder groups would commence with the completion of the EED and agency EA process. If based on the EA, it was determined that an EIS is warranted, a more detailed, comprehensive and formal public hearing process would be conducted. Similar EIS processes have taken an average of 18 months to complete. Regulatory authorization by FERC or the Regulatory Commission of Alaska (RCA) may also be required depending on the nature of the project.

Once Notice to Proceed is acquired, numerous permits relating to the construction of the spur pipeline would be necessary. In seeking these permits careful attention would be paid to the central issue of

regulatory compliance and the design of a plan to mitigate potential adverse effects on the physical, biological and human environments. Mitigation measures are designed around avoidance (of sensitive areas e.g., wetlands, fish and wildlife habitat; minimization (limit the extent or magnitude of an action to keep unavoidable adverse effects as small as feasible); rectification (of an adverse effect by repair, rehabilitation, reclamation, or restoration of the damaged environmental feature as closely as feasible to pre-project conditions); reduction (measures taken by stages over time to reduce the adverse effect's severity or extent); and compensation (create a new environmental feature comparable in value to that feature that was adversely impacted).

An in-house comprehensive quality assurance and quality control program should be designed and implemented to assure compliance with applicable requirements of statutes, regulations, environmental and technical stipulations, and final design specifications.

Other important permit and compliance related features of the program may involve identification and protection/avoidance of archaeological and historic sites; air quality modeling and monitoring; water quality and water consumption monitoring; liquid, solid, and hazardous waste management programs.

A list of permits and estimated duration of time required for obtaining such permits that may be required for all phases of a spur pipeline project along the Fairbanks or Delta Junction Spur is located in Appendix 6-1. Without further field study and finalization of route selection for each route, it is difficult to determine the actual length of time required for permitting along the Fairbanks or Delta Junction Spurs. Issues related to extent of wetlands crossed, design and engineering concerns, routing through Denali National Park and Preserve, and NEPA are some of the factors that may impact the duration of permitting along either spur.

Section 7. Socioeconomic Considerations

This section describes the various governmental jurisdictions and unorganized communities located within both the Fairbanks and Delta Junction Spur corridors, the salient demographic features characterizing each, identified historical and archaeological properties, recreational areas, and subsistence use areas. The Fairbanks Spur corridor crosses three boroughs: the Fairbanks North Star Borough, the Denali Borough, and the Matanuska-Susitna Borough. The Delta Junction Spur corridor crosses the Matanuska-Susitna Borough.

In the Alaska system of municipal incorporation, larger communities such as Fairbanks, Palmer and Wasilla, are designated as First Class Cities responsible for levying local taxes (these vary from property to sales taxes) and providing most public services other than schools and may have land use management responsibilities. Some smaller communities are designated as Second Class Cities. These usually have very limited jurisdictional powers and other than town councils and the responsibility for conducting elections and promulgating case specific public ordinances, they do not have land planning and management authority. Second Class Cities may lie within organized boroughs, or as is the case for many rurally dispersed communities, are considered part of the unorganized borough which contains state supervised school districts and other public services.

A quasi-governmental entity consists of communities lying within lands owned by Native corporations. Native corporations exercise land planning and management upon lands within their region.

Historical and archaeological properties include sites of prehistoric occupation and use by indigenous populations and historic sites. Because the spur pipeline alignments fall relatively close to present highway, railroad and utility corridors, many sites have been previously surveyed and identified.

Subsistence use in both corridors is heavy because the road network provides access to major fishing and hunting areas. In this regard, the two corridors differ from most of the rest of Alaska which is roadless. The impacts that the spur pipeline may have on subsistence relate both to protection of the resources (fish

in anadromous fish streams, terrestrial mammals [caribou, moose, bears, wolves, furbearers], birds and waterfowl) and access to those resources, especially access from the road network. A spur pipeline would not produce incremental impacts on fish and wildlife subsistence resources in either corridor with the possible exception of temporary impacts during the construction phase, and would neither enhance nor reduce access for hunters and fishermen since construction would occur primarily within existing ROW. However, where the pipeline routing deviates from existing ROW, new access routes to the backcountry may be opened.

Recreational uses are the dominant activities within most parts of both corridors, although subsistence should not be considered as a recreational activity as it is a basic socioeconomic institution upon which both Native and non-Native rural populations depend for annual family and household incomes. Designated recreational areas (national and state parks and preserves) would be minimally impacted by the construction phase.

Businesses within both corridors are largely associated with tourism and recreational activities. There is heavy use of the highways (and the railroad in the case of the Fairbanks corridor) during the summer months to transport sightseers, hikers, wildlife observers and photographers. These service area businesses would not be affected negatively by pipeline construction insofar as access to them is not restricted for more than brief periods during construction and might well benefit from providing services to the construction contractors.

Spur pipeline construction could temporarily increase local wage employment opportunities in the construction phase. The project could add to the tax revenues of local governmental jurisdictions as well as to rental earnings of land-owners (public and private). The project could enhance the availability of local energy supplies by take-off and conditioning of natural gas fuels at various locations. This would be true for either of the proposed spur pipeline routes.

Section 8. Delivered Price of North Slope Gas to South Central Alaska

Evaluation Methodology

Delivered price of North Slope gas to Cook Inlet in Southcentral Alaska was estimated for both the Fairbanks and Delta Junction Spur options. The price of gas delivered to Cook Inlet was calculated as the sum of:

- Price of gas entering the ANS gas pipeline;
- Tariff to transport spur pipeline gas through the ANS line to spur pipeline takeoff point;
- Spur pipeline tariff including capital and operating costs for the associated gas plants.

Gas price entering the ANS gas pipeline was assumed to be that of the base case as described in the Gas Market Assessment. Per the Gas Market Assessment, the base case gas price at the outlet of the ANS pipeline near Chicago will range from $5.00 to $6.00 per million British thermal unit (MMbtu). An average of $5.50/MMbtu was assumed for the delivered price near Chicago. An ANS pipeline tariff of $2.30/MMbtu at a flow rate of 4.5 billion standard cubic feet per day (bscfd) was described as the base case in the Gas Market Assessment. A fundamental premise of the Gas Market Assessment is that the price of gas at the inlet of the ANS pipeline at the North Slope would be determined by subtracting the ANS pipeline tariff from the price of gas in Chicago. The 4.5 bscfd ANS pipeline flow premise was adopted for calculation of delivered gas price to Cook Inlet, thus the price of gas at the inlet to the ANS pipeline was assumed to be $3.20/MMbtu ($5.50 - $2.30).

Estimates for tariffs on spur pipeline gas transported via the ANS pipeline contained in the Gas Market Assessment were used for calculation of the delivered price of gas to Cook Inlet. ANS pipeline tariffs

presented in the Gas Market Assessment are based on the premise that gas destined for the spur pipeline would bear a higher tariff for transport from the North Slope to the spur pipeline take off than other gas so that downstream consumers would bear no adverse economic impact due to the associated reduction in flow. ANS pipeline tariffs of $0.47 and $0.57/MMbtu were derived from the Gas Market Assessment and used for transport of spur pipeline gas to Fairbanks and Delta Junction, respectively. The difference in tariffs is because Delta Junction is located approximately 540 miles from the North Slope along the ANS pipeline route; whereas the corresponding distance to Fairbanks is approximately 450 miles.

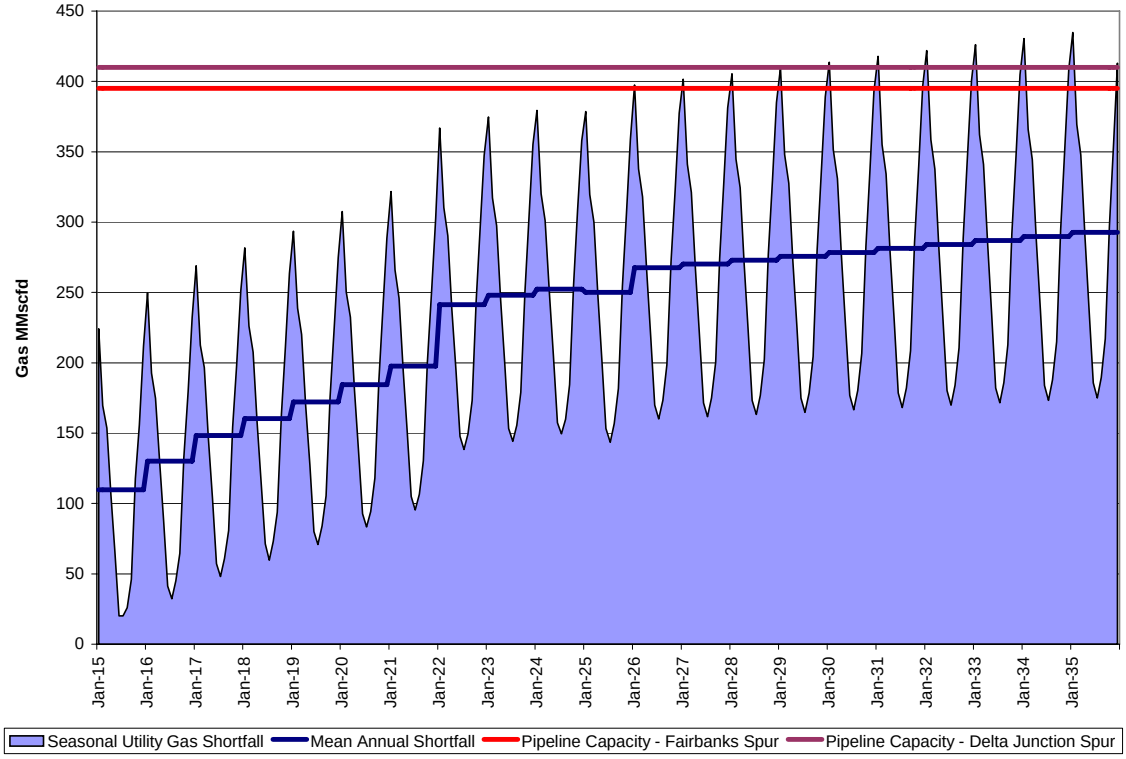
A return on equity (ROE) analysis was completed to determine the tariff of the spur pipeline and associated gas processing plants. Material balances were completed to establish flow rates and compositions on an annual basis for the ANS pipeline and spur pipeline systems. Hydraulic simulations of the spur pipelines were completed to determine when compressor stations would be needed as a function of flow and thereby establish the schedule for capital outlays. Capital cost estimates were prepared for the spur pipeline and compressor stations. Capital costs for the gas processing plants were based on information contained in a report from ANGDA. The ROE analyses were completed by financial consultants of the brokerage firm AG Edwards based on information provided under the direction of Michael Baker. Unlike the J-curve analysis, which is based on the assumption of constant flow throughout the life of the project, the impact of flow ramp-up is included in the tariff calculations.

During a mid-project review meeting held in May of 2006, NETL representatives, the Advisory Committee and contractor team agreed that the delivered price of gas to Cook Inlet would be based on the installation of 20 inch, 2,500 psig pipelines for both Gas Scenarios 1 and 2. **A 20 inch, 2,500 psig pipeline was selected only for the purposes of estimating the delivered price of gas to Cook Inlet and is not to be construed as a recommendation for final selection of a pipeline configuration. Final selection of a gas flow scenario and pipeline configuration would be done by the spur pipeline project sponsors.** The selection of pipeline and station configurations for tariff calculation was based on:

- Estimated capital costs through start-up to provide 110 MMscfd of utility gas flow;
- Estimated cumulative capital costs through late life to accommodate 350 MMscfd of utility gas flow during both summer and winter operation;
- Comparative COS values from J-curve analyses;
- Potential for capacity expansion; and
- Ability to provide for the option of future transport of NGLs.

Hydraulic Simulation Results

Capacity of a 20 inch, 2,500 psig pipeline without compressor stations exceeds the demand for Gas Scenario 1 as derived from the Gas Market Assessment. Hydraulic simulation results for Gas Scenario 1 are shown in Figure ES.6. Gas rate in this figure refers to the rate of utility grade gas delivered via the spur pipeline to Cook Inlet.



NOTE: Labels on x-axis are in years (i.e. 2015 – 2035).

Figure ES.6: Cook Inlet Demand and Summer Spur Pipeline Capacity, Gas Scenario 1

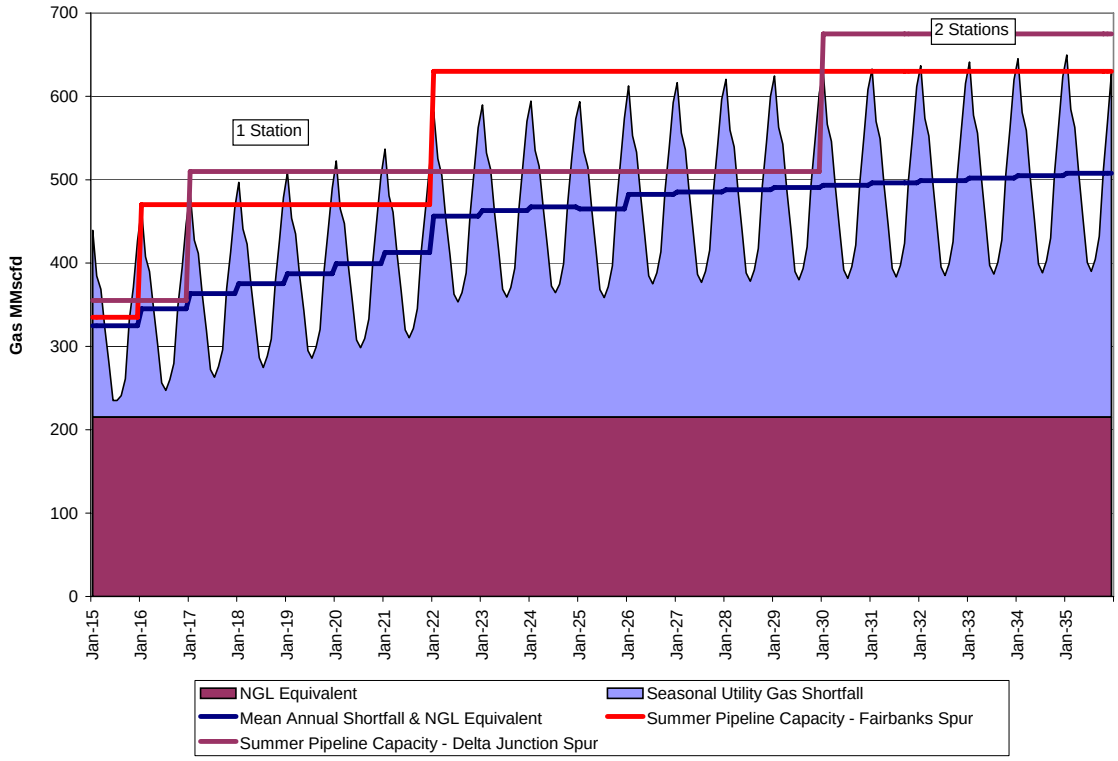
Hydraulic simulation results for Gas Scenario 2 are shown in ES.7. Spur pipeline flow per Gas Scenario 2 exceeds that of Gas Scenario 1 due to spiking of approximately 215 MMscfd gas equivalent of NGL into the gas. Compressor stations for Gas Scenario 2 were assigned whenever the average annual gas demand exceeded the summer pipeline capacity.

Demand values shown in ES.6 and ES.7 reflect seasonal swings in demand, but not the peak daily demand that may be encountered. Pipeline capacity will increase during the winter and it was assumed that shortfalls in between pipeline capacity and seasonal demand would be made up with gas from LNG imports and in-ground gas storage. A discussion of the Cook Inlet gas storage is contained in Section 8.11.

Two compressor stations are required to accommodate late life flow rates for both the Fairbanks and Delta Junction Spur options per Gas Scenario 2. Station locations were selected in order to achieve the maximum possible flow through the respective pipelines even if the resulting flow rate was well in excess of the mean annual Cook Inlet demand.

An evaluation of on-line availability of the spur pipeline is outside the scope of this report. Capital costs for pipeline compressor stations include the installation of an off-line spare gas compressor. All hydraulic results are based on 100 percent on-line availability of the pipeline, compressor stations and associated gas plants.

Spur pipeline capacity will be less in the summer than winter because flow varies inversely with gas temperature and the flowing temperature of the gas will be greater during the summer. Summer pipeline capacities were used for the assignment of compressor stations thereby providing a degree of conservatism regarding installed capacity.



NOTE: Labels on x-axis are in years (i.e. 2015 – 2035).

Figure ES.7: Cook Inlet Demand and Summer Spur Pipeline Capacity, Gas Scenario 2

Capital Cost Estimates and Economic Results

Budget level pipeline capital costs for a 20 inch, 2,500 psig spur pipeline were estimated at $730 million (2006) and $774 million (2006) for the Delta Junction and Fairbanks Spur routes, respectively. Elements that affect capital cost include pipeline size, pipeline length, pumping requirements, environmental factors, and construction challenges.

Compressor station capital costs were based on equipment to provide late life flow rates and were estimated at $36.1 million (2005) for the Fairbanks Spur and $43.4 million (2005) for the Delta Junction Spur. Hydraulic simulation results were used to estimate pipeline gas compression fuel at 0.25 percent and 0.50 percent of pipeline inlet on a thermal basis for one and two stations respectively. Operating cost for the compressors was estimated as five percent of installed capital.

Capital costs for gas processing plants were estimated by factoring cost information contained in the report *Spurline Terminal Conceptual Design* prepared in 2006 by Shaw-Stone & Webster Management Consultants for ANGDA. Capital cost of the gas plant at the inlet of the spur pipeline for Gas Scenario 1 was estimated at $227 million (2006). Capital costs for gas plants at the inlet and outlet of the spur pipeline for Gas Scenario 2 were estimated at $760 million (2006) and $302 million (2006) respectively. Plant fuel was estimated at one percent of feed on a thermal basis. Operating costs for the gas processing plants were estimated as five percent of installed capital.

Overall tariffs for the spur pipeline project, including gas processing facilities at the pipeline inlet and outlet (Gas Scenario 2 only), were calculated by AG Edwards based on input provided by Michael Baker. The price of all hydrocarbons delivered to Cook Inlet, after extraction of fuel for the spur pipeline, Cook

Inlet processing plant and NGL facility, was adjusted until a ROE of 12 percent was obtained over a 33 year project life. The overall tariff for the NGL extraction plant, spur pipeline with stations and Cook Inlet processing plant was determined as the difference between the delivered hydrocarbon price in Cook Inlet and the price of gas purchased from the ANS pipeline. Tariffs were based on the thermal content of the hydrocarbons delivered to Cook Inlet after removal of fuel. Fuel is valued at the price of gas purchased from the ANS pipeline.

Economic premises used by AG Edwards to calculate the tariff for the spur pipeline are the same as those used for the ROI analysis (Appendix 3-6) with the following exceptions:

- Sales price adjusted to yield return-on-equity of 12 percent
- Debt Service Coverage Ratio: Minimum of 1.25x
- Minimum Cash on Hand: $100,000,000
- Debt-Equity Financing: 70-30; equity paid up front
- Debt Structure Assumptions:
    - First Debt Issuance: 2012
    - Last Debt Issuance: 2016 for Gas Scenario 1, 2015 for Gas Scenario 2
    - Principal Payment Amount: equal principal from first principal payment date to last principal payment date
    - First Principal Payment Date : 2021 (consistent in all four scenarios)
    - Last Principal Payment Date (dictated by first year coverage ratio): 2033 for Gas Scenario 1, 2034 for Gas Scenario 2
    - Term of financing: 21 years and 22 years from first debt issuance to last principal payment date for the Gas Scenario 1 and Gas Scenario 2, respectively

Price of gas delivered to Cook Inlet was estimated as the sum of the price of gas at the inlet of the ANS pipeline on the North Slope, the tariff to transport the spur pipeline gas through the ANS pipeline to the spur pipeline take off point and the tariff from the inlet of the NGL plant at the spur pipeline inlet to delivery at Cook Inlet. A summary of the tariff results and estimated delivered price of gas to Cook Inlet are contained in the following table:

Table ES.1: Estimated Price of Gas Delivered to Cook Inlet, $/MMbtu

	Gas Scenario 1 Delta Junction Spur	Gas Scenario 1 Fairbanks Spur	Gas Scenario 2 Delta Junction Spur	Gas Scenario 2 Fairbanks Spur
ANS purchase price	3.20	3.20	3.20	3.20
ANS tariff	0.57	0.47	0.57	0.47
Spur pipeline tariff	1.68	1.75	1.30	1.33
Delivered price	5.45	5.42	5.07	5.00
All values are expressed in $/MMbtu				

Delivered prices in the above table do not contain charges for transportation through ENSTAR's distribution system. ENSTAR estimates the distribution fee at approximately $0.25/MMbtu.

For the same gas scenario, there is no substantial difference in the price of gas delivered to Cook Inlet via the Fairbanks and Delta Junction Spur options. The two spur pipeline options are economically indistinguishable based on the level of accuracy of the capital costs and the supporting engineering specification.

A premise of the Gas Market Assessment is that the price of gas entering the ANS pipeline on the North Slope will be the delivered gas price at the ANS pipeline terminus near Chicago minus the ANS pipeline tariff. The price of gas entering the ANS pipeline will thus be tied to the price of gas near Chicago.

The highest price for gas delivered to Cook Inlet calculated for either Gas Scenario 1 or 2 is $5.45/MMbtu. Economic results support the conclusion that a spur pipeline off of the main ANS pipeline can deliver gas to Cook Inlet at or below the price of gas delivered to the Chicago area via the ANS pipeline. This trend regarding the relative price differential between gas near Chicago and Cook Inlet will hold regardless of the price of gas near Chicago.

This study used the volume ramp up scenarios from the SAIC report. A protracted flow ramp-up as described in the Gas Market Assessment underutilizes the installed capacity of the spur pipeline with a negative impact on project economics. A scenario that might be viable would be to import LNG to replace the projected Cook Inlet gas shortfall and defer installation of the spur pipeline for a number of years to allow the annual shortfall to increase. Deferring construction would enhance the spur pipeline economics by providing a greater flow rate immediately after commissioning, thereby utilizing the installed pipeline capital more efficiently.

The economics of pipeline projects are strongly influenced by the outlay of capital for design, procurement, and construction. Although small compared to the ANS pipeline, the 300 mile spur pipeline would be a significant project by itself. Simultaneous construction of the ANS pipeline and the spur pipeline could result in competition for limited resources. Procurement and construction for the spur pipeline would need to be scheduled to avoid such competition.

Section 9. Considerations for Future Work

Any potential spur pipeline would need to provide a highly reliably source of utility gas to Cook Inlet. Pipeline operability reviews would need to be completed to ensure that the overall pipeline and compression system, including gas processing facilities, would operate safely, reliably and in accordance with all regulatory criteria.

An operability review should, at the minimum, address the following:

- Operation at each discrete ramp-up increment projected for the project;
- Contingency plans for operation if one or more compressor stations or gas processing facility is off-line;
- Operation subject to planned maintenance;
- Procedures for pressure reduction and removal of a high-pressure pipeline from service for scheduled or unscheduled maintenance; and re-pressurization of the pipeline to return it to service;
- Re-wheel of pipeline gas compressors installed early in the project as flow increases; detailed review of the operation of individual gas compressors must be completed to ensure adequate operation over all flow rates;

- Detailed review of the operation of the gas refrigeration systems at peak summer loads and subject to winter temperatures when minimum loads are encountered or possibly the system is not required at all; and
- Seasonal project capacity with respect to peak seasonal and daily loads requiring gas removal from storage in Cook Inlet.

Future work requirements would be predicated upon selection of a single spur pipeline route prior to beginning detailed studies. The future work would include but not be limited to:

- Develop a public outreach program for the project.
- Engage FERC and other regulatory agencies in pre-application dialogue to ensure that the NEPA process is completed in the shortest timeframe possible.
- Preparation of a Geographical Information System (GIS) database for use as a single data repository for the project.
- Preparation of a permit plan and schedule for all phases of the project.
- Start field work including:
    - Surface and sub-surface geo-technical investigations
    - Stream crossing surveys to include fisheries impacts and construction methodologies
    - Initial selection of compressor stations sites
    - Initial selection of material storage and camp sites
    - Initial selection of mining sites
    - Detailed analysis of the route options to finalize a preferred optimum alignment
    - Initial evaluation and selection of access roads required for construction as well as operation and maintenance of the spur pipeline
- Continue to refine the ROW ownership records for the project.
- Define the gas processing requirements including whether the gas will include non-methane components.
- Evaluate potential take-off points for distribution of gas at communities along the spur pipeline.
- Conduct an open season to determine the gas volume that would have to be transported on the spur pipeline.
- Improve the detail and quality of the capital estimates for the project.
- Prepare a project schedule up to and through commissioning of the system.
- Prepare critical material lists for the project.
- Prepare construction and material specifications for the project.

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Acronyms and Abbreviations

AAC	Alaska Administrative Code
ACI	Arctic Slope Regional Corporation Constructors, Inc.
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADL	Alaska Division of Lands
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
AEA	Alaska Energy Authority
AFS	Air Force Station
ANCSA	Alaska Native Claims Settlement Act
ANGDA	Alaska Natural Gas Development Authority
ANILCA	Alaska National Interest Lands Conservation Act
ANS	Alaska North Slope
ANSI	American National Standards Institute
ARRC	Alaska Railroad
AS	Alaska Statute
ATV	all terrain vehicle
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
bpd	barrels per day
Bcfd	Billion standard cubic feet per day
btu	British thermal unit
CFR	Code of Federal Regulations
CIRI	Cook Inlet Regional Corporation
CO	carbon monoxide
COS	cost of service
CPCN	Certificate of Public Convenience and Necessity
cu ft	cubic feet/foot
CWA	Clean Water Act
deg F	Degrees Fahrenheit
DEM	digital evaluation modeling
DOE	United States Department of Energy
EA	Environmental Assessment
EED	Environmental Evaluation Document
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
EPC	engineering-procurement-construction
ESA	Endangered Species Act
FAP	Federal Aid Primary
FERC	Federal Energy Regulatory Commission
FNSB	Fairbanks North Star Borough
FONSI	Finding of No Significant Impact
ft	Feet/foot
GIS	Geographical Information System
GL	Glacial Lacustrine
GVEA	Golden Valley Electric Association
HDD	Horizontal Directional Drilling
HHV	Higher heating value
hp	horsepower (installed capacity)
JPO	Joint Pipeline Office
J-T	Joule-Thompson
Kv	kilovolt
LBC	Local Boundary Commission
Lf	linear feet/foot
LHV	Lower heating value
LiDAR	Light detection and ranging
LNG	liquefied natural gas
MAOP	maximum allowable operating pressure
Mcf	thousand cubic feet
MDTP	Missile Defense Testbed Program
MEA	Matanuska Electric Association
MMbtu	Million British thermal units
MMscfd	Million standard cubic feet per day
MP	Sequential milepost along a conceptual alignment where MP = 0 is the start
MSB	Matanuska-Susitna Borough
msl	mean sea level
NAAQS	National Ambient Air Quality Standards

NEPA	National Environmental Policy Act
NETL	National Energy Technology Laboratory
NGL	Natural gas liquids
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NTP	Notice to Proceed
NWI	National Wetlands Inventory
PLO	Public Land Order
PSD	Prevention of Significant Deterioration
psi	pounds per square inch (differential pressure)
psia	pounds per square inch absolute (psig + 15 psi; used in calculations)
psig	pounds per square inch gage
RCA	Regulatory Commission of Alaska
ROE	return on equity
ROI	return on investment
ROW	right-of-way/rights-of-way
RS	Regulatory Statute
SCADA	Supervisory Control and Data Acquisition
scf	standard cubic foot (or feet)
SHPO	State Historic Preservation Office
TAGS	Trans Alaska Gas System
TAPS	Trans Alaska Pipeline System
Tbtu	Trillion British thermal unit
Tcf	Trillion cubic feet
USACE	United States Army Corps of Engineers
USC	United States Code
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Section 1. Introduction and Project Description

1.1 Authorization

Arctic Slope Regional Corporation Constructors Incorporated (ACI) prepared this Conceptual Engineering/Socioeconomic Impact Study for the proposed Alaska Spur Pipeline under a contract to the United States Department of Energy-National Energy Technology Laboratory (DOE-NETL). The report team is comprised of staff from ACI, NORSTAR Pipeline Company (NORSTAR), and Michael Baker Jr., Inc. (Michael Baker). NORSTAR is an affiliate of ENSTAR Natural Gas Company (ENSTAR), an Alaska-based company, a division of SEMCO Energy, Inc.

ACI provided contract oversight, project management and cost control. ACI staff contributed expertise in socioeconomic evaluation and the permitting and regulatory processes including the National Environmental Policy Act (NEPA). Michael Baker performed a conceptual engineering study including the tasks that pertain to engineering of the pipeline and compressor stations. NORSTAR conducted a right-of-way (ROW) land analysis for both the Delta Junction and Fairbanks Spurs.

The information presented in this report is based in part on two hydrocarbon demand scenarios identified in the Southcentral Alaska Gas Needs Assessment (Gas Market Assessment) (SAIC 2006) provided by the DOE-NETL.

1.2 Purpose of the Study

The of the study is to provide current information pertaining to the potential construction of a buried spur pipeline that would bring gas from the proposed Alaska North Slope (ANS) gas line to Interior and Southcentral Alaska. The study is intended to provide comparative information for each of two currently proposed spur line routings. The study presents findings, conclusions, and vital information considered, but does not include recommendations for construction of any particular pipeline configuration along any route. (The scope of work for this particular study excluded the field work necessary to establish pipeline alignment with sufficient detail for submittal of ROW application(s).)

1.3 General Project Description

Two routes were considered for the primarily buried spur pipeline from the proposed large-diameter main ANS gas pipeline to Alberta to ENSTAR's 20 inch utility gas transmission pipeline in Cook Inlet:

- One route, referred to as the "Delta Junction Spur," originates at Delta Junction and generally follows the Richardson Highway to Glennallen, then follows the Glenn Highway to terminate at ENSTAR's pipeline near the intersection of the Glenn and Parks Highways near Palmer.
- The second route, referred to as the "Fairbanks Spur," originates at Fairbanks and generally follows the Parks Highway to terminate at ENSTAR's pipeline near Wasilla.

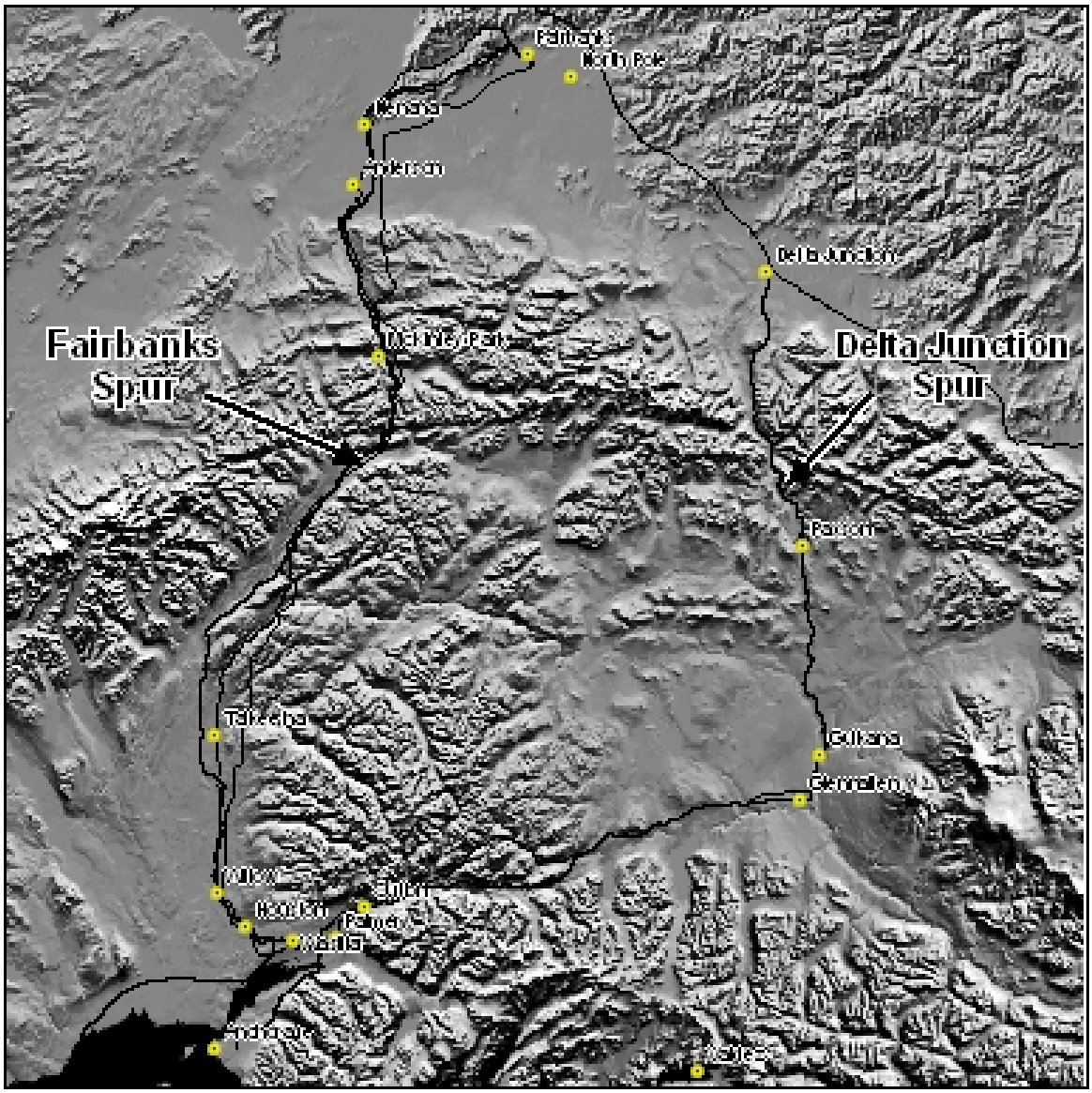


Figure 1.1: Proposed Spur Pipeline Routes

1.4 Report Organization

This document addresses two proposed spur pipeline corridors; presents the engineering design approach including pipeline sizing, compression and alignment; describes a proposed route for each spur; presents the results of preliminary investigation and planning for regulatory compliance and socioeconomic impacts; and describes the economic considerations including cost estimates, tariff calculations and a projection of the potential price of gas to be delivered to Cook Inlet. Consideration of future design work and future public outreach are also presented in this report. Appendices containing technical reports, evaluations, analysis, and assumptions supplement the information presented in each section.

1.4.1 Engineering Primer

Both potential spur pipeline routes traverse permafrost and configuration of the spur pipeline must address pipeline operating temperature with regard to the potential for frost heave and/or thaw settlement. The detailed thermal-hydraulic analyses required to address the long-term integrity of the pipeline with respect to frost heave and thaw settlement are outside the scope of work for this study. Where possible, the pipeline and stations were configured to produce operating temperature profiles within general limits selected based on engineering experience and judgment. A significant amount of engineering work would be required to fully characterize soil and climatic conditions along the spur pipeline and assess the thermal interaction of the pipeline and soil.

1.4.2 Pipeline Sizing and Compression

The objectives of the pipeline-sizing and compression portion of the Conceptual Engineering Study were to identify the major engineering issues that would impact the design of the spur pipeline, assess the relative economic merits of a wide range of pipeline and compression options, and address options for the diameter and operating pressure of the proposed spur pipeline based on specific hydrocarbon demand scenarios.

The information presented in this report suggests various pipeline and compressor configurations for a potential spur pipeline project. Specific pipeline and station configurations were solely selected to serve as a basis for economic comparison of the Fairbanks and Delta Junction Spur options. **This report does not contain recommendations for construction of any specific pipeline configuration or selection of either the Fairbanks or Delta Junction Spur route options.**

1.4.3 Pipeline Routing and Alignment

A matrix of issues regarding both the Fairbanks and Delta Junction Spur routes was developed for use in selection of pipeline alignments (Appendix 4-2). The matrix includes geotechnical, environmental, permitting, construction, land ownership, and related issues that influence alignment selection. Selection of the respective alignments within the two corridors reflects a quantitative and qualitative balance of issues identified in the matrix based on the experience of the study team. The matrix was developed to assist in subsequent pipeline studies and reports.

1.4.4 Right of Way Considerations

Both proposed spur pipeline routes traverse state, federal, Native corporation and privately owned lands. Title investigation and analysis was conducted. ROW alignment selection resulted from engineering design and environmental decisions.

A total of sixty-three potential route variations were developed within the two major route alignments. Along the Fairbanks Spur, 42 alignments were identified within the Fairbanks North Star Borough (FNSB); seven alignments between the FNSB and Willow; and four alignments between Willow and the final destination at ENSTAR's 20 inch pipeline Mile Post (MP) 39 facility. Along the Delta Junction Spur, three alignments were developed between Delta Junction and Glennallen; seven alternates between Glennallen and Palmer to the final destination at ENSTAR's 20 inch pipeline located adjacent to the Glenn Highway and Parks Highway interchange. Data provided by the Alaska Natural Gas Development Authority (ANGDA) was incorporated in the analysis of the Glenn Highway (Glennallen to Palmer) selected alignment.

1.4.5 Environmental Permitting and Regulatory Issues

Route evaluation and alignment selection included an examination of ease of permitting and regulatory approval of each route segment option. In conjunction with the permitting and regulatory research, the

physical and biological environments encountered along both spurs were examined, and potential impacts were evaluated when selecting route segments.

1.4.6 Socioeconomic Considerations

The current socioeconomic environment along potential spur routes was examined. The economic benefits and adverse effects of the construction of a spur pipeline to Southcentral Alaska and communities along the route were evaluated. Potential new jobs and new business opportunities were addressed as well as benefits and potential concerns of the project to Alaska Native groups. Potential impacts to sociocultural systems and energy supply in villages and rural areas were also examined.

1.4.7 Delivered Cost of North Slope Gas to Southcentral Alaska

The relative economic merits of various pipeline operating pressure, diameter, and compression scenarios were determined using budget level capital cost estimates and simple return-on-investment (ROI) analyses. A representative pipeline and compressor configuration was selected based on the results of the comparative economic studies and the Gas Market Assessment. Conceptual pipeline capital cost estimates were prepared for both the Fairbanks and Delta Junction Spur options based on this selected pipeline configuration. Efforts were directed toward pipeline cost estimation and hydraulic simulation. The overall economics of the spur pipeline would also depend on the costs for the facilities located at both ends of the pipeline and how the products are marketed. Capital costs for gas processing plants were estimated by factoring information provided by ANGDA.

Return-on-equity (ROE) analyses were performed to determine comparative pipeline tariffs for the two route options and the projected price of natural gas delivered to Cook Inlet. Calculations for the overall tariff to transport hydrocarbons from the North Slope to Cook Inlet address the expense of natural gas processing plants at the inlet and outlet of the spur pipeline.

1.4.8 Considerations for Future Work

Future work requirements would be predicated upon selection of a single spur pipeline alignment prior to beginning detailed studies. The future work would include but not be limited to:

- Develop a public outreach program for the project.
- Engage the Federal Energy Regulatory Commission (FERC) and other regulatory agencies in pre-application dialogue to ensure that the NEPA process is completed in the shortest time possible.
- Preparation of a Geographic Information Systems (GIS) database and make this the single data repository for the project.
- Preparation of a permit plan and schedule for all phases of the project.
- Start field work including:
    - Surface and subsurface geotechnical investigations;
    - Stream crossing surveys to include fisheries impacts and construction methodologies;
    - Initial selection of compressor stations sites;
    - Initial selection of material storage and camp sites;
    - Initial selection of mining sites;
    - Detailed analysis of the route options to finalize alignment; and

  - Initial evaluation and selection of access roads required for construction as well as operation and maintenance of the spur pipeline.

- Continue to refine the ROW ownership records for the project.
- Define the gas processing requirements including whether the gas would include non-methane components.
- Evaluate potential take-off points for distribution of gas at communities along the spur pipeline.
- Conduct an open season to determine the gas volume that would have to be transported on the spur pipeline.
- Improve the detail and quality of the capital estimates for the project.
- Prepare a project schedule up to and through commissioning of the system.
- Prepare critical material lists for the project.
- Prepare construction and material specifications for the project.

Section 2. Engineering Design Concepts

2.1 Introduction

Design of the spur pipeline would greatly differ from that of a pipeline in the Lower 48 because it would traverse permafrost and areas of discontinuous permafrost. In addition there is potential that a natural gas enriched in non-methane hydrocarbons could be transported through the pipeline. The spur pipeline must be designed with consideration of geotechnical conditions along the route so the pipeline would be compatible with the ground in which it would need to be buried. This section is a primer of fundamental concepts regarding natural gas properties and pipeline design and operation in cold regions. General design trends for pipelines in cold regions are presented at the end of this section.

2.2 Natural Gas Properties

2.2.1 Natural Gas Components

Natural gas leaving oil/water/gas production separators in an oil field consists primarily of methane, but typically contains non-methane hydrocarbons including ethane, propane, butane and light gasoline components, as well as carbon dioxide, hydrogen sulfide and nitrogen. Ultimately, the composition of the natural gas must be adjusted to yield a natural gas of sufficient quality for consumption by residential, power generation and industrial users. A number of different gas processing facilities may be required along the pipeline infrastructure depending on how the respective hydrocarbon components are marketed via the main pipeline through Canada and a spur pipeline to Southcentral Alaska.

Currently, separator gas at Prudhoe Bay is processed at the Central Gas Facility to remove natural gas liquids (NGL) consisting of pentane and heavier components that are spiked into crude oil tendered to the Trans Alaska Pipeline System (TAPS). Ethane, propane and the remainder of the butane are concentrated into a single stream within the Central Gas Facility and then re-injected for enhanced oil recovery (Michael Baker 2005a). It is unknown whether some or all of these non-methane hydrocarbons would be sent to market via the 52 inch pipeline or retained on the North Slope for enhanced oil recovery.

Hydrogen sulfide is toxic in very small concentrations and is typically removed along with carbon dioxide before the gas leaves the oil field. Process facilities for removal of carbon dioxide and hydrogen sulfide can be configured to selectively remove essentially all of the hydrogen sulfide while allowing some of the carbon dioxide to pass through. Removal of carbon dioxide to very low concentrations in the natural gas is expensive and not necessary for most applications unless the gas is to be liquefied. North Slope producers have proposed to remove most of the carbon dioxide from the Prudhoe Bay gas prior to the gas entering the ANS pipeline to Alberta.

Carbon dioxide and hydrogen sulfide are typically removed using an aqueous amine process that saturates the gas with water. The gas will be dehydrated downstream of the amine unit to provide a pipeline gas with a very low water content, which inhibits formation of corrosive liquids and gas hydrates within the pipeline.

Nitrogen content of Prudhoe Bay gas will likely be less than one percent (Michael Baker 2005a). Removal of nitrogen from natural gas typically requires the use of a cryogenic process, is expensive, and not conducted unless the nitrogen is present in concentrations much greater than those anticipated from Prudhoe Bay.

Utility grade natural gas refers to methane-rich gas that meets quality specifications for residential, power generation or industrial use. Utility gas composition can vary and typically includes a small amount of ethane, a smaller amount of propane, and essentially no butane or gasoline components. The combined amount of carbon dioxide and nitrogen in utility gas is typically limited to a few percent.

2.2.2 Gas Heating Value

Natural gas heating value refers to the energy released when the gas is burned. Higher (or gross) heating value (HHV) refers to the energy released, as measured in controlled laboratory conditions. Natural gas purchase contracts are typically based on the HHV.

Lower (or net) heating value (LHV) refers to the energy released when natural gas is burned as fuel and hot exhaust gases are released to the atmosphere. LHV is less than the HHV and reflects the useable energy obtained from gas combustion subject to actual equipment operation. HHV and LHV values of components typically found in natural gas are shown in Table 2.1.

Table 2.1: Higher and Lower Heating Values of Natural Gas Components

Component	HHV (btu/scf)	LHV (btu/scf)
Carbon Dioxide (CO_2)	0	0
Nitrogen (N_2)	0	0
Methane (C_1)	1010	909.4
Ethane (C_2)	1769.6	1618.7
Propane (C_3)	2516.1	2314.9
Iso-butane (IC_4)	3251.9	3000.4
Normal-butane (NC_4)	3262.3	3010.8
Normal-pentane (NC_5)	4008.9	3699

Fuel volume is calculated based on the consumption rate of a given unit of equipment and the LHV of the gas. Once the fuel volume is determined, fuel is then expressed on a HHV basis for use in material balances and economic analyses.

2.2.3 Gas Flow - Volumetric and Thermal Basis

Natural gas pipeline tariffs are routinely expressed on a volumetric, or thousand cubic feet (Mcf), basis because capital costs for pipeline and compression vary primarily with flow. Natural gas is bought and sold on a thermal, or British thermal unit (btu), basis because natural gas is valued for its energy content and not its volume. Natural gas contracts are sometimes expressed on a volumetric basis, but in such cases almost always include an adjustment factor for thermal content.

HHV value of utility gas is typically allowed to vary from 950 to 1,050 btu/standard cubic foot (scf). At 1,000 btu/scf, a pipeline tariff expressed in $/Mcf is mathematically identical to a tariff expressed in $/million British Thermal Units (MMbtu).

A pipeline tariff expressed on a volumetric basis has limited use for economic analysis since it does not account for the thermal content of the gas. Gas prices and pipeline tariffs are expressed on a thermal basis for the purposes of the economic analyses contained in this report. This approach addresses the change in gas composition as it is transported from the North Slope to Cook Inlet.

2.2.4 Pipeline Design and Operation

Pressure

Three units of pressure are used to describe the operation of natural gas pipelines: pounds per square inch gage (psig); pounds per square inch absolute (psia); and pounds per square inch (psi).

Psig refers to the pipeline operating pressure measured in the field using gages and sensors. These instruments measure the differential pressure between the fluid within the pipeline and atmospheric pressure outside of the pipeline.

Engineering calculations are based on a standard reference pressure that accounts for the impact of atmospheric pressure on gage pressure measurement. **Psia** refers to the pipeline operating pressure after adding atmospheric pressure, which is approximately 14.7 psia at sea level.

A differential pressure is expressed in **psi** and is independent of gage or absolute pressure. Differential pressures are determined using values expressed on a similar basis, that is, psi must be calculated by subtracting a psia value from a psia value or psig from psig.

Maximum allowable operating pressure (MAOP) refers to the greatest pressure at which the pipeline may operate according to design codes and standards. MAOP is determined based on the pipe diameter, pipe wall thickness, pipe grade, design factor (class location), pipe fabrication methods, and hydrostatic test methods.

Pipeline Pressure Gradient

Gas pressure drop per unit length of pipeline, or pressure gradient, increases in the direction of flow. The magnitude of the pressure gradient impacts the amount of gas compression horsepower required along the pipeline and pipeline operating temperature.

Natural gas flow rate through a segment of pipeline varies roughly with the square root of the differences in squares of the inlet and outlet pressures of the segment. For example, assume natural gas leaves a compressor station at 1,400 psia and there is a pressure drop of 200 psi over the next 50 miles of downstream pipeline at constant elevation. Operating pressure at a point 100 miles downstream from the station can be roughly estimated using the following approach:

Pressure driving force for first 50 miles of pipeline $= [(1{,}400)^2 - (1{,}200)^2]^{0.5}$

The same pressure driving force is required for the next 50 miles, so:

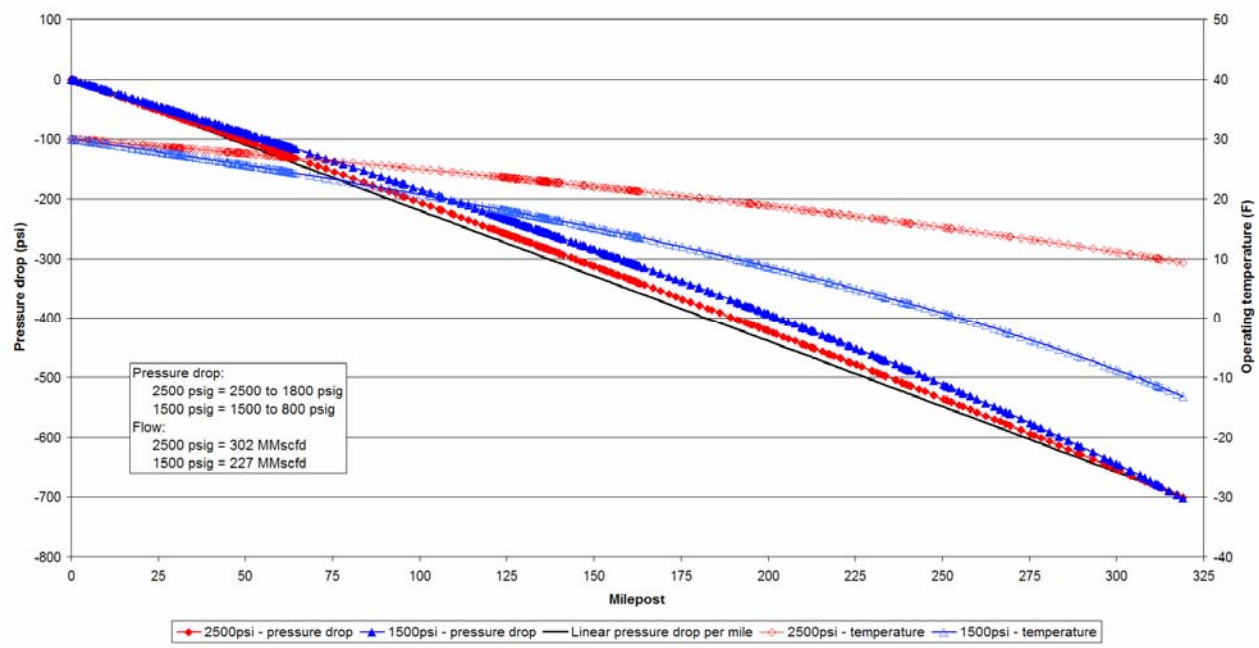
$[(1{,}400)^2 - (1200)^2]^{0.5} = [(1{,}200)^2 - (\text{pressure 100 miles downstream})^2]^{0.5}$

The approximate pressure 100 miles downstream would be 959 psia.

Similarly, the pressure 150 miles downstream would be approximately = 633 psia.

Based on the above example, the pressure drop for the first three 50 mile pipeline segments would be 200 psi, 241 psi (1,200 – 959) and 326 psi (959 – 633), respectively.

Hydraulic simulation results for the 322 mile, 20 inch pipelines with different operating pressures on level ground with no heat transfer through the pipe wall are shown in Figure 2.1. The figure reflects scenarios in which flows through pipelines with inlet operating pressures of 2,500 and 1,500 psig were adjusted to produce a 700-psi pressure drop over the same length of the pipeline. A reference line was added to show a linear pressure drop per mile of pipe.



MMscfd = Million standard cubic ft per day

Figure 2.1: Pressure Gradient and Joule-Thompson Cooling, 20 Inch Pipelines, No Heat Transfer through the Pipe Wall

Pressure curves for both the 2,500 and 1,500 psig pipelines are above the reference line representing the average linear pressure gradient over the entire 322 mile length of the pipe. The upward bow in the pressure curves relative to the pipeline-wide average pressure drop shows that the pressure drop per mile gradually increases as the gas progresses downstream. The more exaggerated deterioration of pressure gradient with the 1,500 psig pipeline relative to the 2,500 psig pipeline is consistent with the rough mathematical approximation method based on the inlet and outlet pressures of sequential pipe segments.

Joule-Thompson Cooling

In the operating range of the proposed spur pipeline, methane cools, ethane remains approximately the same temperature and propane warms slightly when the pressure of the gas drops. Joule-Thompson (J-T) cooling, named after the scientists who pioneered the research, refers to the phenomenon of gas cooling with pressure drop. The degree of J-T cooling in the spur pipeline would depend on the relative amounts of methane and non-methane hydrocarbons in the natural gas mixture. A utility gas consisting primarily of methane will experience more J-T cooling than a natural gas enriched with non-methane components.

The J-T coefficient, that is temperature drop (measured in degrees Fahrenheit [deg F]) per unit of pressure drop (deg F/psi), of methane-rich gas is greater at lower operating pressure than at higher operating pressure. The impact of operating pressure on J-T cooling for a pipeline transporting utility gas is shown in Figure 2.1. Figure 2.1 reflects simulation of a pipeline in which there is no heat transfer through the pipe wall and the temperature profiles depend entirely on J-T cooling. A 700 psi drop in pressure from 2,500 to 1,800 psig results in J-T cooling of approximately 21 deg F over the 322 mile example pipeline. An identical 700 psi drop, from 1,500 to 800 psig, results in J-T cooling of approximately 43 deg F over the same length.

Pipeline operating temperature is an important design consideration where a pipeline would traverse discontinuous or sporadic permafrost with frost-susceptible soils (Section 2.2.5). J-T cooling per mile of

pipeline increases in the direction of flow due to the progressively increasing pressure gradient compounded by the progressive increase in J-T coefficient as the operating pressure declines. Relatively low pipeline operating temperatures can be encountered immediately upstream of compressor stations where the lowest pipeline operating pressures are encountered.

Gas flow rate and composition are critical design issues for a number of reasons including the impact of J-T cooling. A pipeline transporting a natural gas extremely enriched with non-methane hydrocarbons and at a low flow may experience little or no J-T cooling. In this scenario, the J-T cooling would be relatively low because of a combination of gas composition, high operating pressure and low pressure gradient. Conversely, a low pressure pipeline with a high flow rate of utility grade gas will experience significant J-T cooling.

Heat Transfer through the Pipe Wall

Heat will be transferred from the ground surrounding the pipeline through the pipe wall into the flowing gas whenever the temperature of the ground exceeds that of the gas within the pipeline. Conversely, the gas will tend to cool when the ground temperature is less than that of the gas. The amount of heat transfer varies with the temperature difference between the ground and pipeline gas with a large difference resulting in a relatively large amount of heat transfer. Little heat transfer occurs through the pipe wall when the gas and ground are near the same temperature.

J-T cooling will always act to reduce the temperature of a methane-rich natural gas. The combined impact of J-T cooling and heat transfer will vary depending on whether a pipeline operates above or below ground temperature. J-T cooling and heat transfer would be additive during winter and drive pipeline temperature downward.

Figure 2.2 presents the combined impact of ground temperature and J-T cooling on pipeline operating temperature. Pressure and temperature profiles at adiabatic (no heat transfer) conditions in Figure 2.2 refer to the same 20 inch, 1,500 psig pipeline transporting utility gas as shown in Figure 2.1. Summer and winter scenarios are based on hypothetical ground temperatures, of 45 and 10 deg F, respectively, at all locations along the pipeline. These ground temperatures were selected for the purposes of illustration and actual summer and winter ground temperatures will vary along the route. The scenarios are based on 30 deg F gas entering the pipeline, no change in elevation along the route and a gas flow rate that results in a 700 psi pressure drop for the adiabatic scenario consistent with information shown in Figure 2.1.

The hypothetical examples shown in Figure 2.2 are presented for the purposes of illustration and should not be construed as reflecting a recommended design. The scenarios are based on a long pipe segment in order to illustrate operating trends along the pipeline. The trends discussed below will apply to pipeline operation between compressor stations spaced at intervals much less than the 322 mile segment used for illustration.

Ground Temperature Higher than Pipeline Gas

J-T cooling and heat transfer through the pipe wall will be opposing with respect to the influence on gas temperature as long as the temperature of the ground is warmer than the gas. J-T cooling will tend to lower the gas temperature while heat transfer from the pipe wall will tend to warm the gas. The relative impact of J-T cooling and pipe wall heat transfer will depend on the differential temperature between the gas and ground and the pipeline pressure gradient.

Red lines in the example shown in Figure 2.2 depict a hypothetical summer operating scenario where a high-pressure 30 deg F gas is discharged into a pipeline surrounded by 45 deg F ground. Near the inlet of the pipeline, the difference in temperature between the pipeline gas and ground is relatively high and the pressure gradient is low. Subject to these conditions, the influence of ground temperature via pipe wall heat transfer will be dominant relative to the J-T cooling and the gas will warm. Heat transfer will gradually decrease as the temperature of the gas approaches that of the ground. J-T cooling will be relatively weak through the first portion of the pipe segment where the pipeline operating pressure is the greatest and the pressure gradient is the least.

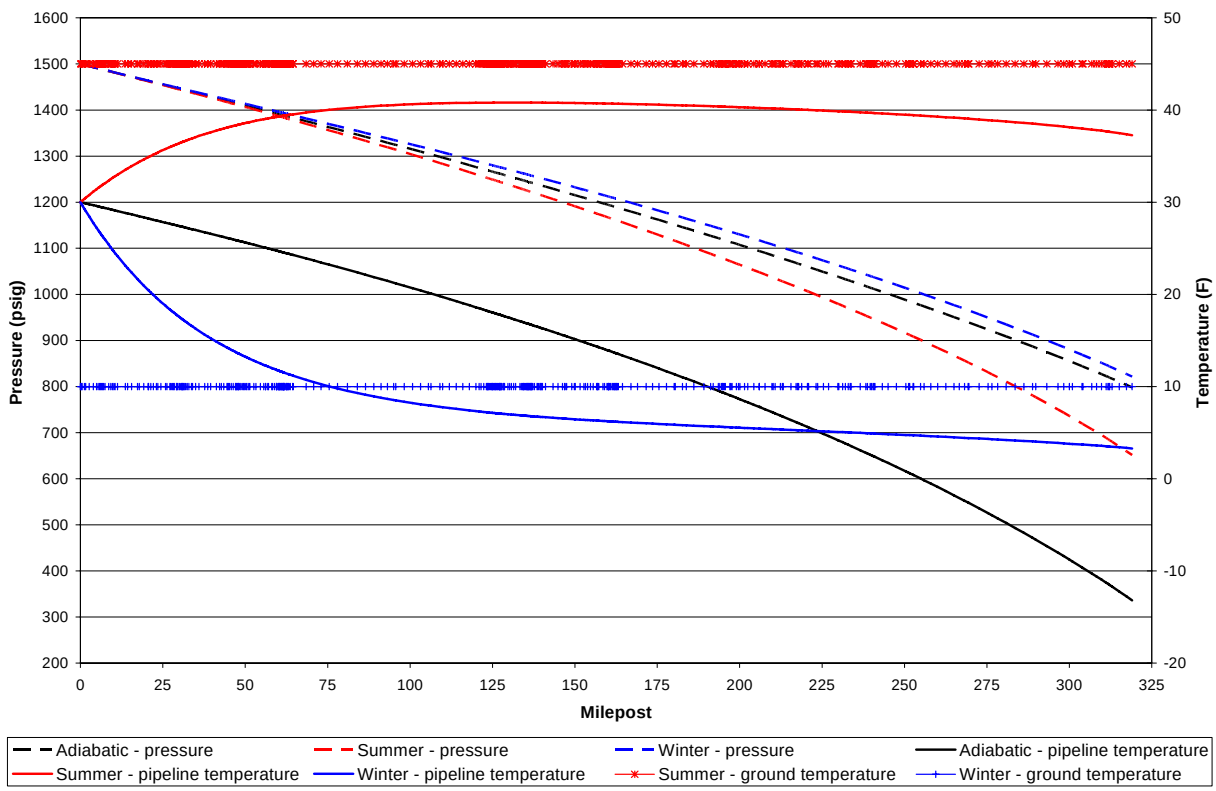


Figure 2.2: Illustration of Combined Impacts of J-T Cooling and Pipe Wall Heat Transfer on Pipeline Gas Temperature

J-T cooling will keep the temperature of the gas from exceeding that of the ground. J-T cooling will tend to reduce gas temperature and increase the differential temperature between the gas and ground, thereby increasing the rate of heat transfer from the ground to the gas. The influence from J-T cooling and pipe wall heat transfer will tend to achieve equilibrium and the temperature of the gas will remain relatively constant.

Pipeline operating pressure will continue to decline and the influence of J-T cooling will tend to increase in downstream sections. At relatively low operating pressures, J-T cooling will become relatively more dominant than pipe wall heat transfer and pipeline operating temperature will tend to drop.

Ground Temperature Lower than the Pipeline Gas

Blue lines in the example shown in Figure 2.2 depict a hypothetical winter operating scenario where a high-pressure 30 deg F gas is discharged into a pipeline surrounded by 10 deg F soil. Initially, the gas is warmer than the ground and both pipe wall heat transfer and J-T cooling will tend to lower pipeline gas temperature. Pipe wall heat transfer will diminish and eventually stop as the temperature of the gas approaches that of the ground. J-T cooling will drive the gas temperature below that of ground.

J-T cooling and pipe wall heat transfer will be opposing once gas temperature drops below that of the ground and pipeline gas temperature will change as described in the prior section for the hypothetical summer scenario.

Adiabatic Operating Scenario

Black lines in the example shown in Figure 2.2 depict a hypothetical adiabatic operating scenario in which there is no heat transfer through the pipeline and gas temperature is governed only by J-T cooling. The adiabatic scenario is provided to show the influence of heat transfer through the pipe wall.

Influence of Gas Temperature on Pipeline Pressure

Pipeline gas flow varies inversely with the operating temperature and greater pressure drops would be expected for scenarios with a higher operating temperature. Dashed lines shown in Figure 2.2 depict the pressure profiles corresponding to the summer, winter and adiabatic temperature profiles generated via hydraulic simulation. As expected, pipeline operating pressure drops to a greater extent for scenarios with warmer operating temperatures.

Cold and Warm Pipeline Operating Modes

Both the Fairbanks and the Delta Junction Spur routes traverse permafrost. Pipelines that traverse permafrost alternating with thawed soils must be designed with consideration of the potential for frost heave and/or thaw settlement (Section 2.2.5).

Natural gas pipelines can be designed to operate below 32 deg F, referred to as the cold mode, by chilling compressor discharge gas prior to it re-entering the pipeline and then relying on J-T cooling with pressure drop to maintain temperatures below 32 deg F. A pipeline can be operated above 32 deg F, referred to as the warm mode, by discharging warm gas from the compressors into the pipeline without chilling. Whether pipeline operation remains in the cold or warm mode downstream of stations depends on the soil temperature, initial gas temperature, gas flow rate, and gas composition.

Cold mode operation is generally applicable to areas where the pipeline traverses continuous or discontinuous permafrost (more permafrost than thawed soil). Warm mode operation is generally selected for areas of sporadic permafrost (more thawed soil than permafrost) and thawed soil.

The spur pipeline can be designed with one transition from cold to warm operation or with multiple transitions from cold to warm and warm to cold. The pipeline may be designed such that the ground around pipe segments seasonally thaws and refreezes. Pipeline operating mode would be determined based on detailed thermal-hydraulic analysis that assesses the thermal interaction of the pipe and surrounding soil (Section 9.4.2). Thermal-hydraulic analysis is outside of the scope of this study.

Dense Phase Operation - Enriched Gas

Natural gas hydrocarbons tend to condense to a liquid as the pressure of the system increases and the temperature is reduced. Natural gas pipelines are designed to avoid condensation of NGL that can result in formation of liquid slugs that can damage the pipeline and/or attendant facilities.

"Phase envelope" refers to the combinations of temperature and pressure conditions at which a portion of a gaseous hydrocarbon mixture will begin to condense or a liquid mixture will begin to boil. Two gas demand scenarios were evaluated in this study and are described in Section 3.5. The phase envelope for the scenario with the most enriched natural gas is shown in Figure 2.3.

"Bubble point" refers to temperature and pressure conditions at which a hydrocarbon liquid will begin to boil. "Dew point" refers to conditions at which a hydrocarbon gas mixture will begin to condense. The portion of the phase envelope between the bubble point and dew point curves, known as the two-phase region, identifies conditions at which both distinct gas and liquid phases will be present. The natural gas mixture will be entirely in the liquid phase at conditions to the left of the phase envelope at conditions of relatively low temperatures. The mixture will be entirely in the gas phase to right of the phase envelope at higher temperatures.

For a given gas composition, there is a unique pressure, called the cricondenbar, above which a distinct liquid phase cannot exist. Gas is referred to as being in the dense phase at any pressure above the cricondenbar. A dense phase gas is sometimes referred to as having properties of both a gas and liquid, or as a compressible liquid. A dense phase gas pipeline refers to a pipeline and compressor system configured such that the minimum pipeline operation pressure is maintained above the phase envelope, thereby precluding formation of liquids.

The two-phase region of a utility gas mixture occurs at temperatures much lower than those encountered with gas transmission pipelines. Considerations regarding dense phase operation typically pertain to a natural gas enriched with non-methane hydrocarbons where operating conditions of traditional gas transmission pipelines could intersect the two-phase region of the phase envelope.

Phase envelope shape varies with the composition of the natural gas. The phase envelope shown in Figure 2.3 is for a gas scenario in which large amounts of non-methane hydrocarbons are blended with a relatively small amount of methane. The phase envelope shown in Figure 2.4 reflects a scenario in which more methane has been blended into the same amount of non-methane components. In this example, increasing the concentration of methane shifts the two-phase region to conditions of higher pressures and colder temperatures.

Lower 48 natural gas transmission pipelines are typically designed with American National Standards Institute (ANSI) 600# flanges, which equates to a MAOP of 1,480 psig. An ANSI 600# pipeline cannot be used for Gas Scenario 2 because it would operate within the two-phase region of the phase envelope and two-phase flow would be expected.

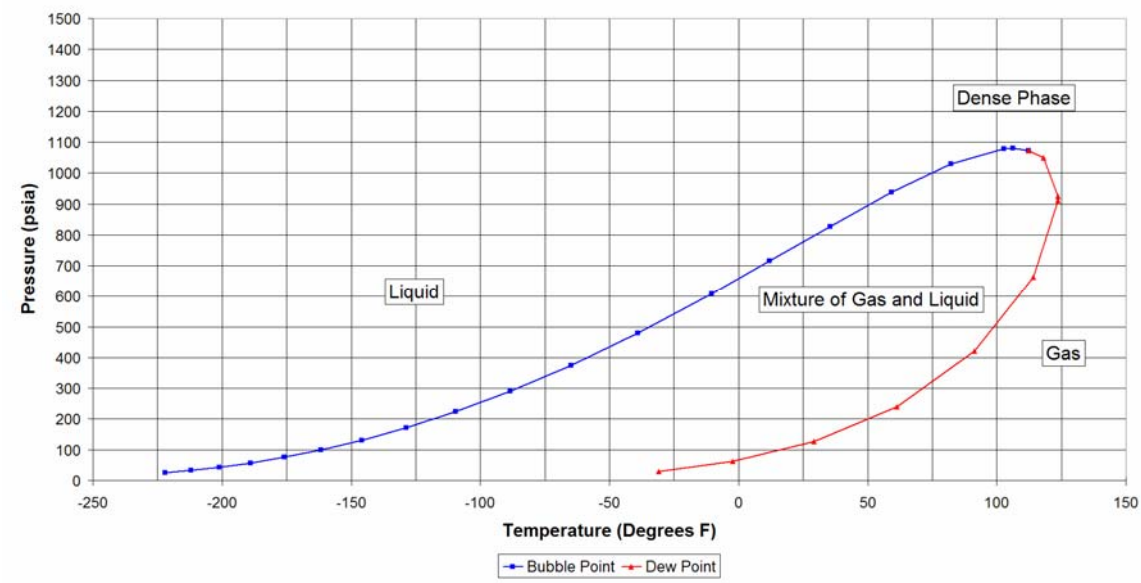


Figure 2.3: Phase Envelope for Gas Scenario 2 – 110 MMscfd Methane, 350 MMscfd Total

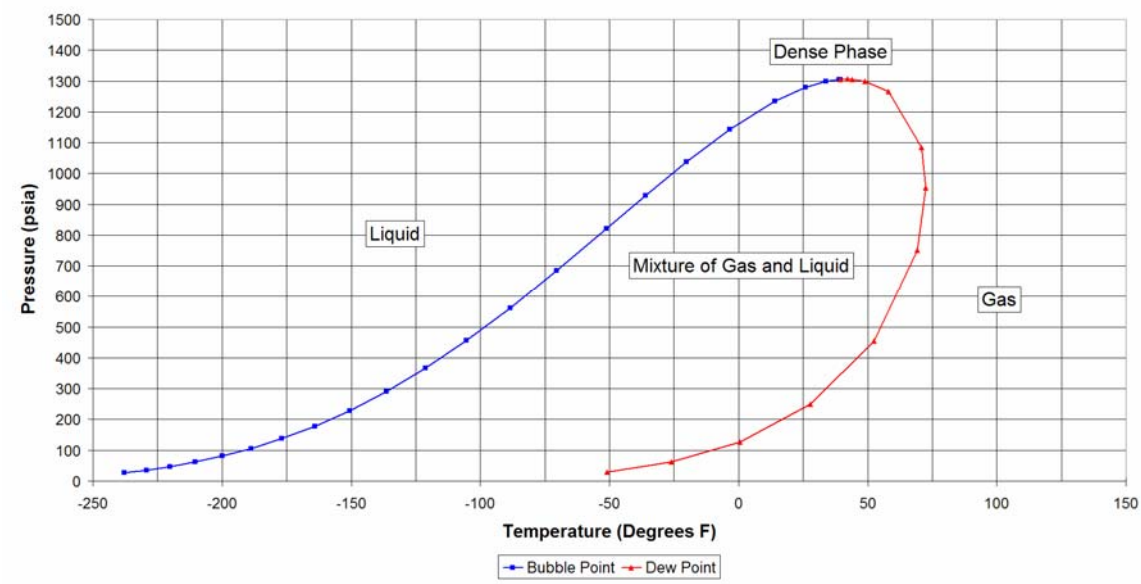


Figure 2.4: Phase Envelope for Gas Scenario 2 - 350 MMscfd Methane, 595 MMscfd Total

Pipeline MAOPs of 2,500 psig have been specified in this study for Gas Scenario 2. A 2,500 psig pipeline would allow a pressure drop of up to approximately 1,000 to 1,300 psi between stations while still maintaining compressor station inlet pressures in the dense phase region (Table 8.3). Pipeline design pressure is not limited to 2,500 psig and spur pipelines with higher MAOPs may be considered during future design efforts.

Impact of Gas Density on Pipeline Operating Pressure and Temperature

Operating pressure of a pipeline traversing areas with elevation changes will be impacted by the weight of the fluid being transported. Fluid weight will reduce the pipeline operating pressure at higher elevations and increase the pressure in low areas. The impact of fluid density is generally a more significant design

issue with liquid than natural gas pipelines. A highly enriched natural gas can be transported via a high-pressure spur pipeline, in which case the gas density will impact the pipeline design and operation.

The range of natural gas densities considered in this study is shown in Table 2.2. Gas density increases with molecular weight, higher pressures and lower temperatures. Molecular weight of an enriched natural gas is greater than that of utility gas. The highly enriched gas during the first years of Gas Scenario 2, chilled at the pipeline inlet will have a density of approximately 46 percent of water.

Table 2.2: Range of Gas Densities, pounds per cubic foot (lb/cu ft)

	Pressure (psig)	Temperature (deg F)	Density (lb/cu ft)
Utility gas at compressor inlet	837	46	3.1
Utility gas at pipeline inlet	1,480	30	6.5
Utility gas at pipeline inlet, high pressure	2,500	30	11.4
Highly enriched gas at pipeline inlet	2,500	30	28.4

Flow profiles for a highly enriched gas (density of 28.4 lb/cu ft) at pipeline inlet conditions transported via a 20 inch, 2,500 psig pipeline over a hypothetical level terrain and topography from Fairbanks to Wasilla are shown in Figure 2.5. Calculations used to estimate ground temperatures along the alignment are contained in Appendix 2-1.

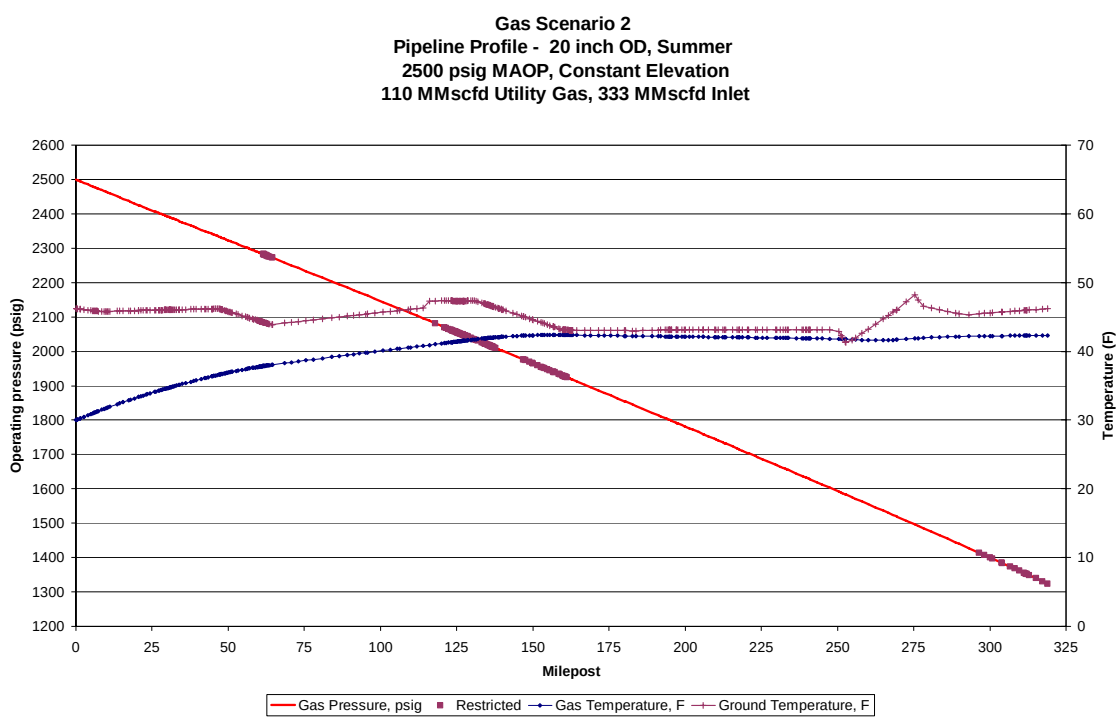


Figure 2.5: Highly Enriched Gas through 20 inch, High Pressure Pipeline with Constant Elevation

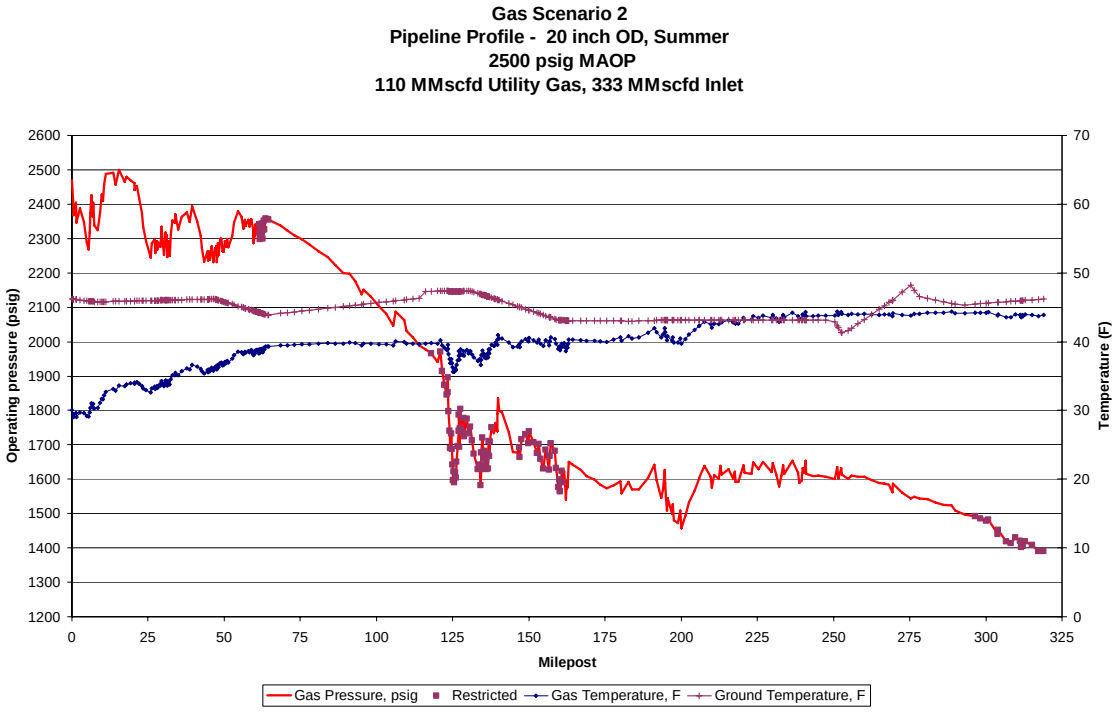


Figure 2.6: Highly Enriched Gas through 20 Inch, High Pressure Pipeline

Figure 2.6 illustrates flow profiles for a highly enriched gas (density of 28.4 lb/cu ft) at pipeline inlet conditions transported via a 20 inch, 2,500 psig pipeline over changing topography. The erratic nature of the pressure and temperature profiles in Figure 2.6, are attributed to the combined influence of gas density and topography. The operating pressure drops when the pipeline traverses higher elevations and increases at lower elevations.

J-T cooling causes the gas temperature to drop with pressure at higher elevations. The gas warms as it is compressed by its own weight as it flows downhill.

The weight of the fluid being transported via pipeline must be addressed to avoid over pressurization of the pipe through areas of relatively low elevation. Such over pressurization is typically a minor concern with natural gas pipelines because the gas density is low. In the above example, gas must enter the pipeline below the 2,500 psig MAOP in order to prevent pipeline over pressuring approximately 15 miles downstream.

Operating pressure drop at high elevations must not be so large as to intersect the phase envelope and cause liquid drop out and two-phase slug flow. Operating pressures at high elevations near or within the gas phase envelope can be avoided by strategic location of compressor stations.

2.2.5 Geotechnical Considerations

The following text for Section 2.2.5 regarding geotechnical considerations has been extracted from the report: "Transport of North Slope Natural Gas to Tidewater" (Michael Baker 2005a) for the Alaska Natural Gas Development Authority. The report is in the public record and the following excerpts are being used with the permission of ANGDA.

Permafrost

Earthen material which remains frozen (<32 deg F) during the entire year for two or more years is defined as permafrost. Included in this definition are certain soils that may not actually be bonded by frost such as some salty and clayey materials, well-drained (dry frozen) sand and gravel, and solid rock. A surficial layer, which is subject to seasonal thawing and freezing, usually overlies permafrost. This is called the **active layer**. Thickness of the active layer depends on ambient temperature variations, slope aspect, and surface cover conditions.

The terms "**continuous**," "**discontinuous**," and "**sporadic**" are used to describe the distribution of permafrost on a regional basis. Areas classified as **continuous** may have some zones such as stream channels or the sediments under deep lakes that are unfrozen but, in general, the entire soil mass beneath the active layer is frozen. **Discontinuous** permafrost indicates an area that is generally frozen beneath the active layer but which may encompass significant zones of unfrozen material as found in south facing slopes in the Fairbanks area. **Sporadic** permafrost indicates that, in general, an area is unfrozen but significant zones of permanently frozen material are present. Isolated frozen zones should be anticipated even in areas classified as permafrost-free along the proposed spur pipeline routes.

Ambient temperature and depth of snow are controlling factors in the regional distribution of permafrost. As a result, latitude, elevation, and snow accumulation often determine distribution patterns. In northern Alaska and in the higher mountain ranges, permafrost is continuous. At lower elevations in the southern part of the state, permafrost distribution is more varied. Also the temperature of the permafrost tends to warm to the south. In many areas, particularly in sporadic zones, the permafrost is degrading under natural conditions. Where fire or other natural or man-made phenomena locally alter the surface cover, permafrost conditions may also be altered.

The creation or degradation of permafrost is not necessarily undesirable. Much of the route corridor is underlain by foundation conditions that are not significantly affected by changes in thermal state. In some cases, however, the effects of thermal change can be detrimental resulting in problems such as pipe stress and disrupted drainage patterns. Freezing unfrozen ground with cold pipelines may result in formation of a **frost bulb**, which may cause **frost heave**. Thawing of frozen ground with warm pipelines may cause **thaw settlement** as permafrost soils drain and consolidate. Changes to the surface cover and drainage patterns as a result of construction and operation activities can accentuate thermal change.

In addition to identifying the distribution patterns of frozen ground, it is important to delineate those areas that are sensitive to thermal change. The temperature of the permafrost and its ice content are the chief parameters to be considered in determining the thermal sensitivity of a given soil mass.

Where possible the final route selected should avoid the most sensitive areas. Established engineering techniques can be evaluated and selected to minimize the subsurface heat loss or gain resulting from the construction and operation of the pipeline and its related infrastructure. Construction mitigation can include scheduling parameters. Seasonal construction and accelerated schedules can be used to limit the thermal exposure in the most sensitive areas.

Frost Bulb

If a belowground gas pipeline is maintained at temperatures below 32 deg F for an extended period of time, the surrounding unfrozen ground will begin to freeze. The newly frozen soil is called a frost bulb because it tends to grow outward in a circular or bulbous fashion. A buried cold gas line may initiate frost bulb growth.

The growth with time of the frost bulb will have certain impacts on the environment in the vicinity of the pipeline. The growth of the frost bulb in previously unfrozen soils will alter subsurface water flow

patterns and temperatures. The growing frost bulb may restrict or redirect subsurface flows and can increase the potential for icings (aufeis) to develop. In some cases, the soil will be displaced upward relative to the surrounding terrain, and may interrupt existing surface flow. In stream crossing areas, it could lead to lower water temperatures that may affect aquatic life and biological organisms.

A growing frost bulb may tend to strengthen the supporting soil but where soils are frost susceptible, segregated ice may form, causing an irregular volumetric growth and frost heave. This activity may place the pipeline in distress.

Frost Heave

A cold gas pipeline passing through unfrozen soils will cause a zone, or “bulb" of frost to develop with time. For a large diameter cold pipeline, this bulb will continue to grow for many years. The presence of the freeze front (the outer limit of the frozen bulb) establishes temperature and pressure gradients within the adjacent unfrozen soils. These gradients move soil water to the freeze front. Frost heave, of soil mass, results from the expansion due to the freezing of the pore water within the frozen bulb and development of segregated ice lenses due to the freezing of soil water as it arrives at the freeze front. Of the two components of frost heave, ice lens growth at the freeze front, is the most significant.

In order for frost heave to occur, three conditions must exist concurrently: 1) soil moisture supply, 2) sufficiently cold temperatures to cause freezing of soil moisture, and 3) a frost-susceptible (fine-grained) soil. If drainage is impeded in non-frost-susceptible soils, freezing of the soil moisture may result in slight upward movements due only to volumetric expansion of water.

The amount of heave a given soil will generate upon freezing (assuming an adequate supply of soil water) is a function of many factors. These include physical soil properties (grain size, soil moisture and density, and the activity of clay particles), thermal gradient at the freeze front (pipe temperature, unfrozen soil temperature), and overburden pressure at the freeze front.

The growth of a frost bulb beneath a pipeline and any attendant frost heave would develop with time and displace the pipeline upward. However, uniform displacement of the pipeline upward would not cause any direct, adverse effects on the pipeline.

The pipeline will be affected by differential frost heave, which can occur site specifically such as at thermal transitions from permafrost to non-permafrost soils. This differential frost heave will displace the pipeline unevenly and may induce strains and associated stresses in the pipeline.

Thaw Settlement

Thaw settlement results from the volume reduction that occurs as over-saturated, ice-rich, frozen soils thaw. In general, thawing can occur anywhere the existing thermal equilibrium within permafrost areas is disturbed.

The drainage of excess water from thawing ice-rich permafrost soils leads to thaw consolidation (volume reduction), which most commonly manifests itself as thaw settlement. The depth of thaw and in-situ soil properties (frozen and unfrozen) determines how much thaw settlement will occur. The rate at which the settlement will occur depends on the amount of excess ice in the frozen soil, the permeability of the unfrozen soil, the rate of advance of the thaw front, and the depth from the surface to the thaw front.

The depth of thaw depends upon the magnitude of the thermal disturbance (surface disturbances, addition of a gravel pad, or a warm gas operating pipeline), the climatic conditions in the area, the frozen and unfrozen soil properties, the average ground temperature, and the impact of groundwater movements.

Thaw settlement generally results in the downward displacement of the pipeline (as opposed to frost heave that displaces the pipeline upward). Differential thaw settlement due to variation in soil types, soil ice contents, and thaw depths, and presence or absence of permafrost can induce strains and associated stresses in the pipe. As with frost heave, these differential movements can occur over relatively short distances and, when considered in conjunction with primary pipeline loading, can create unacceptable pipe strains.

The placement of a gravel (or crushed rock) work pad in permafrost areas may cause thaw settlement to occur adjacent to the pipeline and the thaw can extend laterally beneath the pipeline. ROW disturbances due to ditching, pipe installation, and backfilling may cause some thermal degradation (and possibly thaw settlement) of the near-surface soils during the period prior to pipeline operations. Potential thaw settlement predictions are routinely made using estimates of thaw depth, of soil layer thickness and soil properties, and of thaw strain correlations. These predictions are used to design facilities and/or to develop mitigation measures.

Soil Slope Stability

The pipeline alignment may pass through areas of steep terrain and a variety of geologic regimes. The knowledge gained and geotechnical techniques developed during the construction of TAPS would be utilized wherever appropriate for the proposed spur pipeline. The types of slope instability that could affect a pipeline are summarized as follows:

- Static and dynamic failure of unfrozen soil slopes;
- Static and dynamic failure of thaw plugs on permafrost slopes;
- Static and dynamic failures of cut slopes; and
- Static and dynamic failures of embankments including fill sections, dikes, and berms.

Negative impacts of pipeline construction and operation could include:

- Excessively increasing the slope angle of naturally stable slopes;
- Drainage diversion into sensitive areas;
- Over-loading statically stable rock slopes; and
- Thawing of frost-bonded slopes and subsequent saturation with melt water.

The potential for slope instability must be considered during route optimization. An initial evaluation will be made of the alignment for areas with relatively steep unfrozen slopes and moderate to steep frozen slopes occurring in landforms which exhibit scars indicative of naturally occurring instabilities and/or landforms which experience has shown are sensitive to construction activities. The product of this evaluation would be a list of slopes requiring consideration for realignment and/or detailed stability analysis. Where a significant zone of potential instability is identified in the evaluation process, the potential benefits of realigning the pipeline to avoid the expense of slope stabilization would be considered.

Operational maintenance of drainage ways and slope faces, and visual and instrumented monitoring programs would assure that the pipeline would remain safe and stable throughout its projected lifetime.

Seismic Hazards

A major design criterion for this pipeline would be the ability of the entire system to withstand all reasonably anticipated effects of natural phenomena, including earthquakes. The design for seismic resistance would be based on modern, state-of-the-art seismic design criteria and practices. Extensive

studies would be required in the development of project seismic design criteria and procedures. The knowledge gained and seismic techniques developed during the construction of TAPS would be utilized wherever appropriate for the proposed spur pipeline.

Liquefaction

During long-duration seismic events certain soil types may, if saturated, lose much of their shear strength and behave as a liquid mass with flow capabilities. Seismic liquefaction commonly occurs in saturated loose, cohesionless granular material. Soil deposits will tend to decrease in volume as they consolidate under cyclic seismic shaking. If boundary conditions of the deposit do not permit a rapid drainage of excess water, the resultant increase in pore pressure may be sufficient to produce a loss of strength and a collapse of the intergranular soil structure.

A liquefied soil offers little support or uplift resistance to buoyancy and the entire soil mass may move down slope on slopes greater than two percent or up to the ground surface as sand boils. Under such conditions, structures located in or on level ground will tend to float or sink depending on buoyancy considerations. Even on relatively flat slopes an unconfined soil mass and any structure supported by that mass will tend to slide or flow downhill. Liquefied soils quickly regain their strength once the shaking ceases and drainage occurs.

Seismic liquefaction is a naturally occurring phenomenon, but the potential for occurrence may be affected by pipeline construction and operation if natural drainage patterns are changed resulting in the saturation of sensitive soils. Drainage patterns may be changed by surface features such as road embankment or by subsurface features such as the pipeline ditch or constricting freeze bulb.

Many of the relatively common deposits of uniform silts and fine sandy silts along the proposed spur pipeline route corridors lack cohesion. Because of a general lack of cohesion, these materials are susceptible to seismic liquefaction. The spur pipeline and ancillary structures would traverse areas where soils with low cohesion and high groundwater content may be exposed to strong seismic activity. Therefore, the liquefaction potential along the proposed routes is a significant geotechnical constraint to siting and design.

Areas identified as prone to liquefaction would be avoided as much as possible by minor adjustments in the spur pipeline alignment and facilities siting. Because of the significant expense of stabilizing an area of potential liquefaction and/or constructing a pipeline segment capable of resisting adverse loading because of seismic liquefaction, a relatively high priority would be given to avoiding potentially liquefiable areas.

Active Faults

Both proposed spur pipeline route corridors cross active faults. Faults with suspected Holocene activity that cross or trend directly toward the spur pipeline route corridor would require extensive field investigation and characterization to determine location, return period, and sense and magnitude of movement for proper design of the pipeline.

Thermal Design Issues

Compressor stations are located periodically along a natural gas pipeline to return the gas pressure to the pipeline MAOP. The pipeline diameter, operating pressure, number of compressor stations and size of equipment at the stations are optimized together to yield the lowest cost system for the design rate of flow. In the Lower 48, pipelines and stations are usually configured to minimize installed capital. The spur pipeline to Southcentral Alaska would traverse permafrost and must be designed with consideration of both the beneficial and adverse impact on pipeline operating temperature on the surrounding soil.

The thermal compatibility of the pipeline and soil would be addressed by estimating rate of propagation and long-term growth of frost or thaw bulbs around the spur pipeline, combining the bulb growth data with soil properties to estimate differential ground movement and deformational stresses that may be induced on the pipeline, and assessing the ability of the given pipeline to withstand these stresses. The results of the pipe stress analysis would be used to identify areas at risk for significant long-term frost heave or thaw settlement.

Ultimately, thermal design of a pipeline is an economic assessment of various means to mitigate the long-term risk for adverse frost heave or thaw settlement. Traditionally, pipeline design through discontinuous permafrost has been conducted by first selecting the pipeline route and stations to minimize capital costs and then addressing the costs for mitigating frost heave and thaw settlement (Metz and Whitmore 1999). This traditional approach tends to result in high potential for frost heave and thaw settlement requiring significant mitigation. More recent approaches have focused on configuring a pipeline and stations to yield pipeline-operating temperatures that avoid the formation of adverse thermal conditions.

The operating temperature of the spur pipeline would be influenced by climatic conditions, ground temperature, gas flow rate, gas composition, pipeline operating pressure, and distance between compressor stations. Climatic conditions and ground temperature are outside of the pipeline designer's control. Gas flow rate and composition typically cannot be adjusted by the pipeline designer. The pipeline designer can influence pipeline-operating temperatures by adjusting the operating pressure and location of stations. Designers also can also adjust the pipeline alignment to avoid soils prone to frost heave or thaw settlement.

As mentioned previously, the most optimal design for control of pipeline operating temperature is likely not the most optimal with respect to minimization of capital costs. Thermal design of the spur pipeline would involve trade-offs between increased capital costs and mitigation of risk for anticipated adverse thermal impacts.

The annual schedule for ramp-up of gas flow to the design rate could greatly affect the pipeline operating temperature because flow influences the relative impact of J-T cooling and heat transfer through the pipe wall (Section 2.2.4). At low flow rates, the spur pipeline would operate as an ambient pipeline with the temperature tracking the seasonal ground temperature. The temperature of the spur pipeline may be controlled to some extent at higher flow rates because of the added influence of J-T cooling. The temperature of the spur pipeline would not be as easy to control as the temperature of the 52 inch pipeline operating at design capacity because the surface area of the spur pipeline relative to the flow rate of gas would be much less.

2.2.6 General Design Trends for Spur Pipeline Design

The following general trends can be deduced based on the design issues presented in the previous sections:

- A natural gas highly enriched in non-methane hydrocarbons can be transported in the dense phase via a high pressure pipeline without liquid condensation and formation of slug flow.
- The HHV would cause an enriched gas pipeline to have a lower tariff expressed on a thermal basis than a pipeline transporting utility gas.
- Pipelines traversing discontinuous and sporadic permafrost must be designed with consideration of long-term formation of frost heave and/or thaw settlement and resultant differential movement of the soil.

- J-T coefficient (temperature drop per unit of pressure drop) depends on the methane content of the gas; a natural gas enriched in non-methane hydrocarbons will experience less J-T cooling than a pipeline transporting utility gas.
- For the same gas flow and composition
    - Pressure gradient (pressure drop per unit length of pipe) will be less for a higher pressure than a lower pressure pipeline.
    - J-T coefficient of a methane-rich natural gas will be less for a higher pressure pipeline than a lower pressure pipeline.
    - J-T cooling of a methane-rich natural gas will be less for a higher pressure pipeline than a lower pressure pipeline, thereby tending to flatten the pipeline operating temperature profile.
- Weight of a highly enriched natural gas will cause pipeline gas to expand or compress with elevation change, thereby influencing local operating temperature and pressure of the pipeline.
- Excluding consideration of frost heave and thaw settlement, capital costs of a pipeline and compression system can be minimized by installing the least number of compressor stations with large sized equipment installed at each station.
- Configuring the pipeline and compressor station configuration to restrict the range of allowable pipeline operating temperatures, thereby mitigating potential development of adverse frost heave and thaw settlement would add cost to the overall system.

Section 3. Pipeline Sizing and Compression

3.1 Introduction

Pipeline flow capacity will increase if the pipeline diameter, operating pressure and/or number of compressor stations installed periodically along the route are increased. A given flow rate can be accommodated by more than one combination of diameter, operating pressure and number of compressor stations. Pipeline sizing and compression cannot be considered independent of each other.

An industry approach regarding economic comparison of pipeline and station configurations is to plot the pipeline cost of service (COS) as a function of gas flow rate. COS values are high when the pipeline capacity is underutilized at low flow rates, decline at moderate flow rates achieved by the addition of compressor stations and increase at very high flow rates that require an excessive number of stations. A plot of COS as a function of increasing flow rate is referred to as a "J-curve" because the shape of the curve resembles a backwards "J."

Each COS data point on a J-curve is based on the assumption that gas flow will remain constant from the first day of operation through the end of the project. J-curves are very useful for comparison of pipeline economics for projects with an initial gas rate near or at the project design rate. In such circumstance, a pipeline designer can simply select the configuration that provides the lowest COS at the design gas rate.

"Ramp-up" refers to a progressive increase in pipeline flow rate from a low in the first year of operation to the project design rate that may be encountered many years after start-up. J-curves are less useful, but still valuable, for comparison of pipeline configurations for projects with protracted flow ramp-up schedules such as Gas Scenarios 1 and 2 as described in the Gas Market Assessment (Section 3.5). J-curves can be used to eliminate pipeline configurations that exhibit high COS values over the subject range of gas flow rates. Scenarios could exist where J-curves of two or more pipeline configuration cross within the range of ramp-up flows. In such cases, economic analyses would have to be completed based on the annual ramp-up flow schedule to determine the most economically superior pipeline configuration.

Selection of the spur pipeline configuration would be a business decision that would likely consider aspects other than just project economics. A high pressure pipeline could be installed to allow the transport of large quantities of non-methane hydrocarbons. Installation of a low pressure pipeline to transport only utility grade gas would forever preclude transport of large quantities of non-methane hydrocarbons. Pipeline economies of scale are more exaggerated at lower diameters. Installation of a smaller diameter pipeline could save a small amount of up-front capital costs, but at the expense of limiting the ability of the system to economically accommodate larger flow rates that may occur in the future.

3.2 Work Approach

Work for the pipeline sizing and compression task was structured to progress from preparation of economic information for a wide range of pipeline and compressor configurations to estimation of the delivered cost of natural gas to Cook Inlet based on specific pipeline configurations and gas transport scenarios. With exception of the estimation of the cost of gas delivered to Cook Inlet, the objectives in the Statement of Work for pipeline sizing and compression are independent of gas processing facilities at one or both ends of the pipeline.

Pipeline sizing and compression was addressed by generating J-curves for various-sized pipeline and compressor configurations transporting a generic utility gas. The relationship between pipeline sizing and

compression with respect to capacity and economics is clearly shown in the J-curves. The wide range of J-curves generated for utility grade gas are applicable to Gas Scenario 1. J-curves were generated for a limited number of pipeline configurations transporting an enriched natural gas per Gas Scenario 2.

J-curves were prepared based on a preliminary 322-mile route from Fairbanks to Wasilla using the Moody Creek alignment through the Alaska Range even though the Moody Creek alignment was not ultimately selected. **J-curve analysis is not particular to a specific route and is applicable to both the Fairbanks and Delta Junction Spur routes. Use of a Fairbanks Spur route for generation of J-curves should not be construed as a recommendation for construction along the Fairbanks Spur route or a preference for the Fairbanks Spur route over the Delta Junction Spur route.**

Pipeline COS values expressed on a thermal basis (Section 2.2) vary significantly with gas composition and will be lower for a given flow rate if the natural gas is enriched with non-methane hydrocarbons. J-curves for Gas Scenario 2 show the beneficial impact on pipeline tariff from adding non-methane hydrocarbons to the spur pipeline gas, but do not address overall project economics including associated costs of gas processing facilities to acquire and handle non-methane hydrocarbons.

J-curves were used to screen candidate pipeline and compressor configurations to select a pipeline configuration for the purposes of calculating the delivered price of gas to Cook Inlet subject to Gas Scenarios 1 and 2. **The information presented in this report does not contain recommendations for construction of any specific pipeline configuration or selection of either the Fairbanks or Delta Junction Spur routes. A pipeline configuration was selected for the sole purpose of completing representative tariff calculations.** Calculations for the delivered price of gas to Cook Inlet address the costs to acquire gas from the ANS pipeline to Alberta, process gas to acquire enriching hydrocarbons to add to the spur pipeline depending on the scenario, transport gas via the spur pipeline and separate NGLs from utility gas at Cook Inlet.

3.3 Pipeline Sizes and Operating Pressures Considered in Study

Pipeline MAOP is set by adjusting pipeline wall thickness. However, flanges connected to the pipeline and attendant equipment are available in discrete increments of operating pressure. ANSI 600# flange rating provides for a maximum operating pressure of 1,480 psig at temperatures anticipated for the proposed spur pipeline. Pipelines designed subject to ANSI 600# are referred to in this report as either 1,480 psig or low-pressure systems. A 2,500 psig pressure was selected to provide for transport of an enriched natural gas via a dense pipeline and is referred to as a high-pressure system.

Pipelines of various diameters and compression configurations were evaluated. J-curve analyses were completed for 18, 20, 24 and 28 inch diameter pipelines with design operating pressures of 1,480 and 2,500 psig transporting utility gas.

Transmission pipelines carrying utility gas in the Lower 48 are typically designed for a maximum operating pressure less than or equal to 1,480 psig (ANSI 600# flange rating). Installation of a low-pressure spur pipeline would forever preclude transport of an enriched gas in the dense phase. J-curves for high-pressure spur pipelines transporting utility gas were completed to quantify the costs of providing for future transport of an enriched gas.

Economies of scale are achieved as pipeline diameter increases. Pipelines with diameters of less than 18 inches were excluded from consideration because of the relatively poor economies of scale of small diameter pipelines. A maximum diameter of 28 inches was included in the study in order to address the merits of a pipeline with expansion capacity well in excess of that required for Gas Scenarios 1 and 2.

3.4 Compressors and Compressor Stations

Pressure within a natural gas pipeline declines in the direction of flow because of "frictional resistance". Compressor stations are located periodically along the pipeline in order to raise gas pressure to pipeline MAOP. Compressor stations located in permafrost areas would likely be equipped with mechanical refrigeration to chill the compressed gas prior to re-entering the pipeline. Compressor stations located in sporadic permafrost or thawed soils would not be equipped with refrigeration and gas would be returned to the pipeline at compressor discharge temperature.

A wide range of pipeline and compressor configurations were considered in the J-curve analysis with some of these resulting in excessively high compressor gas discharge temperatures. It was assumed that the temperature of the gas would be reduced using fan-type coolers at compressor stations in sporadic permafrost or thawed soils wherever hydraulic simulation indicated that the gas discharge temperature would exceed 100 deg F during the summer. None of these high temperature options were selected for evaluation of either Gas Scenario 1 or 2.

3.4.1 Compressor Sets

Aero-derivative turbines are typically used to drive pipeline compressors instead of larger frame-type units because they can be replaced quickly either for scheduled or unscheduled maintenance. Pipeline sizing and compression analyses were based on use of Solar brand aero-derivative turbine compressor sets ranging from 7,700 to 20,000 Horsepower (hp) because they were within the likely power range for the spur pipeline and capital cost information for these units was available from a study completed by Michael Baker for ANGDA in 2005.

Information regarding the four Solar turbine compressor sets used in the engineering analysis is contained in Appendix 3-2. The Solar units consist of centrifugal compressors driven by simple cycle gas fired turbines with dry, low nitrogen oxide (NO_x) emission technology.

3.4.2 Compressor Station Configuration, Operation and Modeling Approach

Natural gas warms as it is compressed. Engineering analyses in this study were based on use of a closed loop propane refrigeration system to chill compressor discharge gas for a select number of stations along northern portions of the routes. Operation of the chilling systems would vary significantly with seasonal pipeline operation and ambient air conditions. All pipeline hydraulic simulations and station capital cost estimates were based on the simple propane refrigeration system shown in Figure 3.1.

Referring to Figure 3.1, valves VLV-104 and VLV-102 were used to model a 5 psi pressure drop through inlet and discharge piping at the station. It was assumed that the pressure of compressor discharge gas (Comp_Chill_to_DP_valve) would drop 15 psi as it passes through the propane chiller (C3_Evap). Pressure of the propane within the chiller was adjusted so that the refrigerant would boil at 5 deg F below the 30 deg F target temperature for chilled pipeline gas.

Vaporized refrigerant (stream C3_From_Evap) is compressed (C3_Comp) to a pressure at which it can be condensed using air coolers (C3_Cond) with ambient air as the heat sink. It was assumed that the propane refrigerant system would be designed to condense the refrigerant at a temperature 20 deg F greater than ambient air temperature.

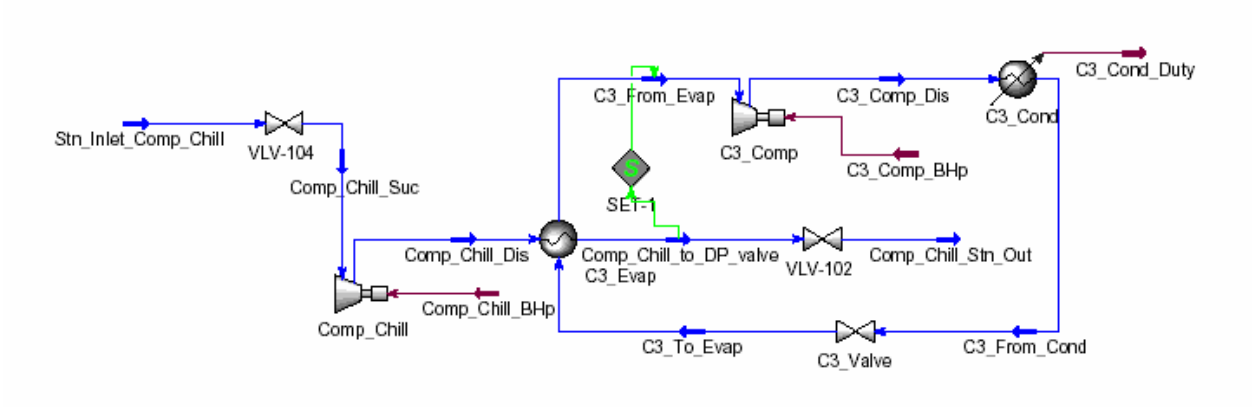


Figure 3.1: Schematic of Gas Compressor and Propane Refrigeration System

Refrigerant compressor inlet pressure is essentially the same as that of the propane evaporator, which will not vary. Refrigerant condensation pressure will change with ambient air temperature. Differential pressure across the refrigerant compressor and thus the load on the compressor will increase with ambient air temperature. Capital costs for the refrigeration system were based on the power load modeled for summer operations.

Load on the propane refrigerant system will decrease as ambient air temperature drops from summer to winter and condensation temperature, condensation pressure and refrigerant compressor power drop accordingly. Theoretically, an ambient air temperature will be encountered below which propane compression will not be needed and a pump could be used to circulate the refrigerant. Such detailed analysis of the operation of the refrigerant system is outside of the scope of this study.

3.4.3 Compressor Station Layout and Supporting Equipment

A typical layout of a pipeline compressor station with discharge gas chilling is shown in Figure 3.2. It is anticipated that smart pigs would be used to establish initial baseline data at project start-up and monitor long-term pipeline integrity. Pigs will be inserted and removed at pig launchers and receivers located at each compressor station.

The extent of fuel gas conditioning will depend on gas composition and pipeline operating pressure. Fuel conditioning will consist of pressure reduction for pipelines transporting utility gas. Fuel conditioning for pipelines transporting a dense phase gas would likely consist of a small NGL extraction facility with extracted NGL pumped back into the pipeline at the station outlet.

It was assumed that compressor stations would operate unattended, be controlled via a supervisory control and data acquisition (SCADA) system and that operating and maintenance personnel would visit the stations periodically to assess equipment condition. It was assumed that temporary living quarters would be provided.

It was assumed that pipeline gas and refrigerant compressor sets would be housed in one or more buildings depending on the size and number of units. Two turbine compressor sets for pipeline gas and one set for refrigeration are shown in Figure 3.2. The actual number and size of gas and refrigerant turbine compressor sets would be determined based on the thermal-hydraulic analysis as well as requirements for redundancy to reduce unscheduled reductions in system capacity.

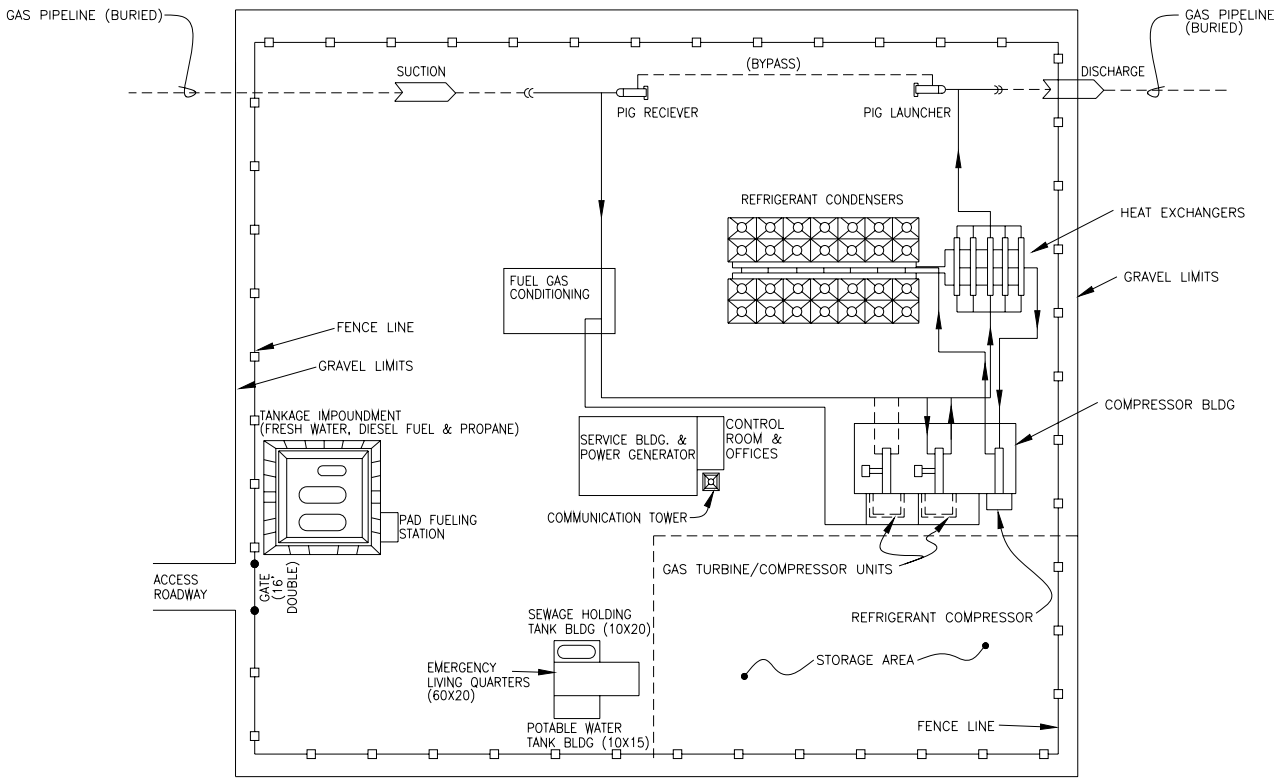


Figure 3.2: Typical Layout of a Compressor Station

Refrigerant heat exchangers and refrigerant condensers depicted in the figure are consistent with the refrigerant system described in the previous section. It is envisioned that the propane evaporators (chillers) would consist of multiple shell and tube heat exchangers arranged in parallel.

3.5 Gas Scenarios (Gas Market Assessment)

Three demand scenarios were identified in the draft of the Gas Market Assessment. During a mid-project review meeting between the NETL, the Advisory Committee, and the study contractor team on May 4, 2006, the contractor team was directed to calculate the price of gas delivered to Cook Inlet for Gas Scenarios 1 and 2 generally described as follows:

Gas Scenario 1:

A 350 MMscfd dry gas pipeline based on the reported "base-case" assumptions. The dry gas refers to a utility gas with a HHV of 1,035 btu/scf. Pipeline capacity is based on an annual average supply shortfall of 110 MMscfd by 2015, 250 MMscfd by 2025 and 300 MMscfd by 2035. The 350 MMscfd nominal design capacity is based on the assumption that the pipeline would be coupled with storage capacity in Cook Inlet capable of providing 80 MMscfd from storage to meet a peak winter demand of approximately 435 MMscfd.

Gas Scenario 2

A 590 MMscfd enriched gas pipeline based on the dry gas Gas Scenario 1, but with the addition of 75,000 barrels per day (bpd) of ethane for feed to a petrochemical plant in

Cook Inlet, 63,000 bpd of a propane and butane mix for sale as liquefied petroleum gas, and 15,000 bpd of pentane and heavier components sold for gasoline blending.

Mid-way through the term of the study, the Governor of Alaska posted information on a website pertaining to his proposed contract with North Slope gas producers regarding the ANS gas pipeline to Alberta. The posted information included compositional data for a "rich" pipeline gas that was developed by the Alaska Department of Natural Resources (ADNR). Calculations regarding Gas Scenarios 1 and 2 contained in this report are based on the ADNR gas composition as described in Section 3.5.3.

3.5.1 Gas Scenario 1

Gas Scenario 1 is based on transport of a "rich" gas via a 52 inch pipeline from the ANS to Alberta and installation of a gas plant at the spur pipeline inlet to remove non-methane NGL components to produce a utility gas for transport to Cook Inlet. A schematic diagram of Gas Scenario 1 is shown in Figure 3.3. NGL extracted from ANS pipeline gas at the spur pipeline inlet could either be fractionated for in-state markets or returned to the ANS pipeline. It is assumed that all NGL would be returned to the ANS pipeline for the purposes of the tariff calculations.

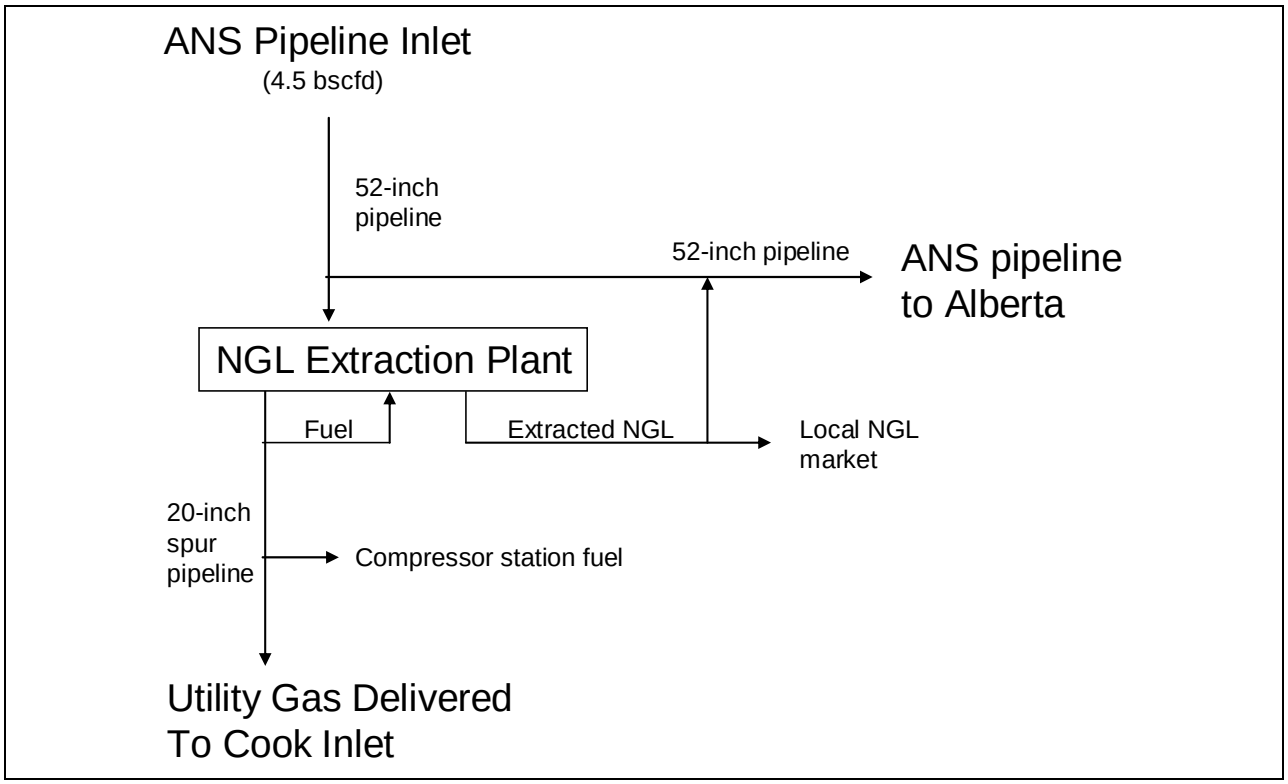


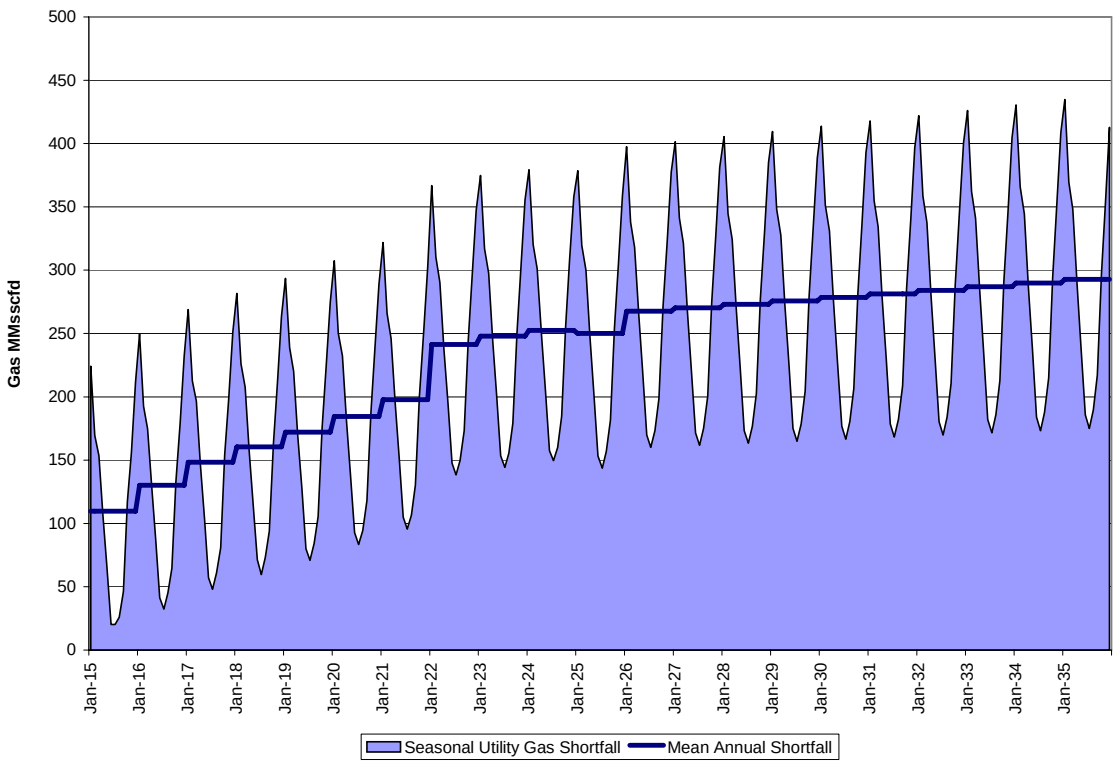
Figure 3.3: Gas Scenario 1 – Project Configuration

According to information provided by the North Slope gas producers, the initial design capacity of the ANS gas pipeline to Alberta would be approximately 4.5 billion standard cubic feet per day (Bcfd) with the ability to expand capacity to approximately 5.6 Bcfd via addition of compression. It was assumed that gas flow within the ANS pipeline upstream of the spur pipeline take-off point would remain at 4.5 Bcfd. Subject to this premise, gas conditioning facilities on the North Slope would not be impacted by the spur pipeline, thus the spur pipeline project would bear no incremental costs for conditioning. The spur pipeline project would not adversely impact future expansion of the ANS pipeline system.

The Gas Market Assessment (SAIC 2006) contains tables of estimated tariffs on spur pipeline gas transported via the ANS pipeline from the North Slope to the spur pipeline take-off in Fairbanks. These tariffs are based on the premise that a disproportionately higher tariff would have to be paid on gas dedicated to the spur pipeline in order to compensate for adverse economic impacts because of a reduction of flow through the ANS pipeline downstream of the spur pipeline take-off. The ANS pipeline tariffs to Fairbanks per the Gas Market Assessment were adopted for calculation of the price of gas delivered to Cook Inlet via the spur pipeline. It was also assumed that the spur pipeline project would bear the costs for NGL extraction, including fuel for re-compression of residue gas to ANS pipeline pressure.

Schedule of Utility Gas Delivered to Cook Inlet

Spur pipeline capacity is defined in the Gas Market Assessment as the shortfall between demand for utility gas in Cook Inlet and projected supply of gas produced in the Cook Inlet region. Seasonal and average shortfall of utility gas in Cook Inlet per the base case scenario of the Gas Market Assessment is shown in Figure 3.4.



NOTE: Labels on x axis are in years (i.e. 2015 – 2035).

Figure 3.4: Cook Inlet Gas Demand – Gas Scenario 1

Utility gas composition is not specified in the Gas Market Assessment other than stating that it would have a higher heating value of 1,035 btu/scf. Thermal content of the utility gas schedule per the Gas Market Assessment was calculated based on a 1,035 btu/scf heating value and the average annual volumetric schedule shown in Figure 3.4 (Gas Market Assessment, 2006).

Pipeline sizing in the Gas Market Assessment was based on an annual average gas shortfall of approximately 300 MMscfd at a date 20 years after project start-up plus an additional 50 MMscfd to

partially account for peak seasonal demand. It was assumed in the Gas Market Assessment that an additional 80 MMscfd would be removed from in-ground gas storage to meet a peak winter demand of approximately 435 MMscfd. No support for selection of the 50 MMscfd value was presented in the Gas Market Assessment other than to state that 80 MMscfd could be obtained from in-ground storage.

Calculations for the price of natural gas delivered in Cook Inlet (Section 8) were based on a 33-year project life. Annual gas shortfalls for years 21 through 33 were estimated by extrapolating the shortfall curve provided in the Gas Market Assessment by the average increase in annual rates over the last few years of the 20 year data. The schedule of the annual thermal target for utility gas delivered to Cook Inlet is shown in Appendix 3-1.

An annual average shortfall of approximately 350 MMscfd will occur in year 33 based on the extrapolated gas shortfall curve. It was assumed for the purposes of estimating the price of gas delivered to Cook Inlet that the spur pipeline would need to be sized only to provide an average annual rate of 350 MMscfd in project year 33 and that peak seasonal demand would be met through a combination of liquefied natural gas (LNG) imports and removal of gas from in-ground storage (Sections 2.3.6 through 2.3.9 regarding gas storage as prepared by ENSTAR). The gas shortfall forecast in the Gas Market Assessment is based on the assumption that the Kenai LNG facility will shut down in 2009, thus this facility should be available for conversion to LNG import.

It was assumed that fuel for the NGL extraction plant at the spur pipeline inlet would be extracted from the spur pipeline. Additional fuel required for the compressor stations would also be extracted from the spur pipeline.

3.5.2 Gas Scenario 2

Gas Scenario 2 as described in the Gas Market Assessment is the same as Gas Scenario 1 except that a base load of 75,000 bpd of ethane plus associated propane and heavier hydrocarbons would be spiked into the spur pipeline for delivery to Cook Inlet beginning in the first year of operation and every year thereafter.

Project Configuration

The project configuration for Gas Scenario 2 is shown in Figure 3.5 and differs significantly from that of Gas Scenario 1. A large amount of ANS pipeline gas would be processed at the spur pipeline inlet to extract ethane and heavier components for spiking into the spur pipeline. A portion of ANS pipeline gas would be diverted around the NGL plant as necessary to produce both the prescribed Cook Inlet delivery rates of utility gas (same as Gas Scenario 1) and 75,000 bpd of ethane for petrochemical plant feed. It was assumed that fuel for the NGL plant would be removed from the NGL plant residue gas prior to entering the spur pipeline.

The Statement of Work addressed calculation of tariffs to deliver hydrocarbons to Cook Inlet, but not the subsequent handling and disposition of delivered products. For the purposes of tariff calculations, it was assumed that the spur pipeline project would bear the costs for the NGL extraction plant at the required locations along the spur pipeline.

It was assumed that a utility gas and NGL product mix would be delivered from the Cook Inlet gas plant at the terminus of the spur pipeline via separate pipelines and that the spur pipeline project would bear no costs for NGL fractionation or storage. Economics for Gas Scenario 2 are based on the premise that all hydrocarbons would be purchased from the ANS pipeline project at one price ($/MMbtu) and that utility gas and NGL delivered at the plant boundary in Cook Inlet would be sold for one price.

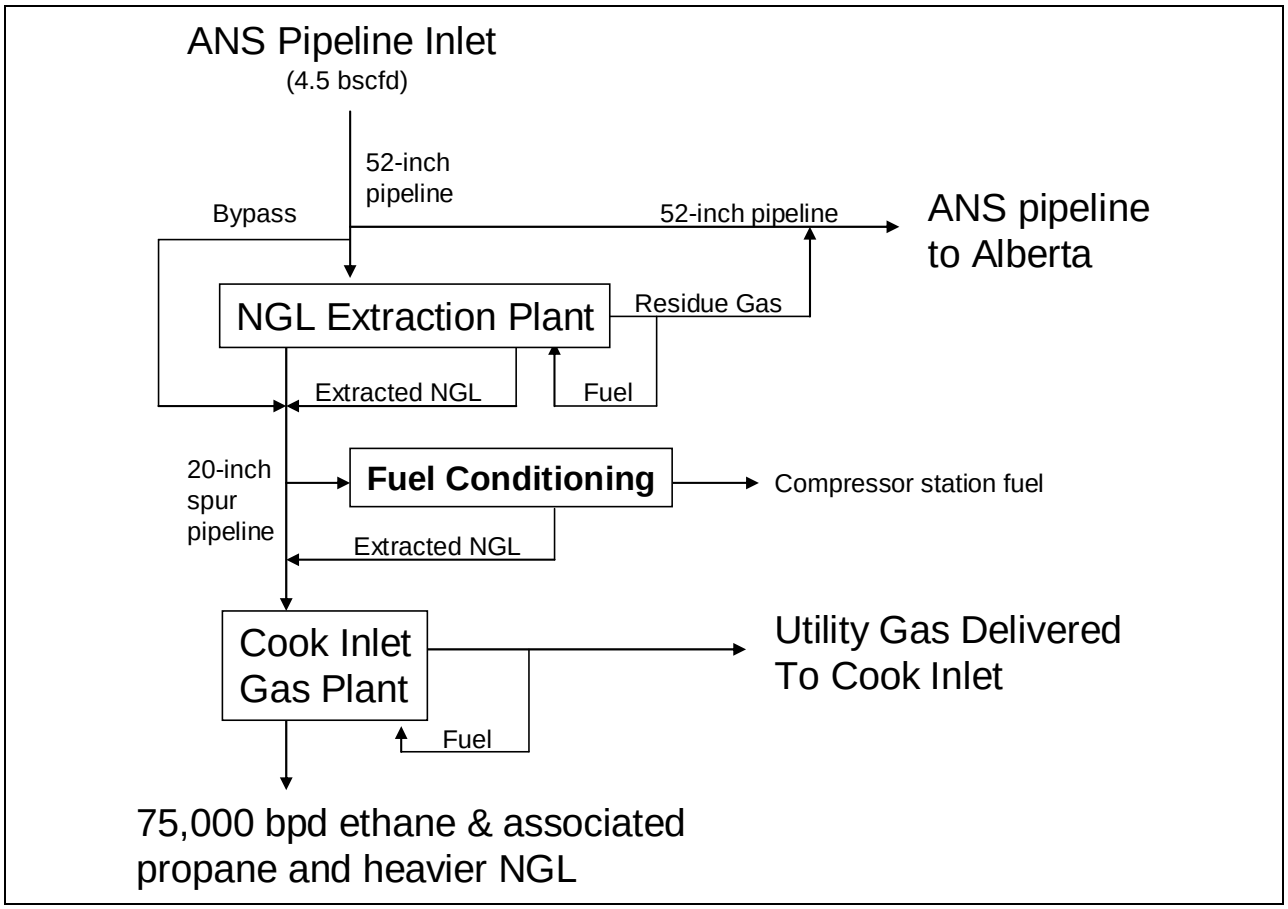
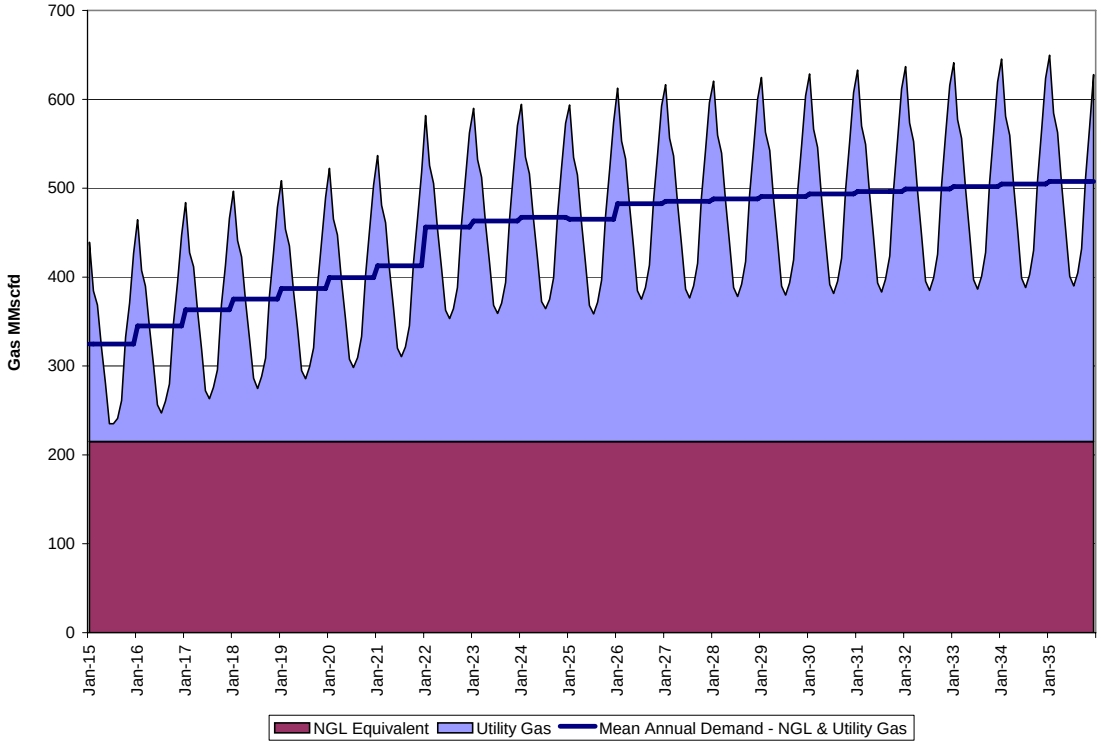


Figure 3.5: Gas Scenario 2 – Project Configuration

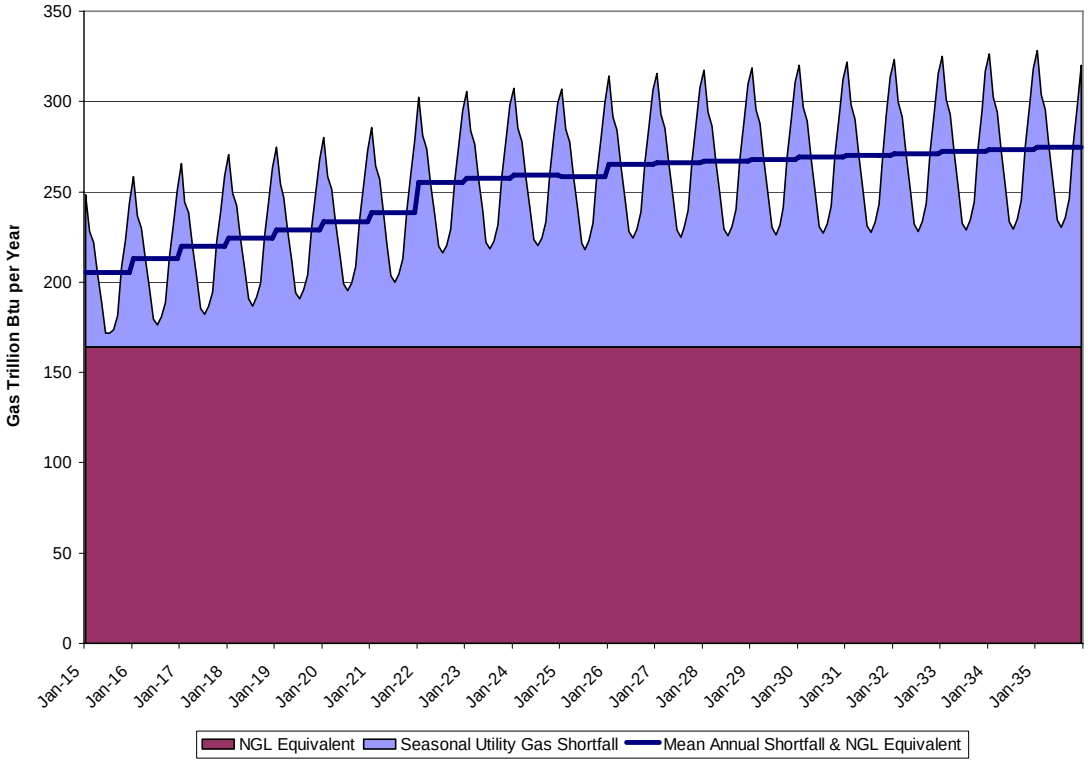
Volumetric average annual and seasonal Cook Inlet gas demand, per Gas Scenario 2, is shown in Figure 3.6. The seasonal Cook Inlet gas demand per Gas Scenario 2 expressed on a thermal basis is shown in Figure 3.7.

The gas equivalent volume of ethane and heavier hydrocarbons is approximately 215 MMscfd. Not only is the flow rate greater per Gas Scenario 2 than Scenario 1, but the heating value of the enriched gas is larger than that of the utility grade gas transported per Gas Scenario 1. The combination higher flow rate, higher gas heating value and baseload sales of NGL components beginning in the first year of operation should enhance the economics for Gas Scenario 2 relative to Gas Scenario 1.



NOTE: Labels on x axis are in years (i.e. 2015 – 2035).

Figure 3.6: Cook Inlet Gas Demand for Gas Scenario 2 – Volumetric Basis



NOTE: Labels on x axis are in years

Figure 3.7: Cook Inlet Gas Demand for Gas Scenario 2 – Thermal Basis

3.5.3 Basis for Material Balances - Composition of ANS Pipeline Gas

North Slope gas producers have not disclosed the composition of the gas to be transported via their proposed ANS gas pipeline to Alberta. The Gas Market Assessment is based on transport of a rich gas via the ANS pipeline.

The Governor's website on the Stranded Gas Act contains a presentation by the ADNR Division of Oil and Gas titled "Alaska/Alberta Working Group, Alaskan Natural Gas Pipeline, Natural Gas Composition" that contains compositions for both rich and lean ANS pipeline gas scenarios. The rich gas composition per the ADNR report on the Governor's website is shown in Table 3.1 and was used as the basis for the material balances for Gas Scenarios 1 and 2 in this study. The value for methane in the ADNR composition was adjusted slightly so that the total would yield 100 percent.

Table 3.1: ANS Compositional Analyses of Pipeline Gas-rich Case

Mole %	ADNR	Gas Market Assessment (see Note)
Carbon dioxide	1.5	1.50
Nitrogen	0.6	0.64
Methane	86.6 (84.4)	85.26
Ethane	7.1	6.84
Propane	3.6	3.44
I-Butane	0.3	0.46
N-Butane	0.4	0.93
Pentanes & heavier	0.1	0.93
Total	100.2 (100.0)	100.00
HHV (btu/scf)	1,116	1,151

Note: The I-butane and N-butane values in the Gas Market Assessment were transposed from the Michael Baker report (2005a) used as the reference. The information shown in this table reflects the analysis per the Michael Baker report.

Calculations for Gas Scenarios 1 and 2 were based on the composition of the ANS pipeline gas and NGL recovery efficiencies assumed for the gas plants. ANS pipeline gas composition would have a minor impact on the size and design of gas plant for Gas Scenario 1 since a utility gas is to be transported via the spur pipeline with the NGL returned to the ANS pipeline.

ANS pipeline gas composition would significantly impact the size, design and operation of the gas plant at the spur pipeline inlet per Gas Scenario 2 to deliver a prescribed amount of ethane for petrochemical feed in Cook Inlet. Because the relative rates of utility gas and petrochemical feed will vary seasonally and annually, operation of the NGL extraction at the spur pipeline inlet would have to be continually adjusted to deliver 75,000 bpd of ethane to a petrochemical facility in Cook Inlet.

Gas composition would impact the phase envelope shape, allowable pressure drop between stations and number of stations along the pipeline. The composition used in the Gas Market Analysis contains significantly more butane and heavier hydrocarbons than the rich ANS pipeline gas composition per the ADNR. The two-phase region of the spur pipeline gas generated per the ADNR rich gas analysis occurs at much lower pressures than spur pipeline gas generated similarly using the composition per the Gas Market Assessment, thereby allowing greater pressure drop between stations and fewer stations.

3.5.4 Summary of Gas Rates and Compositions Used for Gas Scenarios 1 and 2, and the J-curve Analyses

Annual material balances were prepared for calculation of the price of gas delivered to Cook Inlet subject to Gas Scenarios 1 and 2. The initial annual average rates (start-up year), maximum average annual rates (last year of the project) and gas compositions for Gas Scenarios 1 and 2 are shown in Table 3.2. J-curves were based on a constant annual gas flow for all project years.

Table 3.2: Spur Pipeline Gas Flow Rates and Compositions Used for Gas Scenarios

		J-curves	Gas Scenario 1			Gas Scenario 2		
			Initial	Maximum	Fuel	Initial	Maximum	Fuel
Spur pipeline								
Flow	MMscfd	Varies	113	345	Varies	328	566	Varies
HHV	btu/scf	1,035	1,000	1,000	1,000	1,722	1,414	1,130
Flow	Tbtu/yr	Varies	41.5	126	Varies	206	292	Varies
Ratio: max/low Tbtu rate			base	3.0		Base	1.4	
Carbon dioxide	Mole %	0	1.02	1.02	1.02	4.02	2.74	3.64
Nitrogen	Mole %	0.70	0.68	0.68	0.68	0.19	0.40	0.70
Methane	Mole %	95.44	97.46	97.46	97.46	28.60	57.93	76.36
Ethane	Mole %	3.48	0.80	0.80	0.80	40.01	23.31	17.04
Propane	Mole %	0.38	0.04	0.04	0.04	22.20	12.76	2.17
I-butane	Mole %	0	0	0	0	1.87	1.07	0.05
N-butane	Mole %	0	0	0	0	2.49	1.43	0.04
N-pentane	Mole %	0	0	0	0	0.62	0.36	0
Total	Mole %	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Utility Gas delivered to Cook Inlet								
Volumetric	MMscfd		113	345	345	110	342	
Thermal	MMscfd		41.5	126	126	41.5	126	
Liquids delivered to Cook Inlet								
Ethane	Bpd					75,000	75,000	
Propane	Bpd					47,200	46,700	
Butane	Bpd					10,900	10,800	
Gasoline	Bpd					1,800	1,700	

Tbtu = trillion British thermal unit

3.6 J-curves for Utility Grade Gas (Gas Scenario 1)

An individual data point on a J-curve is generated by selecting a pipeline diameter and operating pressure, selecting a flow rate, determining the number of compressor stations required to produce the selected flow with the selected pipeline, and then completing an economic analysis to determine the COS over the lifetime of the project. A J-curve is produced by repeating this procedure for a number of individual gas flow rates. J-curves are used to screen candidate pipeline and station configurations and eliminate those that are not suited for a given project flow rate.

A premise inherent in J-curve analysis is that gas flow will remain constant over the life of the project. For example, a COS value corresponding to a flow of 100 MMscfd is based on the assumption that the pipeline will operate exactly at 100 MMscfd beginning the first day after commissioning and continuing unchanged until the project is shut down. In practice, pipeline flow usually ramps-up to a design rate over a number of years. J-curves are useful for comparison of the relative economic merits of pipeline and station configurations. Impact of flow ramp-up is addressed in tariff calculations contained in Section 8.

3.6.1 Alignment Used for J-curve Analysis

J-curves prepared for reasonably similar terrain are essentially independent of the pipeline route. Pipeline sizing and compression was analyzed concurrent with development of alignments for the Fairbanks and Delta Junction Spur routes in order to meet the project schedule. The J-curves are based on a preliminary 322 mile route from Fairbanks to Wasilla using the Moody Creek route through the Alaska Range even though that alignment was not ultimately selected for the Fairbanks Spur route.

J-curves are sometimes generated on a theoretical basis with the assumption that compressor stations can be placed at the optimum location anywhere along the alignment. In practice, compressor stations would not be located in certain locations because of topographical, population, environmental or other considerations. J-curves in this study account for the practicalities of locating stations along the Fairbanks Spur route. Compressor stations were not assigned in the following areas:

- 0.5 miles proximate to known geological faults;
- Cities of Nenana, Healy, Cantwell and Willow;
- Mountainous topography through the Alaska Range;
- Relatively narrow canyon area immediately north of Cantwell; and
- Kashwitna area south to the pipeline terminus to avoid populated areas and to preclude placement of a station near the end terminus.

3.6.2 J-curves Completed

The J-curve analysis was structured to provide information to support a discussion of options for the diameter of a possible spur pipeline. J-curves were prepared for a range of pipeline diameters and operating pressures to accommodate flows required for Gas Scenario 1 and the largest flow rate identified in the draft Gas Market Assessment. A set of 32 J-curves was prepared to address transport of utility gas during the summer, subject to all possible combinations of the following:

- Outside pipeline diameters of 18, 20, 24 and 28 inches
- Operating pressures of 1,480 and 2,500 psig; and
- Gas compressor sets of 7,700; 10,000; 13,000 and 20,000 hp.

J-curves were based on summer conditions to account for the impact of warm ambient air temperatures on operation of equipment at the compressor stations. Pipeline gas compression capacity would be lower during the summer because of warm ambient air temperatures. Maximum seasonal load on refrigeration equipment would occur with peak ambient air temperatures. Chilling loads would drop significantly during winter operations. Modeling pipeline operation using summer conditions resulted in the highest compression equipment loads and station capital cost, according the cost estimation methodology used for this study.

3.6.3 J-curve Development

A single J-curve was constructed by plotting pipeline COS as a function of gas flow rate. Individual J-curve data points were generated by simulating pipeline operation at a selected flow rate, determining the number of compressor stations required to accommodate the flow, and then completing a ROI analysis to determine the COS at that given flow. COS values were generated using an ROI approach as a straightforward evaluation of cash outlays and revenues based on time value of money and requires no financing assumptions.

Individual hydraulic simulations were prepared for each individual data point on the J-curve plots. Hundreds of individual hydraulic simulations were completed. A ROI analysis was conducted to generate

a unique COS value based on pipeline and compressor station capital cost estimates, gas composition and equipment fuel consumption estimated via hydraulic analysis. The hydraulic simulations methods used are contained in Appendix 3-3. Assumptions and premises used for the COS calculations are contained in Appendix 3-6.

Eight separate budget level capital cost estimates were prepared for 18, 20, 24 and 28 inch pipelines along the representative 322 mile Fairbanks to Wasilla alignment at operating pressures of 1,480 and 2,500 psig. Pipeline capital costs were developed using a common methodology and are described in Appendix 3-4.

Capital cost estimates for individual compressor stations were based on information contained in the "Transport of North Slope Natural Gas to Tidewater" report (Michael Baker 2005a) for ANGDA commissioned by Willbros Engineers to prepare station capital cost information based on four gas compressor sets and use of propane refrigeration. Information prepared by Willbros for ANGDA report is contained in Appendix 3-2. Procedures for generation of station capital cost estimates based on the Willbros information is described in Appendix 3-5.

3.6.4 J-curve Results - General

J-curves can be plotted a number of ways. J-curves for the eight pipeline configurations considered in the study (four diameters at both 1,480 and 2,500 psig MAOP) at flow rates based on the use of one 20,000 hp compressor assigned at each station are shown in Figure 3.8. J-curves for 20 inch high and low pressure pipelines at flow rates achieved using various sized compressor sets are shown in Figure 3.9. J-curve results for all pipeline and compressor configurations are contained in Appendix 3-7.

J-curves allow concise presentation of a large amount of economic data generated via a huge amount of supporting work. COS values for hundreds of individual pipeline hydraulic simulations are shown on the J-curves plots contained in this section and Appendix 3-7.

J-curves shown in Figure 3.8 reflect the expected result that COS for a given pipeline will decline with flow as compression is added to a point at which COS values rise because costs to add large amounts of incremental compression do not justify the modest incremental increase in flow. Data shown in this figure is based on the use of up to nine compressor stations over the 322 mile route. The seven and nine compressor station scenarios reflect an unrealistically short distance between stations and would likely not be considered for an actual pipeline. Those scenarios are presented only to show the increase in COS at high flow rates.

The J-curves show the expected result that smaller pipelines are more economical at lower flow rates. Referring to Figure 3.8, although a 28 inch diameter 2,500 psig pipeline would have the lowest COS of any option considered at flow rates of 1 Bcfd and greater, it would have the highest COS at flow rates below 400 MMscfd and would be quickly excluded from consideration for Gas Scenario 1.

At higher flow rates there may be multiple diameter and compression configurations that are economically equivalent. For a given flow the option may exist to install a smaller diameter pipeline with more stations or a larger diameter pipeline with fewer stations.

All points on the J-curve reflect scenarios in which gas flow starts at the given rate and remains the same over the life of the project. J-curves are valuable for general comparison of pipeline options, but do not address the impact of flow ramp-up on project economics.

J-curves for 20 inch pipelines in Figure 3.9 show that high pressure pipelines are less economic than low pressure pipelines for transport of utility gas at relatively low flow rates. Use of a lower pressure pipeline would be more economical for a protracted ramp-up in flow such as that of Gas Scenario 1, but would preclude future transport of an enriched natural gas in the dense phase. The difference in relative economic merits of the low and high pressure pipelines decrease as flow rate increases.

J-curves shown in Figure 3.9 demonstrate that the size of the turbine compressor set at the stations has little influence on the project COS, but does impact the maximum flow capacity of a given pipeline and station system.

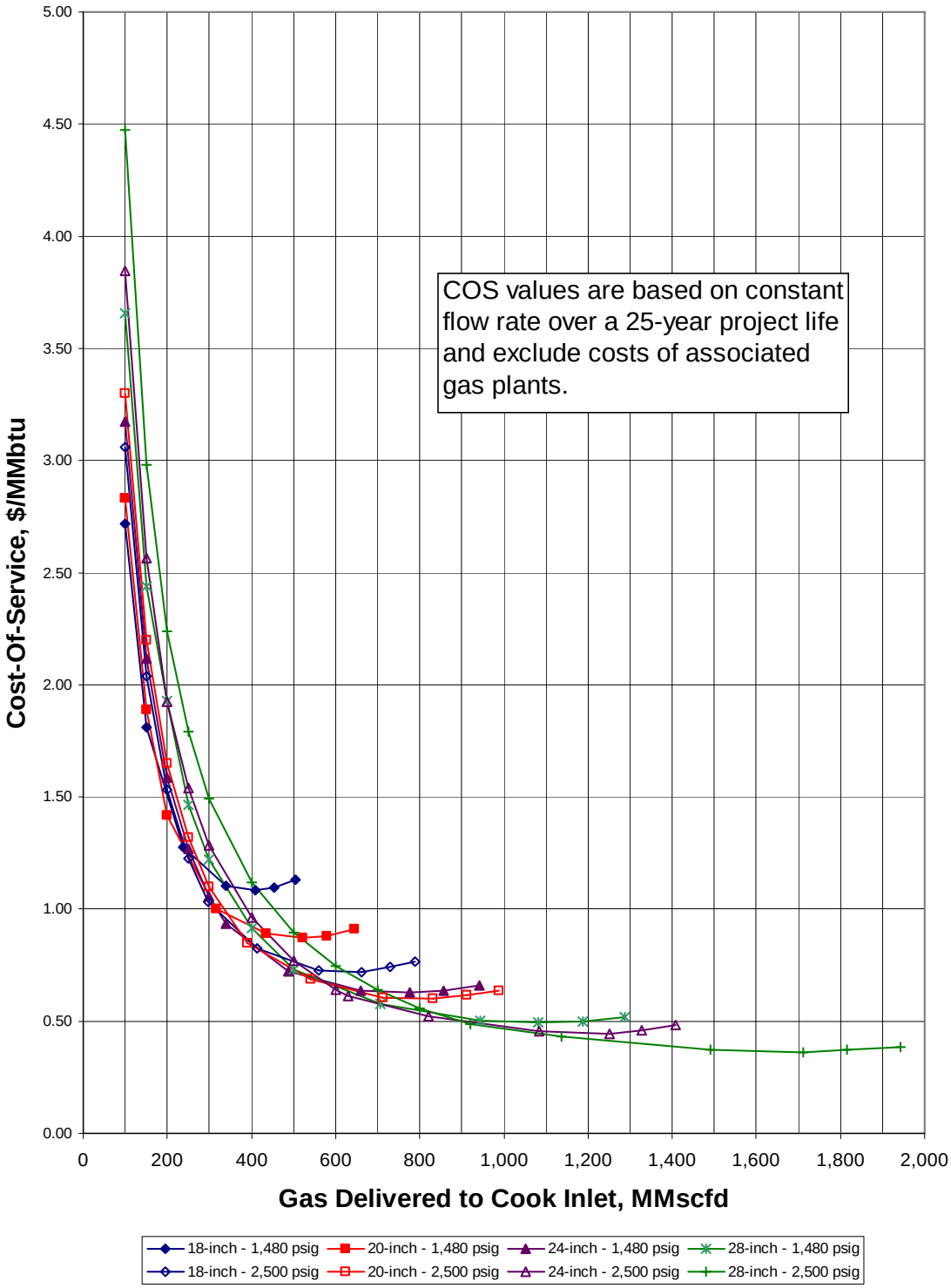


Figure 3.8: J-Curves for 20,000 hp Compressors up to Nine Stations

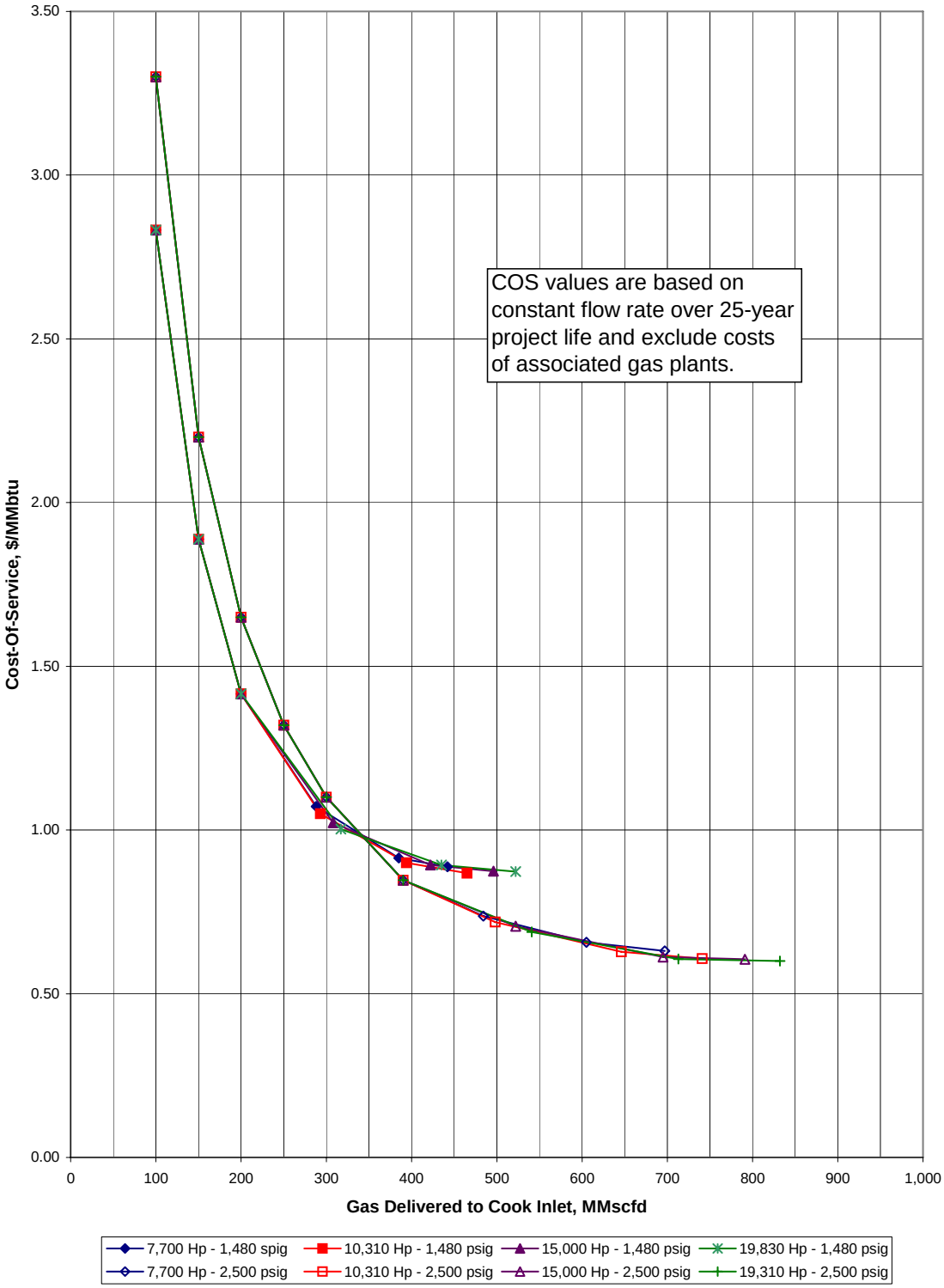


Figure 3.9: J-Curves for 20 Inch Diameter Pipeline up to Five Stations

3.6.5 J-curves for Gas Scenario 1

J-curves for the flow ranges per Gas Scenario 1 are shown in Figure 3.10. Compression requirements for the maximum volume data point shown for each curve are provided in the legend. Utility grade gas per Gas Scenario 1 can be transported via a low-pressure (1,480 psig) pipeline. Selection of a low pressure pipeline would forever preclude transport of large amounts of non-methane hydrocarbons in the dense phase. J-curves for high pressure (2,500 psig) pipelines are shown to illustrate relative costs to provide for future transport of an enriched natural gas.

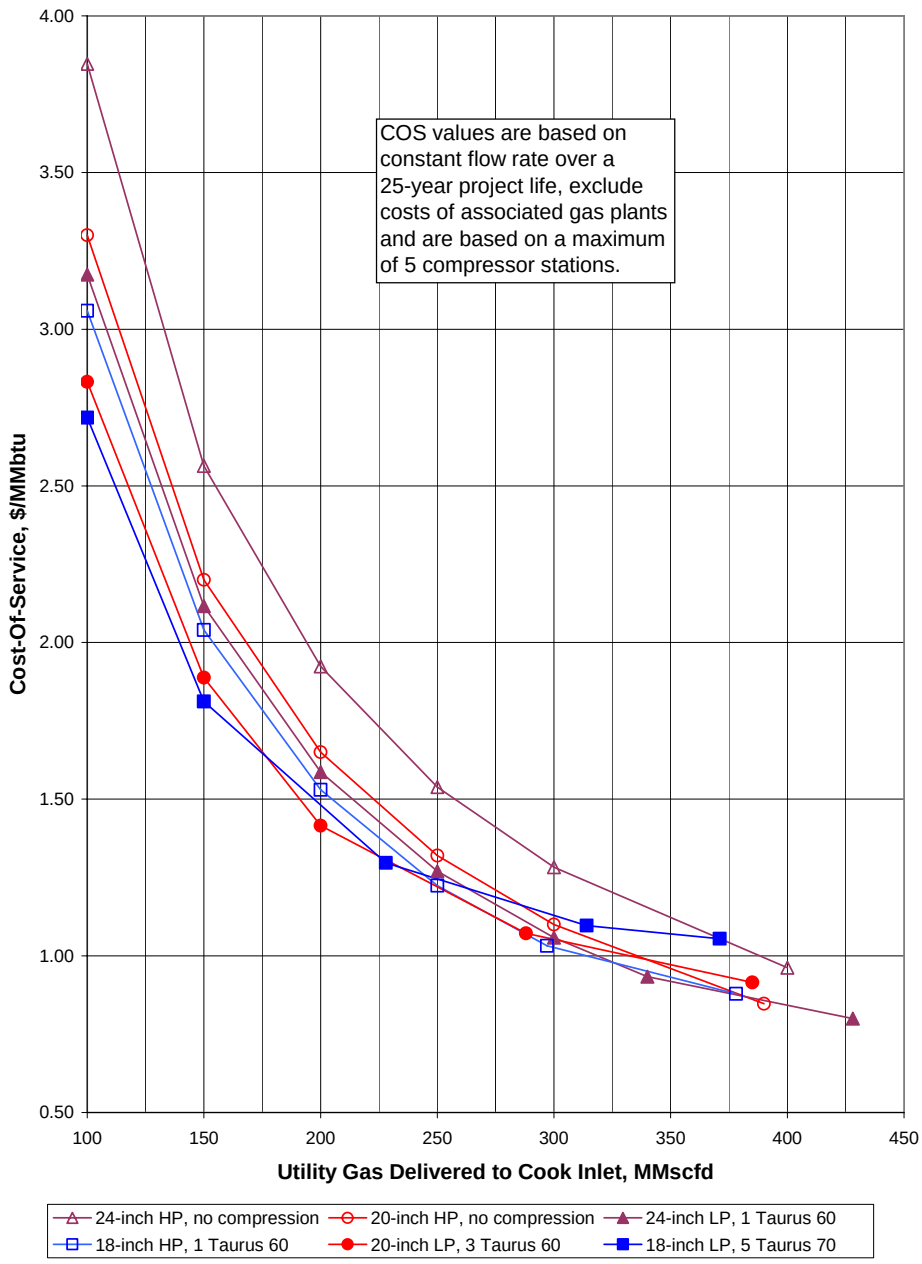


Figure 3.10: J-curves for Gas Scenario 1

A pipeline designed for a maximum flow rate of approximately 350 MMscfd would be required for Gas Scenario 1 (see Section 3.5.1). Annual average flow through the pipeline will ramp-up slowly from

approximately 110 MMscfd at start-up to the maximum design rate at the end of the assumed 33 year project life. Spur pipeline project economics will be greatly influenced by time value of money and the protracted ramp-up schedule.

Individual J-curve data points are based on a constant pipeline flow rate over the life of the project. A pipeline and station configuration that exhibits greater COS values than an alternative configuration at all flow rates under consideration for Gas Scenario 1 can be deemed as being less economic. Detailed economic analyses based on flow ramp-up are required to definitively determine the relative economics of configurations where J-curves cross within the flow ramp-up range. When J-curves cross, the configuration with the higher COS values at lower flows that occur earlier in the project life should be less economically favorable because of discounting for time value of money.

The following can be inferred based on the information in Figure 3.10 for Gas Scenario 1:

- A 24 inch diameter high-pressure pipeline can be excluded from consideration because the COS values are greater than those of all other options at all flow rates except the highest rates that would not occur until late project life.
- A 20 inch diameter high-pressure pipeline should be less economic than an 18 inch diameter high-pressure pipeline because the COS values for a 20 inch pipeline are greater than those of the 18 inch diameter pipeline at all flow rates except the highest rates that would not occur until late project life.
- Economics for 18 inch and 20 inch diameter low-pressure pipelines over the life of the project may be roughly equivalent since the respective J-curves cross within the range of flow ramp-up.
- A 24 inch diameter low-pressure pipeline should be less economic than an 18 inch diameter high-pressure pipeline since the COS values for a 24 inch low pressure pipeline are greater at all flow rates, except the highest rates that would not occur until late project life. Selection of an 18 inch high pressure pipeline would provide for the transport of a natural gas enriched in non-methane hydrocarbons.
- J-curves for a 20 inch diameter high-pressure pipeline and 18 inch diameter low pressure cross at relatively high flow rates. Detailed economic analysis would be required to determine the relative economic merits of these options; the 20 inch diameter high pressure pipeline may be found to be less economically favorable because its COS values are significantly higher at lower flow rates encountered early in the project.

3.7 J-curves for Gas Scenario 2

Procedures used to prepare J-curves for Gas Scenario 2 are identical to those of Gas Scenario 1 except only high pressure pipelines were considered because Gas Scenario 2 involves transport of an enriched natural gas. J-curves for Gas Scenario 2 are shown in Figure 3.11.

Gas Scenario 2 is the same as Gas Scenario 1 except that approximately 215 MMscfd of non-methane hydrocarbons would be blended with the utility gas. The flow rate along the x-axis of Figure 3.11 refers to the rate of utility gas delivered to Cook Inlet and excludes NGL hydrocarbons extracted in Cook Inlet. Relatively flat or upward sloping portions of the curves reflect the impact of incremental capital costs for addition of compression.

Similar to the logic described for evaluation of the J-curves for Gas Scenario 1, the following can be inferred for Gas Scenario 2 based on the information shown in Figure 3.11:

- A 24 inch diameter pipeline can be excluded from consideration because the COS exceeds that of a 20 inch diameter pipeline at all flow rates.
- Economics for 18 inch and 20 inch diameter high-pressure pipelines over the life of the project should be roughly equivalent because the COS values are similar in early life and the J-curves cross within the flow ramp-up range.

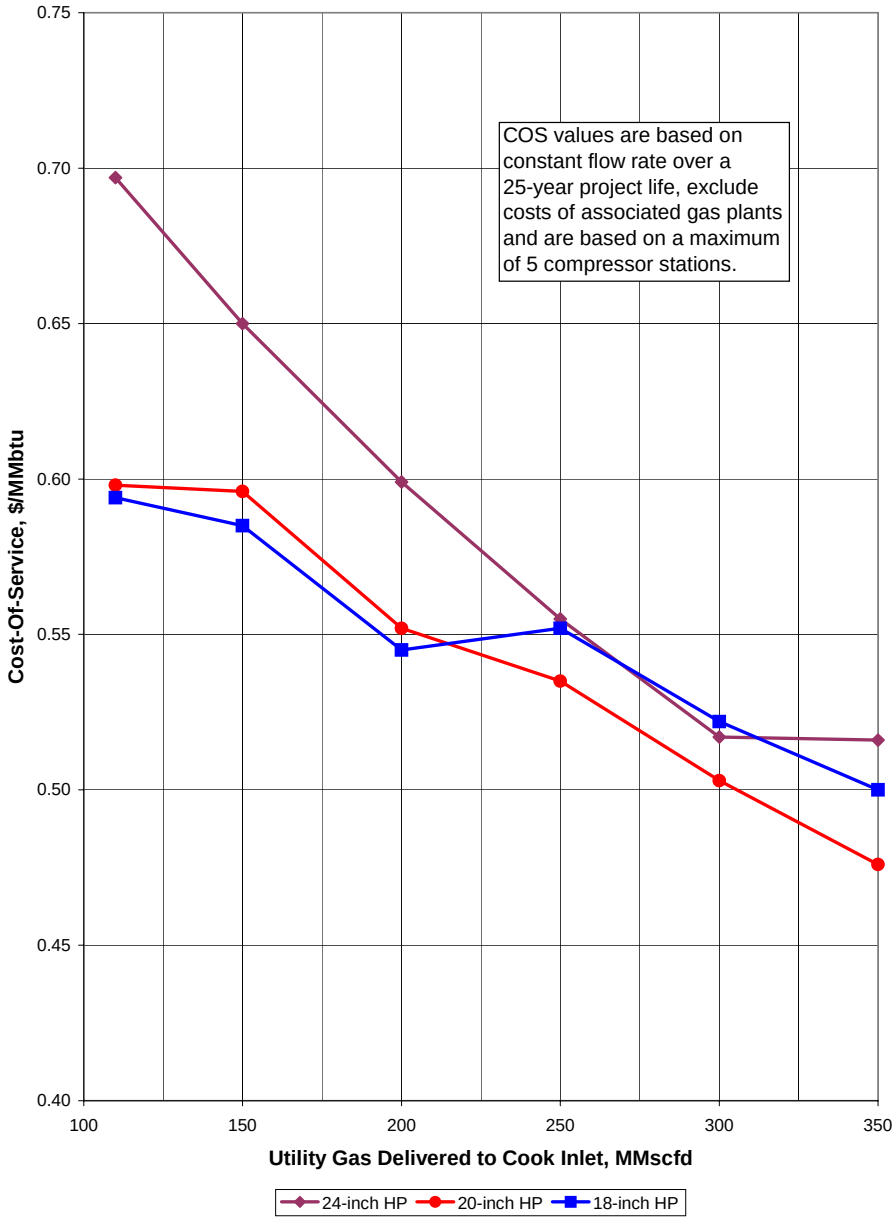


Figure 3.11: J-curves for Gas Scenario 2

3.8 General Conclusions

The J-curves presented in the section are a useful tool for comparison of relative economics of a wide range of pipeline and compression options. **The COS values shown in the J-curves reflect only the**

pipeline and stations and exclude associated gas processing costs. Analysis including the cost of gas processing plants is addressed in Section 8.

Information developed during the J-curve analyses support the following conclusions regarding transport of utility gas (Gas Scenario 1):

- Pipeline COS for transport of a utility gas only is more sensitive to flow rate than the COS of a pipeline transporting both utility gas and NGL.
- Pipeline COS is more sensitive to pipeline diameter at lower flow rates than at higher flow rates.
- COS values for smaller diameter pipelines with high operating pressures are similar to COS values of larger diameter pipelines operating at lower pressure; for example and referring to Figure 3.10, the COS values for a 24 inch, 1,480 psig pipeline are close to and fall between the COS values of 18 inch and 20 inch diameter 2,500 psig pipelines.
- Because of high unit transport costs at lower rates, installation of smaller diameter pipelines would be more economically favorable for scenarios based on a protracted ramp-up of gas flow; this is further discussed in Section 8 of this report.

Information developed during the J-curve analyses support the following conclusions regarding transport of enriched gas (Gas Scenario 2):

- Pipeline diameter has less impact on the COS as compared to Gas Scenario 1.
- Thermal (btu basis) pipeline flow for Gas Scenario 2 is significantly greater than that of Gas Scenario 1 and the COS for the pipeline portion of the project is much lower for Gas Scenario 2 than for Gas Scenario 1; the added base load thermal flow of NGL components per Gas Scenario 2 is independent of the rate of utility gas and tends to flatten the J-curve as compared to Gas Scenario 1.
- Pipeline COS to transport utility gas is significantly reduced via the addition of large quantities of non-methane hydrocarbons; assessment of the merits of such additions must address the incremental gas processing costs to acquire and separate these non-methane hydrocarbons.

Section 4. Pipeline Routing and Alignment

4.1 Introduction

This section describes the Fairbanks Spur and Delta Junction Spur routes considered for the spur pipeline (Figure 4.1) for this study and a summary of the processes and considerations used to select alignments of segments within each route. The intent of this section is to provide a general understanding of the physical and biological environment within each corridor, the conditions that may affect final spur pipeline alignment and design and the process that was used to determine the selected routing for each corridor. Figure 4.1 shows the general route corridors for the proposed spur pipeline.

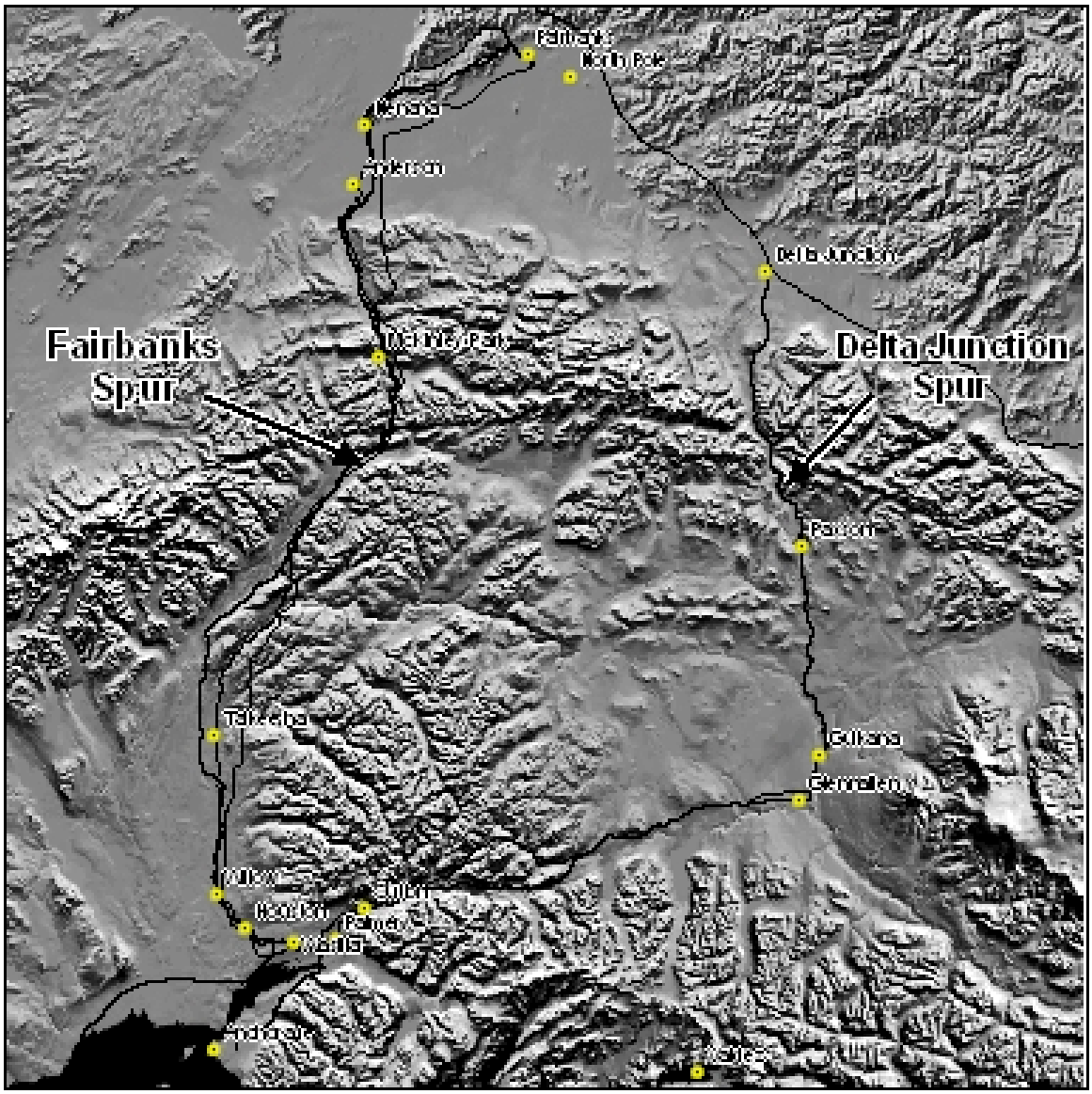


Figure 4.1: Proposed Spur Pipeline Routes Route Descriptions

4.1.1 Fairbanks Spur

The Fairbanks Spur route extends south from Fairbanks along the Parks Highway terminating in Wasilla at the existing ENSTAR transmission pipeline, a distance of approximately 322 miles. The route passes through both lowland river valleys and steep mountainous terrain. The route begins at an elevation of approximately 450 feet (ft) above mean sea level (msl) in Fairbanks and rises to elevations greater than 2,400 ft msl in the Cantwell area, and then gradually drops to approximately 150 ft msl in the Wasilla area.

Beginning in Fairbanks, the route proceeds south through the Tanana Flats and Nenana River basin before traversing the Alaska Range between the communities of Healy and Cantwell. Just south of Cantwell, the route enters the Susitna River Valley, flanked to the west by the Alaska Range and to the east by the Talkeetna Mountains. The valley broadens just north of the community of Trapper Creek. The route remains in the Susitna River Valley from Trapper Creek to the community of Willow, and beyond to Wasilla.

The Fairbanks Spur passes through the FNSB, Denali Borough, and Matanuska-Susitna Borough (MSB). The route avoids densely populated areas in both Fairbanks (pop. 30,224) and Wasilla (pop. 5,469). The presence of private property and population density progressively increase along the route between Willow and Wasilla. The route traverses through several smaller communities ranging in size from 222 people in Cantwell to 1,658 people in Willow (Census 2000).

4.1.2 Delta Junction Spur

The Delta Junction Spur begins in Delta Junction, proceeds along the Richardson Highway to Glennallen and then along the Glenn Highway before terminating at the existing ENSTAR transmission pipeline a few miles southwest of Palmer, a total distance of approximately 281 miles. The route passes through river basins and steep mountainous terrain. The route begins at an elevation of approximately 1,175 ft msl in Delta Junction and rises approximately 3,600 ft msl in the vicinity of Summit Lake then gradually drops into Glennallen at approximately 1,400 ft msl. From Glennallen to Eureka, the route rises to approximately 3,400 ft msl and then the route drops into the Sutton area, terminating in Palmer at approximately sea level.

Beginning in the eastern corner of the Tanana Flats, the Delta Junction Spur route proceeds south along the Delta River valley past Donnelly where it begins to traverse the Alaska Range. From Donnelly to Paxson the route is flanked to the east and west by the steep mountainous terrain of the Alaska Range. At Paxson, the route enters the Copper River basin and proceeds south to Glennallen, where it veers to the west, remaining in the Copper River basin to Eureka. From Eureka, the route drops into the Matanuska River valley and generally follows the Glenn Highway through the Sutton area into Palmer.

The Delta Junction Spur passes through the MSB and unincorporated areas. Most of the route avoids densely populated areas. Beginning in the Sutton area, east of Palmer (pop. 4,533), the presence of private property and population density gradually increase toward the route termination between Wasilla (pop. 5,469) and Palmer near the intersection of the Glenn and Parks Highways. The route passes through several smaller communities ranging in size from 554 people in Glennallen to 840 people in Delta Junction (Census 2000).

4.2 Route Corridor Characteristics

Understanding the physical and biological characteristics along each considered spur pipeline route is necessary to distinguish the engineering and construction challenges. For example, understanding topography (e.g., flat plains, rolling, steep hills, mountainous, rivers) and the type of soil and terrain (e.g.,

gravel, grassy, silty, sandy, permafrost, bedrock, cobble) are important aspects during route selection that may significantly impact the time and effort required to build and/or design a pipeline in that area.

Similarly, ice-rich soils encountered within each corridor likely would affect the costs associated with construction, design, and maintenance of a pipeline constructed in that area. Local climate also plays a key role in pipeline routing because of its affect on pipeline hydraulics and the compression requirements for a pipeline in each corridor. Construction efficiency is also largely affected by climate as maintenance becomes more and more significant as the temperatures decrease.

Understanding the biological characteristics of the proposed routes is important to making informed, long-term decisions regarding resource management. Knowledge of the biological environment in which the proposed pipeline may be constructed is essential to determining a final route, preparing permit applications and developing a mitigation plan.

Some of these aspects are discussed in this section. They have also been accounted for, to the degree possible, during the development of the capital cost estimates (Section 8.8.1 and summarized in Appendix 8-2) for the final selected pipeline alignments along each route.

4.2.1 Physiographic and General Geologic Setting

Fairbanks Spur

The Fairbanks Spur lies within the Tanana-Kuskokwim Lowland, Alaska Range, Talkeetna Mountains, and Cook-Inlet Susitna Lowland (Plafker and Berg 1994 and Wahrhaftig 1965). The northern portion of the route lies within the Tanana-Kuskokwim Lowland, which is comprised of coalescing alluvial fans and glacial deposits. The terrain in the area consists primarily of flat to gently sloping surfaces, moraine ridges, and outwash plains formed during glaciation.

Between Healy and Cantwell, the route traverses the Alaska Range. Terrain in the area includes varied bedrock of the Alaska Range, floodplain deposits, some landslide debris, and extensive glacial drift. The glacial drift includes till, outwash, and lacustrine deposits. Geomorphology of the area is mainly attributed to the advance and retreat of glaciers.

South of Cantwell, the route enters the broad Susitna River valley, which is comprised of unconsolidated glacial drift and organic-filled depressions. The unconsolidated sediments are largely comprised of gravelly or sandy silts locally overlain by organic deposits.

The southern portion of the route is in the Cook Inlet-Susitna Lowland. This is a glaciated lowland region with ground moraines, stagnant ice deposits, drumlin fields, eskers, and outwash plains. The terrain is generally rolling and muskeg areas are common. In general, glacial moraines of silty gravel and outwash deposits of sand and gravel underlie the Cook Inlet-Susitna Lowland and windblown loess and sandy silts blanket the area.

Delta Junction Spur

The northern portion of the route lies within the Tanana-Kuskokwim Lowland and includes parts of the Yukon-Tanana Upland on the northeast and the Alaska Range on the southwest. The Tanana-Kuskokwim Lowland is characterized by glacial and alluvial deposits.

Continuing south and traversing the Alaska Range between Donnelly and Paxson, the terrain includes varied bedrock, floodplain deposits, landslide debris, and extensive glacial drift. The glacial drift includes till, outwash deposits, and lacustrine deposits. Geomorphology in the area is of glacial origin related to the advance and retreat of glaciers.

Between Paxson and Eureka, the route lies in both the Copper River Lowland and Talkeetna Mountains while transitioning through the Copper River basin on a terrace above the Copper River. The route contains thick glacial deposits composed primarily of glacial lacustrine (GL) sediments. During the Pleistocene Epoch, glaciers advancing from the mountains covered parts of the basin floor and dammed the Copper River to form a proglacial lake. GL soils are typically composed of clay, silt and sand with varying amounts of coarser materials such as cobbles and boulders.

From Eureka, the route traverses through floodplain deposits in the Talkeetna Mountains. The route transitions from bedrock ridges and rolling foothills into the northeastern portion of the Matanuska River valley.

Granitic rocks of the western Talkeetna Mountains and volcanic rocks of the eastern Talkeetna Mountains border the valley to the north. Metamorphic and granitic rocks of the Chugach Mountains border the valley to the south. The route terminates in the Cook Inlet-Susitna Lowland in an area dominated by glaciated lowlands and muskeg covered terrain.

4.2.2 Permafrost and Thaw Settlement

Permafrost exists between Fairbanks and Talkeetna and between Delta Junction and Eureka. A discussion of geotechnical considerations regarding the impact of permafrost on pipeline design is presented in Section 2.2.3. Conditions related to permafrost in the Copper River basin are very complex because of the presence of the GL sediments and warm permafrost found in the region. Local permafrost areas exist south of Talkeetna and Eureka in isolated pockets protected by thick organics and positioned with northern aspects.

Discontinuous permafrost is present in the northern sections of both routes. Each route contains both thaw-stable and thaw-unstable soils. Thaw-stable soils consist of well-drained soils that exhibit minor subsidence or settlement when thawed. Thaw-unstable soils are comprised of poorly drained soils that generally contain large amounts of ice. When thawed, characteristics of thaw-unstable soils include loss of strength, excessive settlement, and flowing soil due to excess moisture.

When the soil freezes, the free water freezes and expands. Once formed, ice lenses continue to grow as long as a source of free water is available. Free water migrates through the soil to a forming ice lens by capillary action (wicking).

Some soils are more susceptible to the formation of ice lenses than others. Silts or silty clay soils are considered amongst the most frost susceptible. Silt, because of the extremely small size of its particles, or gradation, permits and encourages the flow of water by capillary action through its pores. Consequently, silts supply the water necessary to promote the formation of ice lenses in the freezing zone.

The only soils that can be considered to be non-frost susceptible are very clean mixtures of sand and gravel. These soils drain freely by gravity and do not create capillary moisture movement.

It was estimated that approximately 84 percent of the selected alignment for the Delta Spur route, opposed to 71 percent of the Fairbanks Spur, is located in areas where permafrost exists (estimate generated from information available on the United States Geological Survey (USGS) website: http://agdcftp1.wr.usgs.gov/pub/projects/fhm/permafrost.html)

4.2.3 Climate

Monthly average precipitation, temperature and wind speed data from the Western Regional Climate Center is compiled in Table 4.1 and Table 4.2 (http://www.wrcc.dri.edu/ and http://climate.gi.alaska.edu/climate/Wind/mean_wind.html).

Table 4.1: Climate Data – Fairbanks Spur

	Average Precipitation (inches)				
	Fairbanks	**Nenana**	**Cantwell**	**Talkeetna**	**Wasilla**
Jan	0.58	0.54	0.97	1.38	0.55
Feb	0.42	0.46	0.68	1.53	0.61
Mar	0.35	0.31	0.46	1.30	0.66
Apr	0.27	0.19	0.41	1.34	0.80
May	0.59	0.51	0.78	1.55	0.91
June	1.30	1.37	1.76	2.29	2.25
July	1.87	2.17	2.94	3.45	2.95
Aug	1.86	2.22	3.24	4.69	2.59
Sept	1.06	1.14	2.59	4.16	2.94
Oct	0.80	0.67	1.16	2.77	2.08
Nov	0.68	0.65	0.83	1.76	0.98
Dec	0.72	0.54	1.07	1.73	0.99
Annual Total	10.50	10.77	16.89	27.95	18.31
	Average Monthly Temperatures – Mean Air Temperature (ºF)				
	Fairbanks	**Nenana**	**Cantwell**	**Talkeetna**	**Wasilla**
Jan	-9.8	-9.7	1.7	10.8	13.6
Feb	-2.7	-3.8	6.2	16.0	20.3
Mar	10.9	7.9	13.0	21.7	27.3
Apr	31.3	27.4	26.5	33.9	35.9
May	48.6	45.9	40.5	45.5	45.9
June	60.0	57.4	51.5	55.4	52.7
July	62.1	59.3	55.2	58.7	56.4
Aug	56.5	54.2	50.3	55.5	54.5
Sept	44.9	43.0	40.0	46.2	46.5
Oct	24.9	27.7	23.1	31.9	33.7
Nov	3.6	-2.5	8.3	18.1	21.8
Dec	-7.1	7.3	4.5	11.6	14.4
Annual	26.9	25.0	26.7	33.8	35.3

	Average Annual Wind Speed		
	Wind Speed (mph)	**Calm**	**Non-Calm**
Fairbanks	4.0	23%	77%
Nenana	5.0	*	*
Cantwell	7.8	*	*
Talkeetna	4.4	24%	76%
Wasilla	5.4	*	*

Table 4.2: Climate Data – Delta Junction Spur

	Average Precipitation (Inches)				
	Big Delta	**Paxson**	**Glennallen**	**Eureka**	**Palmer**
Jan	0.32	0.99	0.54	0.70	0.87
Feb	0.31	0.79	0.57	0.84	0.76
Mar	0.25	0.77	0.35	0.66	0.64
Apr	0.25	0.62	0.22	0.43	0.50
May	0.87	1.17	0.61	1.12	0.70
June	2.25	2.41	1.45	3.02	1.31
July	2.65	3.17	1.66	2.75	2.07
Aug	1.99	2.91	1.67	2.02	2.28
Sept	1.09	3.21	1.16	1.30	2.47
Oct	0.62	2.24	0.97	0.86	1.57
Nov	0.46	1.06	0.70	0.75	1.05
Dec	0.36	1.42	1.26	0.99	1.11
Annual	11.42	20.76	11.16	15.44	15.33
	Average Monthly Temperatures – Mean Air Temperature (°F)				
	Big Delta	**Paxson**	**Glennallen**	**Eureka**	**Palmer**
Jan	-3.3	-9.1	-5.9	-0.6	12.6
Feb	3.9	0.2	2.3	4.8	18.1
Mar	12.7	9.7	14.8	8.2	25.3
Apr	30.6	23.8	30.9	22.1	36.7
May	46.9	39.1	43.6	36.5	47.3
June	57.2	48.7	53.1	48.1	55.0
July	60.0	53.2	56.8	51.6	57.8
Aug	55.2	50.6	52.6	49.6	55.6
Sept	43.9	41.6	42.6	40.5	47.7
Oct	25.2	24.9	25.6	22.8	33.8
Nov	7.2	5.5	4.5	7.7	20.2
Dec	-1.9	-3.2	-2.7	0.1	14.6
Annual	28.1	23.7	26.5	24.3	35.4

	Average Annual Wind Speed		
	Wind Speed (mph)	**Calm**	**Non-Calm**
Big Delta	9.7	10%	76%
Glennallen	5.3	29%	71%
Eureka	4.4	*	*
Palmer	7.0	*	*

4.2.4 Seismicity

Some regions of Alaska are characterized by high seismicity because of the active subduction of the Pacific Plate beneath the North American Plate. The subduction of the Pacific Plate occurs at a rate of approximately five to seven centimeters per year (Hansen et al. 2001). Portions of both the Fairbanks

Spur and Delta Junction Spur routes are considered seismically active. At least four known active faults (or fault zones) are located within the two corridors.

Faults

Both proposed spur pipeline routes cross active faults (defined as faults where differential ground movements have occurred within the Holocene Epoch, or the last 10,000 years). All documented active faults in this area trend east-west, and the proposed route corridors are generally north-south. Known faults crossed by the Delta Junction Spur route include Donnelly Dome, McGinnis Glacier, Denali and Castle Mountain faults. The known faults crossed by the Fairbanks Spur route include the Castle Mountain and Denali faults. Fault locations are based on research by the USGS, Alaska Division of Geological and Geophysical Surveys, and other sources.

Tsunami

The two routes have no potential of being affected by tsunamis. A large earthquake with an epicenter located in the Cook Inlet area could conceivably generate a tsunami that might damage shoreline structures around the inlet. However, a tsunami is not expected to affect the project area because of the inland location, which provides substantial separation between the proposed pipeline and the inlet.

4.2.5 Wetlands

The U.S. Fish and Wildlife Service (USFWS) defines wetlands as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of the year" (Cowardian et al. 1979).

Alaska has over 170 million acres of wetlands which support various bird species including swans, geese, ducks, and over 100 million shorebirds as well as mammals. Alaska's freshwater wetlands include bogs, tundra, marshes, and meadows covering nearly 110 million acres (Glass 1996). Wetlands also act as a filter and can hold excess surface waters during flood events. Wetlands may be sensitive to disturbance caused by construction if restoration work is not properly completed. The National Wetlands Inventory (NWI) is a database of identified wetlands maintained by the USFWS.

Both pipeline routes cross wetlands however the extent of wetlands traversed by each proposed route cannot be ascertained without field survey and wetland delineation because wetlands data from the NWI is incomplete for Alaska at this time. Avoidance or minimization of impacts to wetland resources will be determined in part by the wetlands identification and classification found in the NWI. The U.S. Army Corps of Engineers (USACE) regulates dredging and filling of wetlands through Section 404 of the Clean Water Act (CWA). Wetland crossings can provide engineering and permitting challenges. A thorough wetlands delineation will need to be completed prior to application for CWA Section 404 permits from the USACE.

4.2.6 Air Quality

The air quality along both pipeline routes can be characterized as very good in part because of limited human settlement and little industrial development. Impacts to air quality may be caused by man-made air pollutants such as industrial, residential and transportation related sources and natural sources such as windblown dust and forest fires. In the Fairbanks area, winter temperatures, topography and atmospheric conditions combine to produce a temperature inversion which traps carbon monoxide (CO) and other atmospheric pollutants close to the ground. The U.S. Environmental Protection Agency (EPA)

considered Fairbanks as a nonattainment area with respect to National Ambient Air Quality Standards (NAAQS) for CO from 1992 through 2004, but the EPA changed the designation to attainment in 2004 (EPA 2006 [Greenbook]). Denali National Park is managed by the U. S. Department of the Interior, National Park Service as a Class I area for protection of air quality. Under its program, ambient air quality is monitored for pollutants. These include fine particles, sulfur dioxide, nitrogen oxides, ozone, CO, and lead (NPS 2002). Construction of a spur pipeline and its subsequent operation including the use of compressor stations may have both short-term and long-term impacts upon air quality along both routes. Air quality and emissions regulations may preclude the installation of compressor stations at some locations.

4.2.7 Biological Resources

Vegetation

Using the descriptions from Viereck et al. (1992), both routes pass through the upland tundra and boreal forest zones. The Fairbanks Spur would cross upland tundra in the Alaska Range and the Delta Junction Spur route passes through upland tundra in the northern foothills of the Chugach and Wrangell-St. Elias Mountains. The upland tundra zone includes the major vegetation zones of moist tundra, dry or alpine tundra, and shrub or high brush tundra. Above treeline, *Dryas* dwarf shrub tundra and *ericaceous* tundra (heaths) are the dominant plants of the alpine tundra community (Viereck et al. 1992). Below treeline, the plant community is mainly shrub brush tundra dominated by low shrub dwarf birch (Viereck et al. 1992). Wetlands may occur in the Alaska Range either above or below treeline, generally on valley bottoms or lower slopes with poorly drained soils (BLM 2002). These wetland communities may consist of low willow shrub, low alder-willow shrub, and low mixed shrub-sedge tussock tundra (BLM 2002). Tall trees are uncommon, but shrubs including birch, Labrador tea, cranberry and blueberry may be found. Additionally, the community may be underlain by herbaceous plants such as moss mats, tussock cottongrass, and sedges (BLM 2002).

The boreal forest zone covers the areas of Southcentral and Interior Alaska between the coastal forest and the northern limit of forest growth (Viereck et al. 1992). The zone consists of evergreen forests of black and white spruce, but also contains deciduous forests of paper birch, aspen and balsam poplar (Viereck et al. 1992). Shrub and herbaceous communities include subarctic lowland sedge, sedge-moss bog meadows and willow, sweetgale and graminoid bogs (Viereck et al. 1992). Successional communities of alder and willow may be formed after fire and alluvial deposition (Viereck et al. 1992). Black spruce forest is the dominant wetland type but wetlands may also be composed of willow shrub, birch shrub, herbaceous wetlands and collapse-scar bogs (BLM 2002). No Endangered Species Act (ESA) listed plant species are known to exist along either route.

Fish/Aquatic Species

Anadromous and resident fish species are present in many of the waterbodies along both routes. Anadromous fish are defined as fish that hatch in fresh water; spend part of their life in the ocean; then spawn in fresh water. Fish resources account for a significant portion of the subsistence harvest in Interior Alaska and recreational fishing is a major economic activity throughout Alaska.

The Fairbanks Spur would cross the Tanana and Susitna River drainages and would cross approximately 134 streams (Denali Pipeline 1993). Crossings north of Cantwell would include the Tanana and Nenana Rivers. Both rivers are important for migration of adult and juvenile king, chum, and silver salmon. Within the Tanana drainage there are a total of four streams that have been classified as anadromous fish bearing by the Alaska Department of Fish and Game (ADF&G) (Denali Pipeline 1993). The anadromous streams, and an additional seven streams, are known to support resident fish species. Resident fish may include whitefish, burbot, northern pike, arctic grayling, Dolly Varden, and sheefish (Denali Pipeline

1993). There may be additional streams that support anadromous and/or resident fish that have not been identified by ADF&G biologists at this time.

South of Broad Pass, the Susitna River drainage provides migration, spawning and rearing habitat for all five species of Pacific salmon (king, chum, silver, red and pink). The Fairbanks Spur would cross approximately 35 streams that have been classified as anadromous fish-bearing by ADF&G and are also likely to support populations of resident fish species (Denali Pipeline 1993). Additional streams that would be crossed may also sustain resident fish populations.

On the Delta Junction Spur route between Delta Junction and Glennallen, there are approximately 49 stream crossings (URS 2005). Of the 49 streams, eight have been classified as anadromous and 22 are likely to support resident fish (URS 2005). The route from Glennallen to Palmer would have approximately 81 stream crossings. Further field study would be required to develop a comprehensive list of streams affected along each route.

Birds

Alaska is home to more than 470 documented bird species (USFWS 2006). Numerous waterfowl, shorebirds, gulls, birds of prey, and boreal species utilize habitat found along both pipeline routes for migration, nesting, or year-round habitat. Of special concern are areas of concentration or specialized habitat which may be located near the proposed pipeline routes. Further field studies would be needed to better verify the presence of particular species along each route.

Determining the location of eagle nests along the pipeline routes will be very important in the granting of a ROW. Bald eagles utilize habitat along both pipeline routes for nesting, hunting, and migration. In many cases, bald eagles will use and rebuild the same nest each year. In Southcentral Alaska, bald eagles prefer nests in old cottonwood trees usually located near water. Eagles begin nest construction in April and will have laid two or three eggs by the end of April. Egg incubation lasts approximately 35 days and eaglets usually fledge 75 days after hatching (ADF&G 2006a). Golden eagles are primarily cliff-nesting, but nests in trees are not uncommon. Golden eagles are known to nest in and around Denali National Park and Preserve (Denali Pipeline 1993) as well as in the mountainous areas of the Delta Junction Spur route (BLM 2002). Potential threats to bald eagle populations include loss of undisturbed habitat and human encroachment and development in remote areas (ADF&G 2006a). Bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 United States Code (USC) §§ 668 -668d) and under the Migratory Bird Treaty Act (16 USC §§ 703-712). It is illegal to kill or molest an eagle, and remove or destroy nests (16 USC § 668(a)).

Potential habitat for waterfowl can be found in or along most streams, rivers, lakes or ponds adjacent to both routes. A great number of sandhill cranes are known to nest along the Tanana River floodplain near Delta Junction and between 200,000 and 300,000 cranes pass through the region during the spring and fall migration (BLM 2002). The Matanuska-Susitna Valley also harbors a small breeding population of sandhill cranes (ADF&G 2006a). The Copper River basin area supports a large nesting population of trumpeter swans which may be by the Delta Junction Spur route (BLM 2002).

The Susitna River wetland area paralleling the Parks Highway between Talkeetna and Willow is used for nesting and rearing by trumpeter swans (ADF&G 2006a). Swans are very sensitive to disturbance and may have an unsuccessful breeding season if human activity occurs near their chosen nesting site (ADF&G 2006a). Alaska supports all five species of loons (arctic, common, Pacific, red-throated, and yellow-billed). The common, pacific, and red-throated loons are all known to nest in Interior and Southcentral Alaska. Loons nest along small lakes and return to the same nesting area every year (ADF&G 2006a). Loons are particularly sensitive to human disturbance. Many other species of ducks and geese nest and/or migrate through the route corridors.

Over 170 passerines (songbirds) have been observed in Alaska (BLM 2002). All the habitats potentially affected along the pipeline routes will support some songbirds in addition to other avian species. Migrant species usually arrive late March through June and begin breeding soon thereafter (BLM 2002). Young are usually fledged by August or September, in time to participate in the fall migration southward. Redpolls, common raven, magpies, and chickadees are year-round residents.

All three species of ptarmigan (willow, rock, and white-tailed) may be found in the higher elevations along both spur pipeline routes. Willow ptarmigan are found throughout the treeless high country while rock ptarmigan range throughout much of the treeless tundra areas of the state and white-tailed ptarmigan are generally found at higher elevations than the other two species. Ptarmigan are an important species for recreational and subsistence hunting (ADF&G 2006a).

Terrestrial Mammals

Large game animals such as moose, caribou, bear, sheep and mountain goat are found throughout both pipeline routes. All species are hunted for subsistence as well as recreational uses.

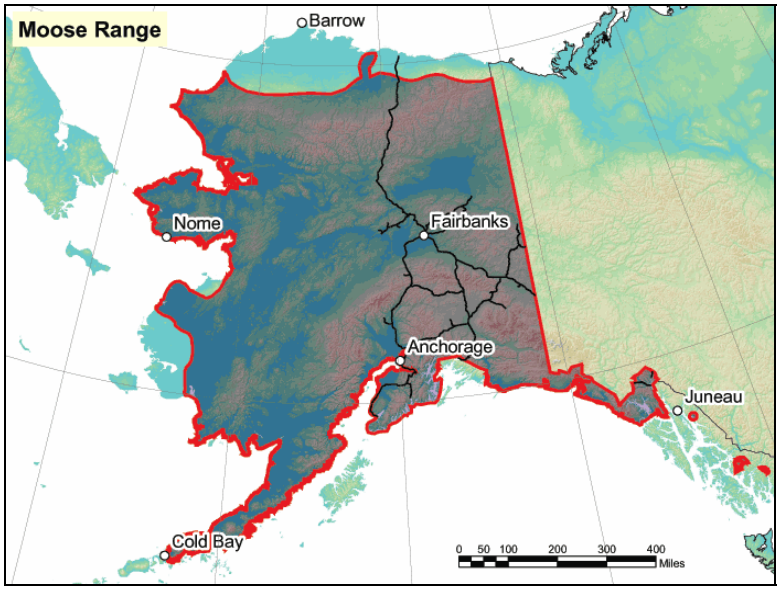


Figure 4.2: ADF&G Moose Range Map

Moose (Alces alces)

Moose require a broad range of habitats that include breeding grounds, winter feeding areas, calving grounds and summer feeding areas (ADF&G 2006a). Figure 2-3 depicts moose range in Alaska (ADF&G 2006a). This requirement for habitat diversity may cause moose to migrate as much as 60 miles as seasonal abundance changes. Moose are most often found in willow and birch shrub habitats, on timberline plateaus, and along the river systems of Southcentral and Interior Alaska. Moose feed on a variety of vegetation, depending on seasonal abundance. During fall and winter as food diversity dwindles, moose consume mostly willow, birch, and aspen twigs. In spring, moose consume a range of foods, particularly sedges, equisetum (horsetail), pond weeds, and grasses. Moose populations are limited by predation from wolves and bears, hunting and severe weather (ADF&G 2006a). Approximately 6,000 to 8,000 moose are harvested annually (ADF&G 2006b).

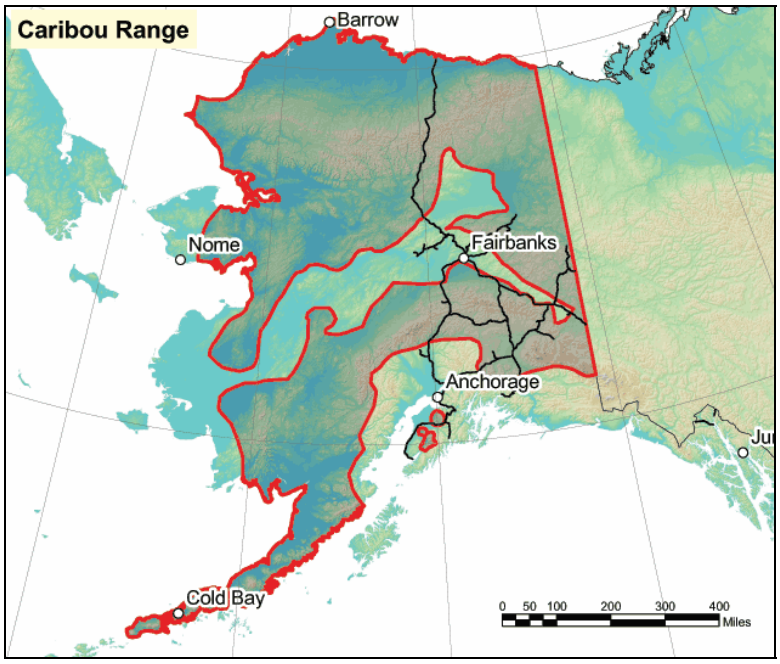


Figure 4.3: ADF&G Caribou Range Map

Caribou (Rangifer tarandus)

Caribou are generally migratory animals and large herds may travel as much as 400 miles between winter and summer ranges while smaller herds may not migrate at all (ADF&G 2006a). Figure 2-4 depicts caribou range in Alaska (ADF&G 2006a). Caribou diet consists of willow leaves, flowering tundra plants, grasses, and mushrooms in the summer and lichens, grass, and shrubs in the fall and winter. Population dynamics are most affected by climate, overpopulation, predation, and disease (ADF&G 2006a).

Both proposed pipeline routes intersect the areas used by the Delta, Denali, and Nelchina caribou herds. Caribou are an important resource to both urban and rural residents. ADF&G reported a five-year average harvest of 34.6 caribou for the Delta herd and a five-year average harvest of 1,092 for the Nelchina herd (ADF&G 2006b)). The range of the Denali herd is within the boundaries of Denali National Park making harvest of caribou from the Denali herd illegal.

Bear

Black and brown bears are present along both of the proposed routes. Figure 2-5 depicts bear range in Alaska (ADF&G 2006a).

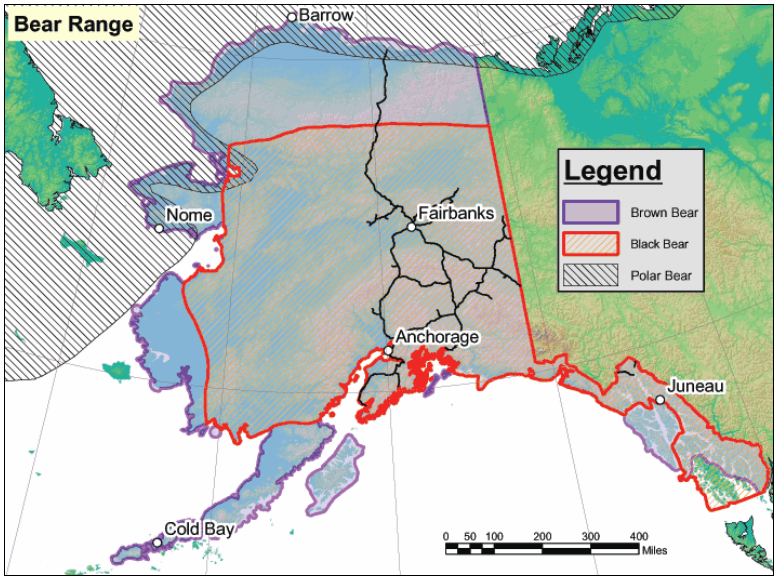


Figure 4.4: ADF&G Bear Range Map

Black bears (*Ursus americanus*) are the smallest of the species and are most often found in forested areas from sea level to alpine elevations. Black bears range in color from white to black.

Black bears hibernate throughout Alaska, although the duration of dormancy depends upon the length and severity of winter. A typical black bear diet consists of whatever food is available to them. New spring vegetation is usually what black bears begin to eat after emerging from dens, although winter-kill game or occasionally newborn moose calves supplement their diet. Salmon and/or vegetation provide the bulk of black bear nutrition in the summer until berries begin to appear in late summer to fall. Throughout the year, black bear diets are supplemented by ants, grubs or other insects. Black bears are hunted throughout Alaska.

Brown or grizzly bears (*Ursus arctos*) are larger than black bears and also range in color from dark brown to light blond. Brown bears are found throughout the state and, within Interior and Southcentral Alaska, have a density of one bear per 15 to 23 square miles (ADF&G 2006a). Brown bears are a sought-after animal for big game hunters.

Brown bears may hibernate for up to seven months in the northern portions of the state or may be semi-active throughout the winter in areas where weather is mild. Brown bears are considered omnivores and will consume vegetation, roots, berries, fish, insects, and small and large mammals (ADF&G 2006a).

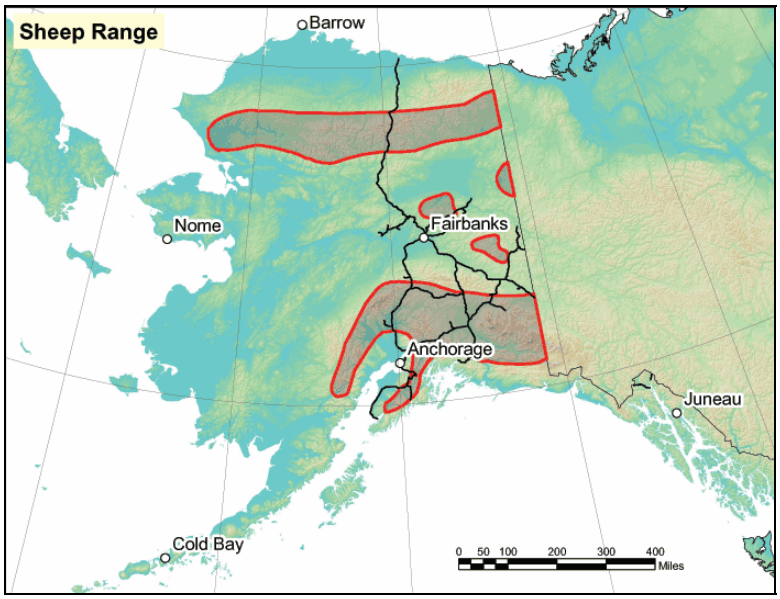


Figure 4.5: ADF&G Dall Sheep Range Map

Dall Sheep (Ovis dalli dalli)

Dall sheep are found along both proposed pipeline routes in the Alaska Range on the Fairbanks Spur route and the Alaska Range and Chugach Mountains on the Delta Junction Spur route (Denali Pipeline 1993). Figure 2-6 depicts Dall sheep range in Alaska (ADF&G 2006a).

Dall sheep are not considered migratory; however, herds travel throughout their range during the year in search of food, shelter or protection from predators (ADF&G 2006a). Ewes and rams generally remain in separate groups throughout most of the year, but intermingle in the fall during breeding season. Dall sheep eat a variety of food and forage is dependant upon the season and location. In addition to vegetation, sheep will seek out mineral or salt licks as an integral part of their diet (ADF&G 2006a). Ewes give birth to a single lamb in late May or June on rugged steep cliffs. Usually within a week after birth, ewe-lamb pairs will begin to move to areas of better forage and generally remain with a larger group of ewes and lambs.

Dall sheep are sensitive to human activity and increased noise production with the most critical periods being during the lambing season. Predation, low reproductive rates, and weather severity are the primary factors that limit sheep populations (ADF&G 2006a). Dall sheep are sought after by trophy hunters.

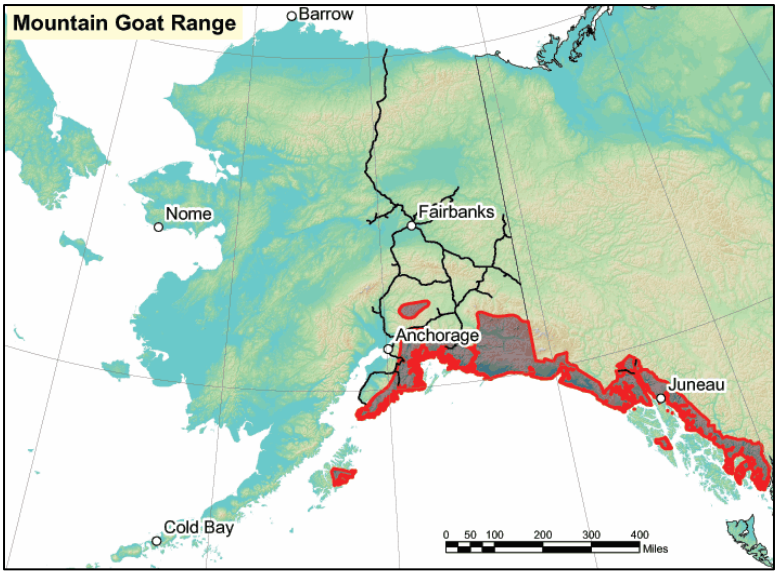


Figure 4.6: ADF&G Mountain Goat Range Map

Mountain Goat (Oreamnos americanus)

Mountain goats are also found in the Chugach Mountains and goats have been reported from the Talkeetna Mountains to Denali State Park (ADF&G 2006a). Figure 2-7 depicts Mountain Goat range. However, the areas crossed by the pipeline routes are thought to be the extreme northern limits of mountain goat range.

Like Dall sheep, mountain goats are found in very rugged terrain with cliffs, ledges and scree or rubble covered slopes. Goats feed on grasses, sedges, and tundra shrubs. Availability of winter habitat, winter severity, and snow accumulation are the main predictors of mountain goat reproductive rates (ADF&G 2006a).

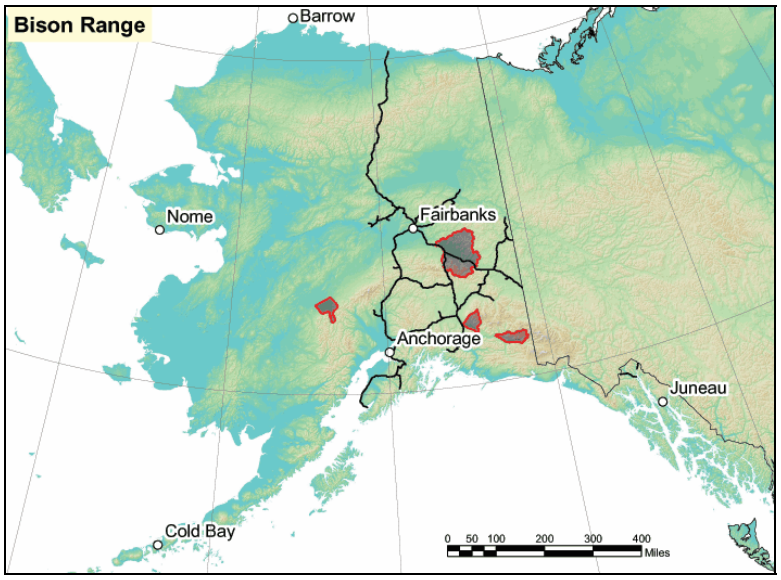


Figure 4.7: ADF&G American Bison Range Map

American Bison (Bison bison)

The Delta Junction Spur route crosses through habitat used by the Delta herd of American bison. Figure 2-8 depicts American bison range (ADF&G 2006a).

The herd ranges from the lower delta plain in the Delta Junction Bison Range to the upper reaches of the Delta River. Between mid-February and mid-March, the herd travels the Delta River floodplain, crossing the Richardson Highway (BLM 2002). In the spring, cows move to more secluded areas to calve. The herd can be found along the Delta River floodplain and adjacent uplands during the summer months. In late summer or fall, the herd migrates from the Delta River floodplain, across the Richardson Highway, onto the Delta Junction Bison Range. Bison are grazing animals and forage along the rivers and streams and in recently burned areas for food (ADF&G 2006a).

Controlled hunts are conducted each year to maintain sustainable bison populations.

Gray Wolf and Other Furbearers

The gray wolf (*Canis lupus*) is present throughout Alaska and established packs are present along both routes (ADF&G 2006a). Wolves normally breed in January or February and pups are born in May. By early winter, pups have grown large enough to travel and hunt with the rest of the pack. Wolves are carnivores and primarily rely on moose and caribou for prey, but also feed on Dall sheep to some extent. Summertime abundance allows wolves to expand their diets to include small mammals such as voles, ground squirrels, hares, beaver and occasionally fish or birds (ADF&G 2006a). Wolves' only predator and competitor for prey are humans. Hunting and trapping are the primary factors regulating population dynamics but disease, malnutrition, and violent confrontations with other wolves also contribute to wolf mortality (ADF&G 2006a).

Several other species of furbearers are considered abundant in Interior and Southcentral Alaska and may be found along or near one or both routes. These species may include snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), coyote (*Canis latrans incolatus*), arctic fox (*Alopex lagopus*), red fox (*Vulpes vulpes*), marten (*Martes americana*), short-tailed weasel or ermine (*Mustela erminea*), least weasel (*Mustela rixosa*), mink (*Mustela vison*), wolverine *(Gulo gulo)*, river otter (*Lutra canadensis*), and lynx (*Lynx canadensis*) (ADF&G 2006a). These mammals are important for trapping and hunting but small mammal populations are also important sources of food for larger carnivores (ADF&G 2006a)

4.2.8 Threatened and Endangered Species and Alaska Species of Special Concern

The USFWS and the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service jointly administer the ESA under 16 USC §§1531-1534. While there are currently 18 species listed as endangered or threatened in Alaska, neither spur pipeline route crosses habitat known to be utilized by the listed species (ADF&G 2006c and USFWS 2006).

However, several Species of Special Concern are known to occur within the pipeline routes. A species of special concern is managed by the ADF&G as "any species or subspecies of fish or wildlife or population of mammal or bird native to Alaska that has entered a long-term decline in abundance or is vulnerable to a significant decline due to low numbers, restricted distribution, dependence on limited habitat resources, or sensitivity to environmental disturbance" (ADF&G 2006d). The olive-sided flycatcher *(Contopus cooperi)*, gray-cheeked thrush *(Catharus minimus)*, Townsend's warbler *(Dendroica townsendi)*, and blackpoll warbler *(Dendroica striata)* are all songbirds considered species of special concern which are found within both spur pipeline routes (ADF&G 2006d). Additionally, the American peregrine falcon *(Falco peregrinus anatum)* occurs within much of Interior Alaska, and is a species of special concern. The American peregrine falcon was removed from the state and federal endangered species lists in 1999, but is still being monitored by state and federal wildlife officials.

4.3 Pipeline Alignment Selection

Various pipeline alignment options were identified within the Fairbanks and Delta Junction Spur routes. Appendix 4-4 presents the route alignment sheets. The alignment options were evaluated from engineering, permitting, socioeconomic and ROW perspectives and a single pipeline alignment was selected within each spur corridor. The selected alignments were used as the basis for generation of capital cost estimates for specific pipeline configurations and subsequent pipeline tariff analyses. Alignment selection was based on a limited amount of field reconnaissance and more field work would be required before a final alignment would be selected for project financing and ROW permitting.

4.3.1 Alignment Selection Methodology

The process used to assess the various alignment options for the Fairbanks and Delta Junction Spur pipelines was:

- Identify all possible alignment options with each spur corridor;
- Divide the corridors into logical segments based on candidate alignments identified;
- Summarize information for alignment alternatives in a matrix on a segment-by-segment basis;
- Assign a relative rating to each alignment option by engineering, permitting, socioeconomic and ROW category (one rating for each category);
- Assign a percent weighting factor for each category and determine an overall relative ranking for each alignment option within a given segment;
- Select the alignment based on the relative rankings per the matrix and judgment of the team;
- Conduct field investigation as necessary for critical or more complex portions along the routes; and
- Characterize the selected alignment for each spur, and refine the alignment as required.

4.3.2 Identify Routing Options

A list of all reasonable alignment alternatives within each spur pipeline corridor was developed with reasonable consideration of constructability, engineering, permitting and environmental issues. Routing

options that were considered included existing infrastructure such as roads, power lines, railroads, and existing pipeline ROW. ROW for proposed pipeline projects were also included.

Fairbanks Spur Corridor

The Fairbanks Spur corridor is located along the most direct path between Fairbanks and Wasilla as shown in Figure 4.8. The Fairbanks Spur corridor contains infrastructure linking Alaska's two largest communities. From Fairbanks, this corridor passes southwest along the Tanana and Nenana Rivers, crosses the Alaska Range via Broad Pass, and traverses the entire length of the Susitna Valley before ending at the 20 inch diameter ENSTAR pipeline near Wasilla.

Existing routes and potential alignment options within the Fairbanks Spur corridor include the Parks Highway, Alaska Railroad, Alaska Energy Authority (AEA) Intertie, Denali Pipeline (proposed in 1993), and a pipeline alignment identified by ANGDA in 2005 (Michael Baker 2005a). Maps that depict individual alignment option are included in Appendix 4-1. The following are brief descriptions of these considered alignment options:

Parks Highway

The Parks Highway is a well-maintained two-lane paved highway that was constructed in 1971 (http://www.themilepost.com/hwy_north.shtml#Parks) connecting Fairbanks and the Cook Inlet area. It is the primary transportation route through the corridor and would be used considerably to support pipeline construction.

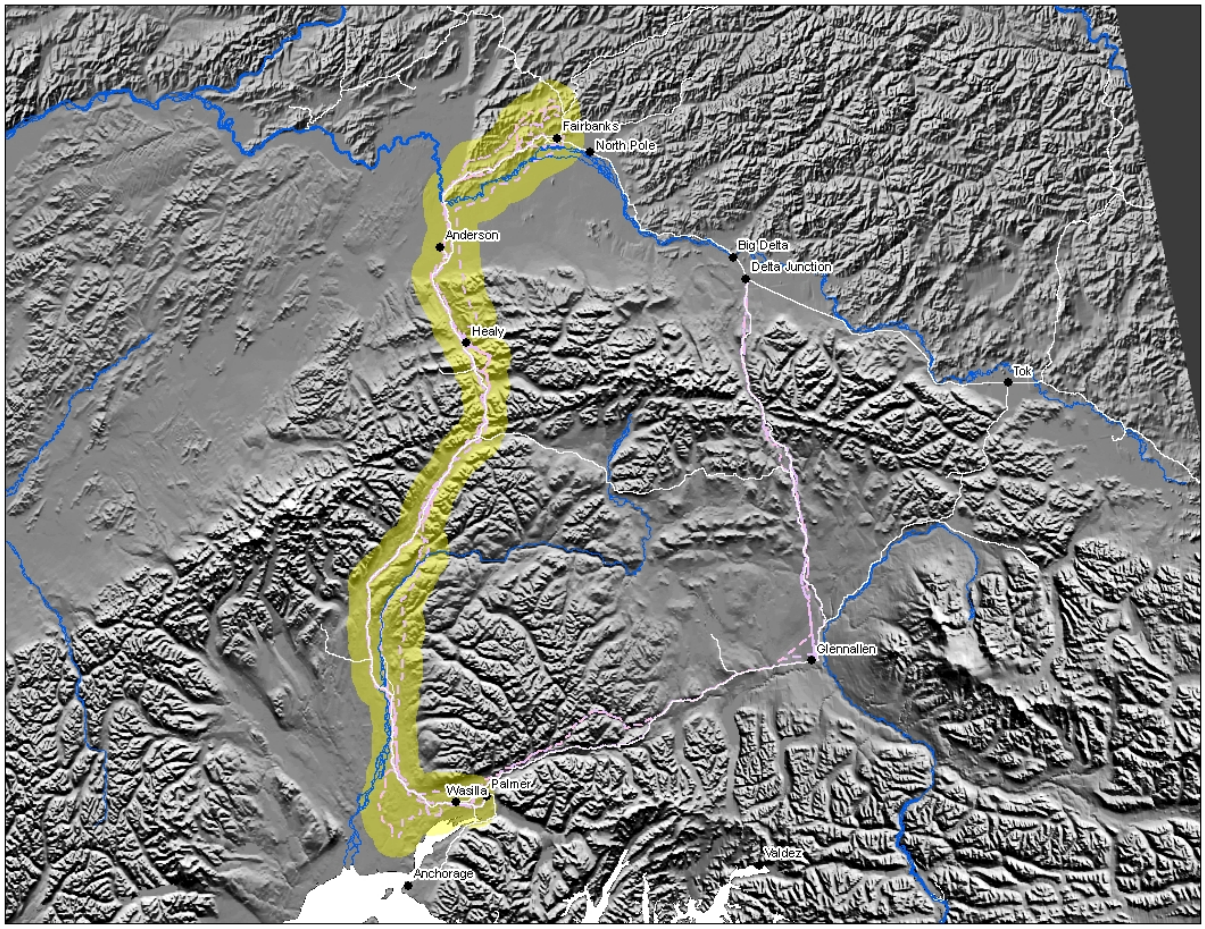


Figure 4.8: Fairbanks Spur Corridor

Alaska Railroad

The Alaska Railroad connects Fairbanks to the Cook Inlet area and is vital infrastructure for the transport of resources between Anchorage and Fairbanks. The railroad continues past Anchorage to the year-round, deep water, ice free port of Seward. The railroad could be used to transport pipe and other materials imported to Seward and for equipment marshalling and storage locations along the Fairbanks Spur route. The option exists to locate the pipeline within the railroad ROW.

AEA Intertie

Between Fairbanks and Healy, the intertie consists of two power lines; the Northern Intertie which is a 138 kilovolt (kV) electrical transmission line along the Parks Highway, and the Southern Intertie which is a 230 kV electrical transmission line that crosses the Tanana Flats south of Fairbanks and takes a more direct, but much more remote, route between Fairbanks and Healy.

South of Healy, the intertie becomes a single electrical transmission line that is generally within a few miles of, but is rarely visible from, the Parks Highway. The intertie passes through Wasilla (the southern destination of this study) and terminates in Anchorage.

Denali Pipeline – 1993

An Environmental Assessment (EA) for a refined petroleum products pipeline (diameter no larger than 24 inch) between the North Pole Refinery and the Port of Anchorage was submitted to the State of Alaska in 1993. The Denali Pipeline was not built and the route was considered an obvious candidate for the spur pipeline.

ANGDA – 2005

ANGDA issued a report in 2005 in which an alignment for a 24 inch gas pipeline from Fairbanks to Cook Inlet was identified (Michael Baker 2005a). The proposed route began north of Fairbanks near the Chatanika River and intersected the ENSTAR 20 inch pipeline near the Glenn-Parks Highway interchange.

Delta Junction Spur Corridor

The Delta Junction Spur route is shown in Figure 4.9. From Delta Junction, the corridor generally follows the Richardson Highway to the Glennallen area and then the Glenn Highway to Palmer. A portion of TAPS is contained in the Delta Junction Spur corridor as well as the ROW for the proposed pipeline of the Trans Alaska Gas System (TAGS). The corridor from south of the Alaska Range to the entrance to the Matanuska Valley passes through the Copper River basin, which is noted for challenging soil conditions regarding frost heave and thaw settlement. The corridor ends at the existing 20 inch diameter ENSTAR pipeline located near the intersection of the Glenn and Parks Highways near Palmer.

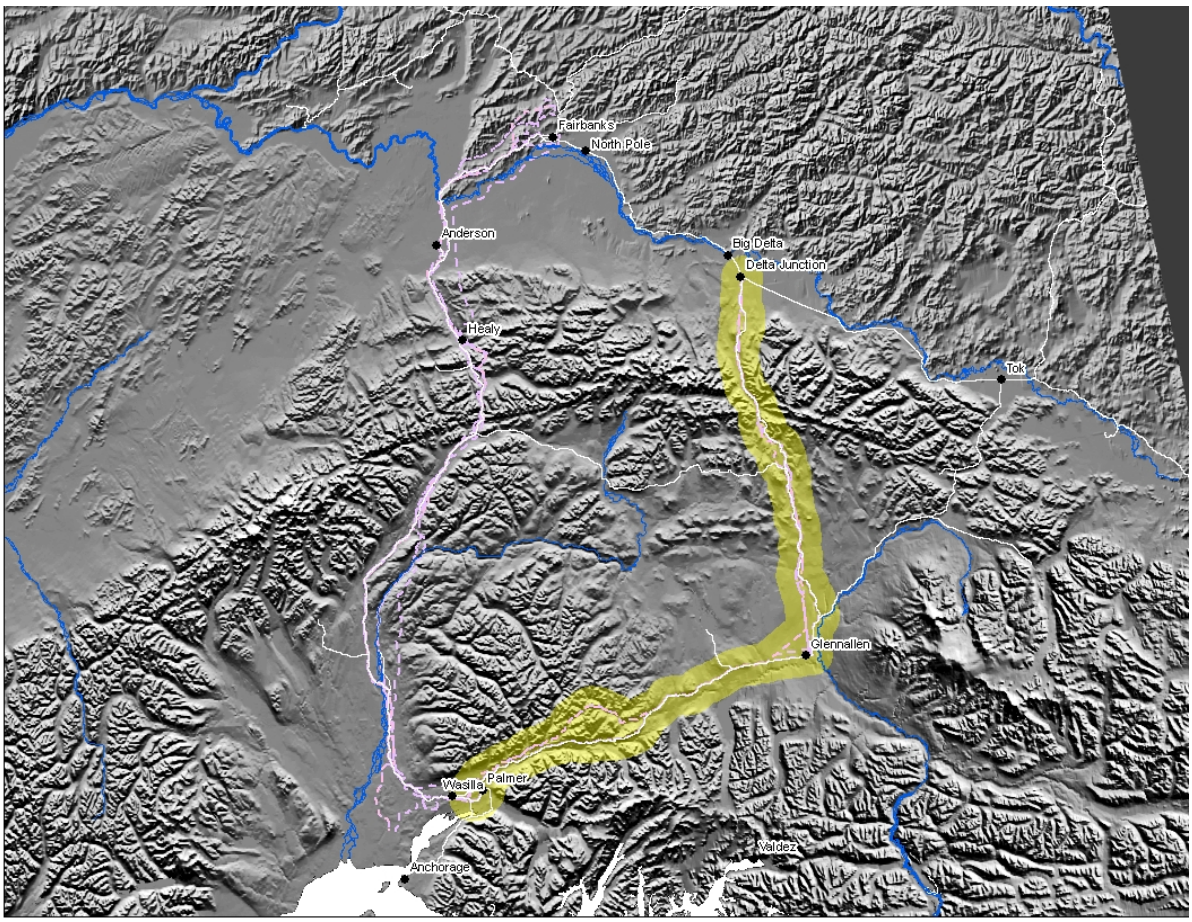


Figure 4.9: Delta Junction Spur Corridor

Existing routes and potential alignment options within the Delta Junction Spur corridor include the Richardson Highway, TAPS, and TAGS for the Delta junction to Glennallen portion of the corridor and the Glenn highway and ANGDA alignments for the Glennallen to Palmer portion of the corridor. Maps that show these individual alignment options are provided in Appendix 4-1. The following alignments were identified and considered for the Delta Junction Spur route:

Richardson Highway (Delta Junction to Glennallen)

The Richardson Highway was constructed in 1942 (http://www.karo-ent.com/richardson.htm) and connects Fairbanks with the port of Valdez. The Richardson Highway is paved and in generally good condition along much of its length; however, frost heaves are frequently encountered within 50 miles either side of Glennallen.

TAPS or ANGDA (Delta Junction to Glennallen)

TAPS was commissioned in 1977 and remains in operation today. The design operating temperature of TAPS is approximately 145 deg F and TAPS was aligned through thawed ground and thaw-stable permafrost as much as possible to avoid costly aboveground construction on vertical support members.

ANGDA has stated that they intend to bury their proposed spur pipeline along the TAPS ROW from Delta Junction to where the spur pipeline alignment turns southwest just north of Glennallen (URS 2005).

Trans Alaska Gas System (TAGS) (Delta Junction to Glennallen)

TAGS consists of a proposed pipeline to transport natural gas from Prudhoe Bay to Port Valdez where it would be liquefied for shipment for export from Alaska. The TAGS project secured a ROW for an alignment across federal lands and a conditional ROW where the alignment crosses state lands.

Similar to the spur pipeline, TAGS was designed to operate chilled and be buried. The TAGS pipeline from Delta Junction to Paxson was aligned through soils that would be compatible with a chilled buried pipeline as much as possible. The TAGS alignment from Delta Junction to Glennallen was vetted during the permitting process with little controversy except for the alignment west of Summit Lake. The TAGS permitting process addressed the proximity of the gas and TAPS pipelines.

Use of the TAGS alignment would not conflict with the TAGS project because if the TAGS were built, the spur pipeline would likely originate at Glennallen instead of Delta Junction.

Glenn Highway (Glennallen to Palmer)

The Glenn Highway between Glennallen and Palmer is a two- to three-lane paved highway that is regularly maintained and is the primary vehicle route from the Cook Inlet area to much of the interior of Alaska and Canada. The State of Alaska has recently improved significant portions of the highway.

ANGDA (Glennallen to Palmer)

ANGDA received a conditional state ROW for a spur pipeline from Glennallen to Palmer in 2006. The ANGDA route would begin at the TAPS ROW approximately two miles north of Glennallen, follow the Glenn Highway to Eureka, and then is routed to the northwest over Chitna Pass in the Talkeetna Mountains before termination at ENSTAR's 20 inch pipeline near the Glenn and Parks Highways interchange between Wasilla and Palmer (Michael Baker 2005b). The majority of this alignment crosses state owned land.

4.3.3 Route Segment Maps and Evaluation Matrices

The spur pipeline routes were divided into the following logical segments for the purposes of evaluating alignment options:

- Fairbanks Spur evaluation segments
  - Fairbanks area to southwest of Ester
  - Ester to Nenana
  - Nenana to Healy
  - Healy to Cantwell
  - Cantwell to Hurricane Gulch
  - Hurricane Gulch to Talkeetna Junction
  - Talkeetna Junction to Willow
  - Willow to ENSTAR pipeline west of Wasilla
- Delta Junction Spur evaluation segments
  - Delta Junction to Paxson
  - Paxson to Glennallen
  - Glennallen to Eureka
  - Eureka to Chickaloon
  - Chickaloon to ENSTAR pipeline near intersection of the Glenn and Parks Highways

Route Segment Maps

Route maps were developed for each evaluation segment and are contained in Appendix 4-1. Segments of each route are described above. The various alignment alternatives are shown on the maps in Appendix 4-1 with the selected optimal alignment highlighted.

Route Segment Evaluation Matrices

An evaluation matrix was generated for each segment that summarizes the factors that were used during assignment of ratings for each route option during the route selection process. Route segment comparison matrices are presented in their entirety in Appendix 4-2. The matrices were developed by members of the project team that represented the various route selection categories (engineering, permitting, ROW, and socioeconomic). These four categories were identified for input on route selection based on their involvement with this study and their importance to route selection. The detailed matrices identify the pros and cons for each route and discuss the key issues that affected the overall decision on the route rating. Reduced matrices identifying the overall scores and the sub ratings from the different entities have been developed and are included in the body of the report for each segment.

4.3.4 Alignment Selection – General Approach

A pipeline alignment must be selected that would be acceptable to the project sponsors, regulatory agencies, and other stakeholders, including the public. All things being equal, the shortest alignment is generally the most favorable for the project sponsors and regulatory agencies, because it usually costs the least and impacts the least amount of land.

The shortest route may not necessarily be the most favorable to all stakeholders along the route, the most environmentally benign, or the easiest to permit. Alignment selection criteria also included avoiding population centers, environmentally sensitive areas, or areas that would be challenging for pipeline construction. Each alignment was selected to minimize the extent or magnitude of impact along the route

as much as practicable. Alignment selection also addressed access to the ROW for construction, operation and maintenance, and avoids locating compressor stations in remote areas.

Potential pipeline routes were evaluated with the objective of optimizing conditions set out in the following criteria for this conceptual design:

Minimize total length of the route. Total length of the pipeline was considered as a major factor in determining environmental impacts and project costs.

Avoid environmentally sensitive areas. Routing around areas where the quality or integrity of the environment would be adversely affected was considered as related to environmental impact, mitigation, and permitting.

Avoid high consequence areas. Routing around areas where large populations exist, or facilities that are likely to contain large populations (e.g., hospitals, schools, play grounds), was considered as related to safety and associated code requirements (e.g., increased pipeline wall-thickness required in high consequence areas as per Code of Federal Regulations [CFR] 192).

Minimize the number of stream and river crossings. Crossing streams and rivers and traversing floodplains and deltas, especially those with a high habitat value, was considered as related to environmental impact, mitigation, permitting, engineering, and cost.

Avoid geohazard areas. Routing to avoid areas with potential geohazards, including slope failure, ice scour, thermal erosion and seismic disturbance was considered as related to engineering, safety, and cost.

Provide high degree of pipeline constructability. Characteristics of construction conditions (e.g., topography, climate, structure, soils, and hydrology) were considered as related to environmental impact, engineering, safety, scheduling, and cost.

Additional criteria that should be considered in any further micro-routing (routing optimization as required, on the order of 100 meters) in further stages of design:

Minimize blocking cross drainage. Routing to minimize areas where cross drainage would be blocked, impounding water and/or exacerbating erosion as related to environmental impact, engineering, operation, and mitigation.

Maximize routing in geotechnical conditions favorable to pipeline operating characteristics. Routing to minimize potential thaw settlement, thermal erosion and buoyancy as related to environmental impact, reliability, engineering, and cost.

Use existing infrastructure to the extent possible and appropriate. Use of existing roads, winter trails, airstrips, disposal sites, communication facilities and developed townsites as related to environmental impact, mitigation, schedule, maintenance, and cost.

Locate pipeline to facilitate maintenance and repair work. The ability to access the pipeline for repair and maintenance work as related to environmental impact and safety.

Selection of a final alignment would be decided by the project sponsors and be based on more detailed route evaluation, public input, and interaction with numerous regulatory agencies.

4.3.5 Fairbanks Spur Corridor: Evaluation

It is recommended that while reading this section, the corresponding segments maps (Appendix 4-1) be referenced. These maps are best viewed in color and at full size (11 inches by 17 inches).

Fairbanks Area

Particulars extracted from the evaluation matrix are shown in Table 4.3 (complete evaluation matrices are available in Appendix 4-2).

Table 4.3: Matrix Values – Fairbanks Area to Ester

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	24	1.0	1.5	2.5	1.5	1.6
ANGDA	23.9	2.5	2.5	2.5	1.5	2.3
Alternative 1	27.6	3.5	2.5	2.5	4.0	3.1
Alternative 2	25.7	3.0	2.5	2.5	2.5	2.6

The exact locations of the ANS pipeline to Alberta and the spur pipeline take-off from this pipeline were not specified in the Statement of Work and various locations were considered for the potential beginning terminus of the spur pipeline. All of the alignment alternatives considered through the Fairbanks area terminate at the Parks Highway alignment southwest of Ester.

The route identified in a 2005 ANGDA report (Michael Baker 2005a) branches off from TAPS about 15 miles north of Fairbanks and travels south along the western edge of Fairbanks and the University of Alaska Fairbanks before connecting with the Parks Highway. The Denali Pipeline route starts at the North Pole Refinery (approximately 10 miles due east of Fairbanks) and proceeds west along the southern limits of Fairbanks before crossing the Chena River and intersecting the Parks Highway. An Alternative 1 was identified that follows the Old Murphy Dome Road north and proceeds cross country northwest of Fairbanks crossing Goldstream Road, the Alaska Railroad, and Goldstream Creek before heading cross country straight south through rolling hills to the old Parks Highway and eventually the Parks Highway. An Alternative 2 alignment was identified that follows Goldstream Road west from TAPS before heading south and southwest cross country near Murphy Dome and connecting to the old Parks Highway before joining the Parks Highway.

The Alternative 1 alignment was selected, although it is the longest, primarily because it avoids the heaviest populated areas resulting in the least impact of the four options. Field reconnaissance was completed in this area (Section 4.3.7) and this route was also considered to have the greatest likelihood of being located in areas with favorable soil conditions as it generally follows ridges and south facing slopes.

Ester to Nenana

Particulars extracted from the evaluation matrix are shown in Table 4.4 (complete evaluation matrices are available in Appendix 4-2).

Table 4.4: Matrix Values – Ester to Nenana

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	38.6	3.5	2.5	3.0	2.0	2.8
ANGDA	39.4	3.5	3.5	3.5	3.0	3.4
Parks Highway	40.1	3.5	3.5	3.5	3.0	3.4
AEA Intertie – north	37.7	3.5	3.0	2.0	2.0	2.6
AEA Intertie – south	46	1.0	2.0	2.0	2.0	1.8
Alaska Railroad	38	3.0	2.5	2.5	1.5	2.4

The southern AEA Intertie is included among the alignment alternatives only for completeness because this alignment was rejected for the previous segment. The Alaska Railroad alignment is also not a candidate for the first portion of this segment because it is not within reasonable proximity to the start of the evaluation segment that is located southwest of Ester. Both of these alignments follow lowland routes and cross more wetlands than the other more upland routes.

The Denali Pipeline and northern AEA Intertie alignments are concurrent from Ester to Nenana. In this segment, the ANGDA alignment deviates only slightly from the Parks Highway. These four alignment options are essentially coincident for the first third of the way from Ester to Nenana.

The alignment selected for this segment follows a combination of the Denali Pipeline/Northern Intertie and Parks Highway/ANGDA alignments. The alignment was selected to minimize crossings of potential wetlands as much as practicable by keeping to high ground. The alignment that provided the best crossing of the Tanana and Nenana Rivers near Nenana was selected.

The selected alignment follows the Parks Highway/ANGDA route approximately 15 miles at which point it leaves the highway, drops off of the ridge, and follows the Denali Pipeline/Northern Intertie alignment across moderate cross slopes until all four alignments meet again north of Nenana. The four alignments are considered to be essentially equivalent and the deviation from the Parks Highway/ANGDA route to that of the Denali Pipeline/Northern Intertie reflects a minor optimization. The selected alignment follows more level terrain to the west of the Alaska Railroad, away from the hills near the highway for a few miles north of Nenana, before crossing the Tanana and Nenana Rivers.

Nenana to Healy

Particulars extracted from the evaluation matrix are shown in Table 4.5 (complete evaluation matrices are available in Appendix 4-2).

Table 4.5: Matrix Values – Nenana to Healy

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	57.3	3.5	2.5	3.0	2.0	2.8
ANGDA	56.2	3.5	2.5	3.5	2.5	3.0
Parks Highway	57.1	3.5	3.0	3.0	3.0	3.1
AEA Intertie – north	57.6	3.5	2.5	3.0	2.0	2.8
AEA Intertie – south	50.8	1.0	2.5	2.0	2.0	1.9
Alaska Railroad	55.2	3.0	3.0	3.0	1.5	2.6

The alignment selected for this segment follows the ANGDA route which is near (but not within) the Alaska Railroad for part of the northern portion of the segment, and then within the vicinity of the Parks Highway along the southern portion of the segment. There is little difference between five of the six alignment alternatives in this segment as they generally follow the same corridor and are near one another. Significant engineering obstacles along the selected alignment are the crossings of the Nenana River and the Denali and Healy Creek faults.

The southern AEA Intertie route is remote, beginning south of Nenana first on flat land, but through mountainous terrain before approaching Healy from the east side of the Nenana River. The southern AEA Intertie route was rejected because of its relative remoteness and significantly more rugged terrain.

Proximity of each route option to a tie-in with potential Healy coal bed methane and Nenana Basin developments in the area was considered. Each of the route options are in fairly close proximity to one another and each traverses virtually the same types of terrain, therefore, it was determined that no particular route would provide an advantage for a tie-in with these, or any other future exploration or development.

Healy to Cantwell

Particulars extracted from the evaluation matrix are shown in Table 4.6 (complete evaluation matrices are available in Appendix 4-2).

Table 4.6: Matrix Values – Healy to Cantwell

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	42.7	1.5	2.0	2.5	2.5	2.1
ANGDA	44.7	1.5	2.0	2.5	2.5	2.1
Parks Highway	39	3.5	3.5	2.5	4.0	3.4
AEA Intertie	42.2	1.5	2.0	2.5	3.0	2.3
Alaska Railroad	39.6	2.5	1.5	2.5	1.0	1.9

The AEA Intertie, ANGDA, and Denali Pipeline alignment options are essentially the same and head southeast from Healy, cross the Nenana River, go up the rugged Moody Creek drainage, over Moody Creek Pass and descend back to the Nenana River drainage. The remaining two options, the Alaska Railroad and the Parks Highway, leave Healy to the south and enter Nenana Canyon. The Alaska Railroad is located along the west side of the Nenana Canyon on Denali National Park and Preserve land. At the south end of the canyon, the highway crosses the Nenana River and a section of national park land before crossing the Nenana River a second time and leaving Denali National Park and Preserve.

The significant engineering obstacles in this segment include the crossings of the Nenana River, the Nenana Canyon, and the Denali/Dry Creek Strand/Hines Creek Strand/McKinley Strand faults.

The alignment selected for this segment leaves Healy along the Parks Highway and enters the Nenana canyon north of the Alaska Railroad. The alignment follows a route developed during two field visits to the area that passes through Nenana Canyon and involves five crossings of the Nenana River. At the south end of the canyon, the selected alignment re-enters an estimated Parks Highway ROW, which it follows to Cantwell.

Although pipeline construction through either the Nenana Canyon or Moody Creek would be challenging, the selected Nenana Canyon alignment is considered to be the easier of the two. Comparative budget level cost estimates were generated for the two alternatives and showed the Nenana Canyon as the more favorable by approximately $27 million (the complete cost summary comparison is presented in Appendix 4-5).

Near the south end of Nenana Canyon, the selected alternative must cross a small portion of land in Denali National Park and Preserve on the west side of the Alaska Railroad. Time to acquire congressional authorization to cross national park land must be included in a permitting plan and project schedule.

Cantwell to Hurricane Gulch

Particulars extracted from the evaluation matrix are shown in Table 4.7 (complete evaluation matrices are available in Appendix 4-2).

Table 4.7: Matrix Values – Cantwell to Hurricane Gulch

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	37.4	3.5	2.5	2.5	2.0	2.6
ANGDA	37.5	4.0	3.5	2.5	2.5	3.1
Parks Highway	37.2	3.0	3.0	2.5	3.0	2.9
AEA Intertie	35.3	2.0	2.5	2.5	2.0	2.3
Alaska Railroad	38.2	2.0	3.0	2.5	1.5	2.3

The Parks Highway, ANGDA, and Denali Pipeline routes follow one other closely from Cantwell to a location near the East Fork of the Chulitna River where the ANGDA and Denali Pipeline routes climb southeast into the foothills of the Talkeetna Mountains to cross Honolulu Creek and Hurricane Gulch upslope, thereby avoiding the deep ravines. The Alaska Railroad follows the middle of the valley and crosses Hurricane Gulch at very deep point via a large bridge. South of Cantwell, the AEA Intertie ascends the eastern slopes and remains on the east side of the valley.

The selected alignment in this segment follows the ANGDA route which differs from the Parks Highway and Denali Pipeline routes only at the crossing location of both Hurricane Gulch and Honolulu Creek. This location for crossing these drainages was considered superior to the other routes because of its location higher upstream on the drainages where the crossings have much gentler slopes. Constructability of the river and stream crossing locations was verified during a site visit in June 2006.

Hurricane Gulch to Talkeetna Junction

Particulars extracted from the evaluation matrix are shown in Table 4.8 (complete evaluation matrices are available in Appendix 4-2).

Table 4.8: Matrix Values – Hurricane Gulch to Talkeetna Junction

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	72.0	4.0	2.5	2.5	2.5	2.9
ANGDA	71.8	4.0	2.5	3.0	3.0	3.1
Parks Highway	72.6	4.0	3.0	2.5	3.0	3.1
AEA Intertie	65.9	1.0	2.0	2.5	5.5	2.0
Alaska Railroad	68.5	1.0	2.0	2.5	1.5	1.8

This segment is comprised of five alignment options.

The Alaska Railroad and AEA Intertie alignments both leave the Parks Highway and traverse relatively remote terrain along the Susitna River. The Parks Highway, ANGDA, and Denali Pipeline alignments are essentially coincident from Hurricane Gulch to Talkeetna Junction and thus received identical engineering ratings in the evaluation matrix.

The alignment selected for this segment follows the ANGDA route, except for small deviations to provide for more optimum crossings of the Chulitna and Susitna Rivers. The Alaska Railroad and AEA Intertie alignments were rejected because access for pipeline construction and maintenance would be difficult because of the remote alignment. The selected alignment has good access for construction, operations, and maintenance and provides an easily accessible location for a compressor station.

Talkeetna Junction to Willow

Particulars extracted from the evaluation matrix are shown in Table 4.9 (complete evaluation matrices are available in Appendix 4-2).

Table 4.9: Matrix Values – Talkeetna Junction to Willow

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	28.7	2.5	3.0	2.5	3.0	2.8
ANGDA	27.3	3.5	2.5	3.0	2.5	2.9
Parks Highway	28.8	2.5	3.0	2.5	3.0	2.8
AEA Intertie	27.1	3.5	2.0	2.5	1.5	2.4
Alaska Railroad	28.4	3.0	2.5	2.5	1.0	2.3

The segment from Talkeetna Junction to Willow consists of relatively flat land containing many lakes and streams with the population density gradually increasing toward Willow. All five candidate alignments are viable for use within this segment.

The Parks Highway and Denali Pipeline routes are essentially the same from Talkeetna Junction to Willow. The Alaska Railroad and Parks Highway are in relative close proximity over this segment and cross once. The ANGDA route follows the Parks Highway corridor for the first seven miles and then takes a more easterly route along a north/south section line to Willow, thereby avoiding residences and other infrastructure along the highway. The AEA Intertie alignment is the most easterly of the options.

The selected alignment in this segment follows the ANGDA route, with the exception that the selected alignment moves to the north/south section immediately south of the Talkeetna Junction. There are no significant engineering obstacles in this segment.

Willow to ENSTAR Pipeline

Particulars extracted from the evaluation matrix are shown in Table 4.10 (complete evaluation matrices are available in Appendix 4-2).

The ENSTAR 20 inch pipeline traverses the north side of Cook Inlet and terminates near the intersection of the Glenn and Parks Highways. The Parks Highway, ANGDA, Denali Pipeline, AEA Intertie, and Alaska Railroad alignments generally follow each other through Wasilla. Alignment along the Parks Highway to the end terminus of the ENSTAR pipeline was rejected because shorter alternatives exist that pass through less infrastructure and fewer population centers.

Table 4.10: Matrix Values – Willow to ENSTAR Pipeline

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
Denali Pipeline	15.9	2.5	2.5	2.5	2.0	2.4
ANGDA	26.6	2.5	2.0	2.5	2.0	2.3
Alternative 1	29.9	4.5	3.0	3.0	4.5	3.8
Alternative 2	36	3.5	3.0	2.5	3.0	3.0
Alternative 3	24.6	3.5	3.0	2.5	2.5	2.9
Alternative 4	25.4	3.0	2.5	2.5	2.0	2.5

Four alternative alignments were developed to connect the spur pipeline to various locations along the ENSTAR pipeline from due south of Big Lake to the eastern terminus of this pipeline; all of which would be roughly the same length. These alternative alignments would have different impacts on private properties and subdivisions in the area. Alternative 3 and the AEA Intertie ROW intersect ENSTAR's pipeline at the same location. The AEA Intertie alignment was rejected because Alternative 3 follows the Parks Highway through Wasilla, which was considered a better alignment than the AEA Intertie.

Alternative 1 was selected because it traverses mostly state owned property west of Nancy Lake and Big Lake and would have the least impact on private property owners. Alternative 1 was also considered the most favorable alignment regarding remote location of a gas-processing plant at the pipeline terminus.

4.3.6 Delta Junction Spur Corridor: Evaluation

It is recommended that while reading this section, the corresponding segment map should be referenced (Appendix 4-1). These maps are best viewed in color at full size (11 inches by 17 inches).

Delta Junction to Paxson

Particulars extracted from the evaluation matrix are shown in Table 4.11 (complete evaluation matrices are available in Appendix 4-2).

Table 4.11: Matrix Values – Delta Junction to Paxson

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
TAPS	76.5	2.0	2.5	2.5	1.5	2.1
TAGS	77	4.0	2.5	2.5	2.5	2.9
Richardson Highway	79.9	3.0	2.5	2.5	2.5	2.6

The segment from Delta Junction to Paxson follows the Delta River and crosses the Alaska Range via Isabel Pass and Summit Lake. The Richardson Highway and TAPS are within close proximity for essentially this entire segment. The TAGS alignment deviates from the other two near Donnelly Dome and Summit Lake.

Issues regarding location of the spur pipeline on the TAPS ROW include:

- Access for construction equipment and materials;
- Added stipulations for construction of the spur pipeline in close proximity to TAPS;
- Aboveground portions of TAPS do not travel in a straight line, whereas the spur pipeline most likely would;
- Security regarding co-location of two significant energy projects;
- Interferences with the fiber optic cable that runs periodically within the TAPS work pad; and
- The TAPS alignment was routed through soils favorable for a warm pipeline, which may not be as favorable for burial of the chilled spur pipeline.

Pending resolution of co-location issues with TAPS, the TAGS alignment was selected for the spur pipeline project. The length of the TAPS and TAGS ROW are essentially the same for this segment of the route. The TAGS alignment has also been vetted by numerous regulatory agencies and an Environmental Impact Statement (EIS) was issued for this alignment.

Construction issues related to crossing the Donnelly Dome, McGinnis Glacier, and Denali faults do not significantly favor one alignment over another. The TAGS alignment crosses no anadromous streams before the Gulkana River at Paxson.

Paxson to Glennallen

Particulars extracted from the evaluation matrix are shown in Table 4.12 (complete evaluation matrices are available in Appendix 4-2).

Table 4.12: Matrix Values – Paxson to Glennallen

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
TAPS	65.4	2.0	2.5	2.5	1.5	2.1
TAGS	64.2	4.0	2.5	2.5	2.5	2.9
Richardson Highway	71.2	3.0	2.5	2.5	2.5	2.6

The TAGS alignment was selected from Paxson to just north of Glennallen for the same reasons as described in the previous section. A new alignment was selected beginning north of Glennallen traversing southwest to the Glenn Highway near Tolsona Lake. This new alignment was selected to avoid interference with the city of Glennallen and reduce the length of the spur pipeline as compared to a route through the city.

No significant engineering obstacles are anticipated for the segment from Paxson to Glennallen; however, soils within this portion of the Copper River basin can be encountered that are predominantly ice rich and would require winter construction and possibly specialized engineering design. Rigorous thermal-hydraulic design would be required for the alignment throughout the Copper River basin to address potential frost heave and/or thaw settlement depending upon whether the spur pipeline is operated in cold or warm mode.

Glennallen to Eureka

Particulars extracted from the evaluation matrix are shown in Table 4.13 (complete evaluation matrices are available in Appendix 4-2).

Table 4.13: Matrix Values – Glennallen to Eureka

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
ANGDA ROW	62.6	4.0	2.5	2.5	3.0	3.0
Glenn Highway	62.7	3.5	3.0	2.5	2.0	2.8

The Richardson Highway, TAPS, and TAGS alignments continue south out of Glennallen to Valdez and thus are not candidates for the spur pipeline to Cook Inlet. The ANGDA and Glenn Highway alternatives are indistinguishable from Tolsona Lake to Eureka and either could be chosen. The ANGDA alignment

was selected because it is passes through the most favorable terrain for pipeline construction and maintenance, and is located either within or just outside of the Glenn Highway ROW.

The Copper River basin extends through Eureka and special design segments may be required depending upon the nature of the soil along the alignment. Pipeline construction in this segment would occur during the winter months because of the large areas of permafrost throughout the area.

Eureka to Chickaloon

Particulars extracted from the evaluation matrix are shown in Table 4.14 (complete evaluation matrices are available in Appendix 4-2).

Table 4.14: Matrix Values – Eureka to Chickaloon

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
ANGDA ROW	49.2	2.5	2.0	2.0	2.5	2.3
Glenn Highway	46.6	3.0	3.0	2.5	2.5	2.8

The ANGDA and Glenn Highway alignments differ radically from Eureka to Chickaloon. Both routes contain significant construction challenges that would require detailed engineering evaluation in the future. Pipeline construction would be difficult along this segment regardless of the alignment chosen.

The ANGDA route leaves the Glenn Highway west of Eureka, follows the Squaw Creek drainage to the Caribou Creek drainage and then goes over Chitna Pass at an elevation of more than 5,000 ft msl. The ANGDA alignment then generally follows Boulder Creek down slope and joins the Chickaloon Trail continuing along the north side of the town of Chickaloon.

The Glenn Highway alignment enters the Matanuska River valley west of Eureka and follows this valley to Chickaloon and on to Sutton. The Glenn Highway alignment presents significant construction challenges, including the crossing of Caribou Creek where steep slopes will be encountered. The Glenn Highway route through the Matanuska River valley is characterized by cliffs immediately adjacent to the road, steep cross slopes, and pinch points constrained by the river and local topography.

Engineering challenges include the Castle Mountain and Caribou fault crossings. Construction along the Glenn Highway would be complicated by the high volume of vehicular traffic.

An alignment generally following the Glenn Highway with numerous excursions away from the highway to avoid obstacles was selected over the ANGDA ROW for this segment. Furthermore, following field visits to both routes by a team that included construction, engineering, and operational experts it was concluded that a route along the Glenn Highway alignment could cost as much as $20 million less than the ANGDA alignment. Field reconnaissance was completed for Chitna Pass and Caribou Creek to assess the challenges associated with construction through each area and is discussed in Section 4.3.7.

Chickaloon to ENSTAR Tie-in

Particulars extracted from the evaluation matrix are shown in Table 4.15 (complete evaluation matrices are available in Appendix 4-2).

Table 4.15: Matrix Values –Chickaloon to ENSTAR Tie-in

		Relative Ranking (0 to 5, 5 being more favorable)				Weighted Average
		Engineering	Permitting	Socio-economic	ROW	
		Weighting Percentage				
Alignment	Length (miles)	25	25	25	25	
ANGDA ROW	36.4	3.0	2.5	3.0	2.0	2.6
Glenn Highway	36.6	2.5	3.0	2.5	2.0	2.5

The alignment selected for the spur pipeline follows the Glenn Highway from Chickaloon to just north of the confluence of the Chickaloon and Matanuska Rivers where it leaves the highway and follows the ANGDA alignment into Palmer. The highway route was selected for the first portion of this segment as a consequence of following the highway into Chickaloon from the east.

The selected alignment follows a ridge and electrical power line along the north side of the Glenn Highway, thereby avoiding interference with the Matanuska River and potential erosion on the river side of the highway. The most significant engineering challenges in this segment are the crossing of Chickaloon River and Moose Creek and Pinnacle Mountain. This alignment passes through areas of Palmer with relatively high population densities and terminates at the 20 inch ENSTAR pipeline near the intersection of the Glenn and Parks Highways.

The ANGDA alignment was selected over the highway alignment from Sutton through Palmer because it avoids interference of construction with highway vehicular traffic and challenging pinch points involving residential areas, the highway, and the Matanuska River just northeast of Palmer.

4.3.7 Field Reconnaissance

A limited number of field site visits were conducted during this study to evaluate, compare, and collect additional data for the various proposed alignment options. Field visits focused primarily on areas where uncertainty of pipeline construction was a concern, and where existing data and mapping was insufficient to support routing recommendations. The other focus of the field visits was to provide terrain knowledge for the pipeline cost estimates. During all field visits persons with extensive knowledge of pipeline construction in Alaska were present and this information incorporated into the estimates. The full field reconnaissance reports are presented in Appendix 4-3.

In one case, a comparative cost estimate between two alignments (Glitter Gulch versus Moody Creek) was developed following the field trip (see Denali Park/Healy - June 20, 2006 below) in order to help determine the more economical route. Results of that comparison are summarized and discussed in more detail in Appendix 4-5.

In another case, (Chitna Pass/Caribou Creek – June 27, 2006) a constructible alignment was found where it was previously thought not to be feasible. This alignment was delineated during a helicopter flight, and had not been apparent during field visits from the ground. The result of this field work was the alignment along the road was favored over the more remote and rugged alignment that crosses Chitna Pass.

The text below presents a summary of the 2006 field reconnaissance.

Fairbanks Area (Fairbanks Spur) – March 30, 2006

Figure 4.10: Old Murphy Dome Road

Pipeline alignment options developed for the Fairbanks Spur route were evaluated during the site visit. Figure 4.10 shows the Old Murphy Dome Road. Field verification determined that Alternate 1 alignment that skirted the most northern and western limits of the Fairbanks area provided the best alignment and proved the least intrusive to residential neighborhoods. The alignment follows terrain preferential for construction.

The selected alignment uses the Old Murphy Dome Road north of Fairbanks, following a ridgeline to the west. At the end of the Old Murphy Dome Road, the alignment descends south and west, crosses the Goldstream River and Alaska Railroad, and ascends into the remote hills west of Ester. The alignment would emerge at the Old Parks Highway, which provides a clear path for the alignment to reach the Parks Highway and continue south toward Nenana.

Inspection of the other alignments indicates either more interference with local population and/or longer segments of the alignment that crossed areas with potentially difficult soils (e.g., permafrost, frost heaving, and swamps).

Healy to Cantwell (Fairbanks Spur) – April 7, 2006

This purpose of this field visit was to find a feasible alignment for a spur pipeline to be constructed through Nenana Canyon and develop, if possible, an alignment that remains east of the Nenana River, and therefore remains outside of Denali National Park and Preserve. A technically feasible alignment through the canyon is possible, but would require the pipeline to traverse the edges of lands designated for the Denali National Park and Preserve and cross the Nenana River within (or near) the canyon more than once.

Construction within Nenana Canyon would be very difficult; however, the length of difficult construction is less than five miles, whereas the length of equally challenging construction along the Moody Creek alignment may be as much as 16 miles.

Another factor that weighed significantly in the comparison of these two alignments is access to the alignment during construction, operations, and maintenance. The impacts to productivity of construction along Moody Creek would be significantly affected by the time required to access the work site, while productivity along the canyon route would not be impacted because of the proximity to the existing road and railroad. The result of the cost estimate comparison for this segment is summarized in Appendix 4-5.

Eureka to Kings River (Delta Junction Spur) – April 14, 2006

Figure 4.11: Near Eureka Summit

The site visit was conducted to establish a reasonable alignment for a spur pipeline along the Glenn Highway between Eureka and Kings River. Figure 4.11 shows the Glenn Highway near Eureka summit. The alternate alignment to the road is north, and away from the road, as the alignment negotiates the Caribou, Boulder, and Squaw Creek drainages to cross Chitna Pass. The focus of the site visit was to find the best alignment along the road through this segment.

Denali Park/Healy (Fairbanks Spur) – June 20, 2006

The site visit was conducted to primarily preview the Moody Creek alignment alternative between Healy and the south side of Denali National Park and Preserve. A helicopter was used to travel over this remote alignment. The route over Moody Creek is very rugged and in some cases very difficult to imagine construction of a pipeline (Figure 4.12).

Figure 4.12: Moody Creek Drainage (looking southeast near Healy)

The Nenana Canyon alignment was also evaluated (the alternate to the Moody Creek alignment). The Nenana Canyon alignment passes through a canyon along with the Parks Highway and Alaska Railroad, and is bordered on one side of the Nenana River by Denali National Park and Preserve. Findings from the site visit verify the assumptions from a previous visit (April 7, 2006 visit documented above) that a route through the canyon was feasible, but would likely be required to cross national park land in two areas where topography makes continuation of the pipeline east of the railroad very difficult (Figure 4.13).

Figure 4.13: Fairbanks Spur Route Must Cross National Park Land in Nenana Canyon

During the site visit areas of interest along the route between the ENSTAR tie-in and Healy were evaluated. The section of the route just north of the tie-in at ENSTAR MP 39 tie-in and Willow (Figure 4.14) is remote and is mostly flat terrain and fairly heavily wooded with some swampy areas. Construction in this area would likely occur during winter months to minimize impacts to the wetland areas encountered. Refer to the trip report in Appendix 4-3 to see a more complete summary of the field visit.

Figure 4.14: Terrain between Willow and ENSTAR Tie-in Location

Chitna Pass/Caribou Creek (Delta Junction Spur) – June 27, 2006

The Chitna Pass alternate, portion of the route proposed by ANGDA for a spur gas pipeline between Glennallen and Palmer (Michael Baker 2005b) was visited by the study team in late June 2006. This visit was used to determine the feasibility of the Chitna Pass route versus an alignment along the Glenn Highway. The visit also included a preview of the adjacent Glenn Highway road route (the alternate to the remote Chitna Pass route). A helicopter was used to access both route alternatives.

South of Eureka Roadhouse, the proposed ANGDA alignment travels away from the highway via the Squaw Creek and Caribou Creek drainages (Figure 4.15) before ascending Chitna Pass (Figure 4.16). On the south side of Chitna Pass, the alignment drops into the Boulder Creek drainage and heads southwest toward Chickaloon. During the route visit, a feasible route along the Glenn Highway road route was determined. While a route over the Chitna Pass corridor was also confirmed, it was also considered to be a very difficult route and the road route was selected as preferred. Refer to the trip report in Appendix 4-3 for a more complete summary of the field visit.

Figure 4.15: Caribou Creek

Figure 4.16: Chitna Pass

4.4 Conceptual Design Alignment Sheets

For the considered spur pipeline routes, a series of alignment sheets were generated and are provided in Appendix 4-4. These sheets provide details of the terrain by presenting the profile generated by draping the proposed alignments over digital elevation modeling (DEM) data that is publicly available via the Internet. In plan view, a combination of aerial photography and satellite imagery was combined to create background images along the alignments.

For each alignment, information is provided in the data bands along the top and bottom of the plan and in profile windows to summarize land-ownership data, compressor station locations, material lay-down areas, camp locations, and other available information.

Section 5. Right-of-Way Considerations

5.1 Introduction

Both major pipeline routes traverse state, federal, Native and privately owned lands. Title investigation and analysis were conducted to support future ROW and permitting objectives along either major route. This analysis does not recommend a particular route. Instead, it has been determined that either route is potentially usable, and that the routes are comparably similar. This section identifies ROW issues and presents alignment data. Permitting and environmental issues are mentioned because of their integral relationship to the ROW function. Certain route variations were eliminated because of engineering, design, and environmental considerations.

Information gathered for this analysis was integrated into a computerized land data base. The information was used to identify land ownerships which could affect the complexity of easement acquisition, or permitting challenges. Additionally, existing ROW were identified which are available to be utilized for a pipeline project. As specific information is needed for land descriptions or land owner contacts, the data collected would continue to be of service.

This section presents results of ROW land analysis of the Fairbanks Spur and Delta Junction Spur routes. A total of 63 alignments were developed within the two major routes. Along the Fairbanks Spur route, 42 alignments were identified within the FNSB; seven alignments between the FNSB and Willow, Alaska; and four alignments between Willow and the final destination at ENSTAR's 20 inch pipeline MP 39 facility. From Delta Junction to the Palmer area, (Delta Junction Spur Route), three alignments were developed between Delta Junction and Glennallen; seven alignments between Glennallen and Palmer to the final destination at ENSTAR's 20 inch pipeline located adjacent to the Glenn Highway and Parks Highway interchange. Portions of ANGDA data are incorporated into this analysis for the Glenn Highway selected alignment.

The ROW title investigation and analysis supports ROW acquisition, permitting and design activities for either of the two selected alignments, including a portion of the Fairbanks Spur alignment that is situated within the Denali National Park and Preserve (formerly McKinley National Park). Additional consideration of federal law and regulations as well as a potential congressional mandate is needed for a minor segment of the selected alignment that is situated in a developed area of the national park.

5.2 Report Methodology

This section presents a summary of the land title research as supported by specific documentation. The documentation includes land conveyance documents such as deeds and patents, surveys, subdivision plats, governmental master title plats, United States Surveys, and government agency information. Additional data was obtained from electronic and paper document resources from the MSB, FNSB, City of Fairbanks, State Recorder's Offices in Fairbanks, Palmer and Chitna/Valdez, ADNR Division of Mining, Land & Water, Alaska Department of Transportation and Public Facilities (ADOT&PF), U. S. Department of the Interior, Bureau of Land Management (BLM), Alaska Railroad Corporation (ARRC), ANGDA, and Ahtna Native Corporation, Inc. (Ahtna), and from ENSTAR ROW records, and other private sources.

Land ownership was identified for both selected pipeline alignments within private, state, federal or Native-owned lands. Land information is presented for the two major alignments; 322 miles along the proposed Fairbanks Spur route and 281 miles along the Delta Junction Spur route.

Nearly all of the selected alignment along both the Fairbanks Spur and Delta Junction Spur is situated within the limits of existing highway ROW, section-line easement, and some power-line ROW. However, limited segments of ROW would need to be acquired. These acquired ROW are proposed to ameliorate topographic, wetland, or constructability challenges. A temporary ROW width of between 60 and 100 ft would provide a wide enough area to allow the construction and installation of the spur pipeline. Temporary ROW up to 0.5 miles wide may be required at some locations where special construction issues are presented by topography, wetlands, or other factors. After construction, a reduced permanent ROW sufficiently wide to allow monitoring and maintenance of the spur pipeline and related facilities would be required. A typical permanent ROW width for similar pipelines ranges between 20 ft and 50 ft.

Existing unrelated facilities within established ROW could affect temporary and permanent ROW widths. Existing facilities include highway, drainage, electric utility, telecommunication, and certain privately owned improvements. Some improvements may encroach into the selected ROW, and would need to be removed or circumvented in accordance with jurisdictional agency rules and regulations.

Development of relocation plans for homes and businesses encroaching upon the selected alignment were not a requirement for this report. Identification of these types of issues and their resolution would be a part of a specific study once a pipeline centerline survey was completed, and after authority was granted to proceed with extended ROW activities. Because neither of these has occurred, this analysis presumes that existing ROW are free of encroachments by homes and businesses, and no further analysis is provided. Note however, that one of the criteria for the selected alignment was to identify a route in less-developed areas in order to minimize such encroachments. For any incidental encroachment conflicts, the appropriate authorities would be contacted for encroachment removal determinations within existing ROW. For other pipeline alignment conflicts, compensation would be proposed to compensate for damages resulting from the selected spur pipeline ROW.

ROW acquisition would be accomplished in two ways. First, lands owned or managed by the various governmental agencies and public land trusts are regulated and managed under specific processes. Each entity has a particular policy for land disposition. The process for acquisition may include easement acquisition applications, application for permits, surveys, mapping, and in some cases, attending public hearings.

The second general method relates to privately owned lands. These include properties within private - sector ownership and some quasi-private lands that may be under the control of Alaska Native corporations; for example, Native allotments, and trust lands. Individual discussions with these landowners would be necessary to determine specific spur pipeline alignments and to complete procedural requirements and contractual agreements.

Approximately 75 percent of the land adjacent to the selected spur pipeline alignment is publicly owned and designated for highway ROW, parks, forests, or public recreation. Some lands are under the jurisdiction of the military and coordination would be needed to assure that no impacts would occur in these areas. Typically, land title records frequently change because of sale or agency-conveyance actions, and portions of the proposed alignment would need updating in the future.

The following land parcelization table (Table 5.1) includes the portion of the selected alignment that crosses within Denali National Park and Preserve. To permit crossing of a portion of the national park land, it is likely permit application and resulting agency review and stipulations would address typical engineering and constructability. However, it is anticipated that Congressional and legal allowances would also be required because of legal distinction of Denali National Park and Preserve. In 2002, Congress passed Public Law 107-223 which authorized the Secretary of the Interior to issue ROW permits for natural gas pipelines within the boundaries of the Great Smoky Mountains National Park.

Similar legislation would need to be passed to authorize the Secretary of the Interior to grant a ROW permit for the construction and operation of a natural gas pipeline through or across Denali National Park and Preserve lands. Table 5-1 presents the land ownership parcelization for the Fairbanks and Delta Junction Spur routes and the total project land parcelization.

FAIRBANKS SPUR								
Land Owner	Federal	State DOT&PF/ DNR	Borough	State ARRC	State University	Native Corp./ Allotment	Private	Spur Total
Total Land Parcels	**16**	**452**	**121**	**9**	**5**	**61**	**495**	**1159**
PLO ROW	**8**	**148**	**81**	**4**	**5**	**24**	**169**	**439**
RS 2477	**0**	**23**	**12**	**0**	**0**	**6**	**16**	**57**
ROW Application	**8**	**281**	**28**	**5**	**0**	**0**	**0**	**322**
Other ROW Types	**0**	**0**	**0**	**0**	**0**	**31**	**310**	**341**

DELTA JUNCTION SPUR								
Land Owner	Federal	State DOT&PF/ DNR	Borough	State ARRC	State University	Native Corp./ Allotment	Private	Spur Total
Total Land Parcels	**70**	**285**	**16**	**0**	**0**	**82**	**562**	**1015**
PLO ROW	**0**	**206**	**8**	**0**	**0**	**7**	**349**	**570**
RS 2477	**0**	**2**	**0**	**0**	**0**	**0**	**54**	**56**
ROW Application	**70**	**77**	**8**	**0**	**0**	**0**	**0**	**155**
Other ROW Types	**0**	**0**	**0**	**0**	**0**	**75**	**159**	**234**

Table 5.1: Land Ownership Parcelization for Fairbanks and Delta Junction Spur Routes

5.3 Right-of-Way Types

5.3.1 Parks/Richardson/Glenn Highway Easement for Highway Purposes

Where the proposed spur pipeline alignment is within a highway ROW, ADOT&PF is the permitting agency. The spur pipeline would be constructed within the ADOT&PF Northern District (Fairbanks) and Southcentral District (Anchorage).

Federal Public Land Order (PLO) 1613, Section 3, of April 7, 1958, states that "an easement for highway purposes, including appurtenant protective, scenic, and service areas over and across the lands described in paragraph 1 of this order, extend 150 ft on each side of the centerline of the highways mentioned therein is hereby established." Paragraph 1 of PLO 1613 describes, in part, public lands in Alaska lying within 300 ft of each side of the centerline of the Alaska Highway and within 150 ft of each side of the centerline of the Parks, Richardson, and Glenn Highways. Consequently, those areas have been established as easements for highway purposes.

The 1959 Alaska Omnibus Act (73 USC 141), transferred ownership of all Alaska highways from the federal government to the State of Alaska. In doing so the easement for highway purposes created by PLO 1613 remains intact.

ADOT&PF allows utilities within its ROW under permits issued pursuant to 17 Alaska Administrative Code (AAC) 015.011 as authorized by Alaska Statute (AS) 19.25.010.

5.3.2 AS 19.25.010 and 17 AAC 15.011

AS 19.25.010 provides that a utility may be constructed, placed, or maintained across, along, over, under, or within a state ROW only in accordance with regulations permits issued by ADOT&PF. Section 17 AAC 015.011 states that upon written application, ADOT&PF will, in its discretion, issue a permit authorizing the applicant to construct or install utility facilities within a Department ROW.

5.3.3 ARRC Act, AS 042.40.010 through AS 042.40.990

The Alaska Railroad ROW are railroad utility corridors. The Act authorizes the ARRC (subject to certain restrictions) to lease, grant easements in or permits for, or otherwise authorize use of portions of a utility corridor for transportation, communications, and transmission purposes and support functions associated with those purposes, and for commercial and other uses authorized under this chapter if the use does not restrict the other parallel uses of the utility corridor.

5.3.4 Alaska Railroad Transfer Act

The Alaska Railroad was established under the authority of the Act of March 12, 1914 (43 USC 975 et seq.), "Alaska Railroad Act", as a rail carrier in Alaska to serve the transportation and development needs of the Territory of Alaska.

On January 14, 1983, the Secretary of the Interior transferred to the State, under the authority of Public Law, 45 USC 21, 1202 (10) all right, title, and interest of the United States to lands, buildings, facilities, machinery, equipment, supplies, records to the State, including that portion within the Denali National Park and Preserve. Particularly, the Alaska Railroad ROW was transferred as an exclusive-use easement. Exclusive use is described as the right to use, possess, and enjoy the surface estate of the land for transportation, communication, and transmission purposes or the support of such purposes. This includes the right to use so much of the subsurface of the lands subject to the ROW as is necessary for the transportation, communication, and transmission purposes and the support of such purposes. The Alaska Railroad ROW is 200 ft or 100 ft wide from its centerline.

The disposition of that part of the railroad ROW and related properties within the Denali National Park and Preserve are addressed at Section 1211 of the Alaska Railroad Transfer Act. Pursuant to the transfer, those properties owned by the federal railroad that included the hotel property, and other lands within the park boundaries were reserved for the national park. The exclusive-use ROW was conveyed to the State for all that portion within the Denali National Park and Preserve according to Section 1203 (b)(1)(D). The Alaska Railroad under these authorizations allows and provides permitting functions for the use of the ROW for electrical transmission. Currently, Golden Valley Electric Association (GVEA) maintains a

transmission line within the railroad ROW. The allowance could potentially be extended for gas transmission purposes as well. For engineering and permitting purposes extended to third parties, the Alaska Railroad and the national park have entered into an Inter Agency Land Management Agreement.

5.3.5 Regulatory Statute (RS) 2477 Section Line Easement

In the case of Fisher vs. Golden Valley Electric Association, Inc., 658 P2d 127 (Alaska 1983), the Alaska Supreme Court found that a utility may construct a power line on an unused section easement reserved for highway purposes under AS 19.10.010. There are no Alaska cases which address the question whether installation of a gas pipeline within a RS2477 easement requires obtaining additional rights from the owner of the land on which the easement is situated. However, such a question placed before the state Supreme Court would likely extend the Fisher decision to installation of a pipeline within a RS2477 easement. The effective date of RS2477 is April 6, 1923 when the Territorial Legislature accepted the privilege from the federal government.

5.3.6 AS 19.10.010

Pursuant to AS 19.10.010, "A tract 100 ft wide between each section of land owned by the state, or acquired from the state, and a tract four rods wide between all other sections in the state, is dedicated for use as public highways. The section line is the center of the dedicated ROW. This statute can be simplified by stating that if the state has ever owned the land upon which a RS2477 easement can be verified, then the width of the easement is adjusted to a width of 50 ft from centerline of the easement. If the highway is vacated, title to the strip inures to the owner of the tract of which it formed a part of by the original survey."

5.3.7 Federal Issues

The authority for obtaining ROW for gas lines on federal lands is found in the Mineral Leasing Act of 1920 (30 USC 185). The federal administration of ROW has been established by the Federal Land Policy and Management Act of 1976 (Public Law 94-579) and the CFR promulgated there under (43 CFR 2800).

Acquisition by an applicant of a ROW on federal lands administered by the BLM entails the following steps: 1) pre-application meetings with BLM; 2) completion of the application forms; 3) payment of costs involved in the ROW grant, including the processing fees to reimburse the United States for the cost of monitoring compliance with the terms and conditions of a ROW grant, including the requirements for protection and rehabilitation of the lands involved, and the annual rental, which is a fee payable before the grant is issued and based on the fair market value rental of the authorized rights.

The Alaska Native Claims Settlement Act (ANCSA) (Public Law 92-203 of December 18, 1971) provides for acquisition of federal lands by the appropriate Regional corporations and the appropriate Village corporations. Until the interests in land are conveyed from the federal government to the appropriate Native corporation, the BLM or the Bureau of Indian Affairs (BIA) has jurisdiction over these lands and, with the consent of the appropriate Native corporation, issues ROW permits and other easement authorizations.

In the case of the spur pipeline project, the Regional and associated Village corporations are as follows: Ahtna Regional and Tazlina and Sta-Keh Village Corporations; Doyon Regional and Toghottele Village Corporations; and Cook Inlet Regional Corporation (CIRI); and Chickaloon Native Association Village Corporation.

5.3.8 Alaska Native Allotments

Under provisions of the Alaska Native Allotment Act and 25 CFR 169, any rights of way obtained over lands claimed by Alaska Native allotees mandates federal action. In those cases where the Alaska Native

Allotment is not certified, the ROW process is administered by the BLM and/or BIA. In those cases where the Alaska Native Allotment is certified, the ROW process is administered by the BIA. This split in authority is documented by an agreement between the State Director of the BLM and the Alaska Area Director of the BIA.

5.3.9 Alaska ROW Leasing Act

ADNR would issue a ROW grant under and according to the provision of the Alaska Right of Way Leasing Act, AS 38.35, for all State of Alaska owned lands affected by this project. The State Pipeline Coordinator, through the Joint Pipeline Office (JPO) processes the application and ROW lease.

5.3.10 University of Alaska Lands and State Mental Health Trust Authority Lands

The State Pipeline Coordinator manages pipeline ROW leasing for lands owned by the University of Alaska or State Mental Health Trust Authority. However, both agencies have independent boards and land management authority and should be included in the state ROW application stage.

5.3.11 Municipal/Borough Permits

According to AS 29.40.40 – 29.40.200, municipal governments have planning, platting and land use authority. The affected jurisdictions include the City of Fairbanks, City of Palmer, City of Wasilla, MSB, Denali Borough, and the FNSB. Acquisition of easements on respective lands is determined by their local land planning departments, and municipal assemblies.

5.3.12 Private Land Interests

The acquisition of ROW from private interest owners (including ANCSA-related properties after interim conveyance or patent from the federal government) would be accomplished by negotiated purchase. To facilitate the transaction, a title report, field survey, and appraisal would first be obtained. In the event the purchase of a required easement cannot be negotiated for a reasonable price under reasonable terms, Alaska State laws of eminent domain may be utilized to compel the transfer.

5.4 Fairbanks Spur Alignment and Lands Description

5.4.1 Old Murphy Dome Road, Pipeline MP 0.00 to MP 18.3

The presumed connection of the spur pipeline to the producer's line is north of Fox at TAPS. The location of the ANS gas line has not been determined. This alignment begins at TAPS crossing on Old Murphy Dome Road, continues on Old Murphy Dome Road near its intersection with Spinach Creek Road, then continues southwest within several private properties to a crossing of the ARRC ROW.

The Old Murphy Dome Road ROW is 100 ft wide. The subject ROW was established by virtue of the Alaska Statehood Act, and was confirmed in the Omnibus Act of 1959. Portions of the 100 ft wide ROW are confirmed by plat dedications. Subsequent authorization is confirmed in the ADNR, Alaska Division of Lands (ADL) 407124 case file. Private easement interest and permits would need to be acquired across privately owned lands, borough, state university and Native lands. Figure 5.1 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

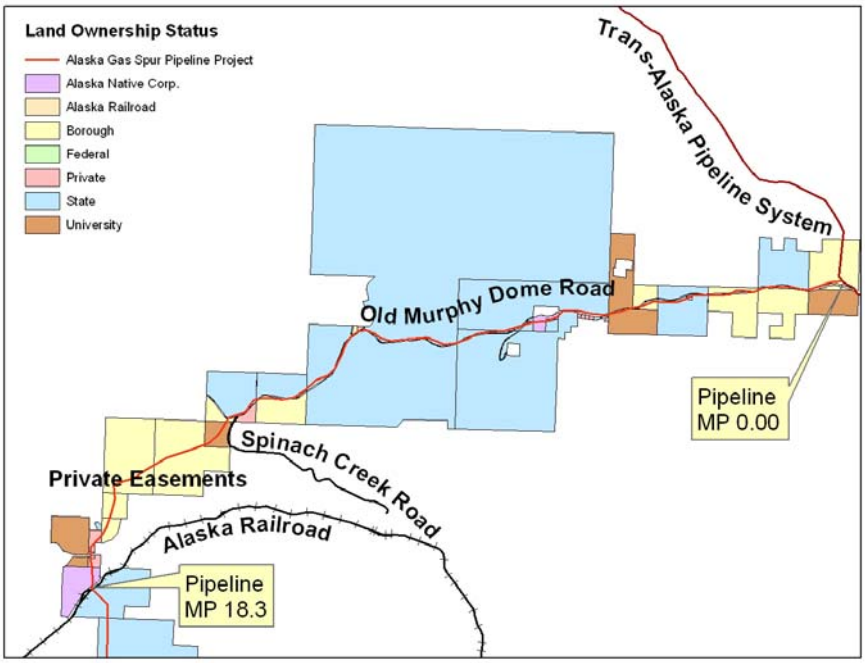


Figure 5.1: Old Murphy Dome Road, Pipeline MP 0.00 to MP 18.3

5.4.2 RS2477 Fairbanks Area, Pipeline MP 18.3 to MP 23.7

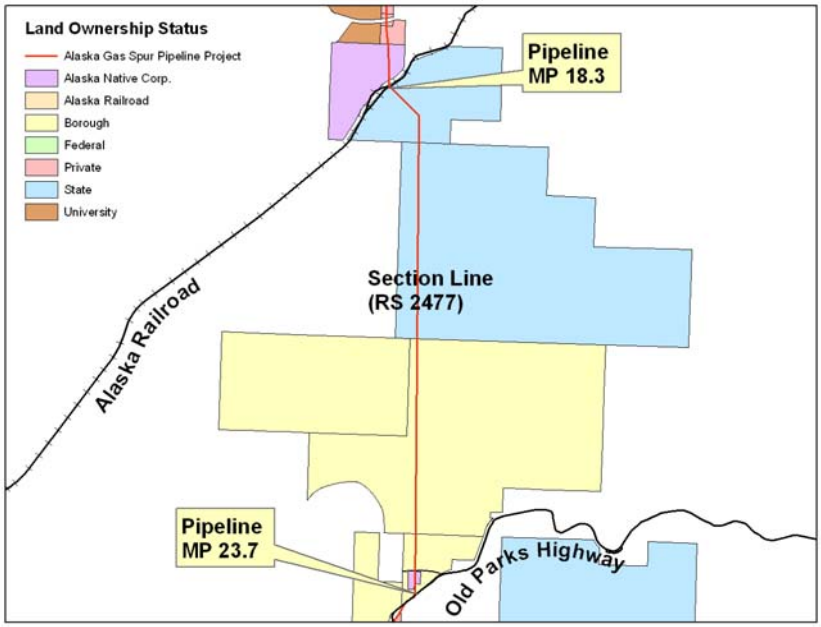


Figure 5.2: RS2477 Fairbanks Area, Pipeline MP 18.3 to MP 23.7

<u>ARRC ROW to the Old Parks Highway ROW</u>: This alignment crosses the 200 ft wide ARRC ROW, continues south along RS2477 easements to the 300 ft wide Old Parks Highway (formerly the Old Nenana Highway).

Easement interests and permits would be acquired across ARRC, borough, state, and Native lands. Figure 5.2 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.4.3 Parks Highway Fairbanks Area, Pipeline MP 23.7 to MP 41.8

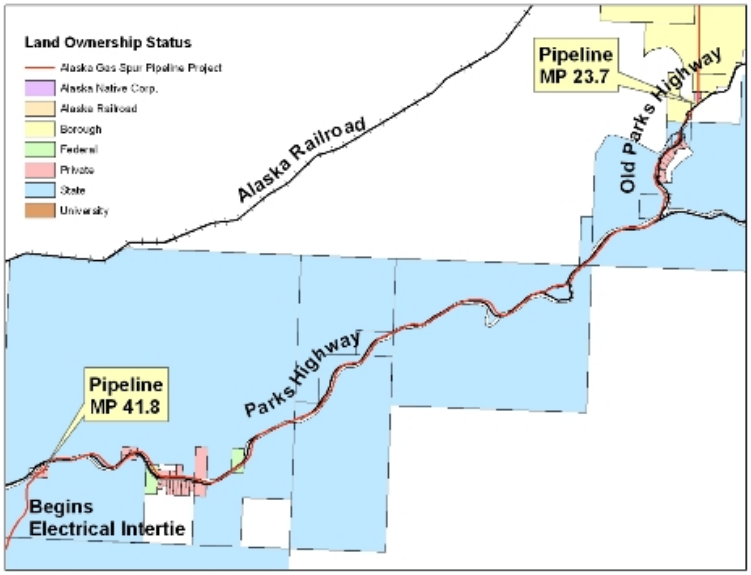


Figure 5.3: Parks Highway Fairbanks Area, Pipeline MP 23.7 to MP 41.8

Old Parks Highway onto the New Parks Highway, and exit to Electrical Intertie: Beginning at the 300ft wide Old Parks Highway (formerly the Old Nenana Highway), continuing south within the Old Parks Highway ROW to its intersection with the 300 ft wide New Parks Highway ROW.

Highway ROW are established by virtue of the Alaska Statehood Act and PLO, and confirmed in the Omnibus Act of 1959. Portions of the highway ROW are confirmed by plat dedications, and have also been increased by acquisition of additional lands by the ADOT&PF. If necessary, easement interests, and permits would be acquired across state, borough, Native and private lands. Federal lands are not affected. Figure 5.3 illustrates the selected alignment and Appendix 5-1 identifies those lands lying adjacent to the selected alignment.

5.4.4 Electrical Intertie, Pipeline MP 41.8 to MP 53.4

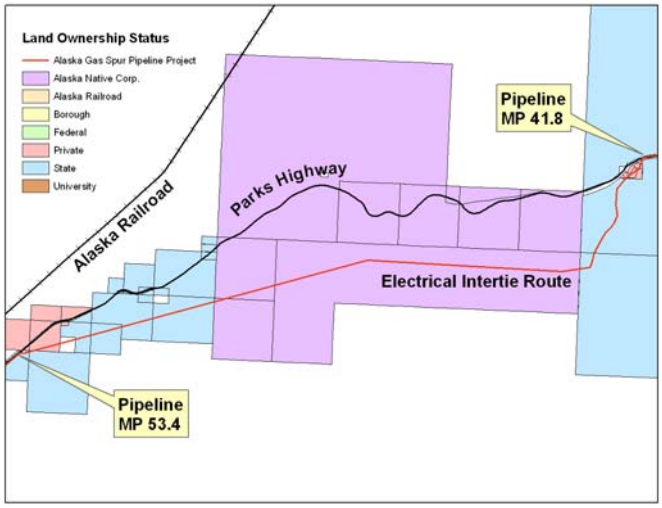


Figure 5.4: Electrical Intertie, Pipeline MP 41.8 to MP 53.4

From the New Parks Highway, exit to electrical Intertie, then re-enter Parks Highway: Easement interests and permits would be acquired across state, borough, Native and private lands. Figure 5.4 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.4.5 Parallel ARRC/Parks Highway, Pipeline MP 53.4 to MP 85.3

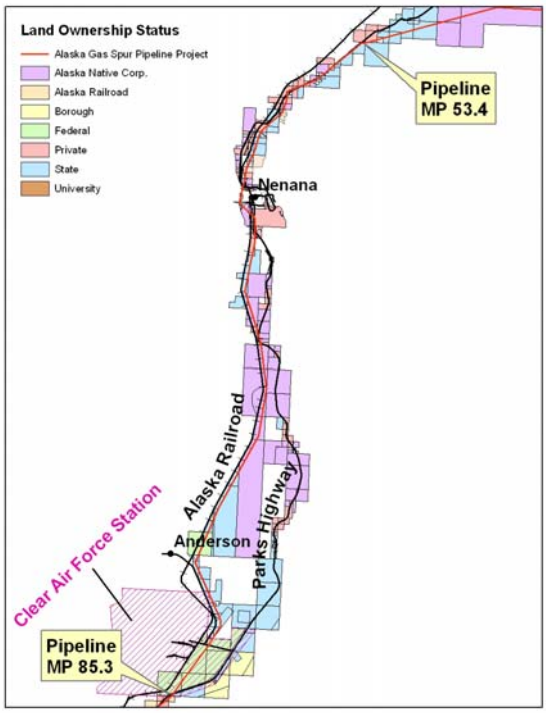


Figure 5.5: Parallels ARRC/Parks Highway, Pipeline MP 53.4 to MP 85.3

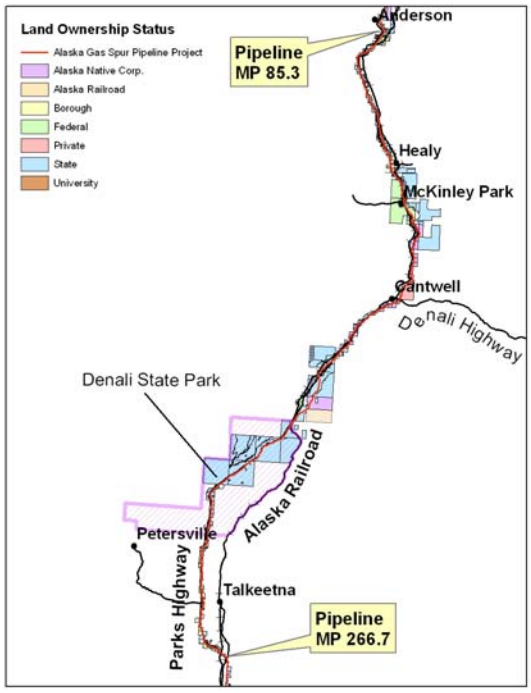


Figure 5.6: Parallels ARRC/Parks Highway, Pipeline MP 85.3 to MP 266.7

The alignment exits the northerly intertie onto the Parks Highway ROW and continues within the highway ROW for approximately four miles, then exits and parallels the highway ROW on lands that would be developed for a spur pipeline ROW. From the Nenana River crossing, the alignment parallels the ARRC outside its ROW, and then enters the Parks Highway ROW near the south boundary of Clear Air Force Station (AFS).

This alignment traverses Native, state, and federal lands. Private easement interest and permits would need to be acquired across these lands. A portion of this alignment traverses Clear AFS, requiring permits from the U.S. Air Force and its land management advocate, the BLM. Figure 5.5 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the alignment.

5.4.6 Parallel ARRC/Parks Highway, Pipeline MP 85.3 to MP 266.7

Beginning at the south boundary of the Clear AFS, the alignment continues within the highway ROW to the second Nenana River crossing near Anderson. The Nenana River crossing is situated on private lands. After the river crossing, the alignment continues primarily within the highway ROW, moderately entering private lands then re-enters the highway ROW. The alignment continues within the highway ROW through Denali National Park and Preserve, excluding a portion that is described in the next alignment description section. After the Denali National Park and Preserve, the alignment is situated primarily within the Parks Highway ROW, moderately entering private lands at two locations, then remaining within the highway ROW to the Talkeetna railroad spur. The alignment also crosses Denali State Park lands within the highway ROW.

This alignment traverses Native, state, and federal lands. Private easement interest and permits will need to be acquired across these lands. Figure 5.6 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.4.7 Parks Highway Focusing on Denali National Park and Preserve

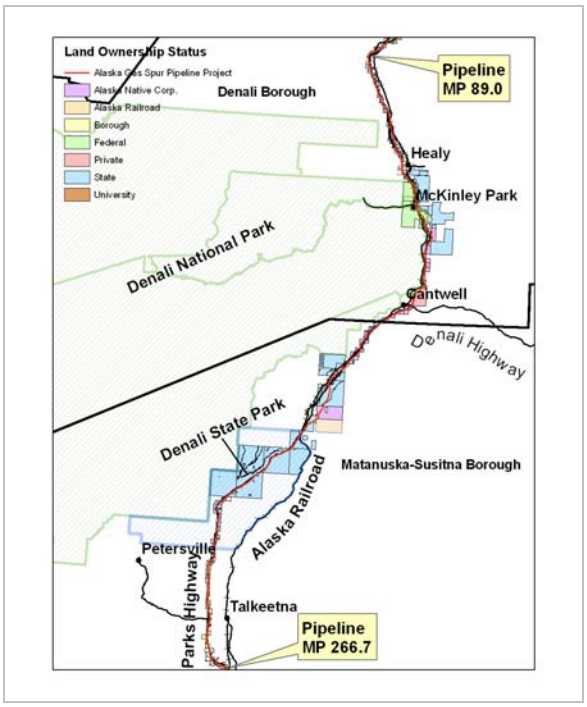


Figure 5.7: Parks Highway Focusing on Denali National Park and Preserve

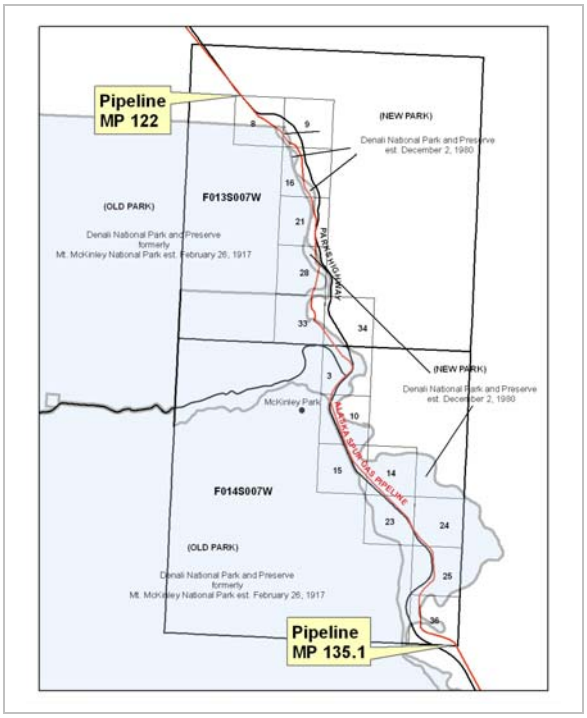


Figure 5.8: Denali National Park Alignment

<u>Beginning at the north edge of Denali National Park and Preserve, within the Parks Highway ROW, south to the Denali Highway intersection:</u> The ROW is established by PLO, is known as an "Omnibus" ROW. This portion of the Parks Highway ROW is identified by Federal Aid Primary (FAP) Number F-037-2(2); FAP Route No. 52. ADOT&PF and its predecessors have augmented portions of the ROW by acquisition of additional lands. Plat dedications also increased the ROW.

FAP Number F-037-2(2); FAP Route No. 52, approved February 26, 1957; amended that portion through Denali National Park and Preserve; Paxson via Cantwell through to the north park boundary:

Mt. McKinley National Park was established by a United States Act of Congress, February 26, 1917, (16 USC 347). Mt. McKinley National Park eastern boundary was extended on January 30, 1922 to the 149th meridian. A supplemental addition extended the park boundary to the west bank of the Nenana River on March 19, 1932.

The Parks Highway ROW was established by PLO 601. The State of Alaska was admitted by Alaska Statehood Act, January 3, 1959. The Secretary of the United States Department of Commerce conveyed all rights, title, and interest in all real properties that it owns, including the Denali Highway, some portions now known as the Parks Highway through the Omnibus Act of 1959.

Mt. McKinley National Park was incorporated into Denali National Park and Preserve by virtue of the Alaska National Interest Lands Conservation Act (ANILCA), Public Law 96-487, December 2, 1980. Public Law 96-487 extended the Denali National Park and Preserve boundary to include lands east and west of the existing Parks Highway ROW boundary. According to ANILCA Public Law 96-487, December 2, 1980, Section 602, said land conveyance is subject to **"valid existing rights"** including those of the Parks Highway ROW. The spur pipeline alignment through Denali National Park and Preserve and Denali and State Park is illustrated in Figures 5.7 and 5.8. For a discussion on the ROW through Denali National Park and Preserve, see Section 5.3.4.

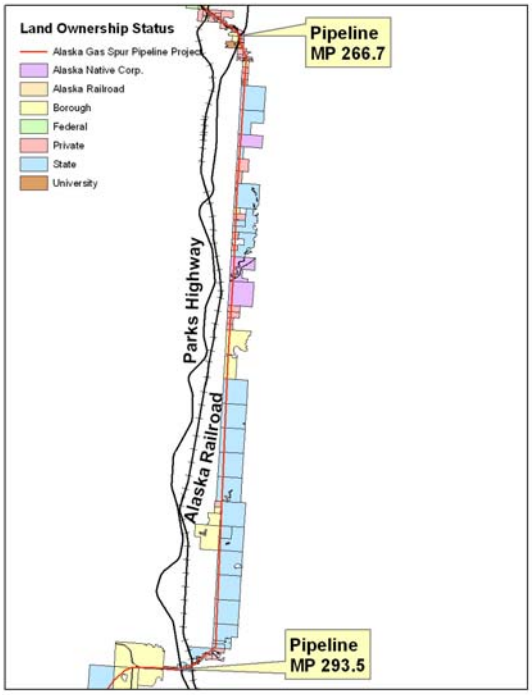


Figure 5.9: RS2477 Talkeetna Spur, Pipeline MP 266.7 to MP 293.5

5.4.8 RS2477 Talkeetna Spur, Pipeline MP 266.7 to MP 293.5

From the Talkeetna railroad spur, the alignment exits the Parks Highway ROW onto private lands, then parallel to the electrical intertie along RS2477 section line easements near Willow: Approaching Willow, the alignment exits RS2477 ROW onto private lands and continues to a crossing of the Parks Highway ROW.

Easement interests and permits would be acquired across state, borough, Native and private lands. Figure 5.9 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

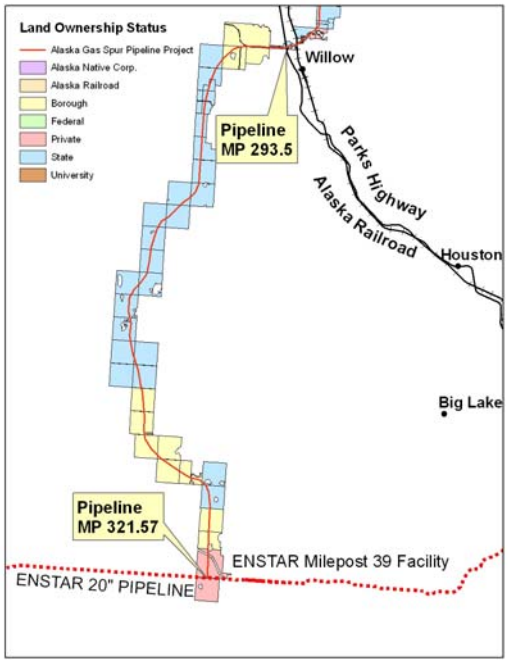


Figure 5.10: Willow to ENSTAR 20" Pipe, Pipeline MP 293.5 to MP 321.57

5.4.9 Willow to ENSTAR 20 Inch Pipe, Pipeline MP 293.5 to MP 321.57

From the crossing of the Parks Highway ROW near Willow, the alignment continues along West Willow Creek Parkway to its intersection with North Crystal Lake Road, where the alignment then traverses borough, state, and private lands to its destination at ENSTAR's MP 39 facility located on Ayshire Road in the Point McKenzie area of the MSB. Figure 5.10 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.5 Delta Junction Spur Alignment and Lands Description

5.5.1 Delta Junction to Glennallen, Pipeline MP 0 to MP 133

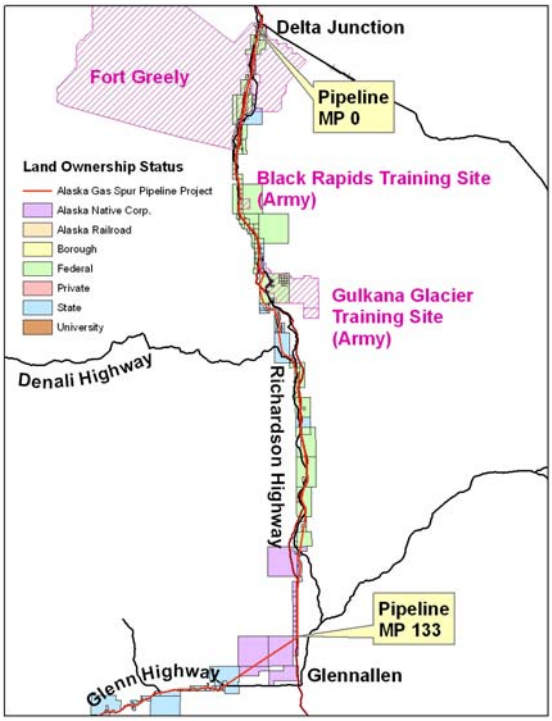


Figure 5.11: Delta Junction to Glennallen, Pipeline MP 0 to MP 133

From Delta Junction to Glennallen within the TAGS ROW, the location of the ANS main line has not been determined. Thus, the connection location to the producer's spur pipeline is unknown. The selected alignment is situated within the TAGS ROW and parallels the Richardson Highway and TAPS. Currently the alignment remains undeveloped.

The selected alignment would be situated on private easements to be acquired across state, federal, Native, and private lands. This portion of the alignment also traverses Fort Greely Military Reserve previously scheduled for closure. However, development of the 2004 Ballistic Missile Defense System placed Fort Greely prominently in the national defense strategy and is unlikely to be re-aligned. Additional military reserves include the Black Rapids Training Site and Gulkana Glacier Training Site. The selected alignment bypasses the City of Glennallen nine miles to the north crossing Ahtna lands. It is anticipated that the spur pipeline would be in close enough proximity to Glennallen to make a distribution line to that community economically feasible. Figure 5.11 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

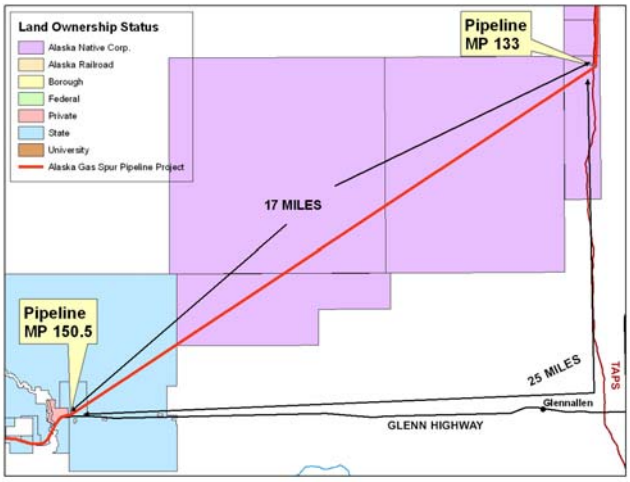


Figure 5.12: Glennallen Bypass, Pipeline MP 133 to MP 150.5

5.5.2 Glennallen Bypass, Pipeline MP 133 to MP 150.5

<u>A bypass of the City of Glennallen</u>: As stated in the previous section, the selected alignment exits the Richardson Highway ROW nine miles north of the City of Glennallen. The spur pipeline alignment then travels a southwest direction, bypassing the City of Glennallen. This segment of the alignment is situated primarily on Ahtna and Sta-Keh Native Corporation lands, and state land. The status of some Ahtna lands is in Interim Conveyance. The acquisition of easements across Native lands should be coordinated with the BIA. The alignment exits Native lands near MP 173 of the Glenn Highway where the alignment enters the highway ROW.

Easements would need to be acquired across private and Native lands, and permits acquired over state lands. Figure 5.12 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.5.3 Glenn Highway, Pipeline MP 150.5 to MP 247.9

This alignment situated within the Glenn Highway ROW beginning near MP 173 to MP 73 of the Glenn Highway. The Glenn Highway ROW is 300 ft wide established by PLO easement and confirmed by virtue of the Alaska Statehood Act, and the Omnibus Act of 1959. Portions of the ROW are confirmed by plat dedications and other portions of the highway ROW have been augmented by ADOT&PF acquisitions. An ADOT&PF utility permit would be needed within the highway ROW. Figure 5.13 illustrates the selected alignment (first the overall route segment, followed by two larger scale illustrations of MP 150.5 to MP 197.7 and MP 197.7 to MP 247.9). Appendix 5-1 identifies those lands adjacent to the selected alignment.

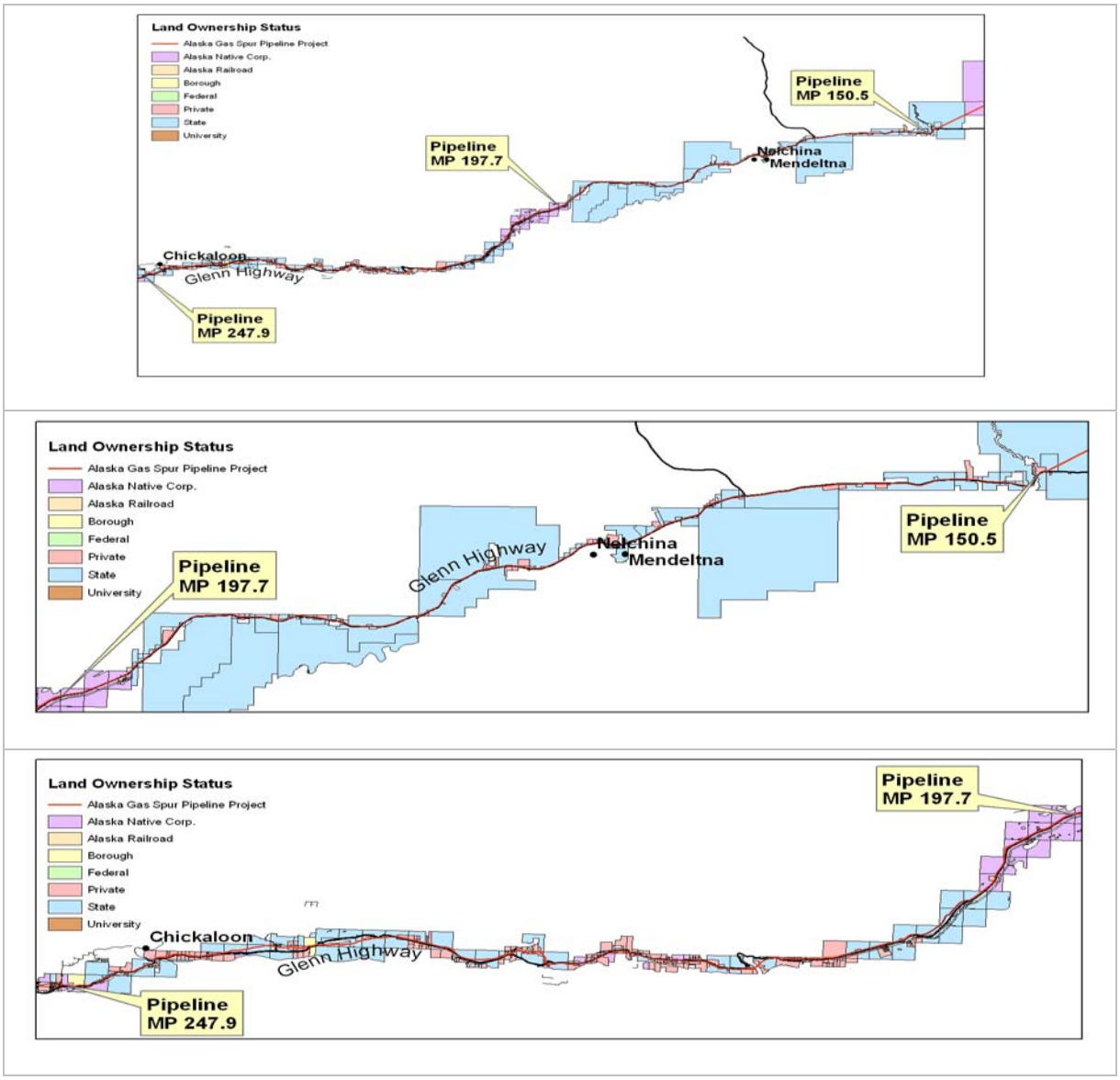


Figure 5.13: Glenn Highway, Pipeline MP 150.5 to MP 247.9

5.5.4 Chickaloon to Palmer, Pipeline MP 247.9 to 281

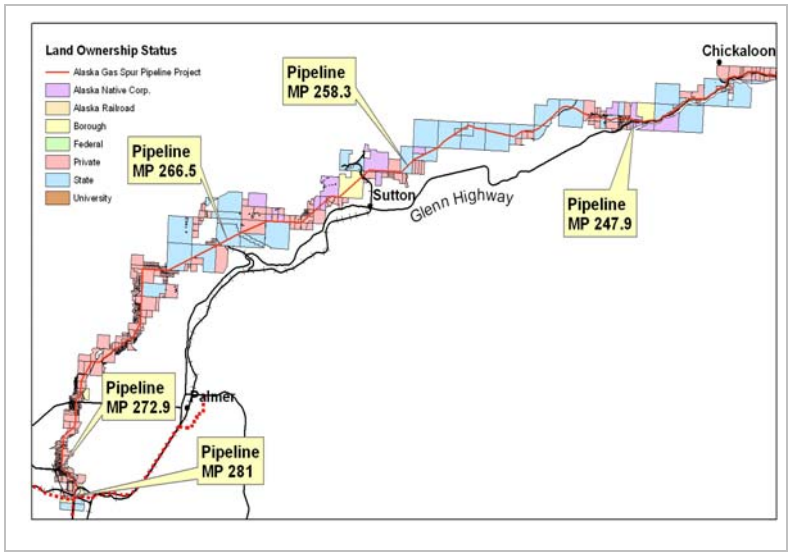


Figure 5.14: Chickaloon to Palmer, Pipeline MP 247.9 to MP 281

From the Glenn Highway ROW, approximately MP 73 through Palmer to the Parks and Glenn Highways Interchange, then to the ENSTAR 20 inch pipeline destination: The selected alignment utilizes RS2477 ROW and existing electrical ROW. The alignment follows the ANGDA alignment through state, Native, borough and private lands. Figure 5.14 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.5.5 Granite Creek, Pipeline MP 247.9 to MP 258.3

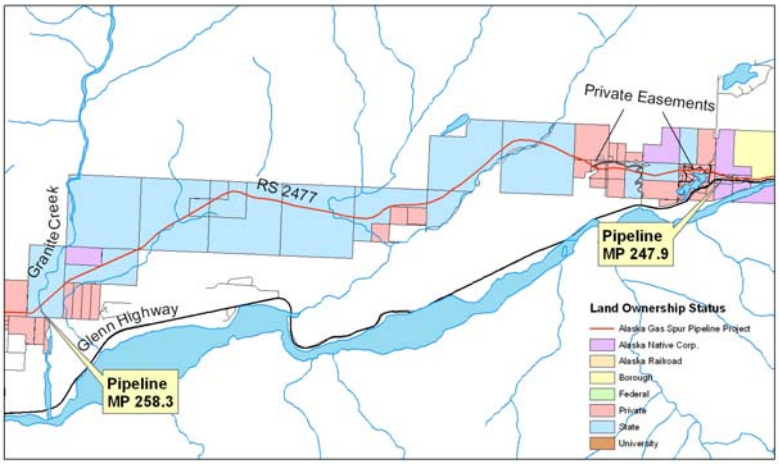


Figure 5.15: Granite Creek, Pipeline MP 247.9 to MP 258.3

From the Glenn Highway ROW, approximately MP 73 to the Chickaloon-Knik-Nelchina Trail: This alignment exits the highway ROW near Young Creek and the King River and enters the RS2477 Chickaloon-Knik-Nelchina Trail ROW and continues to Granite Creek. Private easements and state permits would be needed. Figure 5.15 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.5.6 Granite Creek to Moose Creek, Pipeline MP 258.3 to MP 266.5

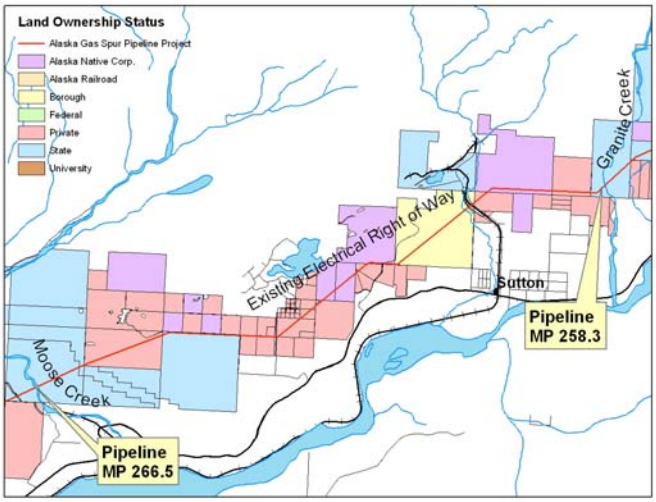


Figure 5.16: Granite Creek to Moose Creek, Pipeline MP 258.3 to MP 266.5

<u>An alignment beginning near Granite Creek and ending near Moose Creek</u>: This alignment crosses state, Native, borough and private lands. A large portion of this alignment is situated within Matanuska Electric Association (MEA) privately acquired easements and also within ADL 202787 MEA ROW. Figure 5.16 illustrates the selected alignment and Appendix 5-1 identifies those lands lying adjacent to the selected alignment.

5.5.7 Moose Creek to Palmer Fishhook Road, Pipeline MP 266.5 to MP 272.9

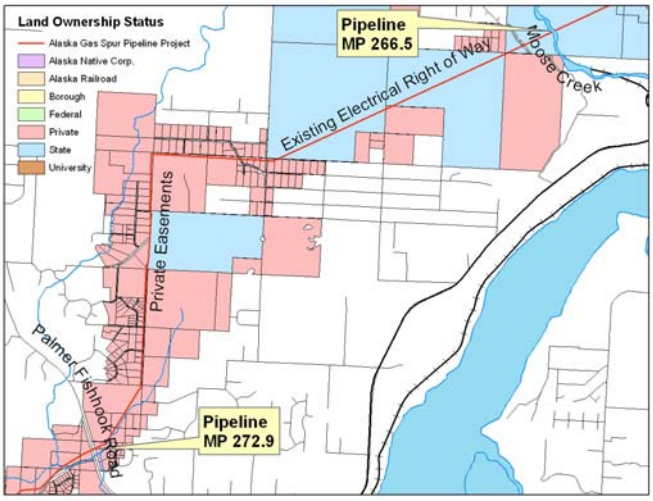


Figure 5.17: Moose Creek to Palmer Fishhook Road, Pipeline MP 266.5 to MP 272.9

<u>From Moose Creek within the ADL 202787 MEA electrical ROW to Palmer-Fishhook Road</u>: This alignment is situated mostly within the MEA privately acquired ROW, State ADL 202787. This alignment crosses state, Native, borough and private lands. Figure 5.17 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment.

5.5.8 Palmer-Fishhook Road to ENSTAR's 20 Inch Pipe, Pipeline MP 272.9 to MP 281

An alignment that continues from Palmer-Fishhook Road on private easements would need to be acquired across private, state and borough lands and also along a portion of the Parks and Glenn Highway ROW. This alignment ends at ENSTAR's 20 inch pipeline. Figure 5.18 illustrates the selected alignment and Appendix 5-1 identifies those lands adjacent to the selected alignment

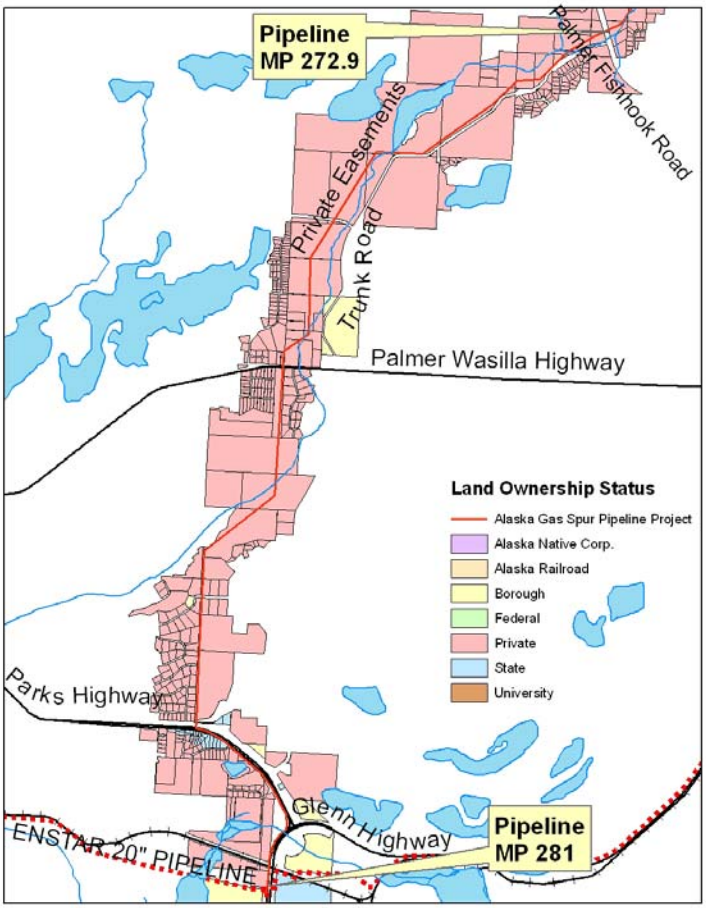


Figure 5.18: Palmer-Fishhook Road to ENSTAR's 20 Inch Pipe, Pipeline MP 272.9 to MP 281

5.6 Excluded Alignments

In determining the ROW for each spur pipeline alignment, issues related to constructability, engineering, permitting, and environmental constraints were considered. Each potential route for the spur pipeline presented unique ROW acquisition challenges. Further reconnaissance focused on the physical environment and topography along both corridors resulting in the final pipeline alignment for each spur route. The three alignments below serve as examples of reasons why alignments were ultimately excluded from further consideration.

5.6.1 Glenn Highway, City of Glennallen

This alignment is situated within the Glenn Highway ROW from TAPS, and situated on the highway ROW. Generally, the Glenn Highway ROW is known to be 300 ft wide, varying at locations where the

ADOT&PF augmented the ROW with acquisitions. Based on an ADOT&PF ROW determination, dated 1961, the width in this section was believed to be 200 ft (Figure 5.19). Current ADOT&PF determinations have corrected the width to 300 ft (Figure 5.20). A considerable number of privately owned improvements were installed outside of the 200 ft limitation, which now is considered to be in trespass. These encroachment issues were potentially detrimental to the spur pipeline project, leading to the exclusion of this alignment. Figure 5.21 illustrates the selected alignment. These lands are not included in the Appendix 5-1.

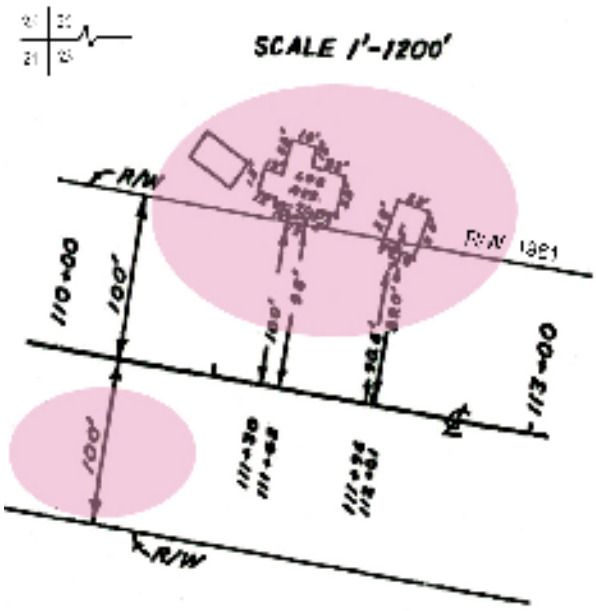


Figure 5.19: 1961 ADOT&PF ROW Plan

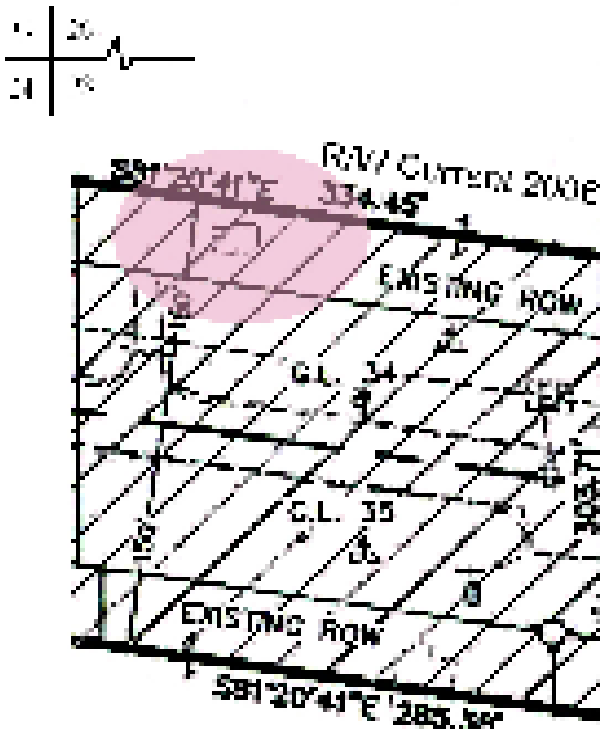


Figure 5.20: 2004 Revised ADOT&PF ROW Plan

Figure 5.21: Glenn Highway, City of Glennallen

5.6.2 RS2477, Squaw, Caribou, Boulder Creek Trail

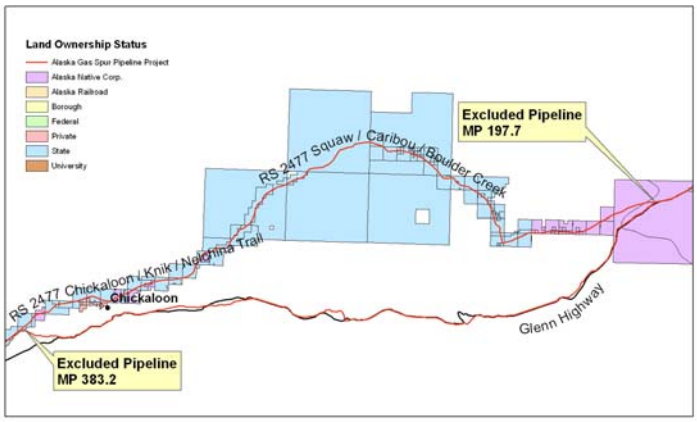


Figure 5.22: RS2477, Squaw, Caribou, Boulder Creek Trail

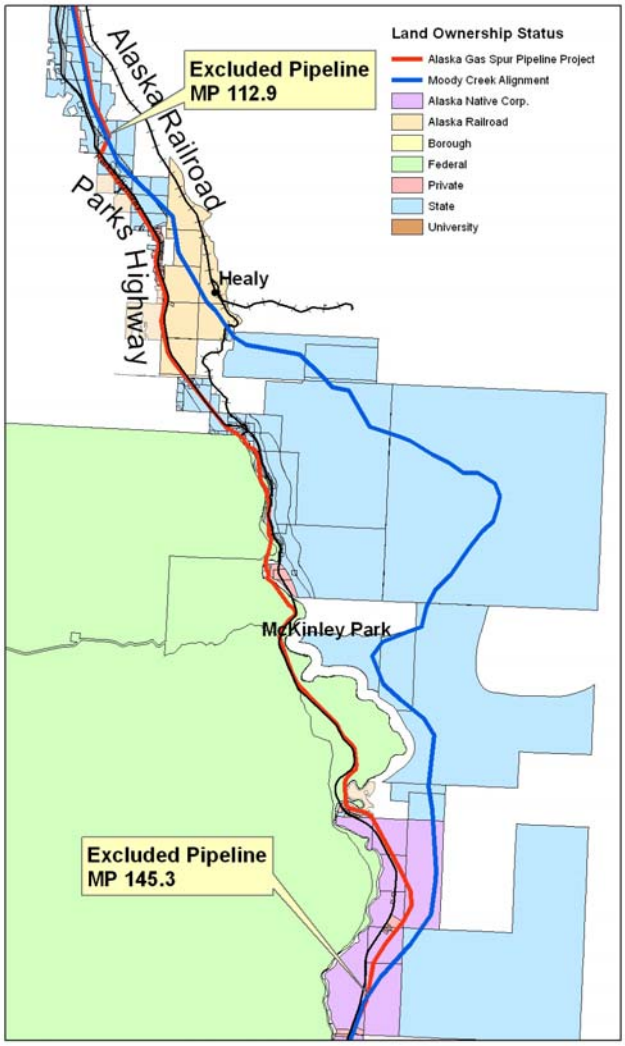


Figure 5.23: Moody Creek, Parks Highway Alternate

An alignment within an RS2477 ROW known as Squaw/Caribou/Boulder Creek Trail: The alignment leaves the highway ROW near MP 122 and enters tentatively approved lands to be conveyed to the State. This RS2477 ROW proceeds along Squaw Creek Trail for approximately 6.5 miles to Caribou Creek Trail. Caribou Creek Trail and Boulder Creek are part of another RS2477 ROW which is approximately 32 miles long and ends at the Chickaloon-Knik-Nelchina Trail. The alignment has been excluded because of engineering concerns. Figure 5.22 illustrates the selected alignment. These lands are not included in Appendix 5-1.

5.6.3 Moody Creek, Parks Highway Alternate

An alignment known as Moody Creek: The alignment leaves the Parks Highway ROW and enters lands under multiple jurisdictions of the state, Native corporation and ARRC. The alignment has been excluded because of engineering concerns related to topographical and soils issues. Spur pipeline construction in this alignment would pose extreme challenges because of multiple water crossings of Moody Creek and rugged rock and soils conditions. An electrical intertie alignment parallels this alignment; however, it has an advantage of suspension from high-tower power poles and in some areas crosses up to a mile or more over conditions that would require extraordinary methods for pipeline installation. Figure 5.23 illustrates the selected alignment. These lands are not included in Appendix 5-1.

Section 6. Permitting and Regulatory Issues

6.1 Introduction

If constructed, the spur pipeline would require significant time and cost devoted to the acquisition of environmental and regulatory permits and approvals. Preconstruction planning for environmental protection should be the first step in this process. Primary emphasis should be placed on preventing adverse effects from occurring in the first place through the early and continuing incorporation of environmental protection measures into engineering design and construction planning. This early planning would support permit applications, requests for regulatory authorization and the NEPA process. By the time applications were submitted for regulatory permits, the results of preconstruction planning for environmental protection would be internal components of facility designs, plans, and field schedules for construction and operation. Permit applications would reflect recommendations already provided by the agencies through their involvement in the planning process.

6.2 Permits and Authorizations

Although permitting details would vary based on physiography, hydrology, and land-use specifics, the permitting process for the proposed spur pipeline would not differ significantly between the two routes. Development of a comprehensive project description would be vital to creating a permitting application package that could be approved by local, state, and federal agencies. It is anticipated that this report would form the basis of any future project description.

Because of the sheer size and scope of the project, the projected timeframe for completion of all studies, plans, permitting, and the NEPA process would be a minimum of two years. In order to accomplish this, a minimum of one to two field seasons for study and planning would be necessary. Key permits the project would require include the Section 10 and 404 permits, issued by the USACE; the National Pollutant Discharge Elimination System (NPDES) and air quality permits variously administered by the USACE, EPA and the Alaska Department of Environmental Conservation (ADEC); and the state and federal pipeline ROW, which would be administered by the JPO. The NEPA process may include an Environmental Evaluation Document (EED), EA, and/or an EIS. Regulatory authorization by FERC or the Regulatory Commission of Alaska (RCA) may also be required depending on the nature of the project.

Once initial siting of major project facilities was completed, detailed environmental and construction permits would be sought from the appropriate agencies. This second stage of permit acquisition would not begin until after ROW had been granted. An extensive list of permits that may be required for all phases of the project is presented in Appendix 6-1 and summarized in section 6.1.1. An estimated duration of time and potential plans or studies required to obtain each permit is listed in Appendix 6-1. However, these are only preliminary estimates of what may be required to permit a potential spur pipeline between Fairbanks and Southcentral Alaska. Future field study, surveys, design, and engineering considerations are all required to compile a complete permitting plan. A potential future project sponsor could utilize the information in Appendix 6-1 as a foundation for developing such a plan.

6.2.1 Permits to be Sought during Detailed Design

Federal Permits			
	USFWS		
		Special Land Use Permits	
			▪ Material sites ▪ Preconstruction and construction camps ▪ Permanent camps ▪ Access roads ▪ Lay-down areas ▪ Solid waste disposal sites
		Temporary Use Permits	
			▪ Solid waste ▪ Spoil disposal ▪ Material storage ▪ Pipe storage
	U.S. Army Corps of Engineers		
		Section 10/404 Permits for	
			▪ Material sites ▪ Preconstruction and construction camps ▪ Permanent camps ▪ Access roads ▪ Lay-down areas ▪ Pump stations ▪ Solid waste disposal sites
	EPA		
		NPDES Permits	▪ Pump station wastewater discharge ▪ Campsite wastewater discharge ▪ Prudhoe Bay Maintenance Facility wastewater discharge
State Of Alaska Permits			
	ADNR		
		Material Site Permits	
		Special Use Permits	▪ Campsites ▪ Disposal sites ▪ Water rights ▪ Parks Permit ▪ Title 41 Stream Crossings Permit
	ADEC		
		Prevention of Significant Deterioration (PSD) Air Quality Permit for	
			▪ Compressor Stations ▪ Construction Activity ▪ Gas Processing Facilities ▪ Solid Waste Disposal Sites ▪ Wastewater Disposal

6.2.2 NEPA

NEPA regulates any activity that may be considered a major federal action. A major federal action may include issuance of a Section 10 or Section 404 permit by the USACE; development of natural gas facilities on federal land; the granting of a gas pipeline ROW by the JPO; and the cumulative impact of the construction, operation, and maintenance of a natural gas spur pipeline.

JPO, established in 1990, is six state and six federal agencies sharing similar regulatory or management responsibilities related to oil and gas pipelines in Alaska, most notably TAPS. Representatives from six of the 12 agencies are co-located and coordinate oversight of pipelines, and issue right-of-way leases and other permits needed for oil and gas projects. Cooperative agreements were developed between agencies to share staff, knowledge, equipment, and office space. This unique working environment eliminates

duplication of work, is more customer oriented, and simplifies complicated and lengthy government processes.

A NEPA review must take into account the environmental impacts of the proposed action; all regulatory approvals; alternative and cumulative impact analysis; and consultation and coordination with all levels of government, interested public, and non-governmental organizations. The resulting environmental document is intended to provide clear and concise information of physical, biological, and human resource impacts either through an EA and/or an EIS. The NEPA document must encourage and facilitate public involvement in project decisions; identify and assess reasonable alternatives to the proposed action that would avoid or minimize impacts; and provide an outcome that mitigates impacts to a fair and reasonable level.

Preparation of a "Pre-NEPA" EED can be a helpful first step in initiating a NEPA and permitting process for the proposed project. The EED is meant to provide the lead agency, all other state and federal regulatory authorities with mandated jurisdictional consultation and review authorities, stakeholder groups, and members of the interested public with a full description of the proposed project, the human and natural environmental settings in which the proposed project would be built and the potential impacts to those environments. The EED provides a means to identify significant concerns that need further evaluation or mitigation. The EED may also be utilized to identify possible flaws and data gaps and may assist in the early identification of the lead federal agency; determine early if an EIS will be necessary; addresses field season requirements; and may help to facilitate the lead agency scoping process.

The EED and the results of environmental studies and field work should be utilized by the lead agency in preparing the NEPA Permit Evaluation and Decision Documents. NEPA directs federal agencies to use a systematic and interdisciplinary approach to environmental impact analysis, requiring that if any action taken by a governmental agency may "significantly affect the quality of the human environment," (42 USC § 4332 (C)) an EIS must be prepared. However, the lead agency may determine that the federal action will not cause a significant impact and issue a finding of no significant impact (FONSI) based on the preparation and evaluation of an EA. If the project requires crossing into Denali National Park and Preserve lands, an EIS will be required as mandated in 16 U.S.C §3164.

Further route planning should take into account mitigation measures that may avoid or minimize impacts to the physical, biological, and human environment. Pipeline routing, design, and engineering will all contribute to whether the project warrants the preparation of either an EA or an EIS. Avoidance of wetlands and sensitive areas whenever feasible, maximizing the use of horizontal directional drilling (HDD) for stream and river crossings, and utilizing existing ROW and developed lands for pipeline routing and construction facilities all minimize the impacts the project would have upon the environment. The routes contained in this report have been chosen without the benefit of extensive field studies and surveys, but rather through the use of existing public information and limited field investigations. Based on this information, it has been determined that the routes selected may be best suited for initial NEPA evaluation through an EA. This is because the proposed routes primarily impact already disturbed transportation corridors. Route segments that would impact undisturbed wild areas such as Moody Creek and Chitna Pass have been avoided in part to eliminate the disturbance of undeveloped areas. However, the NEPA process may result in a finding of impacts substantial enough to warrant the generation of a full NEPA EIS. Without further field studies, engineering, design, and public scoping it is difficult to say with certainty whether an EA or an EIS would be the final NEPA document for this proposed project.

The construction of the ANS gas pipeline during relatively the same time period as the proposed spur pipeline would inevitably create questions related to the cumulative impacts created by both projects. While the spur pipeline would have its share of impacts to the physical, biological, and human environments, the proposed spur pipeline overall would be a fraction of the size and impact of the larger main line. So while the spur pipeline should be considered in the cumulative impacts associated with the

construction of the main line, it is less reasonable to place much weight upon the impacts of the mainline in the analysis of the spur pipeline.

6.2.3 FERC, RCA and Open Season Considerations

The federal Natural Gas Act (15 USC Chapter 15B) regulates the transportation and sale of natural gas in interstate commerce. Under Section 7 of the Act, a Certificate of Public Convenience and Necessity (CPCN) must be issued from FERC before any natural gas company may engage in the transportation or sale of natural gas in interstate commerce. As considered within this study, the spur pipeline project is an **intrastate** project and would not be under the authority of FERC. However, if a project sponsor were to initiate exportation of natural gas product (NGL's, propane, butane, etc.), then FERC would have jurisdiction over the pipeline.

Whether or not the spur pipeline remains an intrastate pipeline, it will be subject to regulation and oversight by the RCA as either a Public Utility per AS 42.05 or a Pipeline Carrier under AS 42.06. The RCA approves gas supply contracts, issues the CPCN for pipelines, and oversees the establishment and modification of supply rates and tariffs. It may be beneficial to a project sponsor to develop a regulatory and permitting plan with RCA oversight in mind.

The FERC Open Season is a method to determine capacity demand for a pipeline and is required to obtain either the FERC CPCN or the RCA CPCN. Either agency will need to know the capacity demand for the pipeline they are approving. The capacity of the main ANS pipeline will impact the size, engineering, and cost of both the main and spur lines. An open season for the main ANS pipeline has not been called for by FERC; however, the project sponsor of the spur pipeline will have to be involved in the open season process for the main ANS pipeline when it does occur. Further, it may be advantageous for that sponsor to have supply contracts and the spur pipeline CPCN substantially near completion in order to determine demand for capacity in the main ANS pipeline.

6.2.4 Permits during Construction Phase

Numerous other permits would need to be sought during the construction phase. These permits may include individual "authorizations to proceed," permits to obtain access to conduct engineering studies, and construction permits for a wide range of activities. A comprehensive listing of these permits should be presented to the appropriate agencies during the detailed design phase.

6.2.5 Approach to Regulatory Compliance

The project would need to commit to mitigate potentially adverse environmental effects and work closely with regulatory agencies to ensure that this goal was met throughout the life of the project.

The project mitigation program could be based on a five-step mitigation sequence such as the one outlined below:

- Avoidance: Plan or take action to prevent an adverse effect from occurring in the first place through a change in schedule, in facility layout, in route alignment, or in some other project feature;
- Minimization: Limit the extent or magnitude of an action to keep an unavoidable adverse effect as small as feasible;
- Rectification: Once an adverse effect has occurred, repair, rehabilitate, reclaim, or restore the damaged environmental feature as closely as feasible to pre-project conditions;

- Reduction: Take measures by stages over time to reduce the adverse effect's severity or extent; and
- Compensation: Create a new environmental feature comparable in value to that damaged or lost, either on or off the project site; prevent some other action that would otherwise have produced an additional, similar adverse effect; or take an out-of-kind (unrelated) action that increases environmental quality in a manner agreed upon to offset the adverse effect.

Measures to avoid and minimize adverse effects would be built into engineering design and construction planning and would continue to be incorporated and refined as the project develops. Measures to rectify and reduce unavoidable adverse impacts would be implemented during and following construction and throughout the life of the project as facilities are operated and eventually decommissioned. With the mitigation program fully implemented, measures to compensate for adverse effects are not expected to be necessary although the project would be receptive to examining the feasibility of such measures in the event of a demonstrable need.

The mitigation program would be developed in close coordination with regulatory agencies and would be responsive to agency concerns. Agency involvement from the outset would help forestall later costly delays by ensuring that environmental concerns are identified at the beginning of planning and that appropriate mitigative measures are built into designs as integral project components rather than as afterthoughts appended late in the planning process. Agency coordination would be accomplished through frequent meetings, through the EIS, and other environmental documents prepared in accordance with statutory requirements and subject to public and agency review through the permitting process and through field monitoring.

Mitigation strategies must adapt to changing environmental requirements as the project progresses through design, construction, and operation phases. The mitigation program would be continually refined and appropriately modified to ensure that correct environmental protection measures are taken at the proper times and in close coordination with regulatory agencies.

Mitigation would be an essential and inseparable part of project design and implementation rather than an added refinement. Design and alignment of the pipeline and service road; siting and design of compressor stations, camps, material sites, and other facilities; detailed logistic and construction procedures; scheduling of all field activities; and every other aspect of construction and operation would be based on an extensive planning and review process involving the close interaction of in-house environmental specialists with design engineers.

Examples of potential mitigative measures planned early in project design include:

- Terrain unit analyses of pipeline routing alternatives to minimize stream crossings and avoid areas of potential terrain instabilities;
- Review of seasonal migratory patterns to determine optimal pipeline routing for minimizing potential interference with migratory movements;
- Siting of stations, camps, and other facilities to avoid streams and wildlife special-use areas; Development of criteria for facility design and layout, winter construction, water extraction, stream crossings, borrow sites, fuel storage and handling, liquid waste management, and disposal of solid wastes; and
- Development of a continuing environmental education program based on compulsory briefings of all project personnel.

6.3 Preconstruction Field Studies

Baseline information would be required for environmental input to engineering design and construction planning and to support the NEPA process and preparation of permit applications for the project. Available information sources would provide the primary basis for environmental information supporting the project through its preconstruction stages.

Preconstruction field studies should be conducted on environmental topics where there is a definite project-related need to fill data gaps identified from the literature. These studies should consist of two main categories:

- First, site-specific field assessments for proposed locations of all project facilities, stream crossings, sources for water extraction, material sites, spoil disposal sites, access roads, and any other potential disturbances.
- Second, there would be a need for highly focused studies of biological, archaeological, hydrologic, water quality, and other features or processes where existing data may have changed or be insufficient. Both categories of studies would require permits from the USFWS and would be designed in coordination with USFWS and other appropriate state and federal agencies.

6.4 Construction Monitoring

It is anticipated that state and federal agencies would implement a monitoring program during design, permitting, construction, operation and eventual termination of a proposed spur pipeline. The program may include monitoring special construction areas, major river crossings, and sensitive wildlife areas. A plan for accomplishing this task would be developed jointly with the involved regulatory agencies. This plan would be submitted to the participating agencies during the detailed design phase of the project.

An in-house comprehensive quality assurance and quality control program would be implemented to ensure that the applicable requirements of statutes, regulations, environmental and technical stipulations, and final design and design specifications are complied with throughout the construction and operation phases. Continuous inspection should be provided for the pipeline system construction, including temporary facilities to ensure compliance with the approved final design specifications. The quality assurance and quality control program should provide for inspection of all aspects of design implementation including fabrication, assembly, and testing to assure pipeline integrity and protection of the environment.

Project environmental staff should be fully involved in designing and implementing the quality assurance-quality control program and in the construction monitoring program to be developed and undertaken jointly with involved regulatory agencies. Both construction procedures and the timing of construction activities should be monitored to ensure that disturbances of fish, birds, and mammals are avoided where possible or minimized.

6.5 Archaeological and Historic Sites

In accordance with Section 106 of the National Historic Preservation Act, cultural and historic resource sites would need to be identified and either avoided or potential impacts mitigated. Written documentation should be presented which addresses site investigations and proposed mitigation measures. In addition, the methods for dealing with previously unknown cultural or historic resources would be presented before construction within the pipeline corridor begins.

Cultural resource evaluations would be performed by qualified professional staff or contractors prior to large-scale construction activities. The objectives of these evaluations would be to avoid disturbances from pipeline and related facility construction and to assure compliance with federal and state requirements for protection and preservation of prehistoric or historic sites and objects.

6.6 Air Quality

Emissions would be released into the atmosphere from turbines, heat and power generation equipment at camps, incinerators, vehicles, gravel processing plants, and other sources during construction and operation. These emissions are regulated by federal standards, all under jurisdiction of the EPA. Under an EPA-approved State Implementation Plan, ADEC is responsible for directing day-to-day management of air quality programs and for enforcing limits.

The primary emissions of concern would be nitrogen oxides produced by gas-fired turbines and heaters. Turbines are compliance-tested at intervals required by permit. Other gaseous and particulate emissions must remain within NAAQS and PSD increment limits established for the region.

The project would ensure that ambient concentrations of gaseous and particulate emissions from facilities during project construction and operation are below regulatory limits. The permit application should incorporate atmospheric dispersion modeling for the full range of climatic and wind conditions that might occur at the sites under normal and unusual circumstances. Turbines should be modeled for natural gas fuel.

Limits should be established for the equipment through the permitting process. Equipment should be compliance-tested at appropriate intervals to ensure that emissions of criteria pollutants are maintained below stipulated limits.

Although gaseous emissions are the primary long-term concern, other local, short-term air quality impacts could result from fugitive (airborne) dust generated by construction vehicles and gravel processing facilities, primarily during the snow-free summer.

Fugitive dust would be reduced through periodic watering of roadbeds, using water extracted from lakes, ponds, rivers, and streams. A major mitigative measure would be to ensure that juvenile fish or fish eggs are not entrapped during water withdrawal. This would be accomplished by avoiding use of water bodies which support fish and, additionally, by appropriate screening of intake structures.

6.7 Water Quality and Consumption

Construction, operation, and maintenance would have the potential to alter water quality through construction-related soil and streambed disturbances, accidental release of contaminants, aggregate mining and processing, camp pad runoff, blockage of channeled and unchanneled surface flows, and other mechanisms. Flow, turbidity, suspended solids, sediment loads, and other surface water characteristics could be adversely affected. Aquatic organisms, including sport and subsistence fish species and the plants and animals of the food web that supports them, could in turn incur adverse impacts from changes in water quality and flow.

The primary objective of the water resource protection program would be to avoid project-related adverse impacts to water resources and water-dependent fish and wildlife. Equally important, is the safety of project personnel by maintaining healthful water quality at temporary and permanent facilities. Water-related mitigation for the project would focus on two major concerns:

- Avoiding potential contamination of rivers, streams, lakes, and unconfined sheet flows; and

- Avoiding potential conflicts between water extraction for project use and water requirements for winter use by fish and wildlife.

Any large development could, without proper mitigation, create a potential for contamination of surface waters. For this reason, the existing federal, state, and local regulatory framework for Alaska is particularly comprehensive and stringent with regard to protecting water quality. Preconstruction, construction, and operational field activities for the project would be subject to water-related stipulations under laws and permits including, but not limited to:

- Section 404 of the CWA, regulating dredging and fill placement in wetlands, administered by the USACE;
- Section 401 Water Quality Certification, administered by ADEC, evaluating the action in terms of its ability to meet State of Alaska Water Quality Standards and required before any Section 404 permit can be granted;
- NPDES permits for point-source discharges of wastewater to surface waters, administered by EPA under 40 CFR 122, 123, and 125; and
- Alaska Solid Waste Disposal Permits, administered by ADEC under Title 18 AAC 60, requiring substantial information submittals which include descriptions of the proposed development and means for controlling water pollution and detailed quantification of water pollution potential based on water quantity and quality, geology, and hydrologic characteristics of the pipeline route and all facility sites.

In addition to the requirements described above, lease conditions allowing establishment of a pipeline transportation corridor, auxiliary facilities, and extraction of water and gravel would contain general and site-specific water quality protection stipulations. Other state and federal programs would protect water quality through regulations covering hazardous substances control.

Special conditions address site- and design-specific features of the proposed project, including hydrologic characteristics of the site and surrounding area, composition and quantity of potential contaminants which project facilities would be likely to generate, and procedures for avoiding, minimizing, and otherwise mitigating adverse effects from contaminants specifically connected with the project in question. For example, special conditions relating to hydrology may require that a minimum distance be maintained between the toe of a gravel road or pad and the normal high-water contour of adjacent lakes and stream channels. To minimize filling of legally protected wetlands, the applicant must utilize nonwetland areas (and, where possible, existing pads and roads) to the maximum extent practicable, even in terrain where nonwetland areas are considerably less common and of greater biological value than wetlands.

The proposed spur pipeline would cross wetlands along a significant portion of either route. In order to dredge or fill wetlands, under the authority of the CWA, the USACE requires a Section 404 permit for work in waters of the United States. In evaluating a Section 404 permit application, the USACE would determine whether the applicant has considered alternative plans which would avoid or minimize the effects upon wetlands. If avoidance or minimization are not reasonable or if there are still wetlands impacts, the USACE then has the authority to require mitigation. Restoration of wetland habitats can provide credits to offset the debits accrued through dredging and filling of wetlands. A full evaluation of the project in light of the debit-credit guidelines would be completed by the USACE following the submission of a permit application to the USACE. Increases in surface water runoff or sedimentation could also impact wetland communities and would be addressed as well.

In general, measures to mitigate potential water quality impacts are well established project components. Design, construction, and operation would emphasize the knowledge of water quality protection gained by industry and government during the past years. The project would utilize collected information and

federal, state, and local regulatory guidelines to develop water-quality protection criteria for facilities design, construction, and operation. Information gaps would be eliminated or reduced by site-specific field hydrology and water quality investigations and through the continuing involvement of regulatory representatives.

Following development of protection criteria for water quality, these criteria would be incorporated early and effectively into engineering design, construction planning, and operational procedures, including quality control monitoring requirements. Incorporation of measures to protect water quality would be demonstrated in applications for regulatory permits.

Water extraction procedures would avoid naturally-occurring deep pools in rivers and lakes that provide overwintering habitat for fish. Methods by which water has been successfully extracted include excavating deep pools in riverbeds and lakes, insulating ponds to prevent freezing, desalinating sea water, erecting snow fences to trap snow for subsequent melting, and converting depleted material sites for temporary use as reservoirs.

In addition to protecting fish overwintering pools, specific objectives for protecting water resources during preconstruction, construction, and operation of the project would include:

- Establishment of appropriate water extraction methods, water quantity requirements, and water quality criteria necessary to satisfy project requirements for construction activities and for operating temporary and permanent facilities along the spur pipeline route;
- Design, construction, operation, maintenance, and monitoring of non-point-source discharge control structures;
- Design, construction, operation, maintenance, and monitoring of potable water treatment and distribution facilities to ensure compliance with State of Alaska Drinking Water Standards;
- Preparation of a detailed plan for extracting and discharging water for pipeline and process utilities hydrotests; and
- Incorporation of detailed mitigation measures into project descriptions prepared for permit and Notice-to-Proceed (NTP) applications and plan-review data to satisfy State of Alaska requirements for water appropriation and use.

State of Alaska Drinking Water Standards and Water Quality Standards, the CWA, and federal, state, and local stipulations would be used as guidelines for developing and implementing plans to accomplish these objectives.

6.8 Liquid Waste Management

Substantial quantities of liquid wastes would be generated during construction and operation. Waste streams which must be handled, treated, stored, and disposed of would include, but not be limited to, raw sewage, sewage sludge, graywater, camp pad runoff, batch plant discharges, and ditch pumpouts. Construction camps would be point-source generators of wastes that would require characterization with respect to quantity, quality, pathogenicity, and environmentally and logistically acceptable treatment and disposal methods.

Fuel oil would be the most significant liquid waste material to be transported, stored, or used for the project in terms of mass, volume, and potential environmental risk to the project. There could be, however, other liquid waste materials present on the project. These materials may include fuel, glycols, solvents, lubricants, drilling liquids in support of HDD, and liquids for hydrotesting.

Liquid waste treatment and discharge are governed by EPA regulations (40 CFR) and by State of Alaska regulations (18 AAC 72, 74) administered by ADEC. The NPDES, which regulates point-source discharges of wastewater to surface waters of the United States, sets criteria and standards for wastewater treatment systems. An NPDES permit, administered by EPA, would be required to operate a wastewater treatment facility. In addition, under Section 401 of the CWA, State of Alaska certification is required attesting that the federal permit will not violate state water quality standards.

A comprehensive and detailed Liquid Waste Management Plan would be prepared to describe activities that generate, collect, transport, store, treat, and dispose of liquid wastes. The plan would examine all regulatory requirements for liquid waste management and specify how those requirements would be met. It would also identify equipment, staffing, procedures, logistics, and critical path schedules for all elements of liquid waste management associated with the project. These would include liquid waste management system designs for temporary and permanent facilities (camps and stations), logistics for disposing of wastes generated along the spur pipeline ROW during field operations, operator training programs for treatment systems, and operation and maintenance manuals to guide personnel in routine and emergency procedures, including continual monitoring and evaluation of system performance. The Liquid Waste Management Plan would be developed thorough agency consultation and would provide substantive support for permitting and monitoring of project development stages.

The evaluation, selection, and design of liquid waste collection, storage, treatment, and disposal systems for temporary and permanent pipeline facilities would be a major undertaking; throughout the process, project waste management specialists would consult frequently with project design and construction personnel and agency representatives. The program would initially require characterization of sources, constituents, and volumes of liquid waste streams. Early in the design process, information developed in-house and from agency consultation would provide initial input for permit applications for liquid waste management systems and treatment facilities to be used in construction camps. As the design process is completed for temporary facilities, details would be incorporated into NTP applications and into the Liquid Waste Management Plan.

Concurrently with design, operation and maintenance manuals and operator training programs would be developed. Operators would be required to have State-of-Alaska certification in wastewater treatment plant operation and to receive continuing supplementary training. When necessary NTPs and permits have been obtained, construction of the waste management systems would proceed monitored by project and agency personnel; operator training would be implemented; and procedures for operating, maintaining, and monitoring the systems would be put into effect as they become operational. A similar approach would be followed for development of liquid waste management systems for permanent pipeline facilities.

6.9 Solid Waste Management

Solid wastes have the potential to block and contaminate surface waters, attract and habituate bears and other wildlife, spread disease, and create physical hazards to project personnel in the field.

Solid wastes generated during construction and operation would include putrescible kitchen refuse, other domestic refuse from pipeline camps and stations, scrap metal, dunnage, plastics, wood, cardboard, tires, automotive and heavy equipment parts, machine shop refuse, and scrap materials generated during pipeline and ancillary facility construction. Because of their diversity, these wastes would require various and appropriate means of collection, transport, storage, treatment, and disposal. Logistics would play a key role in the solid waste management program.

On federal as well as state-leased lands in Alaska, an ADEC solid waste disposal permit would be required for development and use of any solid waste disposal site. Submittals may include, but not necessarily be limited to, the following components:

- A description of the proposed disposal site, operating procedures, and methods for avoiding water contamination;
- Evaluation of the site's potential for leaching based on types of waste proposed for disposal, topography and soils, hydrology, and other pertinent factors;
- Evaluation of surface water quality in the site vicinity based on recent, original, and site-specific data collection in the field;
- Detailed design considerations, including surface water vicinity, soil borings, construction techniques and schedules, proposed access, and other factors;
- Characterization of habitats and wildlife use in the site vicinity;
- A detailed operations plan, including fluid management procedures;
- A leak-detection system description; and
- A substantive close-out plan.

Requirements for solid waste disposal management practices on federal lands may differ in important ways from those for state-leased lands. For example, federal stipulations for developments on refuge lands may prohibit solid waste disposal sites requiring haul-out of solid wastes not disposed of through incineration. The federal-state aspect of the route would require careful attention in this regard, and early agency consultation would be essential.

To assure all requirements for environmentally safe disposal of solid wastes were met on state and federal lands and in accordance with borough regulations, a detailed Solid Waste Management Plan during engineering design and construction planning would be prepared. Developed in close coordination with EPA, USFWS, ADEC, and other involved agencies, the plan would govern all activities of the project and its contractors which generate solid waste.

The plan would accomplish the following objectives:

- Identify all applicable regulatory requirements for solid waste management and specify how those requirements would be met.
- Perform a solid waste source and volume characterization estimating types and quantities of solid wastes to be generated in the field by location, facility, and month during each year of the preconstruction and construction phases and during the first five years of pipeline operation.
- Develop criteria for the collection, transport, storage, treatment, and disposal of each solid waste category based on predicted quantities, locations, facility types, and timing of generated wastes. Criteria would address such factors as storage capacities for temporary holding facilities, incinerator sizes and performance standards, haulage requirements, disposal specifications, and professional qualifications for waste management technicians.
- Identify special studies required to quantify waste generation, specify equipment requirements, or provide other necessary information.
- Perform an options analysis and evaluation of alternative waste management systems.
- Present engineering designs and construction plans, including critical path schedules for solid waste management systems for temporary and permanent facilities and for pipeline construction field operations along the ROW. Selection and design of waste management systems would be

based in part on the source and volume characterization and on the options analysis and evaluation. The plan would include discussion of rationales governing selection of waste management systems.

- Set forth operator training programs for all solid waste management system components, including operation of incinerators.
- Specify standards for development of operation and maintenance manuals to guide personnel in routine and emergency procedures, including continual monitoring and evaluation of system performance.
- Describe mitigative measures, including regular monitoring of facility performance and of environmental indicators to avoid, minimize, rectify, reduce, or compensate for potential adverse impacts of solid waste disposal.
- Provide a detailed close-out plan for all solid waste disposal systems and facilities, including measure to be undertaken for site rehabilitation.

Information, design products, plans, and schedules in the Solid Waste Management Plan would support applications for establishment of preconstruction and construction camps and, subsequently, for construction and operation of the pipeline and ancillary facilities. In all cases, solid wastes would be collected, transported, stored, incinerated, recovered, and disposed of in compliance with Alaska Air Quality Standards (18 AAC 50), Alaska Solid Waste Disposal Standards (18 AAC 60), U.S. Department of Transportation regulations (49 CFR), and other applicable regulations, standards, stipulations, and permit requirements.

6.10 Hazardous Substances Management

A comprehensive and effective hazardous substances management program would need to be implemented to ensure that risk to human safety and to the environment is kept as low as possible during construction and operation. Planning and execution of hazardous substances management program would be undertaken at the highest levels of priority and would be subject to continuing refinement with full agency participation.

The project would require storage, transfer, use, and disposal of diesel fuel, gasoline, lubricants, hydraulic fluids, solvents, paints, acids, and a variety of other compounds which are legally classified and regulated as hazardous substances. Spills of any of these materials must be prevented to the fullest extent practicable, and handling and disposal of hazardous substances must be safely and properly implemented.

Hazardous substance management is regulated through a complex framework of federal and state controls, ultimately governed by EPA regulations under 40 CFR. A key element would be the spill prevention, control, and countermeasure plan required by EPA oil spill and hazardous substances/waste regulations. Oil and hazardous substances pollution control is regulated also by ADEC.

Early in project development, a comprehensive Hazardous Substances Plan would need to be prepared as the core document for the hazardous substances management program. The Hazardous Substances Plan would specify the names and regulatory classifications of all hazardous substances and wastes used or generated in any stage of project development and operation; procedures for handling, transporting, storing, and disposing of all regulated classes of hazardous substances and wastes used or generated by the project; and hazardous substance spill prevention measures and contingency procedures.

The plan would include:

- Names and signatures of responsible officials;

- Project and route description;
- Contingency Organization: A detailed description of the responsibilities of each member of the Contingency Organization and procedures for mobilizing the organization;
- Spill notification and reporting procedures;
- Construction and operation of pipeline facilities, including engineering design of containment dikes and other suitable structures around all temporary and permanent storage facilities for fuel and other hazardous substances:
- Spill prevention and detection methods and equipment;
- Cleanup logistics, procedures, equipment specifications, and equipment stockpile locations and quantities;
- Handling, storage, transport, and disposal practices for refined petroleum products, and nonpetroleum products, including all pertinent classes of hazardous substances and wastes;
- Emergency evacuation plan;
- Personnel training program; and
- Environmental monitoring and required follow-up studies.

Spill prevention and contingency procedures detailed in the Hazardous Substances Plan would become an essential and familiar part of daily field operations through development of a Hazardous Substances Manual. This document, which would be stipulated in the Hazardous Substances Plan, would be prepared in draft form for agency review and comment early in the project design phase.

6.11 Visual Quality/Viewshed

Both spur pipeline routes pass through landscapes of unique visual value. The spur pipeline would parallel existing transportation corridors for much of both routes and the route would potentially be visible to thousands of motorists, air and rail passengers. In and near Denali National Park and Preserve, the value of the view is an important economic resource. The proposed pipeline would be buried along as much of the route as is feasible. With this being the case, much of the impacts to visual resources would occur during the construction of the pipeline. Following construction, the preferable response would be restoration of the landscape to a condition as close to originally found as possible. Land use permits from ADNR and federal agencies may contain stipulations for restoration activities. Operation of the pipeline would involve regular access and maintenance along the spur pipeline corridor which may include periodic brush clearing of the corridor.

6.12 Noise Disturbance/Noiseshed

Both routes are in close proximity to highways with seasonally high levels of traffic. However, except for Fairbanks, Palmer, and to some extent Glennallen, the ambient noise levels are fairly low. The greatest noise impacts would be during construction. Large truck, earth moving and rock crushing equipment, as well as the construction camps themselves would significantly increase noise levels. Once construction and environmental restoration or mitigation is completed, the only regular noise generation would come from the compressor stations installed along the pipeline and periodic maintenance by the operator. Maintenance and repair activities and the use of aircraft, all terrain vehicles (ATVs), snowmachines, or other vehicles for inspections would contribute to noise generation, but would be intermittent.

6.13 Biological Resources

Measures to avoid or minimize disturbances to fish, wildlife, and the habitats which support them would need to be well-established project components. Accepted designs and procedures to protect biological resources should be built into every phase of the project beginning with the first stages of engineering design and proceeding through preconstruction and construction field activities, operation and maintenance, and eventual decommissioning of facilities in future years. A project mitigation program, should strive to work closely with all regulatory agencies as preliminary and subsequent detailed plans are developed so that agency concerns and recommendations are reflected in engineering design products, construction procedures and schedules, and permit applications required before field operations could begin.

The routing criteria incorporates many environmental safeguards, such as minimizing the total length of pipeline, avoiding environmentally sensitive areas, avoiding unnecessary river and stream crossings, minimizing potential blockage of cross drainage, and emphasizing design features that minimize geohazards and optimize safety and ease of maintenance.

6.13.1 Vegetation

As any potential pipeline route was cleared, terrestrial and wetland vegetation would be disturbed along the established ROW as well as in areas to be used for access, material stockpiling, and construction camps.

Once construction was completed permit stipulations would most likely require that vegetation be restored to as natural a state as is possible. In order to facilitate maintenance and inspection activities that would be required, the route would probably be revegetated with grasses and low shrubs but no trees. The route should be reseeded with native grasses as recommended by state and federal agencies. Areas which are subject to sand and gravel extraction may have different restoration and reclamation requirements as stipulated in the ADNR permit.

6.13.2 Fish/Aquatic Species

Both proposed routes cross major river systems which provide a significant quantity of salmon and resident fish to the Southcentral and Interior regions of the state. Construction of the pipeline near and through fish-bearing waters would have the potential to seriously impact fisheries resources. Specific issues that would need to be addressed include limiting barriers to fish movement, maintaining water flow, quality, and temperature, reducing or mitigating riparian habitat loss, regulating sedimentation, and eliminating contamination of water bodies. The loss of essential fish habitat in areas which are used for spawning, feeding, or rearing of salmonids would be of particular concern. Issuance of ADNR permits including the Title 41 Fish Habitat Permit, Temporary Water Use Permit, and Land Use Permit as well as any federal permits would be conditioned upon the applicant(s) stipulating to measures which address these issues. Scheduling of work during time periods when the least number of fish are present would minimize direct impacts to fish. The use of HDD to cross water bodies wherever physically and fiscally possible would also reduce impacts to fish habitat. Gravel and water removal would be restricted to times and locations that would avoid potential adverse effects on fish and fish habitats.

6.13.3 Birds

Both routes would have the potential to encounter and impact bird populations that use the route corridors for nesting, feeding, and migration. Adverse effects to bird populations as a result of pipeline construction could include habitat loss or alteration, disturbance or displacement of species, mortality, or impeding bird movements within the habitat. Pipeline construction and operation would need to be conducted so as to localize impacts so that species or populations are not impacted and only rarely would

individual birds be impacted. A detailed nest survey of the final routes would need to be completed in order to comply with the Bald and Golden Eagle Protection Act. The applicant would work in cooperation with the USFWS to identify areas where swans or other waterfowl may nest and to implement avoidance strategies whenever feasible. The Migratory Bird Act, administered by the USFWS, restricts clearing of vegetation, including shrubs and trees, during periods of nesting. This restriction window depends upon many factors and consultation with the USFWS for these windows would be imperative to reducing impacts to migratory birds.

6.13.4 Wildlife: Terrestrial Mammals

The proposed pipeline routes cross through areas used by terrestrial mammals for migration, wintering, and calving. In particular, the Nelchina caribou herd is known to utilize habitat near both the Richardson and Glenn Highways along the route for the Delta Junction Spur. The Delta Junction Spur also crosses the southern boundary of the Matanuska Valley Moose Range. For the Fairbanks Spur, caribou and moose migration and concentration areas are present throughout the route corridor from Nenana south to the terminus of the route (Denali Pipeline 1993).

Bear concentration areas are also found near the Fairbanks Spur route from Denali National Park south to the Trapper Creek area (Denali Pipeline 1993). Potential impacts to mammal populations mirror potential impacts to birds including habitat loss or alteration, disturbance or displacement of species, mortality, or impeding animal movement within the habitat. Since both routes would be primarily located within existing transportation corridors, the impacts related to construction and operations should be localized. However, wildlife surveys along the routes should be conducted prior to construction to identify any areas of critical habitat to be avoided altogether or seasonally.

Bears should be the species of greatest concern during construction. Bears can become attracted to human settlement and have been known to habituate to human activity. Bear den locations may be obtained either from ADF&G or by field surveys. During construction, containment of garbage, restrictions on food storage and handling, and removal of waste would be the best means of reducing human-bear interactions.

It would be unlikely that pipeline construction would encounter populations of Dall sheep or mountain goats but if wildlife surveys identify areas utilized by sheep or goats, timing of construction to avoid impacts should be sufficient. Wolves and furbearers are widely dispersed across both pipeline routes. Populations of these mammals should not be adversely impacted by pipeline construction or operations.

6.13.5 Threatened, Endangered, Protected Species, Essential Habitat

Because no known threatened or endangered species utilize the pipeline routes, at this time there would be no impacts. However, an eventual project sponsor should be prepared to cooperate with the USFWS if an impacted species were subsequently listed. Further, the sponsor would need to work with the ADF&G regarding impacts to species of special concern.

Section 7. Socioeconomic Considerations

7.1 Introduction

This section describes the various governmental jurisdictions and unorganized communities located within both the Fairbanks and Delta Junction Spur corridors, the salient demographic features characterizing each, identified historical and archaeological properties, recreational areas, and subsistence use areas. Socioeconomic impacts, both positive and negative, would need to be considered by any potential project sponsor in evaluating and choosing a route for a prospective natural gas pipeline.

7.2 Fairbanks Spur Affected Human Environment

7.2.1 Government Related Institutions

Fairbanks North Star Borough

The FNSB is located in the central Interior of Alaska and is the second-largest population center in the state. Communities located within the FNSB include: College, Eielson Air Force Base, Ester, Fairbanks, Fox, Harding Lake, Moose Creek, North Pole, Pleasant Valley, Salcha, and Two Rivers. FNSB also includes a major part of the Doyon Native Corporation (Doyon) lands (Denali Pipeline 1993).

FNSB has a "strong mayor" form of government and was incorporated in 1964. Other governmental bodies include the assembly, school board, and planning commission. Fairbanks and North Pole have their own city councils which are under the directive of the borough government. The government generates most of its revenue through property taxes (ADCRA 2005). The proposed spur pipeline alignment between the Fairbanks take-off point and Nenana passes primarily through unincorporated lands.

Nenana

Nenana is a small community with a little over 500 residents that is a home rule city outside the borders of both FNSB and Denali Borough. The City of Nenana is the overarching government institution with the Goldstream Community Association, Nenana City School District, and the Nenana Native Village Association as the BIA recognized traditional council. The Toghottele Corporation is the Native village corporation representing the area (ADCRA 2005). Nenana's local government and Native corporations have land management jurisdictions and responsibilities that would impact ROW considerations.

Denali Borough

The Denali Borough is a recently established home-rule borough. It contains four small communities: Anderson, Cantwell, Clear and Healy (Denali Pipeline 1993). The Denali Borough also includes the Denali National Park and Preserve and other Doyon Native lands.

While each community has its own city council, the Denali Borough has a manager form of government with a school district. The Denali Borough, along with FNSB, is the home of the Tanana Chiefs Conference, a regional Native Health Corporation. Its tax base includes a four percent bed tax aimed at the tourism industry and a $0.05 per cubic yard tax for coal mined within the borough (ADCRA 2005).

Matanuska-Susitna Borough

The affected communities along the Fairbanks Spur route within the MSB include Talkeetna, Willow, Palmer and Wasilla (Selkregg 1974). The MSB has a manager form of government and other governmental bodies including the assembly, school board and a mayor. The MSB includes the Southcentral Foundation as its Native Health Corporation and some lands owned by CIRI. The tax base of the MSB has a mix of both property and sales tax levied by individual city governments (ADCRA 2005).

7.2.2 Sociocultural Institutions

Historical and Archeological Properties

Historical and archeological properties are defined as areas where historic artifacts, structures, and sites exist within several recognized periods of human cultural and historical development.

There are few archaeological sites that exist in or near the proposed Fairbanks Spur route, and fewer are dated or contain culturally diagnostic artifacts. While there are several Athapaskan sites along the Parks Highway, none have been excavated by academic or other organizations (Denali Pipeline 1993). The following sites have been excavated: Teklanika West, Dry Creek archaeological site, Carlo Creek site, and Nenana Gorge site. These sites vary in age and have shown artifacts that evidence prehistoric occupation 11,000 years ago.

Subsistence Areas

Residents along and outside the Fairbanks Spur route use fish, terrestrial wildlife, and plants for subsistence purposes. Residents from as far away as Kenny Lake (in the Copper River valley) hunt for moose and caribou along the Denali Highway as far west as Cantwell (Cuccarese et al. 1988). The road network for Interior Alaska defines the primary subsistence use areas because this is the population center. Most residents along the proposed Fairbanks Spur route qualify for subsistence use of nonfederal lands and waters under state law. Residents from Minto use subsistence resources upstream along the Tanana River to the vicinity of Nenana. There are trappers who work along the northern parts of the Parks Highway. The Julius Creek area is used for subsistence harvest of waterfowl and small game, while the Panquinque Creek area is used for small game harvest (Denali Pipeline 1993).

Recreational Areas

Because of access from the transportation corridors, the highway network, and the railroad, there is recreational fishing use of freshwater streams in the Fairbanks Spur route. Major streams in the Susitna River basin that are home to major sport fishing activities are: Chulitna River, Montana Creek, Goose Creek, Sheep Creek, Caswell Creek, Little Willow Creek, Willow Creek, Little Susitna River and Fish Creek. Starting the second weekend in June, certain road-accessible streams in the Susitna River basin are open to king salmon fishing for four consecutive weekends. Peak sport-fishing pressure generally is concentrated in these four weekends. There is no commercial fishery in close proximity to any of the freshwater streams crossed by the Fairbanks Spur route.

The Fairbanks Spur route also has a variety of other recreational activities. There are a range of seasonal activities sponsored and facilitated by commercial, public, and private organizations. Sightseeing, hiking, hunting, photography, and bird-watching are the main recreational activities. There are numerous business enterprises along the Fairbanks Spur route, principally in the small communities situated beside the Parks Highway or Alaska Railroad. Many businesses are linked to the tourism industry.

The Fairbanks Spur route passes the Minto Flats State Game Refuge north of Nenana and travels down the eastern boundary of Denali National Park and Preserve. There is recreational-related travel in the transportation corridors. Denali State Park is on the southeast side of the national park. The master plan of the park designates this general area as being zoned primarily for maintaining the existing natural environment. The northern MSB along the Fairbanks Spur route has many recreational areas for dog mushing, snowmachining, and cross-country skiing especially between Hurricane and Broad Pass. Summer activities include hiking, fishing, floating and camping. The Chulitna River is growing in popularity for floating and boating trips. Byers Lake and Troublesome Creek are developed recreational sites within Denali State Park. Others recreational sites include Montana Creek, Willow Creek, and Deception Creek. Nancy Lake State Recreation Area is located four miles south of Willow Creek State Recreational Area. During the summer, the nearby Little Susitna Recreation River is used by boaters and bank fisherman and during the winter, the river is used for snowmachining.

7.3 Impacts to Fairbanks Spur Human Environment

7.3.1 Sociocultural Institutions

Historical and Archeological Properties

The Athapaskan sites along the Parks Highway have generally not been excavated by professional archaeologists. Four sites have been scientifically excavated and are completed projects: Teklanika West site, Dry Creek archaeological site, Carlo Creek site, and Nenana Gorge site (UAA 1971). Precise identification of archeological sites is prohibited by law as a conservation and protection measure against unlawful artifact removal. For this reason, maps identifying known cultural sites are not included in this report. These sites would be avoided along the Fairbanks Spur route. Employees and contractors would be trained to avoid archeological resources before mobilization and construction. New archeological sites and properties might be discovered during construction, especially along the areas near the Denali National Park and Preserve between Healy and Cantwell. If a cultural resource was discovered during construction, all activities would be stopped and a State Historic Preservation Office (SHPO) qualified archeologist would be contacted to evaluate the site's eligibility for the National Register of Historic Places. If a site were deemed significantly impacted, constructors would have to develop a mitigation plan in consultation with the SHPO.

Subsistence Areas

Impacts to subsistence harvests of fish and game may occur along the Fairbanks Spur route, from Nenana to Willow. While the biological habitat of moose, caribou, fish, and other species are described in Section 4, evaluation of impacts on affected communities would need to be conducted.

A spur pipeline construction project along the Parks Highway could potentially affect subsistence users. The impacts during construction would be related primarily to two factors: temporary disturbance to animals and their habitats, and the presence of a large construction work force (Cuccarese 1988).

Any proposed program of environmental mitigation for construction within the Fairbanks Spur route would address potential significant impacts to fish resources because of pipeline crossings of fish habitats. Construction schedules would have to consider peak periods for fishing and hunting. Because the Fairbanks Spur route would be generally constructed within or near existing transportation ROW, no significant restriction of access to subsistence resources would likely occur. In fact, construction has the potential to open access to lesser used areas.

Recreational Areas

Any proposed construction schedule would need to consider peak periods of human use for recreational and commercial fisheries, and other water-related recreation such as boating. Most of the Fairbanks Spur route would avoid disturbance to recreational areas such as Denali National Park and Preserve, Denali State Park, Nancy Lake Recreational Area, and Big Lake Recreational Area.

The principal nonwater related recreational activities are tourism-related, including hiking, wildlife viewing and hunting. Because the Fairbanks Spur route travels just inside the Denali National Park and Preserve's eastern boundary and would use existing transportation corridors, the major recreational areas for hunting and wildlife viewing from the national park to the MSB would not be significantly impacted.

7.3.2 Economic Institutions

Small and Large Businesses

It is anticipated that no business would be relocated during construction and operation of the spur pipeline. The Fairbanks Spur route avoids major metropolitan areas in Fairbanks and in the MSB, allowing for commercial and residential development to continue at regular pace and direction.

While using the transportation corridors along the Parks Highway near Denali National Park and Preserve, there could be some impact to tourism business if pipeline construction schedules have significant building occurring during the summer. While construction schedules might temporarily disrupt local highway and road patterns, significant construction during the winter would mitigate the effects on tourism schedules and businesses.

Recreational businesses in the Talkeetna and MSB area, related to sight-seeing, boating, and other water and nonwater related activities, would not be affected. Although the Fairbanks Spur route passes adjacent to major recreational areas (e.g. Denali National Park and Preserve, Denali State Park) it would not directly impact lands within those areas.

Entrepreneurship, just as it had during the 1970's construction of TAPS, might go through boom and bust cycles because of a large transient construction work force. Small businesses, especially near the Fairbanks and MSB areas, would experience significant differences in customer markets during and after construction of any spur pipeline along the Fairbanks Spur route.

Enhanced availability of natural gas supplies could benefit the following communities and groups on the Fairbanks Spur route: Nenana, Anderson/Clear AFS, Healy, McKinley, Cantwell, Trapper Creek, Talkeetna, Talkeetna "Y" (at the intersection of the Parks Highway and the road spur to Talkeetna), and Willow. It is estimated that approximately 5,410 housing units could create a demand for 3,320,045 cu ft/day by the year 2010, and a relatively small (commercial) demand is incorporated in that total figure (Table 8.14). The principal benefit would consist of lowered heating and lighting costs over the present reliance on fuel oil for local heating and electrical generating capacity. In addition, natural gas would have less environmental impact than other energy alternatives.

7.3.3 Demographics and Public Services

Transportation Patterns

There would be some temporary disruption of local highway and road traffic patterns, primarily on secondary roads near population centers from Nenana to Houston. Generally, pipeline crossings along transportation corridors would be accomplished via boring; therefore temporary blockage would primarily occur only on open-cut gravel roads, generally lasting no more than one day. In most cases for most other

roads, traffic would be able to pass through work sites, albeit with reduced lanes at certain periods, or through short detours. Otherwise, there would be no significant impacts to the highway systems and local roads in population centers.

Because the spur pipeline would avoid major metropolitan areas in Fairbanks and the MSB, local traffic would not be affected. Scheduling transportation of materials between Fairbanks and Southcentral Alaska would seek to avoid peak summer-use periods. Construction might have to be winter-heavy and summer-light to mitigate significant impacts on resource transportation along the highway or railroad during high road- or rail-freight months.

Fiscal Issues

The Alaska Constitution, in addition to prescribing forms of local government, requires the entire state be divided into organized and unorganized boroughs, based on standards such as natural geographic boundaries, economic viability and common interests. In general, organized boroughs have formed in those areas where economies were better developed. A large portion of the state has not incorporated into organized areas and carries the designation of unorganized borough.

If a local government forms in a portion of the unorganized borough within pipeline ROW, that local government would collect taxes from pipeline owners at that local government's tax levy rate, and the state would credit against its tax levy the amount paid to the local government. The construction and facilities operations of a spur pipeline would be subject to property tax levies in the incorporated jurisdictions through which the pipeline passes. Otherwise, spur pipeline derivative revenues in unincorporated areas, primarily state lands and Native lands, would be in the form of royalty and rental payments. Such revenue sources would not be very large in the case of property tax levies.

Quality of Life Impacts

As with other major construction projects that bring in workers from metropolitan areas or from outside of Alaska, social indicators would need to be analyzed to measure social impacts on certain communities. During the construction of TAPS, an increase in work force generally meant an increase in anti-social behavior, including crimes against persons and property. However, the TAPS workforce was significantly larger than the workforce that would be anticipated for the construction of a spur pipeline.

The Fairbanks Spur route avoids the major areas in Fairbanks and the MSB, however, many construction workers and contractors could take up short-term residence in Fairbanks and Wasilla along the route. No significant impact should be felt in these areas behavior because law enforcement and social standards are quite high in concentrated areas of population.

The same cannot be said for other communities along the Fairbanks Spur route. Places like Nenana, Healy, Cantwell, and Talkeetna, as well as other villages within the FNSB and Denali Borough, might have to cope with increased crime against persons, because of increased short-term residency of construction workers. This is because law enforcement in smaller population areas lacks the public safety resources to deal with enforcement. Some of the smaller communities do not have any law enforcement abilities whatsoever. Therefore, communities from Nenana to Talkeetna would have to depend on state-provided law enforcement and social services.

Cumulative Impacts

Subsistence and recreational fishing and hunting would not be significantly affected by the construction and operation of the spur pipeline.

Air quality would be minimally affected because the spur pipeline would be buried. During construction, airborne dust may increase, but would abate once construction operations were complete. Compressors would emit minimal exhaust into the air. There would be minimal impact to water resources.

Because the Fairbanks Spur route avoids major population centers in the FNSB and the MSB, there would be no harmful cumulative impacts to communities like Fairbanks, Willow, Houston and Wasilla regarding residential and commercial expansion. Beneficial cumulative impacts to the FNSB, the Denali Borough, and the MSB could result from easier and cheaper access to natural gas for both commercial and residential use. This would provide long-term economic benefits to both businesses and individual households as North Slope gas would serve communities along the Fairbanks Spur route. In the short term there would also be increased employment and business opportunities for local residents, Native organizations, and the State of Alaska.

7.4 Delta Junction Spur Affected Human Environment

7.4.1 Government Related Institutions

The Delta Junction Spur passes through an unorganized set of communities from Delta Junction down to Glennallen through the Richardson Highway. Once in Glennallen, the Delta Junction Spur goes down the Glenn Highway through the MSB to Palmer.

Richardson Highway Unorganized Communities

The Delta Junction Spur passes through or near three major communities Delta Junction, Paxon, and Glennallen. Delta Junction is a Second Class City with a population of about 1,000 residents. Delta Junction is located 95 miles southeast of Fairbanks at the interchange of the Alaska Highway and the Richardson Highway. Delta Junction provides services to summer tourist traffic, military operations, farming projects, and the Pogo Mine. Delta Junction's only taxing authority as a Second Class City is through a sales tax that brings in most of its revenue during the summer (ADCRA 2005).

Paxson is an unincorporated town with a population of approximately 37 (ADCRA 2005). It is located at the intersection of the Richardson Highway and the Denali Highway. There are five lodges in the area that serve summer and winter recreational users. This area has been a testing site for snowmachine companies for the past several years. Because it is unincorporated, it has no taxing authority. Most of Paxon's residents depend on subsistence harvest of fish and game as well as income derived from tourism.

Glennallen is another unincorporated town with a population of approximately 600. It is located at the junction of the Richardson and Glenn Highways, 189 road miles east of Anchorage. Glennallen is unincorporated and does not have any taxing authority (ADCRA 2005). Glennallen is the supply hub of the Copper River region. Recreational vehicle parks and lodging are businesses important to independent travelers in the area. The National Park Service's Wrangell-St. Elias Visitor Center and the Copper River Princess Wilderness Lodge were completed in 2002 at Copper Center. While tourism in the Wrangell-St. Elias National Park is a big economic interest in Glennallen, most of its residents also depend on subsistence harvests during the summer months. Ahtna serves most of the Wrangell-St. Elias region and is based in Glennallen (Ahtna 1973).

Matanuska-Susitna Borough Communities

The affected areas of the Delta Junction Spur route through the MSB include Eureka, Chickaloon, and Palmer. The MSB has a manager form of government with other governing bodies including the assembly and school board. Each community has its own city council. The MSB also includes the

Southcentral Foundation as its Native Health Corporation and some lands owned by CIRI. The tax base of the MSB has a mix of both property and sales tax levied by individual city governments (ADCRA 2005).

Eureka is not incorporated, but does provide tourist facilities including lodges, cafes and a gas station (Selkregg 1974).

Chickaloon has a population of about 300 and is located northeast of Sutton. A federally-recognized tribe is located in the community - the Chickaloon Village. The population of the community consists of 17 percent Alaska Native or part Native (Patterson 1981). Because of this status, Chickaloon has both a village corporation (Chickaloon-Moose Creek Native Association) and a village traditional council (Chickaloon Village Traditional Council). The Tribally-owned and operated Ya Ne Dah Ah, or "Ancient Teachings," School located in Moose Creek serves tribal members living in Chickaloon and surrounding communities.

Palmer is one of two major population centers in the southcentral region of the MSB (the other being Wasilla as described with the Fairbanks Spur route). It has an official population of approximately 5,500. Palmer serves many community councils (North Lakes, South Lakes, Gateway, Farm Loop, Lazy Mountain, Buffalo/Soapstone, Alpine) and has the largest farming community in the state. Palmer is the site of the Alaska State Fairgrounds.

7.4.2 Sociocultural Institutions

Historical and Archeological Properties

There are few known archaeological sites within or near the Delta Junction Spur route, and fewer are dated or contain culturally diagnostic artifacts. Most historical and archeological properties that have been excavated are located near Glennallen (within or near the Wrangell-St. Elias National Park) or within the Chickaloon Community Council area (Athapaskan sites) (Cook 1977). Precise public identification of archeological sites is prohibited by law as a conservation and protection measure against unlawful artifact removal. For this reason, maps identifying known cultural sites are not included in this report.

Subsistence Areas

Subsistence and associated values of sharing food and other resources is considered a critical part of being a resident of the Copper River area, especially for Athapaskans from the Tatlatan and Ahtna groups (Mathematical Sciences Northwest 1972). Hunting and trapping occur year-round in the eastern MSB area. Salmon, moose, and caribou are the primary subsistence resources for the area.

The Nelchina Public Use Area includes the Alpine Areas and Caribou Creek with populations of moose, caribou, Dall sheep, and other species. The Lake Louise State Recreation Area is used as winter feeding grounds for the Nelchina caribou herd, but is better known for its subsistence fishing (Reckord 1983a). The Matanuska Valley Moose Range located northeast of Palmer and southwest of the Nelchina Public Use Area, also serves as a subsistence area, especially for the residents of Chickaloon.

Recreational Areas

The Nelchina Public Use Area and the Matanuska Valley Moose Range Area serve not only as subsistence harvest areas, but also as major areas for sport fishing and hunting. State parks and recreation areas in or near the corridor of the Copper River basin and MSB are Long Lake, Moose Creek, Weiner Lake, Kings Mountain State Recreation Site, Coyote Lake, and 17 Mile Lake.

Glacier View and the Matanuska Glacier State Recreation Site provide ample opportunity for tourism-related recreational activities, including trails for backpacking, hiking, dog mushing, cross-country skiing, and sightseeing.

7.5 Impacts to Delta Junction Spur Human Environment

7.5.1 Government Institutions

In 2004, the USACE completed construction of the first phase of the Missile Defense Testbed Program (MDTP) at Ft .Greely. Delta Junction has received almost $20 million in federal funds related to the missile defense project, including money to build a new school on military property (ADCRA 2005). The MDTP is fully operational with 11 missiles installed by the end of 2006. Further, Ft. Greely also is the site of the U.S. Army's Cold Regions Test Center and the Donally Training area under construction.

It is anticipated that spur pipeline construction would not negatively impact Ft. Greely or the MDTP. However, construction of a spur pipeline in close proximity could be beneficial in providing an alternative energy source to the area. Consultation with the federal government would be needed to ensure construction of a pipeline would be coordinated with future military construction in the Ft. Greely area.

7.5.2 Sociocultural Institutions

Historical and Archeological Properties

The Athapaskan sites along the Glenn and Richardson Highways have generally been excavated by Native and other traditional groups, especially near Chickaloon and the Wrangell-St. Elias National Park.

Although Glennallen and the Wrangell-St. Elias National Park area would be avoided along the Delta Junction Spur, and most sites in Chickaloon have already been excavated, employees and contractors would be trained to avoid archeological resources before mobilization or construction. New archeological sites and properties might be discovered during construction, especially along the areas near the Richardson Highway between Paxson and Glennallen where very little underground construction has been conducted. If the proposed activities revealed cultural or paleontological resources all activities would have to be stopped and a SHPO qualified archeologist contacted so consultation per section 106 of the National Historic Preservation Act could proceed. If a site was deemed significantly impacted, constructors would need to develop a mitigation plan in consultation with the SHPO.

Subsistence Areas

Impacts to subsistence harvests of fish and game could occur along the Glenn Highway portion of the Delta Junction Spur route, from Glennallen to Palmer. The biological habitat of moose, caribou, fish, and other species are described in Section 4; however evaluation of impacts on individual communities would need to be conducted. Subsistence impacts would be temporary and limited to the period of spur pipeline construction. Because the project would involve a buried line, no cumulative impacts to subsistence fish or wildlife resources are anticipated.

In a worst-case scenario, affects to subsistence use could occur during construction and be negligible during operations. The impacts during construction would be related primarily to two factors: temporary disturbance to animals and their habitats, and the temporary presence of a large construction work force.

Any proposed program of environmental mitigation along the Delta Junction Spur route would need to address potential impacts to mammal resources because of pipeline crossings of moose and caribou habitats. Because the Delta Junction Spur would generally be constructed within or near existing

transportation ROW part, no significant restriction of access to subsistence resources would likely occur to the Nelchina Public Use Area or the Matanuska Valley Moose Range.

Recreational Areas

Any proposed construction schedule would need to consider peak periods of human use for recreational hunting and non-hunting activities, such as hiking, sightseeing, and camping. Most of the Delta Junction Spur route would avoid disturbance to recreational areas such as the Alpine Areas, Glacier View, Matanuska Glacier State Recreation Site, Lake Louise State Recreation Area and Glennallen access into Wrangell-St. Elias National Park.

The principal recreational activities are tourism related, including hiking, wildlife viewing and hunting. The Delta Junction Spur travels northwest of Glennallen, (the access point into the National Park) and uses existing transportation corridors. The major recreational areas for hunting and wildlife viewing from the national park to the MSB would not be significantly impacted.

7.5.3 Economic Institutions

Small and Large Businesses

Minimal business relocations would occur during construction and operation of the pipeline. The Delta Junction Spur route avoids population areas in Delta Junction, Glennallen, and in the MSB, allowing for commercial and residential development to continue at regular pace and direction, especially in the Palmer area.

While using the transportation corridors along the Glenn Highway, there might be some impact to tourism businesses if construction schedules had significant building going on during the summer months. While construction schedules would temporarily disrupt local highway and road patterns, significant construction during the winter months would mitigate the effects on tourism schedules and businesses.

Recreational businesses in Eureka, Glennallen, and Paxson, related to sight-seeing, hiking, hunting and nonwater-related activities, would not be affected because most of the Delta Junction Spur route does not directly cross major recreational areas, including the Nelchina Public Use Area and the Wrangell-St. Elias National Park.

The Pogo Mine is approximately 37 miles northeast of Delta Junction. Pogo is a world-class gold deposit expected to produce 400,000 ounces of gold per annum over a 10 year mine life. The spur pipeline project would not affect the operations of the Pogo Mine.

Entrepreneurship, just as it had during the 1970's construction of the TAPS, might go through boom-and-bust cycles because of a large influx of construction workers. Small businesses, especially near the Delta Junction, Glennallen, and Palmer would experience differences in customer markets during and after construction of a spur pipeline along the Delta Junction Spur route.

Enhanced availability of natural gas supplies would benefit three communities on the Delta Junction Spur: Glennallen, Ft. Greeley and Sutton. It is estimated that 1,300 housing units could be served by the year 2010 with a demand for 778,650 cu ft/day. Commercial and business demand would be relatively minor (Table 8.14).

The principal benefit would consist of lowered heating and lighting costs over the present reliance on fuel oil for local heating and electrical generating capacity.

7.5.4 Demographics and Public Services

Transportation Patterns

There would be some temporary disruption of local highway and road traffic patterns, primarily on secondary roads near population centers from Paxson to Chickaloon. Generally, spur pipeline crossings along transportation corridors would be accomplished by boring; therefore temporary blockage would primarily occur only on open-cut gravel roads, generally lasting no more than one day. For most other roads, traffic would be able to pass through work sites, albeit with reduced lanes at certain periods, or through short detours. Otherwise, there would be no significant impacts to the highway systems and local roads in population centers.

Because the spur pipeline route avoids major metropolitan areas in MSB (Palmer) as well as the interchange of the Glenn and the Richardson Highways, local traffic would not be affected in those areas. Looking at transportation of materials between Southcentral Alaska and Glennallen to Delta Junction, construction schedules might have to be winter-heavy and summer-light to mitigate significant impacts on resource transportation along the highway especially if more natural resource projects (timber and mining, especially) become a reality along the Richardson Highway.

Fiscal Issues

The Alaska Constitution, in addition to prescribing forms of local government, requires the entire state be divided into organized and unorganized boroughs, based on standards such as natural geographic boundaries, economic viability and common interests. In general, organized boroughs have formed in those areas where economies were better developed. A large portion of the state has not incorporated into organized areas and carries the designation of unorganized borough.

In 2002 the Alaska legislature directed the Local Boundary Commission (LBC) to determine which areas of Alaska's unorganized borough met the standards for incorporation of boroughs. The LBC reviewed conditions in the unorganized borough and reported to the legislature areas identified that met the standards for incorporation. The LBC report, *Unorganized Areas of Alaska that Meet Borough Incorporation Standards* (LBC 2003), identified seven regions in the unorganized borough that met standards for borough incorporation.

If a local government forms in a portion of the unorganized borough within pipeline ROW, that local government would collect taxes from pipeline owners at that local government's tax levy rate, and the state would credit against its tax levy the amount paid to the local government.

Delta Junction is currently examining the creation of a new borough. The LBC report recommended the creation of an Upper Tanana Basin Model Borough. The regions under review are large, with population densities that range between small communities and wilderness, making delivery of services greatly more expensive than in urban areas.

Quality of Life Impacts

As with any major construction project that bring in workers from metropolitan areas or from outside of Alaska, social indicators must be analyzed to measure social impacts on certain communities. During the construction of TAPS an increase in workforce generally meant an increase in anti-social behavior, including crimes against persons and property. However, the TAPS workforce was significantly larger than the workforce anticipated for construction of a spur pipeline.

The Delta Junction Spur route goes through the northwest population center of Palmer, and many construction workers could take up short-term residence in those population centers along the Delta Junction Spur route.

Places like Delta Junction, Paxson, Glennallen, Eureka, Sutton, and Chickaloon could experience increased crime against persons because of increased short-term residency of construction workers. This is because law enforcement in smaller population areas lacks the public safety resources to deal with enforcement. Therefore, communities from Delta Junction to Chickaloon would need to provide solutions to increased crime and other behavior associated with increased short-term increases in population.

Cumulative Impacts

The subsistence and recreational fishing within the Delta Junction Spur route would be minimally affected by the construction and operation of the spur pipeline. Impacts on subsistence and recreational hunting would be low. New areas of access along both the Richardson Highway into the Denali Highway, as well as better access into the Nelchina Public Use Area and the Matanuska Valley Moose Range would be beneficial to both subsistence and recreational user groups.

Air quality should not be affected over time because this pipeline would be buried. During construction, airborne dust could increase, but would abate once construction operations were complete. Compressors would emit minimal exhaust into the air. There would be no impact on water resources.

Although the end of the Delta Junction Spur route goes into the northwest area of Palmer, none of the other parts of the Delta Junction Spur route would have significant cumulative impacts on potential growth and expansion of residential neighborhoods and commercial business. Beneficial cumulative impacts to the FNSB, the Denali Borough, and the MSB could result from easier and cheaper access to gas needs for both commercial and residential use. This would provide long-term economic benefits to both businesses and individual households as North Slope gas continued to serve communities along the Delta Junction Spur route. In the short-term there would also be increased employment and business opportunities for local residents, Native organizations, and the State of Alaska.

7.6 General Conclusions

As with all other subjects discussed in this report, any potential future project sponsor would need to conduct further research and study with regard to the socioeconomic impacts that would accompany the construction and operation of a natural gas spur pipeline between the ANS pipeline and Southcentral Alaska. This would begin with the development of a public outreach program. A public outreach program would be used to introduce potentially impacted communities and stakeholders to the project and would also provide an opportunity for the communities to express concerns or questions regarding the project. A public outreach program would provide a project sponsor with a clearer picture of the communities that would be affected as well as the potential impacts, both positive and negative, that could occur.

Section 8. Delivered Cost of North Slope Gas to Southcentral Alaska

8.1 Introduction

This section addresses the delivered price of gas to Southcentral Alaska for both Fairbanks and Delta Junction Spur routes to allow comparison to current prices of natural gas in this region and make possible a meaningful cost/benefit analysis of the spur pipeline project. Delivered price of gas to Southcentral Alaska was estimated based on the "base case" pricing and gas demand premises contained in the Gas Market Assessment; preliminary pipeline alignments developed for the Fairbanks and Delta Junction Spur routes; specific pipeline configurations for Gas Scenarios 1 and 2 that were selected jointly by the NETL, the Advisory Committee and contractor team; capital and operating expense estimates for these selected configurations; and economic evaluations completed by financial consultants from the brokerage firm AG Edwards.

A fundamental premise of the Gas Market Assessment is that the price of gas entering the ANS pipeline on the North Slope will be equal to the price of gas at the pipeline terminus near Chicago minus the pipeline tariff. Delivered price of gas to Cook Inlet was estimated as the sum of the price of gas entering the ANS pipeline, tariff to transport gas through the ANS pipeline to the spur pipeline take-off point, and tariff for the spur pipeline project including gas processing facilities at both ends of the pipeline. Collectively, the approach adopted in the Gas Market Assessment and methodology for estimation of delivered gas price in Southcentral Alaska result in the price of gas in Southcentral Alaska being tied to the price of gas near Chicago, with the difference being the respective tariffs along the ANS and spur pipeline systems.

The purpose of this study is to prepare information for use as a basis for any eventual route and pipeline selection. **Recommendations for a specific route and/or a pipeline and compression configuration for the spur pipeline are outside the scope of work for this study and are not contained in this report. This section describes the process used to select a pipeline and station configuration solely for the purpose of estimating delivered price for natural gas in Southcentral Alaska. Final selection of a spur pipeline alignment, pipeline size, cost estimates and tariff calculations would be conducted by the spur pipeline project commercial sponsor.**

8.2 Selection of Pipeline Configurations for Tariff Calculations

Selection of pipeline and station configurations for calculation of project tariffs for Gas Scenarios 1 and 2 were based on:

- Comparative COS values from J-curve analyses;
- Ability to provide for the option of future transport of NGLs (Gas Scenario 1 only);
- Potential for capacity expansion;
- Estimated capital costs through start-up to provide the initial 110 MMscfd of utility gas flow; and
- Estimated cumulative capital costs through late life to accommodate 350 MMscfd of utility gas flow during both summer and winter operation.

Selection of the pipeline configurations for use as the basis for calculation of delivered price to Southcentral Alaska for Gas Scenarios 1 and 2 was made during the mid-project review meeting held in

Anchorage on May 4, 2006. NETL representatives, the Advisory Committee and contractor team all agreed at this time that delivered price estimates would be based on the use of 20 inch 2500 psig pipelines for both the Fairbanks and Delta Junction Spur routes and for both Gas Scenarios 1 and 2.

8.2.1 Gas Scenario 1

Both low- and high-pressure pipelines can be considered for Gas Scenario 1 because it is based on the flow of utility gas, and condensation of hydrocarbon liquids within the pipeline is not an issue. A high-pressure pipeline was selected in order to provide the opportunity for future transport of natural gas enriched with non-methane hydrocarbons.

J-curves for 18, 20 and 24 inch were reviewed as described in Section 3.6.5 and the 24 inch option was quickly excluded. Capital costs from the J-curve analyses for 18 and 20 inch high pressure pipelines at start-up and late life (Table 8.1) were compared.

Table 8.1: Capital Costs for Pipeline Options, Gas Scenario 1

		Pipeline	Stations	Total
18 inch high pressure				
110 MMscfd – number of stations			0	
-capital expense	$MM	778	0	778
350 MMscfd – number of stations			1–Taurus 60	
-capital expense	$MM	778	38	816
20 inch high pressure				
110 MMscfd - number of stations			0	
-capital expense	$MM	841	0	841
350 MMscfd - number of stations			0	
-capital expense	$MM	841	0	841

It was acknowledged at the May 4, 2006 meeting that a 20 inch diameter high-pressure pipeline would likely be less economic than an 18 inch diameter high pressure pipeline for Gas Scenario 1. J-curve COS values for a 20 inch diameter high-pressure pipeline are greater than those for an 18 inch diameter high-pressure pipeline at all flows except the largest that will occur late in the project life and the capital costs for the 20 inch pipeline are greater. The 20 inch pipeline was selected in order to provide for future expansion of gas flow.

8.2.2 Gas Scenario 2

A high-pressure pipeline is required for Gas Scenario 2 in order to transport enriched natural gas in the dense phase to prevent hydrocarbon liquid condensation within the pipeline. Pipelines of 24 inch diameter or greater were excluded because the COS values for a 24 inch pipeline exceeded that of a 20 inch pipeline over all flow rates for Gas Scenario 2 (see Section 3.7). Economics for the 18 and 20 inch diameter pipelines would likely be approximately the same because the J-curves for these options cross within the flow range of Gas Scenario 2 and the early and late life capital costs are similar. The 20 inch diameter pipeline was selected over the 18 inch pipeline for the purposes of tariff calculations because it has more potential for flow expansion and would be easier to operate because of fewer compressor stations.

Table 8.2: Capital Costs for Pipeline Options, Gas Scenario 2

Gas Scenario 2, Summer	Units	Pipeline	Stations	Total
18-inch high pressure				
110 MMscfd – number of stations			1-Taurus 70	
-capital expense	$MM	778	36	814
350 MMscfd – number of stations			4–Taurus 60	
-capital expense	$MM	778	127	905
20-inch high pressure				
110 MMscfd - number of stations			0	
-capital expense	$MM	841	0	841
350 MMscfd - number of stations			2-Taurus 70	
-capital expense	$MM	841	68	909
Volumes refer to utility gas delivery.				

8.3 Economic Analysis Approach

Delivered prices of North Slope gas to Southcentral Alaska were estimated for both Fairbanks and Delta Junction Spur options. A 20 inch diameter pipeline with a design pressure of 2,500 psig was selected for the purpose of calculation of the price of North Slope gas delivered to Southcentral Alaska for both Gas Scenarios 1 and 2. The price of gas delivered to Southcentral Alaska was calculated as the sum of:

- Price of gas entering the ANS gas pipeline to Alberta on the North Slope;
- Tariff to transport spur pipeline gas through the ANS pipeline to the spur pipeline take-off point;
- Spur pipeline tariff including capital and operating costs for the associated gas plants.

A ROE analysis was completed to determine tariffs for the spur pipeline and associated gas processing plants. Material balances were completed to establish flow rates and compositions on an annual basis for the ANS pipeline and spur pipeline systems. The composition of utility gas delivered via the spur pipeline to Cook Inlet would vary to a limited extent depending on the composition of gas in the main ANS pipeline and operation of the NGL extraction plant at the spur pipeline inlet. Material balances for Gas Scenario 1 were configured to deliver the thermal rate of the utility gas shown in Appendix 3-1 regardless of gas composition.

Hydraulic simulations of Fairbanks and Delta Junction Spur pipelines were conducted to determine when compressor stations would be needed as a function of flow and thereby establish capital outlay schedules. Capital cost estimates were prepared for the spur pipeline and compressor stations. Capital costs for the gas plants were based on information from an ANGDA report. ROE analyses were completed by financial consultants of the brokerage firm AG Edwards.

Economic analysis methods used to estimate the delivered price of gas in Cook Inlet differ significantly from those used in the J-curve analysis. The spur pipeline tariff reflects the overall project including associated gas processing plants. The impact of flow ramp-up was addressed, whereas J-curve data is based on the assumption that flow will remain constant throughout the life of the project. Tariffs were generated using a ROE analysis method more typical of industry practices than the ROI analysis used in the J-curve analysis.

8.4 Pipeline Hydraulic Simulations

One hydraulic simulation was completed for each of the Fairbanks and Delta Junction Spur routes to verify that no compressor stations are required on a 20 inch diameter 2,500 psig pipeline for Gas Scenario 1. Three hydraulic simulations were conducted for both Fairbanks and Delta Junction Spur routes to determine the maximum flow with no compressor stations, one station and two stations for Gas Scenario 2. The hydraulic analyses were used to determine when compressor stations would be installed to accommodate the progressively increasing pipeline throughput per Gas Scenario 2.

8.4.1 Minimum Pipeline Operating Pressure

Gas Scenario 1 is based on transport of utility gas, thus the minimum operating pressure of the spur pipeline can be set without consideration of condensation of hydrocarbon liquids and generation of slug flow within the pipe. Based on information from ENSTAR, it was assumed that gas delivered via the spur pipeline to Cook Inlet would enter the 20 inch diameter ENSTAR pipeline near Palmer at 800 psig.

Gas Scenario 2 is based on the transport of a base load of NGL plus progressively increasing amounts of methane destined for delivery in Cook Inlet as utility gas. Gas composition, shape of the phase envelope, and maximum pressure at which both gas and liquid phase can coexist, known as the cricondenbar (Section 2.2.4), would vary over the life of the project for Gas Scenario 2.

Gas hydraulic simulations for Gas Scenario 2 were prepared by adjusting flow and compressor stations so that the minimum pipeline operating pressure at any location along the pipeline would be approximately 150 psi above the cricondenbar of the gas being transported. Minimum pipeline operating pressures as a function of flow per for Gas Scenario 2 are shown in Table 8.3.

Table 8.3: Gas Scenario 2 – Minimum Operating Pressures

Approximate Pipeline Inlet (MMscfd)	Utility Gas Delivered (MMscfd)	Cricondenbar (psia)	Minimum Pipeline Pressure (psig)
330	110	1,080	1,215
380	150	1,155	1,290
430	200	1,220	1,355
480	250	1,265	1,400
530	300	1,290	1,425
590	350	1,305	1,440
640	400	1,315	1,450
690	450	1,315	1,450

8.4.2 Pipeline Alignments and Elevation Profiles

Alignments for the proposed Fairbanks and Delta Junction Spur routes are discussed in Section 4. Proposed locations of compressor stations provide reasonably uniform pressure drop between stations accounting for the impact of elevation changes on operating pressure (Section 2.2.4). Elevation profiles of the selected spur pipeline routes are shown in Figure 8.1.

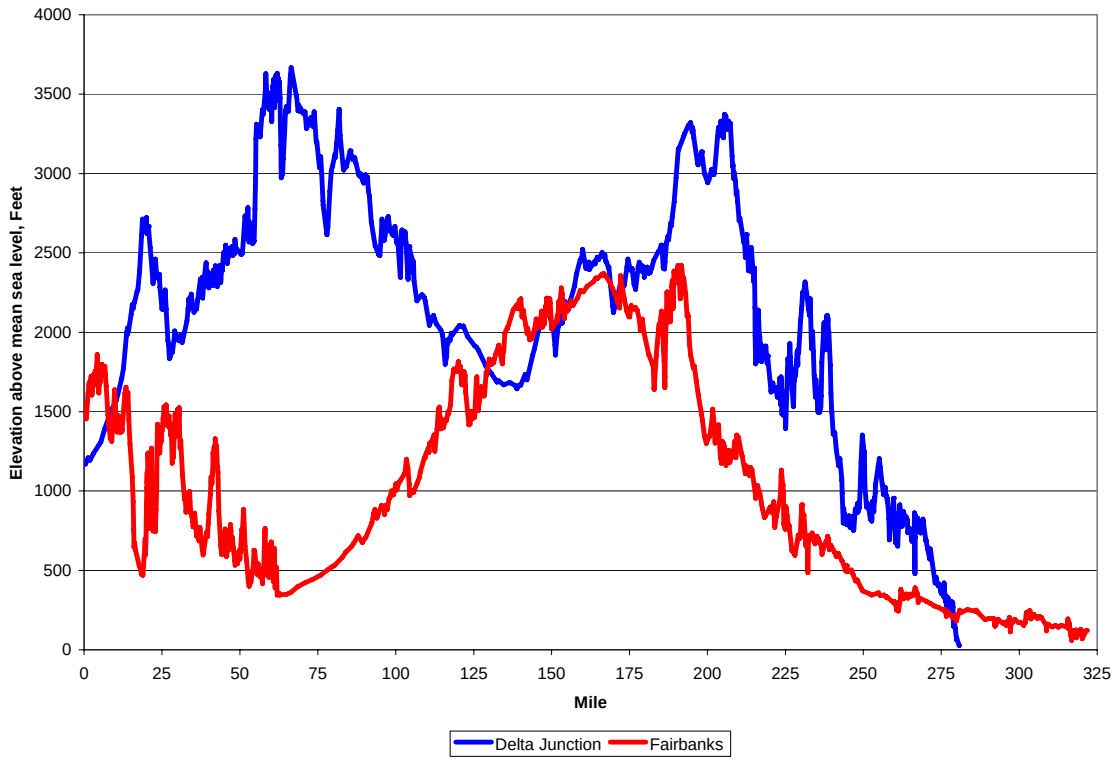


Figure 8.1: Elevation Profiles for Spur Pipeline Routes

8.4.3 Hydraulic Simulation Results

Results of the hydraulic simulations for both spur pipeline routes during summer operations are shown in Table 8.4. At similar pressure profiles and installed compression power, the capacity of the Delta Junction Spur pipeline would be greater than that of the Fairbanks Spur pipeline because it is approximately 40 miles shorter.

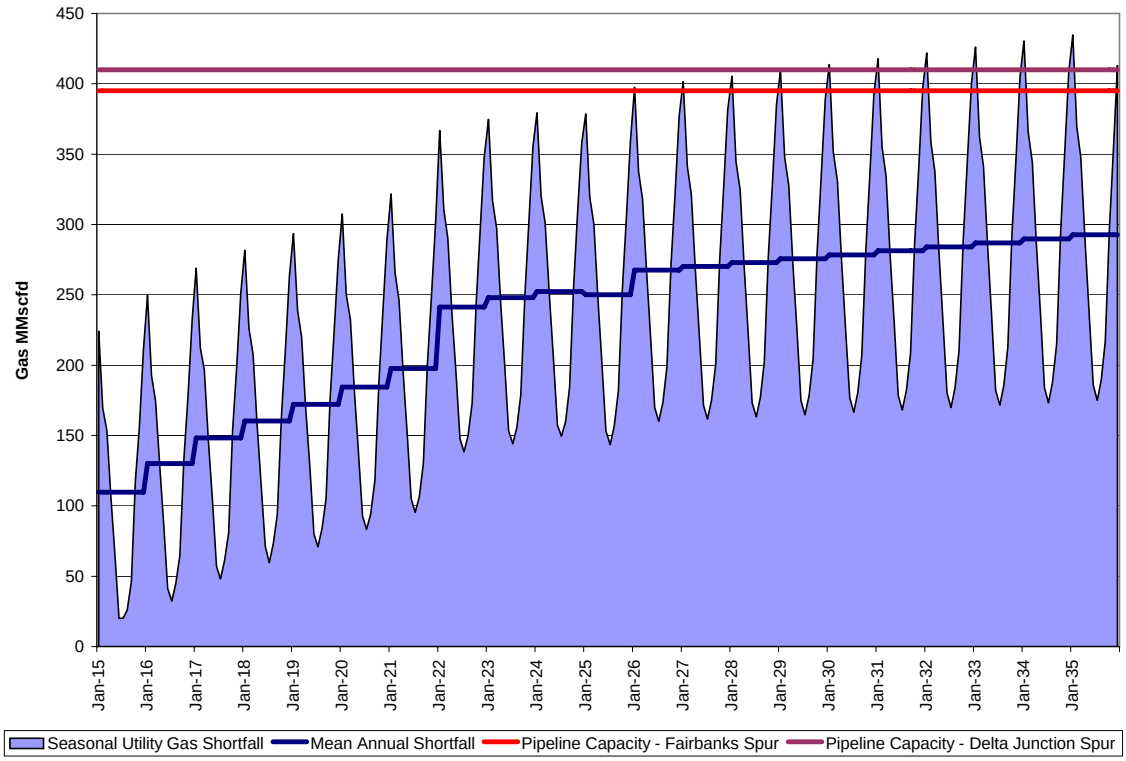
No compressor stations are required along the 20 inch, 2,500 psig pipeline to transport 350 MMscfd of utility gas per Gas Scenario 1. Two compressor stations were required for both routes per Gas Scenario 2 in order to provide 350 MMscfd of utility gas and NGLs to Cook Inlet. Spur pipeline capacities significantly greater than 350 MMscfd of utility gas would be achieved when both compressor stations are utilized to their full capacities.

Pipeline operating profiles for Gas Scenarios 1 and 2 are presented in Appendix 8-1. Locations along the pipeline at which compressor stations would likely not be installed are referred to as “restricted” on the operating profiles. Identical turbine-driven gas compressor sets were used for both the Fairbanks and Delta Junction Spur route options.

Relationships between spur pipeline capacity, Cook Inlet utility gas demand and NGL demand for Gas Scenarios 1 and 2 are shown in Figure 8.2 and Figure 8.3, respectively. Spur pipeline capacities reflect the maximum flow at the inlet of the spur pipeline before consideration of fuel for compressor stations and gas processing facilities. Demand shown on these figures reflects quantities delivered to Cook Inlet.

Table 8.4: Hydraulic Simulation Results - Summer Spur Pipeline Capacity

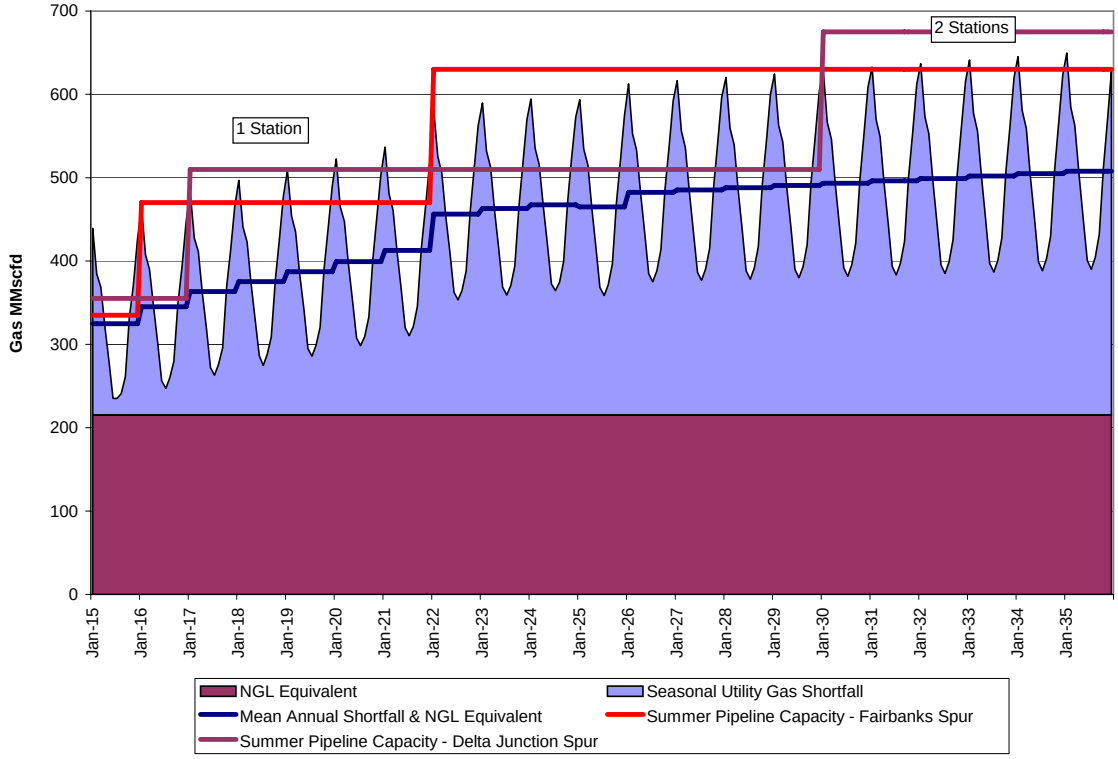
	Fairbanks (MMscfd)	Delta Junction (MMscfd)
Gas Scenario 1		
No Stations	395	410
Gas Scenario 2		
No Stations	335	355
1 Station	470	510
2 Stations	630	675



NOTE: Labels on x axis are in years (i.e. 2015 – 2035).

Figure 8.2: Cook Inlet Demand and Summer Spur Pipeline Capacity, Gas Scenario 1

Demand values shown in Figure 8.2 and Figure 8.3 reflect seasonal swings in demand, but not the peak daily demand that may be encountered. Pipeline capacity would increase during the winter and it was assumed that shortfalls in between pipeline capacity and seasonal demand would be made up with gas from LNG imports and in-ground gas storage. A discussion of the Cook Inlet gas storage is presented in Section 8.11.



NOTE: Labels on x axis are in years (i.e. 2015 – 2035).

Figure 8.3: Cook Inlet Demand and Summer Spur Pipeline Capacity, Gas Scenario 2

An evaluation of on-line availability of the spur pipeline is outside the scope of this report. Capital costs for pipeline compressor stations include the installation of an off-line spare gas compressor. All hydraulic results are based on 100 percent on-line availability of the pipeline, compressor stations and associated gas plants.

Spur pipeline capacity would be less in the summer than winter because flow varies inversely with gas temperature and the flowing temperature of the gas would be greater during the summer. Summer pipeline capacities were used for the assignment of compressor stations thereby providing a degree of conservatism regarding installed capacity.

Spur pipeline flow per Gas Scenario 2 exceeds that of Gas Scenario 1 because of spiking of approximately 215 MMscfd gas equivalent of NGL into the gas. Compressor stations for Gas Scenario 2 were assigned whenever the average annual gas demand exceeded the summer pipeline capacity.

Two compressor stations are required to accommodate late-life flow rates for both the Fairbanks and Delta Junction Spur options per Gas Scenario 2. Station locations were selected in order to achieve the maximum possible flow through the respective pipelines even if the resulting flow rate was well in excess of the mean annual Cook Inlet demand.

Both spur pipeline options require installation of one compressor station shortly after project start-up for Gas Scenario 2. The second station for the longer Fairbanks Spur is required earlier than with the Delta Junction Spur option, but still many years after project start-up as shown in Figure 8.3. The capacity of the Delta Junction Spur with one station is just marginally short of handling late life flow rates. Because

of relatively late dates at which the second stations are required and time value of money, the impact of the second station on project economics would be inconsequential.

8.5 Gas Plant Modeling

Process simulation work required to determine component recoveries within the gas plants was outside of the scope of work for this study. Component recoveries for gas processing plants at the spur pipeline inlet are shown in Table 8.5 and were set based on information contained in the "Spurline Terminal Conceptual Design" report prepared by Shaw - Stone & Webster Management Consultants, Inc. (hereafter referred to as the Spurline Terminal Design Report) and the team's judgment. The component NGL recoveries apply to both Gas Scenarios 1 and 2.

Table 8.5: NGL Plant Component Recovery Efficiencies

	Gas Market Assessment	NGL Extraction Plant at Inlet	Cook Inlet Plant (Gas Scenario 2 only)
Carbon Dioxide (CO_2)	N/A	40%	40%
Methane (C_1)	N/A	C_1/C_2 = 0.025	C_1/C_2 = 0.005
Ethane (C_2)	95%	90%	90%
Propane (C_3)	100%	99%	99%
Butane & heavier (C_{4+})	100%	100%	100%

Cryogenic gas plants are generally designed to reject essentially all methane to the plant residue gas while recovering a large percentage of ethane and heavier components. A methane-to-ethane ratio of 0.5 percent was assumed for the Cook Inlet plant to reflect production of a typical "de-methanized" NGL product. A methane-to-ethane ratio of 2.5 percent was assumed for NGL extraction plant at the spur pipeline inlet because a distinct cut between methane and ethane is not necessary at this facility.

Tariff calculations are based on the premise that no carbon dioxide removal equipment would be installed at the NGL extraction plant at the spur pipeline inlet. Carbon dioxide extracted along with the NGL is returned to the ANS pipeline per Gas Scenario 1 and would result in a reduction of the concentration of carbon dioxide in the spur pipeline gas as compared to the plant feed. Carbon dioxide contained in the NGL spiked into the spur pipeline gas per Gas Scenario 2 would increase in carbon dioxide concentration in the spur pipeline gas.

Carbon dioxide would end up in the NGL product and ultimately in the ethane product if the NGL is fractionated. Tariff calculations are based on the premise that facilities would not be installed at Cook Inlet to remove carbon dioxide from the plant feed, utility gas or NGL product(s). This means that the burden for carbon dioxide removal from NGL products would fall to the entities that receive the NGL from the spur pipeline project.

Combined concentrations of carbon dioxide and nitrogen of 7.4 percent during the first year of operation gradually decreasing to 3.3 percent at project end (33 years later) are predicted per material balances completed for Gas Scenario 2. A typical utility gas specification allows 3 percent inert gases, which includes both nitrogen and carbon dioxide. The tariff calculations in this report are based on the premise that carbon dioxide concentrations in excess of 3 percent would be allowed in the utility gas.

8.6 Price of Conditioned Gas entering the ANS Pipeline on the North Slope

The price of conditioned gas entering the ANS pipeline on the North Slope was set at $3.20/MMbtu per the Base Case presented in the Gas Market Assessment. Per the Assessment, the long-term price of natural gas in the Lower 48 and Alberta is projected to be between $5.00 and $6.00/MMbtu. A tariff of $2.30/MMbtu for the ANS pipeline from the North Slope to Chicago operating at a rate of 4.5 Bcfd was estimated in the Gas Market Assessment. Subtracting a $2.30/MMbtu tariff from the $5.50/MMbtu average of Base Case Lower 48 prices yields a price of $3.20/MMbtu for conditioned gas entering the ANS pipeline at the North Slope.

8.7 Tariff for Transport of Spur Pipeline Gas through the ANS Pipeline from North Slope to Spur Pipeline Take-off Locations

Appendix C of the Gas Market Assessment contains information regarding tariffs for spur pipeline gas transported through the ANS pipeline from the North Slope to Fairbanks. The tariffs on the spur pipeline gas per the Gas Market Assessment were calculated based on the premise that downstream consumers would incur no adverse economic impacts because of gas removed from the ANS pipeline for the spur pipeline. Tariffs on spur pipeline gas transported through the ANS 4.5 Bcfd pipeline to Fairbanks estimated in the Gas Market Assessment were essentially constant at $0.53/Mcf over the range of gas off-take rates for Gas Scenarios 1 and 2. Adjusting this volumetric based tariff to a thermal basis subject to the rich gas scenario (1,116 btu/scf per Table 3.1) equates to $0.47/MMbtu.

The tariff through the ANS pipeline will be larger for the Delta Junction than the Fairbanks option because the spur pipeline gas is transported a longer distance through the ANS pipeline. The tariff through the ANS pipeline to Delta Junction (540 miles) was estimated by adjusting the $0.47/MMbtu tariff from ANS to Fairbanks (450 miles) by the ratio of the respective pipeline distances. A tariff of $0.57/MMbtu was used for transport of ANS gas to Delta Junction.

8.8 Tariff for the Spur pipeline and Associated Gas Plants

Tariffs were calculated for the overall spur pipeline project including gas processing facilities located at the ends of the pipeline. Tariffs were based on project specific material balances and capital cost estimates that include an estimate of owner costs, but do not contain a contingency. The quality of the pipeline capital cost estimates is +/- 30 percent and sponsors may wish to add a contingency depending on their tolerance for risk. The quality of the capital cost estimates for the gas plants was not stated in the reference document from which the estimates were obtained.

8.8.1 Capital and Operating Costs – Spur Pipeline and Stations

Pipeline Capital and Operating Costs

Pipeline capital costs for the Fairbanks Spur were estimated based on an alignment which differed from that used for the J-curve analyses. A capital cost estimate for a 20 inch high pressure pipeline from Delta Junction to Palmer was developed according to the same methodology used for the Fairbanks Spur. Budget level capital cost estimates for the 20 inch high pressure Fairbanks and Delta Junction Spur pipelines are shown in Table 8.6 and Table 8.7. Details of the spur pipeline estimates are contained in Appendix 8-2.

Table 8.6: Budget Level Capital Cost Estimate for 20-inch Delta Junction Spur pipeline (millions of dollars 2006)

	Summer	Winter	Total
Direct contractor costs	98	61	160
Indirect contractor costs	46	33	79
Sub-total contractor costs	145	94	239
Mark-up (20% overhead & profit)	29	19	48
Total contractor costs	174	113	286
Material costs	129	84	212
Miscellaneous	44	35	78
Project indirect costs	59	40	99
Sub-total pipeline costs	405	271	676
Ownership costs at 8%			54
Contingency			0
Total construction costs			730
Cost per mile (281.8 miles)			2.6

Table 8.7: Budget Level Capital Cost Estimate for 20-inch Fairbanks Spur pipeline (millions of dollars 2006)

	Summer	Winter	Total
Direct contractor costs	118	70	188
Indirect contractor costs	37	26	63
Sub-total contractor costs	155	96	251
Mark-up (20% overhead & profit)	31	19	50
Total contractor costs	186	115	302
Material costs	148	88	236
Miscellaneous	31	34	66
Project indirect costs	69	45	114
Sub-total pipeline costs	434	283	717
Ownership costs at 8%			57
Contingency			0
Total construction costs			774
Cost per mile (322)			2.4

Tariff calculations were based on the same schedule of pipeline capital cost outlays developed for the J-curve analyses. The schedule reflects a typical bell curve of capital outlays for pipeline projects. Five percent of the total capital outlay was assumed to occur in the fourth year before start-up with the remaining 25, 45, and 25 percent of total outlay occurring in years 3, 2, and 1 prior to start-up, respectively.

Spur pipeline operating costs excluding compressor stations were estimated based on the experience of ENSTAR regarding operation of their pipelines in the Cook Inlet region. ENSTAR estimates the annual operating cost of their gas transmission pipelines in the Cook Inlet area at approximately $6,000 per pipeline mile. Application of this factor over the length of the spur pipelines equates to an annual operating costs of approximately $2 million. However, operating costs included in this study, for the spur pipelines were increased over that experienced by ENSTAR (as described above) to account for the more

remote location of the spur pipeline relative to maintenance support infrastructure located in the Cook Inlet area. Much of ENSTAR's system can be readily accessed from Anchorage, Wasilla or Kenai. Much of the Fairbanks and Delta Junction Spur routes traverse locations remote from pipeline maintenance support infrastructure in the Cook Inlet region. Economic assessment of whether all portions of the selected spur pipeline route would be accessed from Cook Inlet based maintenance or redundant maintenance infrastructure installed remote from Cook Inlet is outside the scope of work for this report. Pending such future economic evaluation, an annual operating expense of $5 million was used in the calculation of the spur pipeline tariffs to ensure that operating costs were not understated.

Station Assignment, Capital and Operating Costs

Capacity of a 2,500 psig, 20 inch pipeline is large enough to handle the largest annual average gas flow for Gas Scenario 1 without any compressor stations (Figure 8.2). Compressor stations were assigned to the spur pipeline for Gas Scenario 2 as shown in and Table 8.8 and Table 8.9. The pipeline hydraulics were based on the use of Taurus 70 turbine-driven compressor sets.

Capital costs for compressor stations were determined essentially in the same manner as that used for the J-curve analyses (Appendices 3-2 and 3-5). It was assumed that a fully redundant off-line turbine compressor set would be installed at each station. The cost for a spare off-line turbine compressor set was included if one or more compressor stations were required.

It was assumed that gas chilling would be required for both of the compressor stations along the Delta Junction Spur, but on just one of the stations along the Fairbanks Spur because of the respective soil conditions along the routes. Capital costs for refrigeration were estimated as $2,181 per installed hp of refrigerant compression. The difference in station capital costs between the Fairbanks and Delta Junction Spur routes is primarily because of incremental chilling equipment assigned to the Delta Junction Spur.

Table 8.8: Compressor Station Capital Costs, Fairbanks Spur, 2005 (millions of dollars 2005)

	1 Station MP 110.7	2 Stations		
		Station 1 MP 110.7	Station 2 MP 289.4	Total
Turbine compressor sets ($M)	11.3	11.3	11.3	22.5
Refrigeration ($M)	5.0	7.3	0	7.3
General station costs ($M)	22.6	22.6	22.6	45.1
Spare turbine compressor ($M)	4.7	4.7	0	4.7
Total ($M)	43.5	45.8	33.8	79.6
Pipeline capacity (MMscfd)	470			630
Year commissioned	2016			2022
Incremental capital outlay ($M)	43.5			36.1

Table 8.9: Compressor Station Capital Costs, Delta Junction Spur, 2005 (millions of dollars 2005)

	1 Station MP 63.9	2 Stations		
		Station 1 MP 63.9	Station 2 MP 165.1	Total
Turbine compressor sets ($M)	11.3	11.3	11.3	22.5
Refrigeration ($M)	3.8	6.4	7.0	7.3
General station costs ($M)	22.6	22.6	22.6	45.1
Spare turbine compressor ($M)	4.7	4.7	0	4.7
Total ($M)	42.3	44.9	40.8	85.7
Pipeline capacity (MMscfd)	510			675
Year commissioned	2017			2030
Incremental capital outlay ($M)	42.3			43.4

The annual non-fuel operating costs for compressor stations were estimated at five percent of the installed capital.

Pipeline Compressor Station Fuel

It was assumed that the fuel for compressor stations per Gas Scenario 2 would be extracted from the pipeline and processed locally at the station to remove NGL hydrocarbon components as the pressure of the gas was reduced to that of the fuel system.

Pipeline gas per Gas Scenario 2 is highly enriched with non-methane hydrocarbons and the composition would change over the life of the project. Specification of fuel conditioning facilities is outside of the scope of work for this study. Approximations of compressor fuel compositions were estimated individually for each 50 MMscfd of flow from early to late life using a simple process simulation of a J-T type facility with mechanical refrigeration.

Fuel consumption would have a minor impact on the material balance for the spur pipeline project. For simplicity of calculation, an arithmetic average of the simulated fuel compositions modeled over the life of the project was used for the tariff calculations. The early, late and average compressor fuel gas compositions are shown in Table 8.10.

Table 8.10: Approximation of Compressor Fuel Composition

	Early Life	Late Life	Arithmetic Average
Utility Gas (MMscfd)	110	350	110, 150, 200, 250, 300 & 350
Mole %			
Carbon Dioxide (CO_2)	5.04	2.72	3.64
Nitrogen (N_2)	0.82	0.64	0.70
Methane (C_1)	72.68	79.43	76.36
Ethane (C_2)	19.76	14.50	17.04
Propane (C_3)	1.65	2.58	2.17
I-butane	0.03	0.07	0.05
N-butane	0.02	0.06	0.04
Pentane +	0	0	0
Total	100.00	100.00	100.00
HHV (btu/scf)	1,127	1,128	1,130

Pipeline operation was simulated in the same manner as that to support the J-curve analyses (Appendix 3-7). Compressor station fuel was estimated based on the operating hp of the turbine drivers for the gas and refrigerant compressors. Pipeline fuel consumption for both the Fairbanks and Delta Junction Spur routes was approximately 0.25 percent and 0.5 percent of the pipeline inlet on a thermal basis for operation with one and two stations, respectively. Details of the fuel calculations are shown in Table 8.11 and Table 8.12.

Economic calculations, including fuel consumption, are expressed on a thermal basis because of the compositions of the ANS pipeline gas, spur pipeline gas and utility grade gas vary significantly. The heating value of the spur pipeline gas per Gas Scenario 2 is much higher than either the ANS pipeline gas or natural gas typically transported via Lower 48 pipelines. Gas flow efficiency increases with pipeline operating pressure (Section 2.2.4). Compression power varies with the ratio of discharge to suction pressure and fuel consumption per unit of gas transported would be expected to be less for a high pressure spur pipeline than for a lower pressure gas pipeline in the Lower 48. Spur pipeline fuel consumptions rates may appear lower than a typical Lower 48 gas pipelines when expressed as a thermal percent of inlet because of the combination of high gas heating value and high-pressure operation.

Table 8.11: Pipeline Station Fuel Calculations – Fairbanks Spur Pipeline

	Units	1 station	2 stations	2 stations	Total 2 stations
Station milepost		111	111	209	
Pipeline inlet					
Volumetric rate	MMscfd	470			630
Heating value	btu/scf	1,508			1,366
Thermal rate	Tbtu/yr	258.7			314.1
Fuel gas					
HHV	btu/scf	1,130	1,130	1130	
LHV	btu/scf	1,023	1,023	1023	
Fuel gas – gas compression					
Gas turbine hp for fuel	hp	4,930	8,404	7982	
Gas turbine operating heat rate	btu/hp-hr	7,309	7,309	7297	
Gas turbine fuel	MMscfd	0.85	1.44	1.37	2.81
Fuel gas – refrigerant compression					
Gas turbine hp for fuel	hp	2,043	,2981		
Gas turbine operating heat rate	btu/hp-hr	7,960	7,960		
Gas turbine fuel	MMscfd	0.38	0.56		0.56
Total fuel consumption					
Volumetric rate	MMscfd	1.23			3.37
HHV	btu/scf	1,130			1,130
Thermal rate	Tbtu/yr	0.51			1.39
Fuel as percent of inlet	Thermal %	0.20			0.44
Fuel rate used in material balances	Thermal %	0.25			0.50

Table 8.12: Pipeline Station Fuel Calculations – Delta Junction Spur

	Units	1 station	2 stations	2 stations	Total 2 stations
Station milepost		64	64	165	
Pipeline inlet					
Volumetric rate	MMscfd	510			675
Heating value	btu/scf	1,465			1,366
Thermal rate	Tbtu/yr	272.9			336.6
Fuel gas					
HHV	btu/scf	1,130	1,130	1,130	
LHV	btu/scf	1,023	1,023	1,023	
Fuel gas – gas compression					
Gas turbine hp for fuel	hp	4,290	8,247	8,711	
Gas turbine operating heat rate	btu/hp-hr	7,324	7,324	7,288	
Gas turbine fuel	MMscfd	0.74	1.42	1.49	2.91
Fuel gas – refrigerant compression					
Gas turbine hp for fuel	hp	1,445	2,419	2,773	
Gas turbine operating heat rate	btu/hp-hr	7,960	7,960	7,960	
Gas turbine fuel	MMscfd	0.27	0.45	0.52	0.97
Total fuel consumption					
Volumetric rate	MMscfd	1.01			3.88
HHV	btu/scf	1,130			1,130
Thermal rate	Tbtu/yr	0.42			1.60
Fuel as percent of inlet	Thermal %	0.15			0.48
Fuel rate used in material balances	Thermal %	0.25			0.50

8.8.2 Capital and Operating Costs – NGL Extraction Plant at the Spur pipeline Inlet

An NGL extraction facility would be required at the spur pipeline inlet for both Gas Scenarios 1 and 2. The size and configuration of these plants would differ greatly between scenarios. Per Gas Scenario 1, extracted NGLs are returned to the ANS pipeline to produce a utility gas for transport via the spur pipeline. Per Gas Scenario 2, a large portion of the ANS pipeline throughput is processed to extract large amounts of NGL for spiking into the spur pipeline feed.

Tariff calculations are based on capital cost information in the Spurline Terminal Design Report commissioned by ANGDA in 2006. Capital costs for the NGL extraction plant were estimated by factoring costs for similar sized facilities based on the relative capacities per the following industry rule of thumb: New cost estimate = Reference costs * (new capacity / reference capacity)$^{0.6}$.

Capital costs in the reference report are based on U.S. Gulf Coast engineering-procurement-construction (EPC) contractor costs with adjustments from the Gulf Coast region to Fairbanks. It was assumed that gas plant costs would be the same for both Fairbanks and Delta Junction Spur routes.

NGL Extraction Plant at the Spur pipeline Inlet - Gas Scenario 1

A 500 MMscfd NGL extraction plant located in Kenai is described in the Spurline Terminal Design Report. Feed gas composition for this plant is very similar to that of Gas Scenario 1; however, the plant is designed to reject ethane to the plant residue gas stream. The NGL plant per Gas Scenario 1 will be designed to recover ethane to produced utility gas. The cost of the 500 MMscfd plant was increased by 10 percent to cover the cost of equipment to provide a high ethane recovery.

The following cost information was extracted from the Spurline Terminal Design Report and was used as the basis for estimating the capital costs of the gas plant at the inlet of the spur pipeline for Gas Scenario 1:

EPC contractor costs for NGL extraction unit (Gulf Coast)	*$130 million*
Addition of 10% percent for ethane recovery	*$13 million*
Owners costs (percent of EPC contractor costs)	*20%*
Capital cost including owners cost	*$172 million*
Cost factor Fairbanks versus Gulf Coast	*1.517*
Capital costs adjusted from Gulf Coast to Fairbanks	*$260 million*

Feed to the NGL extraction plant at the spur pipeline inlet will increase over the project life. Capital cost of the NGL plant was based on the largest feed flow of approximately 400 MMscfd, which occurs at the end of the project. Capital cost of the 400 MMscfd NGL extraction plant was estimated by multiplying the cost of the 500 MMscfd reference facility by the ratio of flows raised to the 0.6 power as follows:

$$\textit{Capital cost of 400 MMscfd NGL plant} = \$227 \text{ million} = \$260 \text{ million} * (400 / 500)^{0.6}.$$

Plant feed rate during the first year of operation would be approximately 130 MMscfd, thus the NGL plant must be designed for significant turndown. The option exists to install two 200 MMscfd trains, which would allow installation of the second plant to be deferred about four years after project start-up. Installation of a single 400 MMscfd plant would mean that installed capital would go unutilized during the period of relatively low flow during the early years of the project. A 400 MMscfd single train was selected since it represents a slightly more conservative approach regarding project economic analysis.

Plant fuel was estimated at one percent of the feed on a thermal basis.

Fixed operation and maintenance costs were estimated per the Spurline Terminal Design Report at approximately four and two percent of the total EPC contractor costs respectively. This equates to five percent of the total capital costs after a 20 percent adjustment for owner costs. Annual non-fuel operating costs for the spur pipeline project were estimated at five percent of the installed capital costs for the gas processing plants.

NGL Extraction Plant at the Spur pipeline Inlet - Gas Scenario 2

Gas Scenario 2 is based on extraction of ethane and heavier components from ANS pipeline gas for spiking into utility gas to the spur pipeline. Material balances for Gas Scenario 2 are based on removing gas from the ANS pipeline with some of this routed directly to the spur pipeline. The majority of the gas from the ANS pipeline would be processed to extract ethane and heavier components with the plant residue gas re-compressed and returned to the ANS pipeline (Figure 3.5). The relative amounts of bypass and processed gas would need to be adjusted annually and seasonally as necessary to achieve both 75,000 bpd of ethane and the target amounts of utility gas delivered to Cook Inlet.

Approximately 1,940 MMscfd of ANS pipeline gas must be processed during the first year of the project to meet the target amount of ethane delivered to Cook Inlet. Plant feed gas rate would be the largest during the first year of operation and would progressively decline over the life of the project. Capital costs for the NGL extraction plant at the inlet of the spur pipeline are based on installation of two NGL processing trains with a capacity of 1,000 MMscfd each.

The Spurline Terminal Design Report includes an option in which 900 MMscfd of gas would be removed from the main ANS pipeline, transported to Kenai via a spur pipeline and then processed in Kenai to extract 85 percent of the ethane and essentially all of the propane and heavier components. The composition of the plant feed gas is essentially the same as that of the "rich" ANS gas scenario adopted for Gas Scenarios 1 and 2.

Capital costs for the 900 MMscfd plant in the Spurline Terminal Design Report are based on the premise that the residue gas from the processing plant would be re-compressed to the feed pressure. This premise was adopted for the NGL plant at the inlet to the spur pipeline and it was assumed that the ANS pipeline project would be responsible for any compression to raise the pressure of the residue gas higher than that of the feed.

The following cost information was extracted from the Spurline Terminal Design Report and was used as the basis for estimating the capital costs of the gas plant at the inlet of the spur pipeline for Gas Scenario 1:

EPC contractor costs for NGL extraction unit (Gulf Coast)	*$196 million*
Owners costs (percent of EPC contractor costs)	*20%*
Capital cost including owners cost	*$235 million*
Cost factor Fairbanks versus Gulf Coast	*1.517*
Capital costs adjusted from Gulf Coast to Fairbanks	*$357 million*

Capital cost of the 1,000 MMscfd NGL extraction plant was estimated by multiplying the cost of the 900 MMscfd train by the ratio of flows raised to the 0.6 power as follows:

$$\textit{Capital cost of 1,000 MMscfd NGL plant} = \$380 \text{ million} = \$357 \text{ million} * (1{,}000 / 900)^{0.6}.$$

Tariff calculations are based on an overall plant fuel consumption rate of one percent of the feed on a thermal basis consistent with the Spurline Terminal Design Report. The annual non-fuel operating costs for the plant were estimated at five percent of the installed capital costs for the gas processing plants.

NGL Extraction Plant at Cook Inlet – Gas Scenario2

Gas Scenario 2 is based on delivery of a highly enriched natural gas to Cook Inlet at which ethane and other NGL components would be extracted to produce a utility gas. The design and operation of the Cook Inlet plant do not match any of the options described in the Spurline Terminal Design Report. Information in the Spurline Terminal Design Report; however, appears to be the best publicly available and was a reasonable basis from which to estimate the cost of the Cook Inlet facility.

EPC costs in the Spurline Terminal Design Report were increased by 25 percent to account for the addition of propane refrigeration and separation equipment that may be required to handle the enriched feed gas. A premise of Gas Scenario 2 is that an NGL mixture would be sold at the plant boundary via pipeline, thus fractionation is not required.

Capital cost information from the Spurline Terminal Design Report for a 500 MMscfd facility was adjusted as follows to estimate the cost of the Cook Inlet NGL facility for Gas Scenario 2:

EPC contractor costs for NGL extraction unit (Gulf Coast)	*$130 million*
Adder of 25% percent to handle enriched gas	*$33 million*
Owners costs (percent of EPC contractor costs)	*20%*
Capital cost including owners cost	*$195 million*
Cost factor Kenai versus Gulf Coast	*1.44*
Capital cost including owners cost	*$281 million*

Feed to the Cook Inlet facility will increase from approximately 330 MMscfd to 562 MMscfd over the life of the project. It was assumed that a single 565 MMscfd NGL extraction plant would be installed at Cook Inlet. The capital cost of the 565 MMscfd plant was estimated by multiplying the cost of the 500 MMscfd train by the ratio of flows raised to the 0.6 power as follows:

*Capital cost of 565 MMscfd NGL plant = $302 million = $281 million * (565 / 500)* $^{0.6}$.

8.8.3 Tariff from Inlet of NGL Extraction Plant at Inlet of the Spur pipeline to Cook Inlet Outlet

Overall tariffs for the spur pipeline project including gas processing facilities at the pipeline inlet and outlet (Gas Scenario 2 only) were calculated by AG Edwards based on input from Michael Baker. The price of all hydrocarbons delivered to Cook Inlet, after extraction of fuel for the spur pipeline and Cook Inlet NGL facility, was adjusted until a ROE of 12 percent was obtained over a 33-year project life. The overall tariff for the NGL extraction plant, spur pipeline with stations and Cook Inlet processing plant was determined as the difference between the delivered hydrocarbon price in Cook Inlet and the price of gas purchased from the ANS pipeline. Tariffs are based on the thermal content of the hydrocarbons delivered to Cook Inlet after removal of fuel. Fuel is valued at the price of gas purchased from the ANS pipeline.

Economic premises used by AG Edwards to calculate the tariff for the spur pipeline are the same as those used for the ROI analysis (Appendix 3-6) with the following exceptions:

- Sales price adjusted to yield return-on-equity of 12%
- Debt Service Coverage Ratio: Minimum of 1.25x
- Minimum Cash on Hand: $100,000,000
- Debt-Equity Financing: 70-30; equity paid up front
- Debt Structure Assumptions:
  - First Debt Issuance: 2012
  - Last Debt Issuance: 2016 for GS1 scenarios, 2015 for GS2 scenarios
  - Principal Payment Amount: Equal principal from First Principal Payment Date to Last Principal Payment Date
  - First Principal Payment Date : 2021 (consistent in all four scenarios)
  - Last Principal Payment Date (dictated by first year coverage ratio): 2033 for Gas Scenario 1, 2034 for Gas Scenario 2
  - Term of financing: 21 years and 22 years from First Debt Issuance to Last Principal Payment Date for the Gas Scenario 1 and Gas Scenario 2, respectively

8.9 Price of Gas Delivered to Cook Inlet

Price of gas delivered to Cook Inlet was estimated as the sum of the price of gas at the inlet of the ANS pipeline on the North Slope, the tariff to transport the spur pipeline gas through the ANS pipeline to the spur pipeline take off point and the tariff from the inlet of the NGL plant at the spur pipeline inlet to delivery at Cook Inlet. A summary of the tariff results are contained in the following table:

Table 8.13: Estimated Price of Gas Delivered to Cook Inlet, $/MMbtu

	Gas Scenario 1 Delta Junction Spur	Gas Scenario 1 Fairbanks Spur	Gas Scenario 2 Delta Junction Spur	Gas Scenario 2 Fairbanks Spur
ANS purchase price	3.20	3.20	3.20	3.20
ANS tariff	0.57	0.47	0.57	0.47
Spur pipeline tariff	1.68	1.75	1.30	1.33
Delivered price	5.45	5.42	5.07	5.00
All values are expressed in $/MMbtu				

For the same gas scenario, there is no substantial difference in the price of gas delivered to Cook Inlet via the Fairbanks and Delta Junction Spur options. The two spur pipeline options are economically indistinguishable based on the level of accuracy of the capital costs and the supporting engineering specification.

A premise of the Gas Market Assessment is that the price of gas entering the ANS pipeline on the North Slope will be the delivered gas price at the ANS pipeline terminus near Chicago minus the ANS pipeline tariff. The price of gas entering the ANS pipeline will thus be tied to the price of gas near Chicago. Prices of natural gas delivered to Cook Inlet shown in Table 8.13 were calculated using the "base case" assumptions presented in the Gas Market Assessment, which were $5.50/MMbtu (average of range from $5.00 to $6.00/MMbtu) at the ANS pipeline terminus and an ANS pipeline tariff of $2.30/MMbtu. An increase in the price of gas near Chicago would result in a corresponding increase in the price of gas delivered to Cook Inlet as calculated per the methodologies used in the Gas Market Assessment and this report.

The highest price for gas delivered to Cook Inlet calculated for either Gas Scenario 1 or 2 is $5.45/MMbtu. Economic results thus support the conclusion that a spur pipeline off of the main ANS pipeline to Alberta can deliver gas to Cook Inlet at or below the price of gas delivered to the Chicago area via the ANS pipeline. This trend regarding the relative price differential between gas near Chicago and Cook Inlet will hold regardless of the price of gas near Chicago.

8.10 Local Distribution Service Areas

The Fairbanks and Delta Junction Spurs would pass near a number of communities which might benefit from service with natural gas. The communities (based on which route is selected) and the expected usage of natural gas is outlined below and was used to develop an estimate of cost for the infrastructure to provide service. The cost estimate is based on an average service and in some cases the individual service cost could be substantially higher or lower depending on the location of the line in relation to the community. The gas composition in the spur pipeline would also have a significant impact on the cost of the new service with regard to the equipment required to remove the NGL components and deliver utility gas. This estimate assumes the gas will require processing at each tap.

The equipment required to provide service at each location would include a tap on the main line, valves and high-pressure metering. The pressure reduction equipment would be sized for the expected flow rates and may be part of the NGL separation equipment utilizing the J-T effect. The resulting liquids (ethane,

propane, butane etc.), would most likely be re-injected into the downstream pipeline or sold locally. Water bath heaters would be a part of each station to re-warm the gas stream down stream of pressure cuts. The final equipment design would be selected based on the main line pressure, gas composition, flow rate and the quantity of liquids produced at the pressure cut.

Actual cost of installation to each potential customer is highly variable upon population densities. Generally economics are positive when providing natural gas distribution to densities of ten households or more per mile. Such economies of scale do not take into account the transmission line tap or associated gas regulation, measurement, and potential treating facilities. The potential for gas distribution in each of the communities listed in Table 8.14 is therefore dependant upon the total population and the density.

8.10.1 Usage Estimates

The following information was based on data from the 2000 Census with a projection to 2010 to determine the number of households and expected consumption.

Table 8.14: Utility Gas Usage Estimates

LOCATION	2010 Estimated Housing Units	Cu ft per day	Total cu ft per day
Fairbanks Spur			
Nenana	281	645	180,600
Anderson/Clear AFS	200	1,000	200,000
Healy	725	645	467,625
McKinley (Commercial)	150	2,000	300,000
Cantwell	240	645	154,800
Trapper Creek	460	645	296,700
Talkeetna	700	512	358,400
Talkeetna "Y"	980	512	501,760
Willow	1,680	512	860,160
		Totals	3,320,045
Delta Junction Spur			
Glennallen	350	645	225,750
Ft. Greeley	500	645	322,500
Sutton	450	512	230,400
		Totals	778,650

8.10.2 Construction Cost Estimate

This Conceptual Construction Cost Estimate includes J-T equipment for removal and re-injection of the NGL at each location. It assumes a metal building would be used to weatherize the equipment and provide security for the station. Because most of these service locations would have a relatively low number of customers, mains, and meters to maintain these sites may be used as a staging area for other maintenance required in the area. With this in mind, a slightly larger site is allowed for and security fencing included. Land acquisition costs were not included. Table 8.15 summarizes the conceptual construction costs.

Table 8.15: Cost Estimate, NGL Extraction at Remote Tap

Spur pipeline "Farm Tap" Estimate				
A.	**Mainline Tap, Valves and Lateral Pipe.**			
	A.1	Pipeline Tap, Valves & Miscellaneous		$15,000
B.	**Site Work**			
	B.1	Access Road	100 Linear ft (Lf)	$5,000
	B.2	Pad - 100x120		$100,000
	B.3	Fencing	440 Lf @ $50/Lf	$22,000
C.	**Regulator Station and J-T Plant (If Required)**			
	C.1	Metal Building (30 ft X 60 ft)		$144,000
	C.2	J-T Equip for 0.5M-1M scf		$350,000
	C.3	Regulator Metering Station with Water Bath Heater		$300,000
	C.4	SCADA/Communications		$45,000
			Total	$981,000

8.11 Gas Storage in Cook Inlet

Natural gas production from currently producing reserves within the Cook Inlet region is declining. Communities in Alaska that rely on these existing Cook Inlet resources have seen a rise in natural gas supply costs as well as exploration efforts emerging in sometimes unusual places. Traditionally, Southcentral Alaska has enjoyed a vast supply of natural gas measured at 10 trillion cubic ft (Tcf) for the Cook Inlet area. That supply sustained industry and growth of the economy since 1961 when natural gas supplies first were used to generate electricity, heat homes and foster industry.

Recently demand has exceeded production and storage capacities for the first time since 1961. During the winter of 2005 a large industrial gas user was shut down during the coldest portion of the winter due to high gas prices. Large industrial users are now planning reduced or no gas consumption (from traditional sources) during winter peak demand periods. At one time, the natural gas reserves within the Cook Inlet had surplus capacity adequate to satisfy the natural gas demand during peak winter periods. Recently, natural gas storage efforts have emerged as the producer's begin to reverse the process and convert now-depleted gas fields into storage chambers. A small advantage is that some of the needed infrastructure is already in place for gas storage purposes.

The impact of gas storage in the Cook Inlet region has two major impacts on spur pipeline economics. First, the availability and capacity of storage fields has significant effect upon daily throughput needs of the spur pipeline. A constant daily throughput volume throughout seasonal changes allows maximization of pipeline asset potential. The second impact associated with storage is the premise of a back-up supply needed in the event of either production or transportation disruptions. The Cook Inlet region cannot rely upon a sole energy production/transportation system for power and heating needs.

8.11.1 Seasonal Flow Patterns

Gas usage by utilities in Southcentral Alaska dramatically fluctuates because of seasonal temperature variations. It is not uncommon to experience an annual average to winter swing of 2:1 for the combination of electric generation and natural gas heating loads. This does not apply to industrial loads which have exhibited more constant historical flow patterns. Even though the seasonal effect of utility gas use cannot be modified, it is nevertheless important that seasonal pipeline flow volumes remain near constant for economic considerations. For that reason a study of gas storage in the Cook Inlet is required.

8.11.2 Cook Inlet Storage Development

Seasonal peaking capacity has historically been provided by the combination of surplus gas and high production fields. Currently, as daily natural gas production capabilities decline within Southcentral Alaska, natural gas producers have been and will continue to convert existing fields to gas storage. Maximization of production assets requires a means of storage to ensure seasonal delivery. Storage fields are filled during non-peak months, typically April through September. Fields are filled at a slower rate than they are called upon to deliver on peak days. For example, a storage field might be filled at a 5 MMscfd rate, but be called upon to deliver gas at a rate of 20 MMscfd during extended periods of high demand.

Chevron has existing storage projects in place at both the Pretty Creek and Swanson River fields. Marathon is currently converting select wells/formations within the Kenai Gas Field to storage. An important driver for the development of Cook Inlet gas storage is the requirement found in existing gas supply contracts to provide seasonal peaking volumes. As gas production continues to decline, utilization of gas storage is expected to increase.

The geology of Cook Inlet is not as conducive to gas storage as some areas in the Lower 48 where storage facilities are comprised of high volumetric porous reservoirs (e.g. former salt domes and ancient reefs). Cook Inlet reservoirs are generally comprised of discontinuous sands capping water wet zones. Companies that invest in storage in Cook Inlet are not guaranteed that the same amount of gas injected into storage will be retrieved because of the typical geologic formations in this area of the state.

8.11.3 Redundancy Supply: Storage

As discussed above, storage infrastructure is currently in development and will continue to expand for the near term. If a spur pipeline is installed to supply natural gas to Southcentral Alaska and regional production has declined, a redundant gas supply source would be crucial to ensure that both heating and power generation needs are met in the event of either a pipeline or gas conditioning disruption. The output capacity of Cook Inlet storage would need to be close to peak day demand by Southcentral Alaska homes and businesses that do not have an alternate supply of heat and electricity (i.e., businesses and other facilities that have back-up diesel generation that can supply both heat and electric power). In this study, pipeline economics was not applied to the cost of natural gas storage because of critical need for storage in the event of a gas supply disruption.

Section 9. Considerations for Future Work

9.1 Introduction

This section is intended to briefly define certain tasks that would need to be completed during future phases of project development. This section is not intended to be an all inclusive treatment of potential future work but rather a tool to be used to develop a future work plan. Complete definition of all required future tasks would be determined at a later date by an entity that is interested in advancing the project to the next stage.

9.2 GIS

A limited amount of base mapping and land ownership information was developed for this study. This data is geospatially accurate and refers to real locations in a standard coordinate system and as such formed the initial GIS.

The GIS for the spur pipeline project would be the core project database and contain geospatially referenced information with attributes assigned as necessary to fully characterize the project components. The GIS should contain "intelligent" macros, links and features that would allow various products and reports to be derived from the underlying data. The following are descriptions of engineering related components likely to be included in the GIS.

9.2.1 GIS Schema

The schema refers to the detailed architecture of the GIS including all data, intelligent functions and requirements, and products to be generated by the GIS. Schema specification is critical to the success of the GIS and must be performed at the earliest stage of GIS development. The option exists to use an industry standard schema available through professional associations, develop a schema from scratch, or any combination of the two.

9.2.2 Soil Database

Site specific geotechnical properties of the soil along the route would need to be developed to support the thermal-hydraulic modeling, pipe stress evaluation and construction modes. The soil database would be developed and integrated within the GIS. The soil database would consist of terrain unit maps, landform profiles, geospatially referenced boreholes, borehole log data and laboratory analyses of borehole samples.

The soil database would report physical property data obtained from laboratory analysis. The soil database would also contain algorithms to estimate physical properties based on laboratory data.

The quality of the soil database would gradually improve as site-specific data is collected along the selected pipeline alignment. Initially, the soil database would be more statistical and be based on general information. This initial information would be useful for preliminary project design and identification of areas for which site-specific information and design would be required. Ultimately, statistically derived soil information would be replaced with site-specific information as necessary to provide confidence in the design.

A significant amount of proprietary soil data is available for Alaska, primarily along the TAPS corridor. This data would be more directly applicable to the Delta Junction Spur route, but also could enhance the statistical soil database for the Fairbanks Spur route. The expense for acquisition of this proprietary data

could be significant. The expense for field borehole drilling and sampling programs would also be significant.

9.2.3 Climatic Data

The operating temperature profile, and to an extent the pressure profile, of the spur pipeline would be influenced by the seasonal climatic conditions along the route. The ambient air temperature and depth of snow would impact the heat balance at the ground surface and the growth of frost and thaw bulbs around the pipeline. The ambient air temperature would impact the available site-rated hp of the drivers for the pipeline gas and refrigerant compressors.

Propane refrigeration systems have been specified for a number of chilled buried gas pipelines in cold regions to chill the warm compressor discharge gas prior to re-entering the pipeline. These systems use ambient air as the heat sink for refrigerant condensation. The ambient air temperature would significantly impact the operation and design of the propane refrigeration system. In particular, the refrigeration design would need to address operations at the peak ambient air temperatures that would occur only for a few hours on the warmest days of the summer.

Climatic data from government and/or private sponsored recording stations at points along the route would be available. Ambient air temperature can vary significantly with elevation and local terrain. Algorithms would need to be developed to extrapolate regional climatic data to all locations along the route.

The option would exist to supplement climatic data to test the impact of various influences on the ground surface heat balance. In addition to ambient air temperature and snow depth, other factors such as slope angle and surface albedo (i.e., the amount of radiation absorbed or reflected) would influence the surface heat balance. For example, north-facing slopes would be less affected by solar heating than south-facing slopes. The option would exist to develop hypothetical sets of climatic data to test the impact of long-term climate change on the pipeline design.

9.2.4 Material Sites

Gravel material of different qualities would be required to construct access roads, construction work pads and provide select pipe padding and backfill at certain locations. Sites at which such materials could be obtained would need to be identified and the contents characterized in order to support construction logistical planning and cost estimates. Information regarding the material sites would need to be incorporated into the project GIS.

9.2.5 Base Mapping

Base mapping includes:

- Satellite imagery
- Alignments for roads and other ROW
- Land ownership
- Environmental characterization including rivers/waterways, wildlife areas, recreation areas and parks
- Wetland characterization
- Digital elevation model (DEM)
- Terrain units
- Orthophoto imagery

- Light detection and ranging (LiDAR) data

9.2.6 Intelligent Features and Functions

Intelligent features include:

- Alignment sheet generator
- Generation of longitudinal and cross slopes
- Ditchmoding algorithms
- Gravel and rock requirements and hauling distances
- Development of basis for cost estimation

9.2.7 Facilities

The GIS would contain the location of all facilities along the pipeline including valves, pigging facilities, cathodic protection equipment and special design segments. Attributes would be assigned to the facilities to fully characterize the component with information such as: size, material specifications, manufacturer, delivery time, spare inventory required, operating characteristics, and maintenance schedules.

The option would exist to incorporate details of the pipeline, compressor stations, and gas processing facilities into a comprehensive project-wide GIS or create a separate GIS for each major component.

9.3 Seismic Hazard Analysis

Portions of Alaska are considered seismically active and the proposed spur pipeline would traverse a number of active geologic faults. Seismic design criteria would need to be developed and the spur pipeline and attendant facilities designed accordingly to ensure that the project could withstand all reasonably anticipated seismic phenomena without loss of structural integrity. Seismic design criteria should be developed subject to U.S. Standard DOE-STD-1022-94 titled "Natural Phenomena Hazards, Site Characterization Criteria." This DOE Standard addresses geology and seismology including seismic sources, vibratory ground motions, and earthquake-induced flooding, among other issues. Necessary geotechnical studies subject to the DOE Standard include site investigations, site response analysis, soil-structure interaction analysis and ground failure evaluation (seismic liquefaction, subsidence, and slope stability). Site specific designs would need to be developed for all fault crossings.

Much seismic related data is available in the public record. Investigation of fault crossings must be completed on a case-by-case basis and has the potential to be time consuming and costly if significant field work were required.

9.4 Pipeline Design

9.4.1 Vapor Dispersion

Dispersion of hydrocarbon components from a postulated pipeline release of an enriched natural gas to the atmosphere would need to be simulated. The option would exist to transport natural gas enriched with non-methane hydrocarbon components with molecular weights greater than that of air. Among other issues, the simulations would need to address the potential for accumulation of heavy hydrocarbon vapors in low-lying areas.

9.4.2 Thermal-Hydraulic Design

The proposed spur pipeline would traverse discontinuous and sporadic permafrost and would need to be designed with consideration of the potential for frost heave or thaw settlement and any resulting differential movement. The amount of differential movement and corresponding pipe stress depend on various factors including the rate and extent of frost bulb or thaw bulb growth around the pipeline.

The thermal design issues for the spur pipeline would differ significantly from those of the large diameter ANS pipeline. Heat transfer through the pipe wall would likely have a large influence on the smaller diameter spur pipeline especially if it were used to transport a highly enriched natural gas. The operating temperature of the spur pipeline would likely track more with seasonal soil temperature than the larger ANS pipeline.

Thermal-hydraulic simulation of the pipeline should be completed in any future design efforts to characterize both the frost bulb or thaw bulb growth around the pipeline on a segment-by-segment basis and the seasonal operating loads on the station equipment. Thermal-hydraulic analysis consists of coupling gas hydraulics with a finite element soil model to assess the thermal interaction of the pipeline and the surrounding ground. The thermal-hydraulic model would generate a series of steady state pipeline operating profiles for all seasonal combinations of composition, flow, and climatic conditions. The finite element soil model would be used to determine the rate of propagation of thaw or frost bulbs around the pipeline and the extent of bulb development, which would be used as input to pipe stress models.

A properly configured thermal-hydraulic model could provide information for or greatly assist with the following:

- Determining seasonal loads on gas compressors and refrigeration equipment at each compressor station along the pipeline;
- Estimating the rate and extent of bulb growth on a long-term basis for input to pipe stress analysis;
- Assessment of frost heave and thaw settlement risk mitigation methods;
- Pipeline operability review;
- Development of procedures to remove a high pressure pipeline from service (blowdown for emergency or maintenance reasons) and return it to service;
- Assess the impact of numerous postulated climatic conditions on pipeline operation;
- Discussion of pipeline operations with various stakeholders including regulatory agencies; and
- Development of operator training programs.

The accuracy of the thermal-hydraulic model would depend on the accuracy of the site-specific geotechnical information developed for the project. Input to and output from the thermal-hydraulic model would need to be integrated into the project GIS.

9.4.3 Pipe Stress Analysis

Pipe stress analysis can be divided into stress associated with thermal expansion and transitions to associated facilities, and stress associated with differential movement of the pipe. The first type of stress analysis is not unique to cold regions pipelines and can be completed by a number of qualified engineering firms. The latter type, sometimes referred to as “deformational stress”, is unique to cold regions pipelines and would constitute the majority of stress analysis completed for the project.

Differential movement of the pipeline could occur at the transition between frozen and thawed soil, and result in induced stress on the pipe. Differential movement attributed to frost heave could occur where the pipe segment was frozen in permafrost at both ends and traverses frost susceptible thawed soil between. Differential movement attributed to thaw settlement could occur if the pipeline melts thaw-unstable soil between locations where the pipe was supported by stable soil.

Deformational stress analysis could be completed in two phases, both of which would require input from finite element soil models. Initially, finite element models could be run at prescribed pipeline operating temperatures to established general pipeline operating constraints for site-specific conditions along the route. Ultimately, pipe stress would need to be evaluated based on the output from long-term thermal-hydraulic simulation of the pipeline and attendant facilities.

Expertise in deformation stress analysis is very limited. A select group of contractors specializing in deformation stress analysis have been used repeatedly by sponsors of pipeline projects proposed for cold regions.

9.4.4 Ditchmoding Design and Mitigation of Frost Heave and Thaw Settlement

Ditchmoding refers to specification of the site-specific configuration of the pipeline trench. Selection of the ditch mode is based on the local terrain, soil conditions, construction season and potential for adverse frost heave or thaw settlement of the pipe. Ditch mode selection is primarily a civil engineering issue and the option exists to automate selection by developing algorithms based on information contained in the GIS such as the geotechnical database and output from thermal-hydraulic simulations.

Various means exist for mitigation of frost heave and thaw settlement ranging from periodically adjusting pipeline operating temperatures to over-excavation of the pipe trench and replacement with select fill. Mitigation could also consist of planned periodic excavation and maintenance of the pipeline. Selection of the pipeline operating pressure is a mitigation measure because higher pressure pipe with thicker walls are more stiff and better resist induced stress from differential movement than thinner walled pipe. Mitigation planning would need to be an ongoing multi-disciplinary activity occurring at all stages of project development.

9.4.5 Cathodic Protection

Coffman Engineers has developed preliminary engineering information regarding cathodic protection of a potential spur line in support of the construction and operations cost estimates. Coffman's complete report is contained in Appendix 9-1. These recommendations are made with limited preliminary information about the actual type of pipe to be used, soils conditions along a proposed ROW, and the methods and means proposed for construction. A significant amount of work would be required to fully address all the concerns mentioned in the Coffman report and to develop a complete strategy to mitigate the corrosion risks on the proposed pipeline routes.

9.5 Gas Processing

9.5.1 Gas Processing and Handling of Carbon Dioxide

The following section titled "Amine Processing Plant" has been extracted from the report "Transport of North Slope Gas to Tidewater" with permission from ANGDA (Michael Baker 2005a). References in this section have been changed to be consistent with the current report.

Amine Processing Plant

The gas in the Prudhoe Bay Pool contains approximately 12 percent carbon dioxide. All of the recent proposals for a major gas project include a facility on the North Slope to remove carbon dioxide prior to the gas entering the pipeline. The amount of carbon dioxide removed depends on whether the gas is destined for delivery to the Lower 48 markets via a pipeline through Canada or via liquefaction in a facility located in Southcentral Alaska.

Carbon dioxide and hydrogen sulfide form acids in the presence of water and are sometimes referred to as *acid gases*. A gas containing hydrogen sulfide is sometimes referred to as *sour gas* while a gas that contains no hydrogen sulfide is called *sweet gas*. *Gas conditioning* is sometimes referred to as *acid gas removal* or as *gas sweetening*. A general schematic of an amine process for acid gas removal is shown in Figure 9.1. Amine plants have been specified for gas conditioning by the North Slope gas producers both for the Alaska North Slope LNG Project proposed in 2001 and the 4.5 to 5.6 Bcfd Highway Project proposed in 2002.

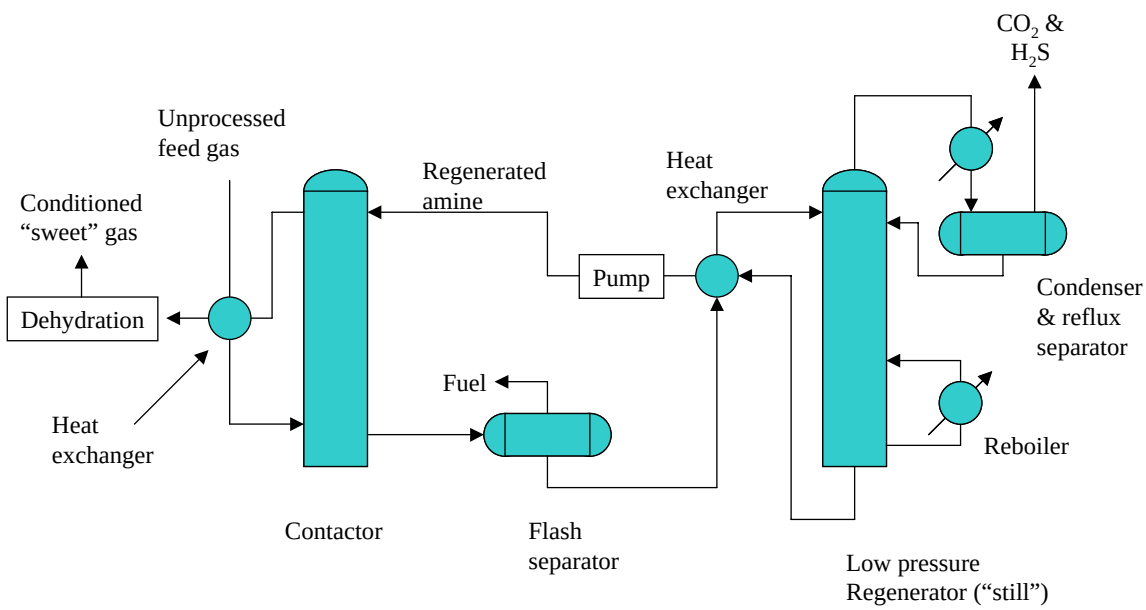


Figure 9.1: Amine Gas Conditioning Process, Simplified Schematic

Referring to Figure 9.1, the unconditioned feed gas at a pressure of approximately 600 to 700 psia is warmed slightly as it passes through a heat exchanger and then is routed to the bottom of the contactor. The feed gas passes upward through the contactor while the regenerated amine solvent flows downward through the column. Packing or trays within the column are used to cause the gas to bubble through or "contact" the amine solvent and the acid gases are removed from the feed gas by chemically bonding to the amine. The conditioned gas leaving the top of the tower is cooled slightly by cross exchange with the feed gas and then is sent to a dehydration facility to remove water picked up from the aqueous amine solvent.

The amine from the contactor is sent to a flash separator at which the pressure of the amine is reduced and absorbed hydrocarbons are vaporized and removed. The amine leaving the flash separator is routed to a heat exchanger and then to the top of the regeneration column. The regeneration column is essentially an atmospheric still with a reboiler at the bottom and a condenser at the top. The carbon dioxide and hydrogen sulfide are stripped from the amine as it passes down the still. The regenerated amine passes through a heat exchanger where it is cooled while warming the amine feed to the regeneration column. A

pump is used to increase the pressure of the regenerated amine to the pressure of the contactor. Water vapor in the acid gases leaving the top of the still is condensed using air coolers and then returned to the top of the still as reflux. The carbon dioxide leaving the top of the regeneration column would be recompressed for re-injection into a reservoir.

Impact of Carbon Dioxide on NGL Extraction Facilities

Modern cryogenic NGL extraction facilities rely primarily on J-T cooling of a methane-rich gas along with advantageous use of heat exchangers to achieve conditions at which ethane and heavier components will condense out of the gas. Cryogenic facilities processing a gas containing carbon dioxide must be designed with consideration of the potential formation and accumulation of solid carbon dioxide (commonly known as dry ice) within portions of the facility. Formation of solid carbon dioxide can be avoided by removing carbon dioxide upstream of the process or by designing the process to avoid temperature and pressure conditions at which solid carbon dioxide can form.

Carbon dioxide tends to condense to a liquid along with ethane and a large portion of the carbon dioxide in the plant feed would end up in a fractionated ethane product. An amine process is typically used to remove carbon dioxide from the ethane product.

The carbon dioxide byproduct from an amine process leaves the facility as a warm low-pressure stream saturated with water vapor. Historically, carbon dioxide from smaller amine plants has been vented directly to the atmosphere. Carbon dioxide emissions to the atmosphere are increasingly becoming more of an environmental concern. The producers intend to re-inject carbon dioxide removed from the North Slope gas into the Prudhoe Bay Reservoir. Disposition of carbon dioxide extracted from facilities along the ANS pipeline or the spur pipeline may be an issue depending upon the location of the facility and the amount of carbon dioxide byproduct produced.

Carbon Dioxide Removal at the North Slope

The ANS producers have indicated that they intend to use an amine facility to process North Slope gas to obtain an ANS pipeline gas with a carbon dioxide content of 1.5 percent. The amine process should also remove essentially all of any hydrogen sulfide contained in the feed. The producers intend to dehydrate the gas prior to entering the pipeline thereby inhibiting corrosion and the potential of forming gas hydrates within the pipeline or attendant facilities. The nitrogen content of gas from Prudhoe Bay is approximately 0.6 percent, thus the total concentration of inert gas including 1.5 percent carbon dioxide would be within the typical pipeline specification of 3 percent for total inert gas.

The option exists to design the North Slope amine facility to remove essentially all of carbon dioxide from the ANS pipeline gas. Theoretically, the ANS pipeline would benefit economically by removing 1.5 percent of the gas which has no heating value and thus provides no project revenue while consuming pipeline capacity. An additional advantage would be the simplification of downstream gas processing facilities including disposition of the carbon dioxide removed. The disadvantage is that significant incremental costs would be incurred to configure the North Slope amine facility to remove essentially all of the carbon dioxide as compared to bulk removal to 1.5 percent. Presumably, the North Slope producers completed a cost-benefit analysis, which resulted in the 1.5 percent carbon dioxide specification.

Carbon Dioxide Handling at the Spur Pipeline Inlet

Issues regarding carbon dioxide handling at the NGL extraction plant at the inlet to any potential spur pipeline subject to Gas Scenario 1 would be limited to process design to avoid formation of solid carbon dioxide. The NGL extraction plant for Gas Scenario 1 would be configured to produce a utility gas for

transport via the spur pipeline with extracted NGL returned to the ANS pipeline. The carbon dioxide concentration of the spur pipeline gas would be less than the 1.5 percent of carbon dioxide in the plant feed because some of the carbon dioxide would be removed along with the NGL that is returned to the ANS pipeline. The concentration of carbon dioxide within the ANS pipeline downstream of the spur pipeline take-off after addition of the relatively small amount of NGL would increase slightly and would remain less than three percent.

Gas Scenario 2 is based on the premise that a large quantity of the ANS pipeline gas would be processed with the extracted NGL spiked into the spur pipeline for transport as a dense phase gas. Because of the amount of carbon dioxide extracted with the NGL, the concentration of carbon dioxide would decrease in the ANS pipeline gas downstream of the spur pipeline take-off and increase in the spur pipeline gas relative to the plant feed. The total concentration of inert components in the enriched spur pipeline gas would likely be in the range of three to four percent and thus exceed a typical pipeline specification.

Future project design work should address the merits of removing carbon dioxide at the NGL extraction plant for Gas Scenario 2. The advantages would be elimination of carbon dioxide related process issues at the downstream plant in Cook Inlet. The disadvantages would be increased capital costs and disposition of the carbon dioxide. The option exists to return the carbon dioxide to the ANS pipeline; however, this would reduce the heating value of the ANS pipeline gas with no economic benefit to this system.

Carbon Dioxide Removal at Cook Inlet

Gas processing at Cook Inlet would not be required for Gas Scenario 1. Gas processing would be required in Cook Inlet per Gas Scenario 2 to separate utility gas from NGL components. NGL fraction may also be required depending on how the NGL is sold at the plant boundary. The following discussion pertains to Gas Scenario 2.

Specifications for utility gas typically allow up to three3 percent inert gas and a maximum higher heating value of 1,050 btu/scf. Future design work for Gas Scenario 2 would need to address the potential for carbon dioxide removal and disposal in Cook Inlet to meet utility gas and/or NGL product specifications.

The amount of carbon dioxide in the spur pipeline gas would depend on configuration of the NGL plant at the inlet to the spur pipeline. A significant amount of carbon dioxide could be extracted from the ANS pipeline gas along with the NGL spiked into the spur pipeline gas. Some of the carbon dioxide entering the plant at Cook Inlet would be extracted along with NGL; however, the concentration of carbon dioxide remaining in the utility gas product could still exceed three percent. A high carbon dioxide concentration in the utility gas reduces the heating value of the gas, which could be advantageous depending upon how much ethane could reasonably be removed without adverse impact on plant economics.

Various options would exist to remove carbon dioxide from the plant feed, utility gas, or NGL product. Future project development work would need to address the following issues, among others, regarding the design of a Cook Inlet gas processing facility:

- Analysis of the relative merits of installing carbon dioxide removal facilities on the plant inlet or on the NGL and/or utility gas product streams;
- Venting carbon dioxide to atmosphere or location of a sink to dispose of any carbon dioxide byproduct and design of associated facilities;
- Potential to market a utility gas with a carbon dioxide content in excess of that typically specified for such gas;

- Potential to blend a carbon dioxide rich utility gas with other utility gas to yield a product which meets specification;
- Potential for formation and accumulation of solid carbon dioxide within portions of the facility; and
- Merits of installing carbon dioxide removal facilities at the NGL extraction plant at the inlet of the spur pipeline.

9.5.2 NGL Extraction from an Enriched Gas

The concentration of methane in a typical NGL plant feed ranges from 75 to 90 percent. Material balances for Gas Scenario 2 subject to a rich ANS gas scenario yield an enriched spur pipeline gas with a methane content ranging from 30 to 60 percent. Based on the relatively low concentration of methane in the spur pipeline gas, one would expect less J-T cooling than that typically achieved within a typical NGL plant and high NGL extraction efficiencies may be difficult to achieve, particularly regarding ethane. More mechanical refrigeration and separation equipment could be required for the Cook Inlet facility as compared to more typical NGL plant configurations.

Extraction of hydrocarbons as NGL tends to reduce the heating value of the utility grade plant residue gas relative to that of the feed. Because of relatively low amount of methane in the plant feed causing a high recovery of NGL components would be required in order to achieve a utility gas with a heating value less than 1,050 btu/scf.

The economic results presented in Section 8 support the conclusion that sale of an NGL product in Cook Inlet could reduce the cost of utility gas delivered via the spur pipeline. Sale of NGL would have the downside of complicating operation of the overall spur pipeline project. A protracted outage of downstream NGL handling facilities could have an adverse impact on the operation of the spur pipeline project and ability to deliver utility gas to Cook Inlet.

Future engineering activities would have to address the following issues regarding NGL extraction in Cook Inlet:

- Design of facilities to handle a feed with a progressively changing hydrocarbon composition over the life of the project;
- Potential impact of downstream NGL operations on spur pipeline operation and on-line availability as well as the need for surge storage capacity;
- Integration of NGL fractionation facilities into the Cook Inlet facility (spur pipeline tariff calculations are based on production and sale of an unfractionated NGL mix); and
- Plant optimization to simultaneously address costs for high recovery of non-methane components, carbon dioxide content and heating value of the utility gas stream and potential need for carbon dioxide removal.

9.6 Operations

Any potential spur pipeline would need to provide a highly reliably source of utility gas to Cook Inlet. Pipeline operability reviews would need to be completed to ensure that the overall pipeline and compression system, including gas processing facilities, would operate safely, reliably and in accordance with all regulatory criteria.

An operability review should, at the minimum, address the following:

- Operation at each discrete ramp-up increment projected for the project;
- Contingency plans for operation if one or more compressor stations or gas processing facility is off-line;
- Operation subject to planned maintenance;
- Procedures for pressure reduction and removal of a high-pressure pipeline from service for scheduled or unscheduled maintenance; and re-pressurization of the pipeline to return it to service;
- Re-wheel of pipeline gas compressors installed early in the project as flow increases; detailed review of the operation of individual gas compressors must be completed to ensure adequate operation over all flow rates;
- Detailed review of the operation of the gas refrigeration systems at peak summer loads and subject to winter temperatures when minimum loads are encountered or possibly the system is not required at all; and
- Seasonal project capacity with respect to peak seasonal and daily loads requiring gas removal from storage in Cook Inlet.

9.7 Construction Plans and Schedules

The spur pipeline would be a periphery project from the large diameter ANS pipeline from the North Slope to Alberta. The ANS pipeline is a "mega-project" that would consume much of the pipeline construction resources of North America. Although small compared to the ANS pipeline, the 300 mile spur pipeline would be a significant project by itself. Simultaneous construction of the ANS pipeline and the spur pipeline could result in competition for limited resources. Procurement and construction for the spur pipeline would need to be scheduled to avoid such competition.

The economics of pipeline projects are strongly influenced by the outlay of capital for design, procurement, and construction, some of which would occur years prior to initial gas flow and start of revenues. All efforts would need to be made to compress the procurement and construction schedules.

The spur pipeline would differ from Lower 48 pipeline projects in that detailed soil data would be required to address the compatibility of the pipeline and the surrounding ground. The potential for long-term adverse impacts because of frost heave and/or thaw settlement would need to be addressed. Acquisition costs for the geotechnical data required to support the project design could be significant. Project planning would need to address the design engineering expertise available to the project and efficient use of this expertise with regard to acquisition of geotechnical data.

9.8 Regulatory Permitting and Compliance

Because a spur gas line as proposed in this report would utilize existing highway ROW, an eventual project sponsor should be prepared to engage in consultation and review with ADOT&PF as well as ARRC, ADNR, BLM and other governmental entities that could be affected by the granting of a pipeline ROW. The ARRC could be an integral partner in any future project, if rail transportation were utilized to supply materials, and would need to be consulted early in the planning process. Additionally, in order to secure permits and authorizations, future field work would need to address river and stream crossings; construction in or avoidance of wetlands; and avoidance of long-term negative impacts to biological resources. Preconstruction planning and permit scheduling would assist a future sponsor in determining time and cost commitments for regulatory permitting and compliance.

9.9 Public Outreach Program Plan

If a spur pipeline project is formally proposed by a sponsor seeking permits and authorizations to construct and operate the facility, a public outreach program would need to be conducted, employing the standard NEPA process and format. The first step in that process would be to determine which governmental entity would be the lead agency in undertaking the EA review and interagency coordination required to assess the potential environmental (natural and human) impacts of the proposed project.

In order to complete an adequate EA review, public and stakeholder meetings would be held. Normally, the first set of public meetings would be described as scoping meetings the intent of which is to identify issues and concerns that stakeholders may have about the proposed gas pipeline project based on the formal permit applications submitted by the project sponsor. The permitting agencies take the issues and concerns expressed at the scoping stage into serious account in giving direction to the sponsor about how to revise the proposed program to insure the least adverse impact on the natural and human environment. This could take the form of additional project mitigation measures, selection of or variations on alternatives to the sponsor's preferred program, and so forth.

Following this first (scoping) step of the public outreach effort, subsequent follow-up public meetings or workshops could be scheduled to address specific issues, concerns, or individual stakeholder constituencies on how the sponsor has responded to these matters.

While identification of specific issues would be the product of scoping meetings, it would be anticipated that the following issues of concern to all stakeholder groups would be specified:

- Temporary disruption of road and transportation access at construction sites;
- Enhanced access to transportation and recreational use (ATV) corridors in areas where the ROW deviates from highway ROW (e.g., along the mid-section of the Delta Junction Spur);
- Environmental impacts to subsistence fish and wildlife resources;
- Potential availability of new energy sources;
- Local employment opportunities for both pipeline construction and operating phases of a spur pipeline; and
- Potential sociocultural impacts from presence of a transient, non-resident labor force.

Following scoping, the next stage of the NEPA process would be the publication of the lead agency's EA of the sponsor's (possibly) revised project and its determination of either a FONSI or the reverse, a finding of impacts substantial enough to warrant conducting a full NEPA EIS. Should the EIS requirement occur, a whole new (and frequently very lengthy) process of public scoping, follow-up, public comment meetings would take place.

While the standard NEPA process for conducting public meetings, workshops, and hearings would undoubtedly be required before a spur pipeline could be permitted, constructed and operated, the sponsor would likely conduct a parallel public outreach program to promote its project. This program would likely have several dimensions. It could include informational meetings in individual communities, consultations with various stakeholder groups (e.g., Alaska Native and village corporations, community councils, sports and recreation associations, chambers of commerce and other business organizations), and school programs as well as facility site visits.

9.9.1 Program Summary

Representatives from all stakeholder groups described in Section 9.9.2 are likely potential participants in the public outreach program. A public outreach program conducted by the project sponsor would need to also make early and continuous contact with all stakeholder entities using the techniques of informational

meetings, periodic project up-date sessions, and possibly a newsletter keeping stakeholders current on all aspects of the project including modifications to project design and proposed mitigations resulting either from agency imposed stipulations on permits and responses to public concerns.

9.9.2 Stakeholders

Stakeholder groups fall into broad categories including governmental agencies, community groups, Native and Tribal organizations, Non-native parcel owners, Natives who have acquired title to Native allotments, business interests, and third-party interests.

Governmental Agencies

Federal, state and local governmental agencies possess jurisdictional authority within the permitting process. These may include those Alaska-chartered boroughs and municipalities which exercise land use (zoning) authority. Three boroughs have this capability in areas where the spur pipeline ROW would cross their lands: FNSB, Denali Borough, and MSB.

Community Groups

Because large areas of Alaska fall outside the boundaries of chartered boroughs, including some areas of both of the possible spur pipeline routes, local community councils constitute a small, but important component of stakeholder groupings. Community councils also exist within the chartered boroughs and represent the interests of local communities even though they lack governmental authority (e.g., taxing authority). Often it is through public meetings within such communities that one reaches the largest segment of this otherwise dispersed rural public population.

Native and Tribal Organizations

Although Alaska is not unique in that its Native groups are often land-owners of parcels through which both public and private facilities are constructed, the form of ownership differs from that of tribal (reservation) lands in the Lower 48. Alaska Natives are organized into 13 Regional Corporations and a large number of village corporations all chartered under Alaska corporation law. For the spur pipeline project, there are three regional corporations that may potentially have interests impacted by the project: Doyon (Fairbanks region), CIRI (areas within the MSB), and Ahtna (areas wholly within the proposed Delta Junction Spur route). Tribal councils exist in all three Native regions, but only the Nenana Native Village Association exists within the Fairbanks Spur routing and the Chickaloon Village Traditional Council exists within the Delta Junction Spur route.

Non-Native Parcel Owners and Natives who have Acquired Title to Native Allotments.

This category is a program initiated in the l930s to convey up to 160-acre parcels of land to Native individuals for the purpose of conducting subsistence activities (hunting, fishing, and trapping) on lands held under fee-simple ownership. Native allotments differ from lands owned by Native corporations.

Business Interests

The primary business groups that could be impacted by the spur pipeline project, besides the Native for-profit corporations, are the owners and operators of tourism-related enterprises (e.g., lodge and tourist services operators, hunting and fishing guides, river-rafting and wilderness guiding services). The business interests are associated with utility companies including: TAPS, ARRC, GVEA, Copper Valley Electric Association, MEA, and Chugach Electric Association, telecommunications providers, natural gas service providers, and distributors of fuel oil and propane.

Third-party Interests

A wide range of specialized groups commonly voice the strongest concerns about proposed energy-related developments such as the proposed spur pipeline. These are environmental protection and conservation organizations (e.g., Trustees for Alaska, Northern Center for the Environment, Audubon Society, Wilderness Society, and Sierra Club) and groups and organizations representing the interests of game hunters, recreational fishers, hikers, campers, water-sports, wildlife photography, off-road vehicle groups, aircraft owners and operators, etc.

Section 10. References and Resources

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